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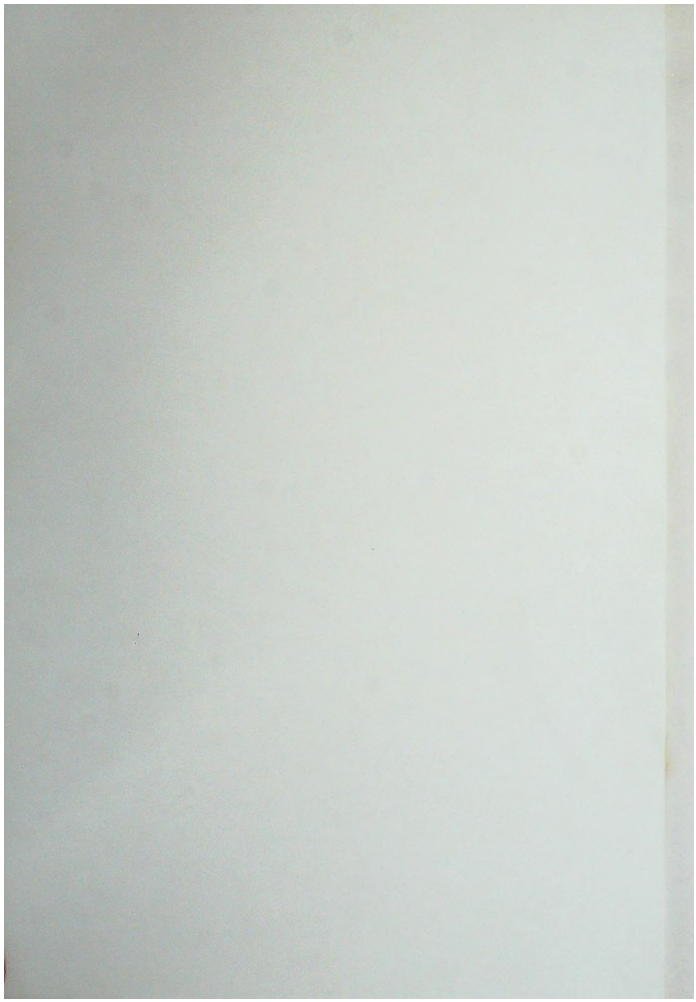
Rubber Based Farming Systems

An Annotated Bibliography

Rubber Research Institute of India



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Editors

V R Sujatha
Kurian K Thomas
Mercy Jose

Library and Documentation Centre
Rubber Research Institute of India
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PREFACE

Rubber plantation industry has played a major role in improving the economy of the rubber growing regions of India. Rubber based farming systems offer a substantial increase in land use efficiency, productivity and generation of additional income. A lot of scientific research has been carried out on different aspects of intercropping in rubber at national and international levels. The research and development in rubber based farming systems have made it necessary to compile a bibliographic database for the interest of different stakeholders like scientists, farmers, extension personnel etc.

I am extremely happy to compliment all those who have worked hard in compiling the relevant information and in bringing out a publication of this excellent quality, viz., **Rubber Based Farming Systems: An Annotated Bibliography** to commemorate the Golden Jubilee of the Rubber Research Institute of India.

N.M. MATHEW
Director

10th February 2006

ABOUT THE COMPILATION

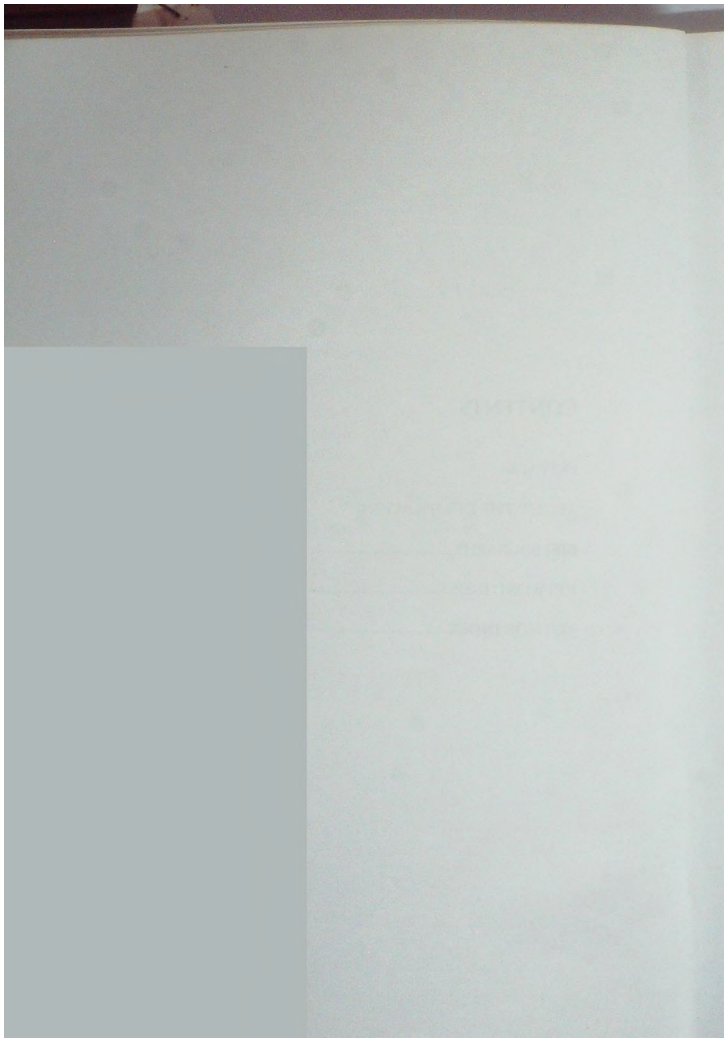
The Rubber Based Farming Systems: An Annotated Bibliography is the third in the series of the bibliography published in conjunction with Golden Jubilee of the Institute. The documents on rubber based farming, intercropping, multiple cropping, agroforestry system, soil properties, land utilization and related aspects, socioeconomics, labour cost etc. have included in this book. The information on plantation crops, fruit crops, food crops, timber crops, vegetables etc. that can be intercropped with rubber in all rubber producing countries was also dealt in. The book covers literature published during the past six decades, ie. from 1941 to 2005. The literature covered include scientific and technical contributions like research articles in periodicals, books and monographs, theses and dissertations, papers presented in national and international conferences, seminars and other relevant sources like Internet, CD-ROMs etc., available in the library.

The compilation consists of three sections viz, **Bibliography, Keyword Index and Author Index**. In the first section, the references are arranged in the chronological order under the surname of each author with individual contribution first and followed by publications of the same author as first author under joint authorship. This is followed by title, bibliographic citation, abstract (in most cases), and keywords. The **Keyword Index** and **Author Index** are suffixed with their entry numbers. The bibliography will serve as a useful reference guide for scientists, researchers, planters, extension workers, etc. associated with rubber based farming systems.

We are grateful to Dr. N.M. Mathew, Director, RRII for giving permission to publish this bibliography. We express our sincere gratitude to Directors of Rubber Research Institute of Thailand (RRIT) and Rubber Research Institute of Sri Lanka (RRISL) for providing beautiful photographs for the printing of this bibliography. The immense help rendered by the scientific staff of Agronomy division and staffs of the library at various stages of the compilation are gratefully acknowledged. Thanks are also due to M/s. Creative Minds, Kottayam for the design of the cover and M/s. Alois Graphics, Kottayam for printing of this bibliography.

V.R. Sujatha
Kurian. K. Thomas
Mercy Jose

CONTENTS



BIBLIOGRAPHY

1. **Abdul Razak, M A and Barizan, R S R** (2001)

Intercropping rattan with rubber and other crops

Unasylva, 52(205): 9.

Only three species of rattan have been found to be suitable for growing under rubber (*Hevea brasiliensis*) in Peninsular Malaysia: *Calamus manan*, *C. scipionum* and *C. palustris*. Although intercropping rattan with rubber tree appears feasible, rattan should be viewed as a supplementary crop only. With intercropping of rattan and rubber, some management problems can occur. Rattan can hinder tapping operations. The advantages and disadvantages of intercropping rattan with other crops, including oil palms and *Gigantochloa levis*, are discussed.

Keywords: Agroforestry; Cane; Rattan; Malaysia

2. **Abraham, P D** (1980)

Increasing earnings of smallholders with catchcrops

Siaran Pekebun, 78(1): 25-26.

Catch cropping young rubber with short-term crops such as maize, soyabean, groundnut and banana has been a common practice among smallholders in Malaysia to increase their earnings. Crop rotation should also be practiced. Catchcrops are encouraged as its integration of in to interrows of immature rubber leads to the maximization of land use and economic returns of the smallholders.

Keywords: Banana; Groundnut; Maize; Smallholding; Soyabean; Malaysia

3. **Adrinal, T; Jamal and Ramlan, M F** (2000)

Effect of intercropping system of immature rubber-banana-pineapple on soil properties and soil erosion: A preliminary observation

Jurnal Stigma, 8(1): 48-51.

Keywords: Banana; Pineapple; Soil conservation; Soil property; Indonesia

4. **Allen, E F** (1955)

Cultivating other crops with rubber

Planters' Bulletin, 16: 10-21.

This paper is concerned with crops which are suitable for inter-planting with hedgerow-planted rubber and which do not require large amounts of bulky organic manures. The crops discussed here include Liberan and robusta coffee, cacao, manila hemp, banana, pineapple, derris, gambier, tea, oil palm, kapok, fruit trees (rambutan, lime, grapefruit, durian and mangosteen), sisal, *Fureraea gigantea*, patchouli, legume leys (*Centrosoma pubescens*), balsa and *Gmelina arborea*. Information is given on culture, spacing, manuring, shading and soils.

Keywords: Banana; Derris; Fibre crop; Fruit crop; Gambier; Kapok; Pineapple; Plantation crop; Sisal; Malaysia

5. **Allen, E F (1955)**

Mixed farming and intercropping

Planters' Bulletin, 17: 38-41.

This article presents an outline of mixed farming and intercropping. All the systems of arable cropping must depend on some degree of mechanization for pre-planting cultivation interrow weeding and harvest. All these operations would be easier with sole crops than with intercropping and possibly a combination of the two systems might be easier to manage than complete intercropping. This would depend on having a certain area set aside for tapioca, sweet potatoes and vegetables, while fodder grasses and leguminous fodder covers would be intercropped with rubber. Whichever systems are adopted, it is essential to guard against physical deterioration of the soil.

Keywords: Ginger; Mixed farming; Pepper; Pigeon pea; Malaysia

6. **Alvim P de T; Lieberei, R; Reisdorff, C and Machado, A D (1996)**

Sustainable land use systems for the Amazon region

Interdisciplinary Research on the Conservation and Sustainable Use of the Amazonian Rain Forest and its Information Requirements: Report on the Workshop, 20-22 November 1995, Brasilia, Brazil, pp. 208-220.

This paper seeks to identify ecologically sound land use systems capable of contributing to the development of selected areas of the Amazon region. Emphasis is given to agricultural products with good market possibilities. Four classes of systems are discussed in the following order of their economic importance in the region: perennial tree crops, ranching, forestry and short-cycle field crops. The tree crops deserving greater attention include African oil palm (*Elaeis guineensis*), cacao (*Theobroma cacao*), rubber (*Hevea brasiliensis*), robusta coffee (*Coffea canephora*), black pepper (*Piper nigrum*), peach palm or pupunha (*Bactris gasipaes*), and several tropical trees usually grown in agroforestry associations. With regard to ranching, special reference is made to large areas of natural pasture formed in the floodplains of large rivers, which are successfully being used to raise water buffalo. On the conversion of forests into pasture provided appropriate management and homogeneous plantings of fast-growing species are comparatively analysed. The need of establishing income forests (national forests) as well as forest reserves for the preservation of biodiversity is underscored. Regarding short cycle field crops attention is drawn to the need of intensifying research on intercropping with nitrogen-fixing species, so as to improve sustainability of the system. It is suggested that the market for traditional tropical products and inadequate technologies presently used by farmers has limited expansion of sustainable land use systems in Amazonia more than by local ecological constraints. Considering the size of the region with nearly 500 million hectares in Brazil it is thought unlikely that economically viable agricultural production systems could occupy more than a relatively small fraction of the original forest area. The paper says that the land use systems, which can presently be regarded as economically viable for Amazonia, will not require more than the land surface, which has already been deforested.

Keywords: Agroforestry; Cocoa; Coffee; Forest management; Grassland; Oil palm; Brazil

(HORTCD 1989-2001/09)

7. **Alvim, R and Nair, P K R** (1986)

Combination of cacao with other plantation crops: An agroforestry system in Southeast Bahia, Brazil

Agroforestry Systems, 4(1): 3-15.

Various crop combinations involving cacao have recently been undertaken by the farmers with encouragement from Brazilian government. As a part of the crop diversification programme in the traditional cacao growing areas of Brazil, extensive areas are being planted to other plantation crops, mainly clove and rubber and, to some extent, coconut. Crop combinations have been adopted in some of these new plantings and cacao is an important component of most of such combinations. Whereas several other crops are combined with clove trees, cacao is usually the only species grown with mature rubber trees. Young rubber trees are, however, interplanted with a number of other species. Productive coconut areas are found mostly in sandy soils along the coast so that there is little intercropping. The paper presents some data on the performance of some of the combinations involving cacao and other plantation crops based on field survey, and discusses the potentials and constraints of extending the system to more areas in the region.

Keywords: Agrosilvicultural system; Cashew; Clove; Cocoa; Coconut; Farming system; Multiple cropping; Bahia; Brazil

8. **Alvim, R; Virgens A de C and De Araujo, A C** (1989)

Agrosilviculture as the science of earning money from the soil: Anticipated recuperation and remuneration of capital in establishing perennial tree crops

Boletim Técnico Comissao Executivo do Plano da Lavoura Cacaueira, 161: 36.

To reduce the period of economic immaturity in rubber, oil palm and cocoa plantations, each crop was interplanted in the following way: rubber with *Pueraria phaseoloides*, bananas or *Euterpe oleracea*; oil palm with *Manihot esculenta*, pineapples, *Piper nigrum* or *Gliricidia sepium*; and cocoa with bananas, *Bactris gasipaes* or *P. nigrum*. This method gave a more efficient use of the land compared with monoculture of each main crop.

Keywords: Banana; Cassava; Cocoa; Land utilization; Oil palm; Pepper; Pineapple; Brazil

(HORTCD 1989-2001/03)

9. **Aminuddin, M** (1992)

Income from harvesting trial of manau cane in rubber plantation

RIC Bulletin, 11(1): 2-3.

Brief data are presented from a seven-year-old (mature) planting of manau (*Calamus manan*) near Selangor, Peninsular Malaysia.

Keywords: Economic aspect; Manau cane; Malaysia

(CAB Abstracts 1995)

10. **Aminuddin, M and Nur Supardi, M N** (1986)

Intercropping of rotan manau (*Calamus manan*), with rubber (*Hevea brasiliensis*)

Pertanika, 9(2): 161-165.

Rotan manau (*Calamus manan*), seedlings were planted between rows of rubber (*Hevea brasiliensis*) trees in a 1.4 ha plantation when the rubber was 13 years old. The relative light intensity (RLI) in the rubber plantation was 50 to 60% measured at midday. Survival of rotan manau at three years after planting was 80.6%. The growth rates were variable. The mean stem length was 45.17 ±32.15cm. The growth rate is encouraging compared to figures obtained from trials in forest areas.

Keywords: Growth; Light Intensity; Rotan manau; Malaysia

11. **Aminuddin, M; Nur Supardi, M N and Abdul Ghani, I** (1991)

Rattan growing under rubber in Peninsular Malaysia: Status, problems and prospects

Malaysian Forestry and Forest Products Research: Proceedings of the Conference, 3-4 October 1990, Forest Research Institute of Malaysia, Malaysia, pp.79-86.

Rattan growing under rubber has been well received by smallholders. Since 1986, a total of more than 650 ha has been planted in Malaysia by variqus agencies such as FELDA, RISDA, RRIM/FRIM, PPK, KESEDAR and Forestry Department. Research thus far has shown that rattan growing under rubber is financially a viable proposition. This has been observed through various trial plots under among different rubber clones. They showed no effect on latex production, no increased in fertilizer requirement and yet resulted in good cane productivity. In estate system, the main problem encountered has been on seedling maintenance between planting and development of climbing apparatus of the rattan plant. This needs to be overcome by an intensive extension programme. Assuming that these problems can be overcome and that the few rémaining unanswered questions are solved, rattan planting under rubber can replace the resources that are being depleted in the natural environment. Demand for rattan will continue to exist and increase with the anticipated price increase. If the plantation sector can participate by going into large scale planting, then Malaysia can enjoy the privilege of being a primary producer of rattan in the world.

Keywords: Planting technique; Rattan; Malaysia

12. **Ani Bin Arope** (1974)

Soyabean (*Glycine Max L*): Intercrop for the smallholders.

Rubber Research Institute of Malaysia, Modernis Committee Report: 3: 49.

The report provides background information and details of techniques for the introduction of soyabean as an intercrop with rubber. The research indicates that soyabean appears to be a suitable intercrop both as a viable crop and that could save considerable foreign exchange by substituting for imports, thus benefiting both the farmers and the nation. Intercropping in immature rubber offers the quickest means of achieving income and maximizing the use of land. Soyabean appears to meet the choice as an intercrop. In addition, it serves as an import

substitution. Suitable varieties are available and soyabeans can be grown successfully as an intercrop in rubber. Economic analysis was carried out based on range of yields and prices.

Keywords: Economic aspect; Smallholding; Soyabean; Malaysia

13. **Ani Bin Arope** (1975)

Maize (*Zea Mays* L.): An intercrop for smallholders

Rubber Research Institute of Malaysia, Agricultural Report, 1: 69.

This report gives an account of the work done by the Rubber Research Institute of Malaysia on the production of hybrid maize varieties and the growing of maize mainly as an intercrop in rubber smallholdings. It also provides a general review of work done in growing maize in Malaysia, an analysis of the supply and demand position and the economic benefits of growing maize locally as well as the details of techniques to be employed for the introduction of hybrid and synthetic varieties of maize as an intercrop with rubber. The aim is to provide an alternative source of income for the smallholders during the immaturity period of rubber, thus, alleviating their hardship and providing maximum utilization of their available land. This report indicates that maize appears to be a suitable intercrop both as a viable crop and one, which would save considerable foreign exchange by substituting for import.

Keywords: Economic aspect; Land utilization; Maize; Smallholding; Malaysia

14. **Anilkumar, D and Jessy, M D** (2005)

Intercropping in immature rubber plantations: Indian experience

Progress and Development of Rubber Smallholders: Proceedings of the ANRPC Ninth Seminar, 9-11November 2005, Cochin, India, pp.14-15.

The present study analyzes the pattern of intercropping in the smallholdings and its impact on socio-economic aspects and on the growth of rubber. The study was taken up in the five major rubber-growing regions in Kerala, which is the traditional rubber growing state in the country. The study, was confined to plantations raised during 1995 and 1996, where intercropping was practised by smallgrowers. For assessing the impact of intercropping on growth of rubber and other socio-economic aspects, data from holdings which have raised rubber as pure crop (control plots). The study has revealed that intercropping has helped in increasing the income level of farmers and banana was identified as the most popular crop. Regionwise difference in choice of crops has been observed. The paper discusses in detail the economics of various intercrops besides analyzing the impact of the intercrops on growth of rubber under different agro-climatic conditions.

Keywrods: Agroclimate; Banana; Economic aspect; Smallholding; India

15. **Anwar, C and Bacon, P** (1986)

Comparison of *Imperata* control by manual, chemical, and mechanical methods for smallholder rubber farming systems

Biotrop Special Publication, 24: 301-316.

In an area dominated by *Imperata* in S. Sumatra, the land was cleared by using 2.16 kg glyphosate/ha, 11-1 kg dalapon followed by 7.4kg dalapon/ha or by traditional clearing

methods. Upland rice was then strip-sown, dibble sown or dead stubble was cultivated and rice direct sown. In a second experiment on a red yellow podzolic soil, plots were cleared by cutting and burning with hand hoeing, or by 2.2 kg glyphosate/ha with zero tillage, or by 2.2 kg glyphosate/ha with minimum tillage or by two ploughings and two harrowings. Rubber was planted four or six weeks after clearing and intercropped with maize, upland rice, groundnuts and *Vigna unguiculata*. The soil was analysed before and after land clearance. From both experiments there was apparently no short-term difference between mechanical clearance or minimum or zero tillage. In the second experiment there were no significant effects on soil fertility and structure for the various treatments. The main advantage of minimum and zero tillage was economic.

Keywords: Farming system; Groundnut; *Imperata cylindrica;* Maize; Smallholding; Upland rice; Weed management; Bogor; Indonesia

(CAB Abstracts 1984/89 May)

16. **Arayarungsarit, L; Chongkid, B; Suwanbutr, S and Weerapat, P** (1985)

Reaction of some upland rice to root-knot nematodes in rubber plantation fields

International Rice Research Newsletter, **10**(4): 23-24.

Out of eleven upland rice lines grown and selected for intercropping in a para rubber crop in Thailand, three selections from IR36/RD25 crosses showed resistance to *Meliodogyne spp.*

Keywords: Root-knot nematode; Upland rice; Thailand

(CAB Abstracts 1984-89/May)

17. **Azwar, R; Sumarmadji; Haris, U and Basuki** (1993)

Intercrops in smallholder rubber-based farming system

Indonesian Agricultural Research and Development Journal, 15(3): 45-51.

Various aspects of introducing permanent intercrops to develop sustainable rubber-based cropping systems (RBCS) for Indonesian smallholders are discussed. These include: a sustainable approach to the development of RBCS for smallholders; RBCS as a response to ecological, economic and socio-institutional conditions; suitable intercrops for sustainable RBCS: rehabilitation and replanting programmes; intercropping patterns: sequential intercropping, direct permanent intercropping, and mixed intercropping. It is indicated that sequential intercropping is practiced under intensive replanting programmes. Its application is limited to fertile soils and flat areas. Permanent intercropping is technically feasible for both replanting and rehabilitation programmes. Direct permanent intercropping is suggested for remote areas where sequential intercropping is not feasible. Permanent mixed intercropping is suitable for more difficult areas, such as steep terrains. Suitable intercrops for sustainable RBFS include rattan, banana, pineapple, salacca (*Salacca edulis)*, and duku (*Lansium domesticum*).

Keywords: Banana; Duku; Multiple cropping; Pineapple; Rattan; Rubber based farming system; Salacca; Indonesia

(ATA No.94073, 1994)

18. **Bagnall, O H; Conroy, C; Faiz, A; Gunawan, A; Gouyon, A; Penot, E; Liangsutthissagon, S; Nguyen, H D; Anwar, C and Garrity, D P** (1997)

Imperata management strategies used in smallholder rubber-based farming systems

Agroforestry Systems, **36**(1-3): 83-104.

Imperata cylindrica is a serious problem for the smallholder rubber farmer in most of South East Asia in three respects: the high cost (labour and/or capital) of opening *Imperata*-infested land, its competitive effect on rubber and annual intercrops, and the fire hazard that it poses during the dry season as a major source of combustible material. This paper describes the precise nature of the *Imperata* problem, with reference to some of the smallholder rubber-based farming systems within South East Asia, the different *Imperata* control strategies currently practised in these farming systems, and some of the constraints on the adoption of currently and recently recommended practices. It then proposes a 10-point agenda for research on *Imperata* control, including two ways in which current research programmes could be usefully reorientated: first, they need to take greater account of smallholder farming systems and constraints; and second they should shift their emphasis from single-method to integrated control systems.

Keywords: Agroforestry; Economic aspect; *Imperata cylindrica*; Soil fertility; Weed management; South East Asia

19. **Blencowe, J W** (1967)

Cocoa growing under rubber: The prospects

Proceedings of the Symposium on Cocoa and Coconuts in Malaya, September 1967, Kuala Lumpur, Malaysia, pp. 57-60.

Keywords: Cocoa; Malaysia

(RRIM Bibliography. 1927-1967)

20. **Blencowe, J W** (1989)

Organization and improvement of smallholder production

In: Rubber (Eds. C. C. Webster and W. J. Baulkwill), Longman Scientific and Technical, New York, pp. 510- 513.

Chapter 12 includes a session of intercropping with details of the factors that influence the choice of the intercrop. In Thailand, upland rice is the first choice intercrop followed by groundnuts. Soyabean or mungbean are occasionally grown.

Keywords: Cassava; Groundnut; Smallholding; Soyabean; Sweet potato; Upland rice; Thailand

21. **Boutin, D; Penot, E and Ilahang** (2000)

Rubber agroforestry system-type 3 (RAS-3): A strategy to convert *Imperata* grasslands

Proceedings of the Indonesian Rubber Conference and IRRDB Symposium, 12-14 September 2000, Bogor, Indonesia, pp. 266-273.

Lalang (*Imperata Cylindrica*) is known to be the most noxious weed in the tropics and a major constraint for food and tree crop development. Chemical herbicides application and promoting

the establishment of Legume Covers (LCC) are the standard control of *Imperata Cylindrica* in estate plantation and government projects. These weed control methods are too expensive to be widely adopted by farmers in self-help development. In SRAP (Smallholder Rubber Agro forestry Project) a different approach for controlling *Imperata* were tested, e.g. by shading, through the association of various cover crops, shrubs and fast growing trees (FGT) with rubber. The system was called "Rubber Agro forestry System-type 3" (RAS 3). All experiments were conducted in smallholders' fields with participatory approach. The association of different species with rubber aims to assess the ability of various plants to control *Imperata* and to evaluate the impact of the association on rubber growth. Leguminious shrub like *Flemingia congesta* was found effective to control *Imperata*. Rubber growth in RAS type-3 was comparable to that grown with conventional technologies using *Pueraria phaseoloides* 3 years after planting. Fast Growing Trees (FGT) such as *Acacia mangium*, *Acacia crassicarpa*, *Paraserianthes falcataria*, *Gmelina arborea* did not affect rubber growth until 42 months after planting. Floral composition changed, in some plots, from *Imperata* to *Chromolaena odorata* and *Melastoma affine*. *Acacia mangium* was the most effetive trees to shade and limit *Imperata* growth. However, it competed rubber growth 42 months after planting. Prunning and felling have to done to prevent a significant effect on rubber growth. Association between fast growing trees (FGT) with rubber may reduce maintenance cost (*Imperata* control). However, the planting pattern of association between tree crops and rubber has to be adapted to a wider inter-row to enable to grow various timber pulp trees as rubber intercrops.

Keywords: *Acacia mangium*; *Acacia crassicarpa*; Agroforestry; *Gmelina arborea*; *Paraserianthes falcataria*, Indonesia

22. **Bovi, M L A; Godoy G, J; Nagai, V and Cardoso, M** (1990)

Planting density for palmito intercropped among rubber trees

Pesquisa Agropecuaria Brasileira, 25(7): 1023-1029.

Forty-year-old rubber (*Hevea brasiliensis*) trees planted at 5 X 5 m were intercropped with *Euterpe edulis* palms spaced at 1 X 1, 1.5 X 1, 2 X 1, 2 X 1.5 or 2 X 2 m. The palm crop was harvested 10 years after planting. The yield of palm hearts ranged from 1033 kg/ha at 2 X 2 m and 2 X 1.5 m to 1612 kg/ha at 1.5 X 1 m. Among the vegetative characters studied, palm girth at a height of 130 cm was best correlated with productivity.

Keywords: Cropping system; Palm; Planting density; Brazil

23. **Brahmam, M** (2002)

Effect of *Hevea brasiliensis* (Willd. Ex Adr. De Juss.) Muell. Arg. tree shade on growth and yield of wild pigeon pea, *Cajanus Cajanifolia* (Haines) Maesen

In: Global Competitiveness of Indian Rubber Plantations Industry: Rubber Planters' Conference, India 2002 (Ed. C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, India, pp. 77-79.

The influence of rubber tree shade on the growth and seed yield of wild pigeon pea, *Cajanus cajanifolia* (Haines) Maesen, inter-crop showed that gradual increase in shade progressively decreased the growth performance and total pulse yield. Visible parameters like number of branches, number of pods, number of seeds per plant and per hectare yield were higher in the

initial five years of rubber (RRIM 600) growth but declined from the sixth year onwards due to closure of free canopy. The decline in the per hectare pulse yield from 775 kg in the first year to 552 kg in the fifth year was gradual but beyond this it was abrupt. Pigeon pea can be profitably grown as an intercrop in rubber for the first five years.

Keywords: *Cajanus cajanifolia*; Wild pigeon pea; Orissa; India

24. **Brahman, M; Pillai, S S K and Pati, U K** (1997)

Influence of rubber (*Hevea brasiliensis*) tree shade on growth performance and seed yield of pigeon pea (*Cajanus cajan*) intercrop

Indian Journal of Forestry, 20(2): 181-182.

In Orissa, India, the scope of pigeon peas as an intercrop in rubber plantations was studied. The effect of shade on the growth and seed output of pigeon pea was assessed. A gradual increase in shade progressively decreased the plant height, number of branches, number of pods, seeds per plant, and grain yield/ha. General growth parameters and pulse yield data of pigeon pea were high in the first, second and third years of rubber (GT 1) growth, but were abruptly reduced in the fourth year due to tree canopy closure. It is concluded that pigeon pea can be grown profitably in the inter-row spaces of rubber in the first three years.

Keywords: Pigeon pea; Shade; Orissa; India

25. **Buranatham, W** (2002)

Mixed farming system in rubber plantation for rubber smallholders in Thailand

Proceedings of the IRRDB Joint Workshop on Plant Breeding, Agronomy and Socio- Economics, 28 August-6 September 2002, Indonesia, pp. 1-7.

Keywords: Cassava; Castor bean; Mixed farming; Pineapple; Smallholding; Sugar cane; Upland rice; Vegetable; Thailand

26. **Buranatham, W; Kongsripun, S and Shugamnert, S** (1992)

Recent advances in multiple cropping with *Hevea* in Southern Thailand

In: Progress and Development of Rubber Smallholders: Proceedings of the Seminar, 1992, Kuala Lumpur, Malaysia, pp. 11.

Most of the rubber plantations in Thailand are smallholdings and spread to 14 provinces in the south which is about 90 percent of the area. The smallholders can earn some income from intercrops in the first 3 to 3 $^{1}/_{2}$ years of immature rubber and help in increasing the growth of young rubber. Sometimes the rubber price is rather low, so that the income of the smallholders from the plantation is not enough for their living, multicropping in mature rubber plantations is one of the solution to support the smallholders for better living. Recent researches show that suitable crops like cardamom, galangol, jack fruit, long-gong (Aglaia dookoo, Griff) and some forest species such as rattan. Experiments on multicropping with perennial or shade tolerant crops in mature rubber were earlier set up about 5 years and information on field, management and cultural practices of some multicrops are also discussed.

Keywords: Multiple cropping; Thailand

27. **Buranatham, W; Wongsukon, P and Jewtrakool, P** (1980)

Research on intercrops in rubber in Thailand

Progress and Development of Rubber Smallholders: Proceedings of the Fourth Seminar, 17-22 July 1980, Colombo, Sri Lank, pp. 121-126.

This paper presents the activities on intercrops conducted by the Rubber Research Centre (RRC) of Thailand. Small-scale variety trials on Hawaiian Sugar E-1 sweet corn (50 700 ears per hectare), Shiny Green mung bean (1 562 kg per hectare), S. J. 2 soyabean, (1 562 kg per hectare), local variety groundnut (1 250 kg per hectare) Koe Muengluang upland rice (1 488 kg per hectare) and Dok Payom upland rice (1 544 kg per hectare). Large-scale intercropping trials in areas planted with GT 1 clone reveal no significant differences in girth increment of rubber due to interrow management. In areas planted with RRIM 600 clone, two of the intercrops grown (sweet corn and upland rice, and mung bean and papaya) have in fact caused significantly better growth of the trees. Agronomic studies of new crops such as pineapple, red roselle, forage crops and cassava are being conducted. Ninety percent of smallholders who intercrop usually do so with upland rice. It is the first crop planted after the old trees are felled. Varietal trials of upland rice were conducted in 1973- 1980. Koo Muengluang (1 488 kg per hectare) and Dok Payom (1 544 kg per hectare) are the recommended varieties. Further trials are being conducted to select upland rice varieties for each province. Taking advantage of the current high prices of natural rubber in the world market, Thailand has accelerated its rubber-replanting programme. Old trees constitute half of the total area under rubber (1.51 million acres). Another quarter of the area has low yielding trees. Only about 15% is planted with high-yielding rubber clones. Therefore, about 1.38 million hectares of rubber holdings in Thailand are ready for replanting. Such substantial areas of immature rubber are suitable for intercropping of food or cash crops. Intercropping will not only help to improve the income of the smallholders but also make a significant contribution towards the improvement of the economy of the country and of the world production of natural rubber.

Keywords: Dwarf castor; Groundnut; Sweet corn; Upland rice; Thailand

28. **Cao Panrong, and Zhou Y, H** (1997)

Allelopathy of the intercropping between rubber and tea

Journal of Tea Science, 17(2): 193-195.

The allelopathic effects of water extracts of rubber leaves on the germination and seedling growth of tea (*Camellia sinensis* var assamica) (*C. assamica*) were investigated. The extract of rubber leaves contained substances, which were allelopathic to tea. The effects were correlated with the concentration of the substances. The extracts promoted seed germination and the growth of tea seedlings at low concentrations, and inhibited them at high concentrations.

Keywords: Allelopathy; Tea

29. **Chandrasekera, L B** (1977)

Potential for intercropping rubber lands in Sri Lanka

Rubber Research Institute of Sri Lanka Bulletin, 12(1): 41-45.

Experiments carried out by the Rubber Research Institute of Sri Lanka have indicated the suitability of cacao, coffee, banana, pineapple, passion fruit for intercropping with rubber.

These crops require only circle weeding as is done with rubber while the rest of the land could remain in ground cover. For intercropping, the rubber is best planted at spacings of 8 ft x 30ft which will give a theoretical stand of 180 planting points to the acre. The present recommendations are to plant a single row of cacao, coffee, passion fruit or bananas between each pair of rubber rows. The possibilities of revising the recommendations involving higher densities of the subsidiary cross are discussed.

Keywords: Banana; Cocoa; Coffee; Passion fruit; Sri Lanka

30. **Chandrasekera, L B (1980)**

Intercropping of rubber replanting in the immature stages

Progress and Development of Rubber Smallholders: Proceedings of the Fourth ANRPC Seminar, 17-22 July 1980, Colombo, Sri Lanka, pp. 115-120.

The Rubber Research Institute of Sri Lanka conducted experiments on the suitability of banana, passion fruit, coffee and pineapple as intercrops in rubber smallholdings. The paper describes the planting densities and planting costs of these intercrops.

Keywords: Banana; Coffee; Passion fruit; Pineapple; Planting density; Smallholding; Sri Lanka

31. **Chandrasekera, L B (1984)**

Intercropping *Hevea* replantings during the immature period

Proceedings of the International Rubber Conference, 17-22 July 1984, Colombo, Sri Lanka, 1(2): 389-393.

The paper describes the details of intercropping trials conducted on the suitability of banana, coffee and passion fruit in three rubber-growing districts of Sri Lanka. Their cultural requirements are outlined, and detailed estimates are given of the costs and returns for planting bananas.

Keywords: Banana; Coffee; Economic aspect; Passion fruit; Sri Lanka

32. **Chee, Y K (1974)**

Intercropping with groundnuts and maize in rubber smallholdings

Proceedings of the RRIM Planters' Conference, 18-20 July 1974, Kuala Lumpur, Malaysia, pp. 93-101.

This paper discusses the information obtained from agronomic and economic investigations on the intercropping of groundnuts and maize grown on rotation for two seasons in nine smallholdings of 0.2-0.8 ha, in Beranand, Selangor in 1971 and 1972.

Keywords: Economic aspect; Groundnut; Maize; Seed quality; Smallholding; Yield; Selangor; Malaysia

33. **Chee, Y K** (1976)

Intercropping of annual crops in rubber smallholding

RRIM Refresher Course on Rubber Planting and Nursery Techniques, 12-17 July 1976, Rubber Research Institute of Malaysia, Kuala Lumpur, pp. 178-181.

Intercropping is practiced in smallholdings to supplement their income during the immature period of rubber. Selected intercropping on replanted and newly planted areas with short term crops such as groundnut and maize under proper management will benefit the growth of the rubber trees because of better maintenance in the holding. The important agronomical factors influencing the success of intercropping are land suitability, spacing and direction of rubber row, planting season, seed quality, labour and farm machinery.

Keywords: Groundnut; Family labour; Maize; Seed quality; Smallholding; Malaysia

34. **Chee, Y K** (1976)

Perfromance of RRIM and foreign varieties of maize and groundnuts

National Plant Propagation Symposium, 19-21 July 1976, Kuala Lumpur, Malaysia, pp. 71-82.

High yielding varieties of maize and groundnut seeds introduced and developed by the Rubber Research Institute of Malaysia (RRIM) for intercropping are compared. The need for propogating high yielding varieties of these two crops for the use of farmers in Malaysia is emphasized.

Keywords: Groundnut; Maize; Malaysia

35. **Chen, H** (1990)

Impacts of intercropping rattan in rubber stands on the growth of rubber trees

Tropical Crops Researches, 39(1): 18-22.

Keywords: Growth; Rattan

36. **Craswell, E T; Sajjapongse, A; Howlett, D J B; Dowling, A J; Nair, P K R and Latt, C R** (1997)

Agroforestry in the management of sloping lands in Asia and the Pacific

Agroforestry Systems, 38(1-3): 121-137.

Steeply sloping lands are widespread in the tropics. Although research shows that alley cropping and other contour agro forestry systems can stabilize the sloping lands, these systems have not been widely adopted by farmers. The Framework for Evaluating Sustainable Land Management (FESLM) has been tested in sloping land areas in the Philippines. Sustainable land management must be productive, stable, viable, and acceptable to farmers, while protecting soil and water resources. Farms on which contour hedgerow intercropping has been adopted meet the multifaceted requirements of FESLM, whereas the farmers' current practice does not. Appropriate land management measures for particular locations depend on a complex suite of social, economic, and biophysical factors, and need to be developed in participation with farmers. The role of agroforestry in sustainable management of sloping land is the subject of

networks coordinated by the International Board for Soil Research and Management (IBSRAM) in seven countries in Asia (ASIALAND) and four countries in the Pacific (PACIFICLAND). Selected outcomes from a wealth of network data are reviewed and conclusions about the sustainability of various agroforestry systems for sloping lands were drawn. In the Pacific, soil loss from sloping lands due to water erosion under farmers' current practices is episodic, unpredictable, and possibly not severe. Agroforestry systems that utilize legume shrubs, fruit trees, coffee (*Coffea spp.*) or rubber (*Hevea brasiliensis*) provide useful economic returns, but are not an essential component in terms of soil protection because grass or pineapple (*Ananas cosmosus*) planted on the contour are equally effective in reducing erosion. Agricultural intensification will lead to nutrient mining, reduction of above-ground biomass, declining yields, and less soil protection unless external sources of nutrients are used; nitrogen can be effectively supplied using legumes. Cash derived from hedgerow trees and shrubs may provide an incentive for their adoption by farmers, as well as funds to purchase external inputs such as fertilizers. Labour may be a major constraint to the adoption of complex agro forestry systems. Also discussed are the information management systems required to manage and utilize effectively the extensive sets of experimental and indigenous data being accumulated. It is believed that such information systems can facilitate technology transfer across and between regions, and improve the efficiency of research into agro forestry and other land-management approaches.

Keywords: Agroforestry; Coffee; Pineapple; Soil management; Sloping land; Sustainability; Thailand

37. **Cunha, R L M Da; Pinheiro, F S V and Viegas, R M F** (1989)

Rubber and black pepper intercropping

Boletim da Faculdade de Ciencias Agrarias do Para, **18**: 27-51.

A rubber (*Hevea brasiliensis*) and black pepper (*Piper nigrum*) intercropping trial was set up on Mosqueiro Island, Para, Brazil, in 1977. The density of rubber was varied from 290 to 513 plants/ha. Details are given of the soil characteristics of the site and of the fertilizers applied. A financial analysis of growth and yield data (given for both crops over the 10 yr of the experiment) showed that production was best for the treatments combining 667 to 889 black pepper plants/ha and 392 to 513 rubber plants/ha. The mixture of black pepper and rubber also reduced the immature period of the rubber clone IAN 717.

Keywords: Economic aspect; Pepper; Planting density; Brazil

(HORTCD 1989-2001/03)

38. **De Oliveira, C R M; Soares, A M; Oliveira, L E M; De Castro, E M and Barbosa, J P R A D** (2004)

Growth and anatomical characteristics of coffee (*Coffea arabica L.*) and rubber (*Hevea brasiliensis* Muell. Arg.) trees cultivated in single and intercropped systems

Ciencia e Agrotecnologia, **28**(2): 350-357.

A study was conducted during 2000-01 in Lavras, Minas Gerais, Brazil, to evaluate the effect of cropping system (single cropping and intercropping) on growth and leaf

anatomical characteristics of rubber tree (*H. brasiliensis*) and coffee (*C. arabica*) in the beginning of the cultivation period. The cropping system had no effect on rubber tree. In general, the cropping system did not affect the coffee leaf structure.

Keywords: Coffee; Cropping system; Leaf anatomy; Brazil

(CAB Abstracts 2005/01-2005/09)

39. **De Vries, D** (1974)

First approximation of potential incomes from intercropping for rubber smallholders

Seminar on the Agriculture Sector in the Development of South Thailand, 8-12 July 1974, Hat Yai, Thailand.

The paper tries to determine an optimum allocation of smallholders, resources to maximize their incomes through intercropping, using linear programming techniques. Details and results given from data of costs and requirements of labour for all agricultural operations, seeds, herbicides fertilizers and the estimated yields and current market prices of intercrops like upland rice, sweet corn, sweet potato, water melon and soyabean. It is concluded that intercropping can be very profitable, increases the net present value of investment in replanting and reduces replanting costs.

Keywords: Economic aspect; Rice; Smallholding; Soyabean; Sweet corn; Sweet potato; Water melon; Thailand

(BPPM Abst. Bibliography of *Hevea* rubber 1975-1976)

40. **De Zoysa, E B A** (1993)

Intercropping tea with rubber

Tea Bulletin, 13: 9-13.

Keywords: Tea; Sri Lanka

(Cited by Jayasuriya, K E and Wettasinghe, D Z.)

41. **Dey, S K; Pal, T K and Singh, R S** (2004)

Soil nutrient status in jhum cultivation and under different plantation crops in Mizoram

National Seminar on Horticulture for Sustainable Income and Environmental Protection, 24-26 February 2004, Nagaland University, Nagaland, India.

Effect of jhum cultivation on soil properties was studied along with plantation crops in Mizoram state. Various soil properties were investigated and compared at five different viz. rubber, arecanut, teak, mulberry and organic plantation crops and wild banana with jhum cultivated land. Organic carbon was decreased after burning while pH, available phosphorous, potassium, calcium and magnesium were increased. Soils under all plantation crops have shown increase in pH and nutrition status. The rise of quantity of an individual nutrient does not occur similarly in all crops. Wild banana plantation accumulated maximum amount of Ca and Mg. Soil is degraded with jhum cultivation in the area. It is unlikely to conclude the nutrition status after seven years of cropping, since these crops have longer economic life. However, it indicates that raising plantation crops can restore the nutrition.

Keywords: Jhum cultivation; Soil nutrition; Soil property; Mizoram; India

42. **Dey, S K; Choudhury, M; Ray, S and Nazeer, M A** (2005)

Intercropping of tea in the immature stage of rubber in Tripura: A preliminary report

International Natural Rubber Conference India 2005: *Preprints of Papers*, 6-8 November 2005, Cochin, India, pp. 201-204.

A preliminary investigation of the feasibility on intercropping of tea with rubber was attempted within the agroclimatic conditions of Tripura. Four rubber clones viz. RRIM 600, RRII 105, GT 1 and PB 235 were planted in a stand of 450 plants/ha in four row bands aligned in the North West-South East direction during the year 1997. However, tea was planted as an intercrop in the subsequent year. Rubber was planted in bands at a spacing of 4.0m x3.7 m with distances between the bands at 7.4m. Four tea rows were planted between the bands at spacing of 1m X 0.7m. No differences in growth were noticed in the immature phase of clones in this intercropping system. Of the total area planted, tea comprised of 25% of the land and 75% was under rubber. Generally the maximum, tea yield was recorded during the months of June and July. Annual average over four years of green tea leaves yield was 945 kg/ha. However, the long-term performance of tea as an intercrop with main crop yield of rubber are yet to be evaluated.

Keywords: Agroclimate; Feasibility study; Tea; Tripura; India

43. **Dillon, H S** (1983)

A social and economic assessment of the North Sumatra smallholder development project

Dissertation Abstracts International, 44(6): 1866.

The study assesses the economic and social implications of the North Sumatra Smallholder Development Project, an intensive-management of high-input effort which has provided land, high-yielding varieties, credit and extension to help participating households establish individual 2 ha rubber holdings. The experience gained from this pilot project may be used to formulate a viable smallholder rubber development policy for Indonesia. The project's economic efficiency and impact at the household and regional levels are evaluated. Data were collected from participants in 1979. Analysis of household labour allocation revealed that families participating in the project experienced considerable stress between 3 and 5 years after rubber tree planting. Rice and vegetables could be intercropped with the rubber saplings only during the first 3 years. Thereafter the tree canopy shaded the ground too much for household food crops to grow; but it look an additional 18 months before the rubber trees could be tapped to generate income. Households that owned additional land used it to produce rice and other food, and fared well. Those with only the 2 ha allotment faced an intense family labour demand that interfered with education. In these families, the head of household worked on nearby plantations to earn the highest wages, while spouse and older children worked long hours to complete the cultivation required for good growth of the young rubber trees, and younger children assumed household duties. Households with few children found it impossible to maintain rubber trees properly; trees took longer to produce, and yields were lower.

Keywords: Agricultural development; Case study; Economic aspect; Rice; Rural development; Socioeconomics; Smallholding; Vegetable; Sumatra; Indonesia

44. **Djamhuri, M; Noor, A; Suriansyah; Sunardi and Hartono, A** (1998)

Rubber-based farming system at wet season dry farming in Central Kalimantan (Indonesia)

Proceedings of the Workshop on Agricultural Development Strategy in Kalimantan, 2-3 December 1998, Banjarbaru, Indonesia, pp. 210-218.

Keywords: Dry farming; Food crop; Rubber based farming system; Indonesia

(AGRIS 1999-2002/09)

45. **Edwards, D G; Sharifuddin, H A H; Mohd Yusof, M N; Grundon, N J; Shamshuddin, J and Norhayati, M** (1991)

The management of soil acidity for sustainable crop production.

Proceedings of the Second International Symposium on Plant Soil Interactions at Low pH, 24-29 June 1990, Beckley, USA, pp. 383-396.

The Australian Centre for International Agricultural Research funded a four year project to develop sustainable food crop production systems on acid, low fertility soils. Field trials were started in 1986 at four sites in Malaysia to evaluate crop responses to amelioration of acidity in three Ultisols and one Oxisol and to relate the responses to solid and solution phase soil chemistry. Ground magnesian limestone (GML) was applied at rates up to 8 t/ha. The University Pertanian Malaysia (UPM) trials involved rotation cropping of groundnut and sweetcorn with two crops per year. The Rubber Research Institute of Malaysia (RRIM) trials involved groundnut and maize (sweetcorn and ground corn), intercropped with young rubber trees for 2-3 years before canopy closure. Initial applications of 4 and 8 t/ha were effective after three years in the UPM trials. Yield responses of all crops occurred up to the maximal rate of 2 t/ha in the RRIM trials. Rubber tree growth benefitted from the intercropping and earlier commercial tapping was possible. Application of GML to groundnut and sweetcorn was economically viable.

Keywords: Cropping system; Groundnut; Maize; Soil property; Sustainability; Sweet corn; Malaysia

(HORTCD 1989-2001/03)

46. **Enjalric, F and Assoumou, H G N** (1998)

Rubber growing in Gabon

Plantations Recherche Developpement, 5(5): 325-332.

Whilst the first rubber trees were planted in Gabon, during the Second World War, rubber growing did not really begin to develop until the early 1980s. The most favourable production areas are in the North of the country. The main obstacles to rubber development are the lack of family labour and the relatively long immature period of rubber trees. An overall approach including intercropping should help to overcome these constraints. Intercropping with rubber means developing crop management sequences for food crops likely to contribute to rubber tree upkeep and provide the planters with an income until the trees mature.

Keywords: Cropping system; Family labour; Plantation crop; Rural development; Gabon

47. **Enjalric, F; Nguema, J; Hugot, N and Chan Ho Tong, S (1999)**

Hevea brasiliensis and food intercrops: A development-oriented cropping system in Gabon

Plantations, Recherche, Developpement, 6(1): 10-11.

Hevea brasiliensis is a perennial species that is tapped as of approximately six years after planting, to provide a steady source of income. Including food crops in the interrows during the immature stages of the trees is a means of providing smallholders with additional income and some degree of food self-sufficiency. It is a determining factor for the establishment of rubber as a new crop in Gabon. The experiment work done since 1987 in northern Gabon by the Technical Support Centre for Rubber Growing (CATH), has resulted in a range of crop management sequences for improving the productivity of traditional holdings. Intercropping with food crops has a positive effect on rubber tree growth. The rice/ groundnut rotation gives satisfactory results, but it is plantain that generates the highest income. Over and above the economic advantages, it would be useful to understand the relations between the plants so as to propose the best crop combinations.

Keywords: Cassava; Economic aspect; Food crop; Groundnut; Maize; Plantain; Rice; Socioeconomics; Gabon

48. **Eschbach, J M (1996)**

European Union Research Projects: *Hevea*-based farming systems

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 96-99.

The European Union has been funding scientific and technological research since 1982, particularly in the agricultural field, in support of economic and social development in developing countries a research project is currently studying the functioning of *Hevea*-based farming systems. The aim of the project is to study the phenomena involved in competition for water, light and nutrients within the functioning of temporary intercropping systems combining *Hevea* with annual food crops, so as to identify the limiting factors and consequently optimize growth and yields in these farming systems.

Keywords: Economic aspect; Food crop; Rubber based Farming system

49. **Esekhade, T U (1997)**

Cooking banana is a promising perennial intercrop with rubber (*Hevea brasiliensis*)

MusAfrica, 11(14).

A sole crop of rubber saplings was planted at Akwete, Nigeria and allowed to establish for 18 months. This plot was then intercropped with cooking bananas (*cv. Cadaba*) planted at 4 densities between the rubber saplings: 6.7 x 3.4, 4.0 x 2.0, 3.0 x 3.0 or 2.0 x 2.0 m. The control treatment consisted of a sole crop of rubber. Fertilizers were applied as appropriate for the rubber saplings and the bananas were mulched with *Pueraria phaseoloides*. During the first two years of cropping, the growth of the rubber plants did not differ between the cooking banana treatments. In the most dense planting, banana

yields averaged 7.3 kg in the first cycle and 9.0 kg in the ratoon crop. The bananas crop created a conductive microclimate for rubber sapling growth.

Keywords: Banana; Nigeria

(HOA No.10998, 1997.)

50. **Esekhade, T U and Ojiekpon, F I** (1997)

Effects and economic viability of intercropping cooking banana with rubber in Nigeria

Indian Journal of Natural Rubber Research, **10**(1/2): 91-96.

Studies on the effects of intercropping cooking banana *cv cadaba* on the growth of rubber (*Hevea brasiliensis*) saplings were carried out from 1993 to 1996 at Akwete Nigeria. Banana was intercropped 18 months after planting rubber and four spacings were incorporated. No adverse effect of intercropping was noticed on the growth of *Hevea* saplings. The rubber + 4x2 m and 2x2 m spacings for cooking banana, had the highest girth increase rate with 0.23 and 0.22 cm per month. The highest mean cadaba bunch yield and production of suckers, of 9.0 t per ha and 3833 suckers per annum respectively, were observed in the rubber + 2x2 m spacing for cooking banana. This treatment also gave net present value of $ 1321.51, a profitability index of 2.59 and internal rate of return of 50 per cent. The 2x2 m banana spacing was the only treatment that had the capacity to optimize returns from the land and ensure cash flow into the rubber based farming business thereby improving the liquidity position of the system during the long gestation period.

Keywords: Banana; Economic aspect; Rubber based farming system; Nigeria

51. **Esekhade, T U; Ugwa, I K and Aigbekaen, E O** (1996)

Suitability and economic viability of intercropping in rubber on acid sandy soil of Southern Nigeria

Indian Journal of Natural Rubber Research, **9**(1): 36-39.

Results from field experiments on intercropping of cassava, cowpea and melon with rubber in sandy acidic (4.0-4.6pH) soil at Akwete Abia State, Nigeria showed that there was adverse effect on the girth and height of rubber plants. The rate of girth increase for rubber was from 0.19 to 0.21 cm/month. The nitrogen contents of the soils increased after intercropping. The rubber + cassava combination gave the highest yield of 6.5 t/ha and a net present value of 2,431 naira and an internal rate of return of 29 per cent, followed by the rubber + cassava + cowpea + melon combination with a yield of 3.8 t/ha, a net present value of 816 naira and an internal rate of return of 29 per cent.

Keywords: Cassava; Cowpea; Economic aspect; Melon; Soil property; Nigeria

52. **Esekhade, T U; Ojiekpon, F I and Ugwa, I K** (1999)

Weed management studies in rubber intercropped with cooking

banana in Southern Nigeria

Indian Journal of Natural Rubber Research, **12**(1/2): 103-107.

Intercropping of perennials such as cooking banana, is a new practice in young rubber plantations in Nigeria. This study was aimed at developing a suitable weed management strategy

under rubber plantations with cooking banana-intercropping system. The study was conducted at the Rubber Research Institute of Nigeria substation, Akwete, Nigeria from January to August 1995. The treatments were manual weeding with the use of hand hoe, spraying glufosinate ammonium (Basta 15) herbicide at 1.5kg ai per ha, mulching with cooking banana dried leaf mulch (CBDLM) to cover the bases of the crops and interrows and an integrated weed management involving slashing with cutlasses followed by a herbicide treatment using 0.75 kg ai per ha glufosinate ammonium (GA) after seven days and mulching with CDBLM on the next day. The predominant weeds in the area were *Chromolaaena odorata, Axonopus compressus, Scleria sp., Alchornea cordifolia* and *Anthocliesta sp.* The cover crops in rubber plantations like *Pueraria phaseolides, Centrosema pubscens* and *Desmodium sp.* were also included as these were not componenets of the intercropping system under the study. In the rubber+ cooking banana intercropping system the integrated weed management approach proved to be the most cost effective as it was able to explore the synergystic effect of optimum factor combination.

Keywords: Banana; Weed management; Nigeria

53. **Esekhade, T U; Orimoloye, J R; Ugwa, I K and Idoko, S O** (2003)

Potentials of multiple cropping systems in young rubber plantations

Journal of Sustainable Agriculture, 22(4): 79-94.

A two-year study was conducted at the Rubber Research Institute of Nigeria, Iyanomo from 1988-99, to evaluate the agronomic significance and economic potentials of utilizing resources in the vast inter rows of young rubber (*Hevea brasiliensis*) plantations. The experiment involved intercropping of 1, 2, 3 and 4 crops selected from cowpea, soyabean, melon, maize and cassava with young rubber. The most robust girth of rubber samplings was observed in the rubber+ soyabean+ melon and rubber+ melon+ maize systems, with 2.25 cm and 3.66 cm, respectively, in the 1998 and 1999 seasons.

Keywords: Economic aspect; Maize; Melon; Soyabean; Nigeria

54. **Esekhade, T U; Okore, I K; Ogeh, J and Idoko, S O** (2005)

Effect of fertilizer and mulch on the growth and yield of intercropped rubber/cooking banana and soil properties

Journal of Sustainable Agriculture and the Environment, 7(1): 26-39.

A field experiment was conducted on an acid sand soil at the Rubber Research Institute of Nigeria Benin city, to evaluate the effect of fertilizer and mulch on the soil properties, growth and yield of component crops in rubber/cooking banana intercropping system. Three cropping systems (sole rubber, rubber+cadaba and rubber+bluggoe cooking bananas) and three treatment applications of fertilizer and mulch (fertilizer, fertilizer+mulch and mulch) in a factorial combinations were taken in triplicates, laid out in a randomised complete block design. Two years after plantation establishment, the effect of cropping system on soil properties did not differ significantly. The application of fertilizer+mulch and mulch alone resulted in 9.6 and 14% increase in organic C, respectively and 14 and 17% decline in soil bulk density in that order, across the cropping systems. Total N, Bray-1P and CEC increased significantly, but no significant effect was recorded on soil pH and exchangeable acidity.

In the initial four years cropping systems effect on rubber stem girth was not significant. However, the application of fertilizer+mulch improved rubber stem girth by 73% relative to the control. Similarly, the combined application of fertilizer and mulch gave higher banana yield. Consequently, intercropping of rubber with cooking banana and combined application of fertilizer and mulch is suitable for soil fertility maintenance and crop growth and yield in the acid sand of southern Nigeria.

Keywords: Cropping system; Mulch; Soil property; Yield; Nigeria

(CAB Abstracts 2005/01-2005/09)

55. **Eugene, Alcala A** (2000)

Development of sustainable rubber-based farming system for smallholders in the Philippines

Proceedings of Indonesian Rubber Conference and IRRDB Symposium, 12-14 September 2000, Bogor, Indonesia.

Keywords: Rubber based farming system; Smallholding; Philippines

56. **FAO** (1975)

Preliminary bibliography of intercropping in rubber and oil palm

FAO, Regional office, Indonesia, No.12. 27p.

This bibliography presents a list of crops that can be grown as intercrops in rubber and oil palm in Indonesia, Thailand and Malaysia.

Keywords: Oil palm; Bibliography; Indonesia; Malaysia; Thailand

57. **Feng, Y Z; Wang, H L; Long, Y M and Zhang, J H** (1982)

Cultivated multistorey and multi specific associations of tropical crop plants, and beneficial effects of these communities on light intensity, soil fertility and soil moisture

In: Collected Research Papers on Tropical Botany, Yunnan Institute of Tropical Botany, Academia Sinica, China, pp. 42-55.

The results of shading experiments showed that *Camellia sinensis* var. assamica, *Coffea arabica*, *Cinchona ledgeriana* and *Rauvvoolfia yunnanensis* all require some degree of shading during the growing period. Growing these species under the shade of rubber trees improved the quality and quantity of their respective products and made better use of the available sunlight. Multistorey crop plant communities can also improve soil moisture conditions in parts of southern China where the rainfall is uneven and particularly heavy in the rainy season. Soil erosion is also reduced and soil fertility maintained or raised.

Keywords: Coffee; Shade plant; Soil fertility; Soil property; Tea; China

(HORTCD 1973-1988)

58. **Feng, Y Z; Wang, H L; Zhang, J H; Zhang, K Y; Ma, W J and Long, Y M** (1982)

Experimental and ecological studies on a mixed rubber and tea plantation

Acta Botanica Sinica, 24(2): 164-171.

From a 20-year study, it is concluded that better tea and rubber crops are produced when rows of rubber trees are interplanted with rows of tea bushes. The annual cropping cycle of the tea is 10 months, compared with 7 under monoculture, and bushes come into full production 3-4 years earlier. The tea crop benefits from the shade of the rubber and the rubber from extra light and sun on the trunks. Water loss from the soil is less and soil erosion reduced compared with monoculture of each crop. It is possible to grow mixed plantations at altitudes up to 1000 m whereas with monoculture the upper limit for rubber is 800 m.

Keywords: Ecology; Stimulant plant; Tea; China

(HORTCD 1973-1988)

59. **Furia, L R R** (2000)

Ecological interactions between maize *(Zea mays)* and rubber tree *(Hevea brasiliensis)* crops in an agroforestry system

Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, Brazil,

Keywords: Agroforestry; Maize; Brazil

(AGRIS 1999-2002/12)

60. **Garot, A** (1958)

Rice as a catch crop on a newly planted rubber estate at Tjikumpaj

Menara Perkebunan, 27:123-127.

In an experiment young rubber and rice are growing well together, the rubber showing 40-60% better growth and coming in to tapping half to one year earlier than plants of the same clone which are not being intercropped. The rice crop more than paid for the cost of cultivation.

Keywords: Economic aspect; Rice

(BPPM Abstract Bibliography of *Hevea* rubber: V 2, 1970.)

61. **Giriappa, S** (1995)

Plantation economy in India, M D Publications Pvt Ltd, New Delhi, India, 151 p.

This book analyses growth trends in area, production and yields of major plantation crops in India since the 1960s and examines the problems and prospects of cultivation of coffee, cocoa, rubber, black pepper (*Piper nigrum*) and cardamom in various regions of Karnataka and Kerala. Coffee cultivation is assessed in major coffee growing districts of Karnataka. The difference between small and large growers is somewhat marginal in *arabica* coffee performance, but on the whole large growers are more successful. Cultivation of intercrops has enabled growers to achieve better returns. The larger holdings have a better cost-benefit ratio. Cocoa has been a promising intercrop in arecanut plantations, as have black pepper and cardamom. The

performance of these crops is evaluated. Rubber is a fast emerging plantation crop which has a promising future. It is important that plantation crops become more export-oriented and competitive globally by means of technical progress, increased productivity and quality.

Keywords: Agroforestry; Economic aspect; Plantation crop; India

(HORTCD 1989-2001/03)

62. **Godon, P and Nguyen, G Q** (1997)

Rubber and cashew intercropping systems

Agriculture et Developpement, 6(15): 169-174.

The current changes in the economic and administrative situation favour the development of tree crops and, in turn, intercropping systems. On traditionally cultivated red soils, correcting aluminimum toxicity increases yields considerably. However, increasing soil tillage gives negligible net yield benefits compared to traditional cultivation techniques. On the under graded red soils of the plateau, chisel cultivation is very productive. Good levels of natural soil fertility are boosted by large applications of thermo phosphate. On sloping degraded soils, direct drilling leads to an efficient use of manure by rain fed rice. The first fertilizer application tested restored soil fertility to these soils. These proposals will optimize the production of intercrops. They will contribute to successful rubber, cashew, and coffee production in village plantations. Combining cash crops and food crops will aid development.

Keywords: Cashew; Coffee; Soil property; Vietnam

63. **Gohain, T; Meti, S; Punnoose, K I; Nazeer, M A and Chaudhuri, D** (2002)

Feasibility studies on intercropping of rubber (*Hevea brasiliensis*) with tea (*Camellia sinensis*) in Dooars area of West Bengal : 1. Initial growth and yield performance

Placrosym XV, 2002, Mysore, India. (Eds. K. Sreedharan, P.K.Vinodkumar, Jayarama and Basavaraj. M. Chulaki). Central Coffee Research Institute, Karnataka, India, pp. 406-409.

To study the feasibility of intercropping rubber with tea, an experiment was conducted at Regional Experiment Station, Nagrakata (West Bengal) during the year 1999. During the first three years of the experimentation, it was observed that rubber and tea were growing well without competing with each other for space, nutrients and soil moisture. Maximum growth (22.16 cm) of rubber was observed in the treatment where rubber was planted at a spacing of 12m x 2.4m along with tea at normal spacing (100 cm x 60 cm). However, in pure rubber plots at normal spacing, growth of rubber was low (16.83 cm). It may be due to irrigation given to tea plants in the mixed cropping system. Tea plants were growing well in all the treatments.

Keywords: Feasibility study; Growth; Tea; Yield; West Bengal; India

64. **Gomez, A A and Gomez, K A**

Multiple cropping in the humid tropics of Asia

IDRC-176e, International Development Research Centre, Ottawa, Canada,248p.

Multiple cropping can comprise sequential, inter- or relay cropping. This publication is concerned with production technology, research methodology and applied research, with particular

reference to multiple-cropping studies in the Philippines. Rice is the main lowland area crop, but the crops studied include those grown in upland and hilly areas (vegetables, tropical fruits, rubber, abaca and spices). Cropping patterns, productivity and economics are discussed.

Keywords: Abaca; Economic aspect; Multiple cropping; Rice; Spices; Tropical fruit; Philippines

(HORTCD 1973-1988)

65. **Grist, P and Menz, K** (1995)

Modelling the economics of *Imperata* control in smallholder rubber plantations

Improving Smallholder Farming Systems in Imperata Areas of Southeast Asia: Imperata Project Paper, No. 5, Centre for Resource and Environmental Studies, Canberra, Australia, 13p.

A version of the BEAM rubber agroforestry model (RRYIELD, developed at the University of Wales, Bangor, UK), modified for use by smallholders in Indonesia, and to incorporate the interaction between Imperata and rubber, is used to examine and promote the use of rubber in grassland regions infested with *Imperata cylindrica*. In this series, the model demonstrated a significant shading impact of rubber on *Imperata*, both in physical and economic terms. The effect of shade in controlling *Imperata* was profitably augmented by increasing the planting density of the rubber trees from 400 to 600-800 stems/ha. There was little difference in profitability at these high densities, and the results were applicable to the low intensity management conditions faced by smallholders. In this paper, the growing of improved rubber planting material (faster growing clones) is examined from the viewpoint of *Imperata* control by shading. Other options considered to augment the shading potential of rubber (by promoting rubber tree growth) are intercropping and chemical control. An economic analysis is made of the *Imperata* control treatments, of which there are a large number of possible combinations, especially when the timing dimension of each is considered. The analysis is restricted to options that are likely to be feasible relative to current practices, and those that looked promising on the basis of an exploratory analysis using the model.

Keywords: Agroforestry; Economic aspect; *Imperata cylindrica*; Weed management; Yield; Indonesia

(HORTCD 1989-2001/03)

66. **Grist, P; Menz, K and Thomas** (1995)

Modified version of the BEAM rubber agroforestry model: Smallholders in Indonesia

Improving Smallholder Farming Systems in Imperata Areas of Southeast Asia: Imperata Project Paper, No. 3, Centre for Resource and Environmental Studies , Australian National University, Canberra, Australia, 28 p.

The RRYIELD model is one of a series of bioeconomic models developed as part of the BEAM Project at the University College of Wales, Bangor, UK. It is a rubber-based model involving a number of bioclimatic, topographical and silvicultural variables. Commodities from it include latex, wood, and intercropped annual and perennial crops. The RRYIELD model is linked to the economic model RRECON, and the two models together are designed to be used as an extension tool for farmers on the viability of rubber intercropping systems.

This paper reviews and assesses the major functions and interactions in the original RRYIELD model, giving a critique, and making changes to reflect conditions facing smallholder producers in Indonesia on *Imperata cylindrica* infested grasslands. The functioning of the RRECON model is also addressed.

Keywords: Agroforestry; Cropping system; Economic aspect; *Imperata cylindrica*; Indonesia

(CAB Abstracts 1996-1998/07)

67. **Grist, P; Menz, K and Thomas** (1998)

Modified BEAM rubber agroforestry models: RRYIELD and RRECON

ACIAR Technical Reports Series, No. 42.

This paper details changes to the BEAM models RRYIELD and RRECON, which are two of a series of bio economic models developed by the Bioeconomic Agroforestry Modelling (BEAM) project based at the School of Agricultural and Forestry Sciences at the University of Wales, Bangor, UK. The RRYIELD model deals with the biophysical components of a rubber based agroforestry system, focusing on changes in output (latex, wood and intercropped annual and perennial crops) in response to a number of bioclimatic, topographic and silvicultural variables. Outputs are measued annually over the life of the plantation. The RRYIELD model is linked to an economic model, RRECON, which is used to determine economic returns from a rubber plantation. The two models are designed to be used in combination as an extension and research tool to supply farmers or researchers with information on the viability of alternative rubber intercropping systems. The work reported here was carried out as part of the project 'Improving smallholder farming systems in *Imperata* areas of Southeast Asia- a bioeconomic approach', based at the Australian National University. The original model was developed for large estates and government plantations and, therefore, embodied high levels of management. The changes outlined here aimed to make the model more applicable to smallholders in *Imperata* infested areas on SE Asia, especially Indonesia.

Keywords: Agroforestry; Cropping system; Economic aspect; *Imperata cylindrica*; Weed management; Indonesia

(CAB Abstracts 1996-1998/07)

68. **Guha, M M; Nd Kwi and Soong Ngin** (1969)

Suitability and prospects of rubber-growing soils for intercropping

Proceedings of Crop Diversification in Malaysia Conference, 1969,Kuala Lumpur, Malaysia.

Keywords: Soil property; Malaysia

(Cited by Mohd Yusoff, M N *et al.*)

69. **Guotai, Bu** (1984)

An Investigation into the effects of intercropping pineapple in rubber plantations

Tropical Crops Science and Technology, 3: 57-58.

Keywords: Pineapple

(Cited by Lin, W. etal.)

70. **Haris, B A; Chozin, M A and Sopandie, D** (1999)

Ecosystem characteristic of upland rice and rubber plants intercropping

Proceedings of the Seminar on Increasing National Rice Production through Tabela (direct sowing) System of Lowland Rice and Utilization of Unproductive Land, 9-10 December 1998, Bogor, Indonesia, pp. 449-454.

The objective of this experiment was to study the ecosystem characteristic of intercropping between upland rice and rubber plants (0, 1, 2, 3 and 4 years old). The specific objective was to determine the critical level of light intensity (LI) for developing upland rice as an intercrop. The results revealed that the average LI under 0,1, 2, 3 and 4 year old rubber canopies were 398.0, 326.7, 237.0, 109.6 and 32.2 cal/cm2/day, respectively. Upland rice showed a normal growth under 0, 1 and 2 years old rubbers. High variabilities in growth performance and yield were observed when they were grown under 3-years old rubbers. Shading treatment of 0, 25 and 50 percent using paranet resulted LI 309.12, 224.3 and 130.1 cal/cm2/day. High variabilities in growth performance and yield were found in a 50 percent shading condition. Tolerant genotypes of upland rice had higher light interception as compared with sensitive lines. The results revealed that critical level for developing upland rice, as intercrop was 50 percent shading, which reflected LI under three years old rubbers.

Keywords: Ecology; Light intensity; Upland rice; Indonesia

(AGRIS 1999-2002/09)

71. **Herath, P H M U and Takeya, H** (2003)

Factors determining intercropping by rubber smallholdres in Sri Lanka: A logit analysis

Agricultural Economics, 29(2): 159-168.

Variables related to farmers' awareness and attitudes towards intercropping of immature rubber (*Hevea brasiliensis*) stand, extension contacts, education level, and experience with farming other crops are positively associated with the probability of adoption. Higher levels of off-farm income are associated with reduced intercropping in immature rubber stands. Farmers who are sole owners of the land and engaged in full or part-time rubber farming show lower adoption rates than other land ownership groups. Social participation, family size, experience with farming rubber, immature and mature rubber stands size, and the nature of the land (flat/sloped) do not significantly influence adoption. These conclusions were obtained from a logit model estimated by employing the results of a survey of 588 smallholder rubber farmers from five major rubber-growing regions in Sri Lanka.

Keywords: Logit model; Smallholding; Survey; Sri Lanka

72. **Hoang, K and Mai, V Q** (1997)

A study on the intercropping of peanut in young rubber plantations in the South-East region of Vietnam

Rubber Smallholdings, NR Processing and Quality and Technology Sessions, IRRDB Symposium on Natural Rubber (Hevea brasiliensis), 14-15 October 1997, Ho Chi Minh City, Vietnam, 3: 32-41.

A study on cropping systems suitable for young rubber (*Hevea brasiliensis*) plantations in the South-East Region (SER) of Vietnam was conducted for six years (1991- 1996) by the Institute

of Agricultural Science of South Vietnam. Intercropping peanut (*Arachis hypogaea L*) in young rubber plantations was an advantageous technology, suitable for the agro-ecological conditions and the economic situation of farmer households. The new technology contributed to improving the effectiveness of land-use, increasing farmers' income and enhancing soil protection and weed control as well as maintaining soil fertility in the rubber plantations. Pea nut variety HL25 was a new peanut variety suitable for intercropping with young rubber and other farming systems in SER. Application of inorganic fertilizer (NPK) and lime as well as the spraying of foliar fertilizers significantly improved the economic effectiveness of intercropping peanut and young rubber. The optimum fertilizer recommendation was 40-60 N+80-100 P_2O_5+60-80 K_2O+300-1000 lime (kg/ha) + 3.5 litres of Biotop/ha. The use of the new peanut variety HL25 with the application of intensive cultural practices might obtain a profit off 1.2 to 3.9 million VND/ha, whilst traditional cultural practices (Using local variety Giay and low fertilizer application) only obtained a profit of 0.2 to 1.9 million VND/ha. The new technology could be widely expanded to young rubber plantations in SER.

Keywords: Cropping system; Economic aspect; Peanut; Soil fertility; Vietnam

73. **Hunter, J R and Camacho, E** (1961)

Some observations on permanent mixed cropping in the humid tropics

Turrialba, **11**: 26-33.

The net returns for 1959 from a mixed planting of rubber and cacao were 35% higher than from a rubber plantation of equal area. In the first plantation there were 145 rubber trees per acre in double rows widely spaced and 305 cacao trees per acre in 7-row stands between the double rows of rubber. In the second plantation there were 207 rubber trees per acre. The undergrowth in the rubber plantation needed cutting 2-3 times a year, but in the mixed plantation there was only a thin growth of weeds between the double rows of rubber with a natural mulch of leaf litter under the cacao.

Keywords: Cocoa; Mixed farming; Humid tropics

(BPPM Abstract Bibliography of *Hevea* rubber: V 2, 1970.)

74. **ICWAI** (1999)

Intercropping in immature rubber plantation

In: Formulations of Farm Accounting Guidelines on Rubber Plantation Industry, Institute of Cost and Works Accountants of India, Calcutta, 1999, pp. 14-18.

Intercropping of suitable crops such as pineapple, banana and ginger in immature phase is carried out by smallholders in Kerala. The net estimated income from the above crops is also worked out.

Keywords: Banana; Economic aspect; Ginger; Pineapple; Smallholding; Kerala; India

75. **Iqbal, S M M** (1993)

Multicropping of rubber with tea

Bulletin of the Rubber Research Institute of Sri Lanka, **30**: 30-33.

The main objective of this paper is to utilize the row space in rubber plantations to grow crops that would give an income during the unproductive period for 5 to 6 years and also

during the productive period on wet days when harvesting of rubber (tapping) is not possible. This would increase productivity per unit area of land thereby increasing the productivity of individual estate units with a view to making such units profitable and economically viable, and also helps to generate more employment, which would enable estates to utilize the available labour resources more efficiently and profitably.

Keywords: Economic aspect; Family labour; Mutiple cropping; Tea; Sri Lanka

76. **Iqbal, S M M; Ireland, C R and Rodrigo, V H L** (2005)

Ecophysiological limitations to the productivity of tea in the rubber-tea intercropping systems

International Natural Rubber Conference India 2005: *Preprints of Papers*, 6-8 November 2005, Cochin, India, pp. 152-156.

The present study aimed to determine how major agro-physiological factors influence the productivity of tea on rubber/tea intercropping system. Field experiments were conducted on a mature rubber-tea intercrop at the Ratnapura Rubber Research Institute field station in S W Sri Lanka. The effect of intercrop spacing in combination with different levels of canopy shade were examined on intercrop yield and on a range of growth and physiological parameters. In a standard rubber-tea intercropping system comprising of single rows of rubber with tea interplanted in alleys, the land equivalent ratio (LER) of the intercrop exceeds unity indicating an improved combined yield. The crop performance ratio(CPR) of rubber exceeds unity, however, the CPR of tea was reduced below unity. The growth and yield of tea is limited by both the extent of the canopy shade, and by the below ground inter root competition. The removal of effective inter-root competition imposing root barrier that effectively separate the rubber and tea root system increases tea growth and yield but has no effect on rubber productivity. The increased productivity shown by tea intercropped with rubber when below-ground inter-plant competition is removed is based on an increase in both radiation and water use efficiency. The main current recommendations offered by the RRISL to smallholders for rubber-tea intercrop establishment are concerned with planting regimes and drainage. Employ a double row system for rubber with tea intercropped in 18m wide alleys and to plant intercrop rows in an east-west orientation on land with gradients not exceeding 1 in 15. On land with steeper gradients planting to follow contours. The present study make some revisions to these recommendations. Obtained improved overall yields from rubber-tea intercrops compared to sole rubber crops.

Keywords: Ecophysiology; Shade; Planting density; Tea; Sri Lanka

77. **Jayasree, K R; Jessy, M D; Nair, A N S and Punnoose, K I** (2005)

Intercropping and its effect on growth of young rubber: A survey report

Rubber Board Bulletin, **28** (1): 2-5.

A survey was conducted in the smallholdings of Kottayam, Kerala, India, during 1999-2000 to study the extent of intercropping on the growth of rubber. Eighty percent of the small holders in the region cultivated intercrops in rubber plantations during the initial two years. Sixty seven percent of farmers cultivated banana as intercrop and fourteen percent cultivated pineapple. Intercropping did not affect the growth of rubber adversely.

Keywords: Banana; Pineapple; Smallholding; Survey; Kerala; India

78. **Jayasuriya, K E and Wettasinghe, D S (2004)**

Impact of white root disease incidence on rubber intercropped with tea or cinnamon

Bulletin of the Rubber Research Institute of Sri Lanka, 45: 60-71.

The arcticle discusses some facts on the importance of controlling the white root disease in tea and rubber intercropped lands during the early stages.

Keywords: Cinnamon; Tea; White root disease; Sri Lanka

79. **Jessy, M D and Punnoose, K I (2001)**

Intercrops (Malayalam)

Rubber Mithram, 3(2): 28-32.

The different intecrops like banana, pineapple, ginger, turmeric, vegetables, tuber crops and medicinal plants etc. that can be planted in rubber plantations are described. The advantageous of planting intercrops and the necessary features to be selected as intercropping rubber plantations are also discussed.

Keywords: Banana; Coffee; Ginger; Medicinal plant; Pineapple; Turmeric; Vegetable; Tuber crop; India

80. **Jessy, M D; Philip, V; Punnoose, K I and Sethuraj, M R (1997)**

Multispecies cropping system with rubber: A preliminary report

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 81-89.

A cropping system experiment, which included diverse annual and perennial intercrops with rubber, was started at the Central Experimnet Station of the Rubber Research Institute of India and State Farming Corporation of Kerala, Punalur, India in 1993. Rubber was planted in paired rows at spacing of 9.0m with a distance within paired rows of 5.1m. Banana, pineapple, pepper and cocoa were planted in the wider interrow spaces and a *Pueraria phaseoloides* legume cover was established in the narrow interrow spaces. Teak and fodder grasses were grown along the boundaries. An increase in organic matter and available phosphorous and a decline in available potassium content of the soil was noticed after 30 months. Growth of rubber was significantly superior in the present system compared to that in monoculture. The nutrient budget of the system indicated a net gain of all nutrients. Land utilization pattern of the present system indicated a possibility of increasing the density of the component crops. Benefit cost ratio of banana, pineapple and fodder grass were 2.58,2.26 and 2.07, respectively. Indicating the economic feasibility of growing banana and pineapple as intercrops with fodder grass along the boundaries during the initial three years.

Keywords: Banana; Benefit cost ratio; Cocoa; Cropping system; Economic aspect; Fodder grass; Pepper; Pineapple, Teak; Soil fertility; Soil property; India

81. **Jessy, M D; Philip, V; Punnoose, K I and Sethuraj, M R** (1998)

Evaluation of a multispecies cropping system during immaturity phase of rubber

Indian Journal of Natural Rubber Research, *11*(1&2): 80-87.

A cropping system experiment including diverse annual and perennial intercrops with rubber was started at the Central Experiment Station of the Rubber Research Institute of India in 1993. Rubber was planted in paired rows 9.0 m apart. The distance within the paired rows was 5.1 m. Banana, pineapple, black pepper and cocoa were planted in the wider intertrow spaces and legume ground cover *Pueraria phaseoloides* was established in the narrow inter row spaces. Teak and fodder grass were grown along the boundaries. An increase in organic matter and available phosphorous and a decline in available potassium content in the soil was noticed after 30 months. Growth of rubber was significantly superior in the present system compared to that in monoculture. Nutrient budget of the system indicated a net gain of all the nutrients studied. Benefit-cost ratio of banana, pineapple and fodder grass was 2.58, 2.26 and 2.07 respectively indicating common feasibility of growing banana and pineapple as intercrops and fodder grass along the boundaries during the initial three years. An evaluation of the system also indicated sustainability in terms of soil fertility maintenance.

Keywords: Banana; Cocoa; Cropping system; Economic aspect; Fodder grass; Pepper; Pineapple; Soil fertility; Soil property; Teak; India

82. **Jessy, M D; Punnoose, K I and Nayar, T V R** (2001)

Crop divesification and its sustainability in young rubber plantation

Journal of Plantation Crops, **33**(1): 29-35.

In an experiment commenced at the Central Experiment Station of the Rubber Research Institute of India in 1993, rubber was planted in paired rows 9.0m apart. The distance within the paired rows was 5.1m. The number of rubber plants per hectare was 406. Diverse annual, short term and perennial crops (banana, pineapple, amorphophallus, dioscorea, colocasia and arrow root, coffee and pepper) were planted in the wider inter row spaces. Legume ground cover *Pueraria phaseoloides* was established in the narrow inter row spaces. Teak and fodder grass were grown along the boundaries. Intercrops were grown during the entire immaturity period of rubber. Growth of rubber was significantly superior in this system compared to the monoculture. An increase in soil available P and K status was noticed after six years. Leaf analyses indicated competition for K at certain stages. Benefit cost ratios of growing banana, pineapple, amorphophallus, dioscorea, colocasia, arrow root and fodder grass along with rubber were 2.58, 2.65, 1.91, 1.27, 0.94, 1.14 and 1.94 respectively. Performance of perennial crops was poor. Light infiltration studies indicated that the availability of photosynthetically active radiation dropped to 1.41 per cent of the open area at the end of six years.

Keywords: Amorphophallus; Arrow root; Banana; Coffee; Colocasia; Cropping system; Dioscorea; Pepper; Pineapple; Soil fertility; Soil property; Kerala; India

83. **Jose, M J** (2002)

Pineapple intercropping in rubber

In: Global Competitiveness of Indian Rubber Plantations Industry: Rubber Planters' Conference, India 2002, (Ed. C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, India. pp. 89-92.

Intercropping pineapple in the initial three years of rubber cultivation is an accepted practice in many parts of Kerala. In a replanting area of 1.40ha planted during 2000, pineapple was intercropped and the cost of cultivation of pineapple for the three years is presented.Similarly, the year wise cost of cultivation for rubber is also worked out and presented. The details of the cultural operations followed, the labour charges and the cost of inputs for the two crops are also presented. The profit from pineapple cultivation for the three years from an area of 1.40 ha was Rs. 1,50,225/-. The cost of cultivation of rubber for three years was Rs. 38, 355/-. The commutative net profit for the three years through pineapple intercropping from an area of 1.40 ha of rubber was Rs.1,11,870/-.

Keywords: Banana; Ginger; Economic aspect; Pineapple; Kerala; India

84. **Joseph, M** (1999)

Studies on some competing factors in the intercropping systems of rubber (*Hevea brasiliensis* Muell. Arg.)

PhD Thesis, Kerala Agricultural University, Thrissur, 95p.

Field experiments were conducted at the Kerala Agricultural University during 1994-97 to study the extent of involvement of root level competition and competition for light in the early years of growth of rubber. Rooting pattern of rubber was studied employing ^{32}P soil injection technique. Activity was applied at varying lateral distances. In another experiment, rubber was intercropped with banana cv. Poovan under two systems of planting. In a third field experiment, the intensity of light infiltration through rubber canopies of varying ages was studied. The active roots of rubber are concentrated in radial distances of 50, 100 and 150 cm from the plant during the first, second and third years of growth respectively. Banana can be grown in the inter row spaces of rubber as a rainfed crop during the initial three years. Insufficiency of filtered light through the rubber canopy will limit the scope for intercropping beyond the third year of growth of rubber.

Keywords: Banana; Fruit crop; Plantation crop; India

85. **Joseph, T; George, K T; Veeraputhran, S and Mohanakumar, S** (1995)

Are medicinal plants viable as intercrops?

Rubber Asia, 9(3): 105-110.

An experiment conducted by the Rubber Research Institute of India on the intercropping of medicinal plants with rubber indicate the possibility of growing six plants which have good market potential. Based on the analysis, the two plant varieties worth considering for intercropping in mature rubber plantations on a limited scale appear to be *Plumbago rosea* and *Kaempferria galanga* in terms of the market potential.

Keywords: Economic aspect; Medicinal plant; Kerala; India

86. **Joseph, T; Punnoose, K I; Haridasan, V; Mathew, M and Mani, J** (1988)

A survey of agro-economic conditions of the small rubber growers in Anakkara village of Idukki District

Rubber Board Bulletin, 24(1): 12-15.

A survey was conducted in 1986 amongst 90 small rubber growers in the high elevation tract of Anakkara village in Idukky District, Kerala to study the practice of intercropping. The growers were members of a social service organization and the data were collected with the help of questionnaires sent through a selected group of volunteers. From the information collected, detailed analysis were made on planting materials used, intercrops cultivated, intercropping pattern in relation to size of holding and economics of intercropping. The survey revealed that the rubber growers were increasingly using modern varieties of planting materials. Small growers preferred one intercrop and black pepper [*Piper nigrum*] was the most commonly used species.

Keywords: Economic aspect; Pepper; Smallholding; Survey; Idukky; Kerala; India

87. **Junaidi, U and Arifin, S** (1989)

Cropping pattern for smallholders' rubber upto three years' old

Proceedings of the Rubber Research Institute of Malaysia, Rubber Growers' Conference, Malacca, Malaysia, 1989, pp.137-165.

Food crops or non- perennial crops have been designed and tested at the Sembawa Research Institute for Estate Crops, to improve farmers' cropping patterns. Two kinds of cropping pattern have been tested: Rubber+ Food crops A (corn+ upland rice –soybean-cowpea), and Rubber+ pineapple. The objective of these experiments was to get information on the potential yield of the intercrops and to determine their impact on rubber growth. The experiments were carried out for three years, from 1985/86 upto 1987/88. The results showed that food crops planted between rows of rubber trees provided good yield in the first year, which gradually decreased during the next two years. Pineapple gave good yields and growing intercrops gave positive impact to rubber growth.

Keywords: Corn; Cowpea; Food crop; Pineapple; Soyabean; Upland rice; Sembawa; Indonesia

88. **Juriprik, S** (1996)

Rubber intercropping: Rubber Smallholders Community Development Project: An ecological and self-reliant new alternative; Thailand case study

Conference on Monocultures, Environmental and Social Effects and Sustainable Alternatives, 2-6 June 1996, Songkhla, Thailand

Keywords: Community development project; Ecology; Smallholding; Thailand

(www.google.com)

89. **Kaewbamroong, M** (1976)

Pineapple (Nenas) as an intercrop between rubber rows at Phuket

In: Progress and Development of Rubber Smallholders: Proceedings of the Second Seminar, 18-23 October 1976, Hat Yai, Thailand, pp161-165.

Intercropping of pineapple has greatly expanded in the Phuket region during the last five years covering around 40% of the total present rubber replanted area. The paper gives information on the varieties, cultural practices, areas and the percentage of rubber replanters involved with this intercrop. It concludes by showing the attractive net returns obtained by the rubber smallholders.

Keywords: Economic aspect; Pineapple; Smallholding; Thailand

90. **Keli, J Z et al.** (1991)

Developmental aspects of young rubber trees intercropped with food crops in the southern Ivory Coast

Agronomie Africaine, 3(2): 77-85.

Keywords: Food crop; Ivory Coast

(ATA No.88133, 1993.)

91. **Keli J Z; Obouayeba, S and Zehi, J K** (1992)

Influence of some food crop systems on young rubber trees in the lower Ivory Coast

Agronomie Africaine, 4(2): 91-101.

A study on the intercropping of rubber (*Hevea*) and food crops was conducted in the Ivory Coast from 1986 to 1988. The effects of food crop rotation and various methods of fertilization on the growth of young rubber trees were determined. Food crops had a favourable effect on the growth of the rubber trees, but yields varied widely. Chemical fertilizer for food crops had positive effects on the rubber trees from the third year onwards. At this time the rubber tree roots began to use the soil of the inter-rows.

Keywords: Food crop; Growth; Ivory Coast

(ATA No. 92644, 1994.)

92. **Keli J Z; Omont, H; Hainnaux, G and Zagbahi, J K** (1990)

The temporary association of rubber and food crops in south Cote d'Ivoire.

Revue Generale des Caoutchoucs et Plastiques, 701: 181-187.

In a trial in 1984-86, rotations of several crops including yams [*Dioscorea*], rice, maize, groundnuts and plantains grown between the rows in plantations of young rubber trees were compared with use of the cover legume *Pueraria*. The performance of the rubber trees in terms of stem circumference was better with the food crops than with *Pueraria*, probably due to the beneficial effects of the fertilizers applied to the food crops. The food crops had no significant effect on the incidence of root diseases or on levels of N and P in

rubber leaves, but they gave lower levels of leaf Ca and Mg and higher levels of leaf K than *Pueraria*.

Keywords: Cover crop; Cropping system; Groundnut; Maize; Plantain; Rice; Yam; Ivory Coast

(HORTCD 1989-2001/03)

93. **Keli, J Z; Omont, H; Dea, B G; Kouadio, A M C and Obouayeba, S** (1997)

Rubber-based farming systems with annual and perennial intercrops in the Ivory Coast: Overview of 20 years of trials

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 46-55.

The problem of stabilizing *Hevea*-based farming systems on rubber plantations in a non-estate environment is looked at from the angle of intercropping rubber with the food and cash crops found in such a smallholder environment. Two types of intercropping system, temporary and long-duration, were studied with a view to guaranteeing farmers: family consumption; possible additional income while the rubber trees are in their unproductive period; diversification and stabilization of their farming systems. Results obtained with rubber/food crop intercropping, both at experimental stations and in the true context shows that these practices can be used in the traditional agricultural environment without damage to the rubber trees, provided that the economic impacts are assessed and varietal and weeding problems are mastered. As regards long-duration intercropping involving a planting design with widely spaced rubber trees, the hope of achieving a permanent association is obviously with a view to stabilizing agriculture in increasingly limited rural areas. In this case, it is too early to draw any definite and comprehensive conclusions but the initial results are promising.

Keywords: Cash crop; Economic aspect; Food crop; Rubber based farming system; Socioeconomics; Ivory Coast

94. **Khan, N A; Khisa, S K; Ya, T and Tulachan, P M** (2001)

An ethnographic enquiry into the adoption of contour hedgerow intercropping agro forestry technology by the farmers in the Chittagong Hill Tracts, Bangladesh

Mountain Agriculture in the Hindu Kush Himalayan Region: Proceedings of an International Symposium, 21-24 May 2001, Kathmandu, Nepal, pp. 75-78.

A study was conducted to investigate the dynamics of the adoption of contour hedgerow intercropping agro forestry technology (CHIAT) by the Upland Settlement Project farmers in Bangladesh. Each farming household was allotted a total of 2.1 ha of land, out of which 0.5 ha was intended for homestead agroforestry, and 1.6 ha for raising rubber intercropped with banana. At the time of survey 42% of the respondent farming households actively practiced CHIA. The farmers who practiced Chiat gave the following reasons: it helps reduce soil erosion, restores soil fertility, encourages diversified cropping and economically more rewarding than shifting cultivation. The constraints to adopting CHIAT, conclusions and recommendations are outlined.

Keywords: Agroforestry; Banana; Contour cultivation; Soil fertility; Bangladesh

95. **Kingsly, P S** (1993)

Economic analysis of banana, tapioca and ginger as intercrops in rubber plantations in Trichur Taluk

Dissertation, P G Diploma in Natural Rubber Production, Kerala Agricultural University, Thrissur, India, 43p.

This study presents an overview of the pattern and economic analysis of intercropping banana, tapioca and ginger in immature rubber plantations in Trichur Taluk of Kerala, India. The growth of immature rubber in terms of growth was favourably influenced by intercropping banana in ginger. Nendran banana was found to be the best profitable intercrop followed by poovan and ginger. Tapioca intercropping in general adversely affects the growth of young rubber.

Keywords: Banana; Economic aspect; Ginger; Tapioca; Trichur; Kerala; India

96. **Kouadio, A M C; Keli, J Z and Dea, B G** (1996)

Food crops association with *Hevea* in Cote d' Ivorie: Resulting effect on production

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 10-16.

The study of the effects of the planting of different foodcrop systems showed that their use leads to a rubber yield per hectare of some twenty-five percent (25%) higher than that a standard plot with leguminous plants as the interrow cover plants. This higher yield appeared to be related to the known precocity of *Hevea* trees in association with food crops. The difference between the trial samples gradually decreases with time. The results indicate the impact of the competition of the leguminous cover plants on *Hevea* trees during their immature growth. This depression, lower with food crops, leads to production gains at the opening of the trees.

Keywrods: Economic aspect; Food crop; Ivory Coast

97. **Krishnankutty, P N** (1977)

A study of intercrops in smallholdings in India

In: Progress and Development of Rubber Smallholders: Proceedings of the Third ANRPC Seminar, 24-30 November 1977, Cochin, India, pp191-195.

The Rubber Board of India is operating a replanting subsidiary scheme in order to replant old and low yielding rubber areas with high yielding planting material. To popularize replanting in smallholdings, intercropping with selected seasonal crops is permitted during the first three years of replanting. A study was made in 1976 to find out the most profitable intercrop cultivated in smallholdings. A sample of ninety replanters was selected for the study. It revealed that ginger was the most profitable intercrop, providing the largest net return per hectare. It was also found to be an acceptable intercrop in many other respects. The 'nenedran' variety of bananas is also profitable as an intercrop although its net returns are not as high as for ginger. Intercropping of tapioca (Cassava) though popular among

smallholders is not as remunerative as ginger or bananas. Further, it has the disadvantage or impoverishing the soil and thereby retarding the growth of young rubber. The cultivation of paddy was least attractive among all the intercrops studied.

Keywords: Banana; Ginger; Tapioca; Kerala; India

98. **Kummerow, J and Ribeiro, S L** (1982)

Fine roots in mixed plantations of *Hevea* (*Hevea brasiliensis* H.B.K Mull. Arg.) and cacao (*Theobroma cacao L.*)

Revista Theobroma, 12(2): 101-105.

Fine roots of both crops occupied, mainly the top 15 cm of the soil, and 2-9 times more rubber tree roots were found in all soil samples. Rubber roots were 3 times thicker than cocoa roots. The findings are discussed in relation to fertilization in a mixed rubber-cocoa plantation.

Keywords: Cocoa; Mixed farming; Root activity; Brazil

(HORTCD 1973-1988)

99. **Lal, R B** (1993)

Choice of species in plantations for rehabilitation of 'jhumias'.

VanVigyan, 31(3-4): 82-89.

The suitability is discussed of plantation crops and other tree species in the development of areas affected by shifting cultivation (jhum), particularly in the northeastern region of India. Tree species such as *Alnus nepalensis*, *Pinus roxburghii* and *Cinnamomum spp.* have been found promising in the regions of Manipur, Mizoram and Nagaland for reclamation of jhum lands. These are fast growing short rotation tree species which can be grown in combination with maize, cotton or other hill crops, and with shade loving cash crops like cardamom, rubber, tea, coffee etc., thus offering an easy means for rehabilitation of jhum lands and use by jhumias (shifting cultivators). Fodder trees such as *Acacia auriculiformis*, *Schima wallichii*, *Leucaena leucocephala*, *Artocarpus chaplasha* and *Gmelina arborea* are suitable on marginal farmland and community lands.

Keywords: Agroforestry; Agrosilvicultural system; Cardamom; Cash crop; Coffee; Cotton; Maize; Tea; North Eastern Region; India

(HORTCD 1989-2001/03)

100. **Lal, V L; Thanh, T P; Pham, T D; Le, M T and Ngo, V H** (1996)

Intercropping with *Hevea* in Vietnam

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 113-116.

Intercropping with annual and perennial crops in rubber fields, which has contributed to the improvement in the income of rubber growers and also the effective usage of land, has

been practised by both estates and smallholdings in Vietnam for a long time. Modified systems, with hedgerow planting techniques, have also been adopted to improve the effectiveness of intercropping in rubber plantations. Social and economic aspects of intercropping with *Hevea* are discussed.

Keywords: Annual crop; Economic aspect; Perennial crop; Socioeconomics; Vietnam

101. **Laosuwan, P; Saengpratoom, S; Kalawong, S and Thongsomsri, A** (1991)

Breeding mungbean for shade tolerance.

Proceedings of the Mungbean Meeting, February 23-24 1990, Chiang-Mai, Thailand, pp. 95-100.

Ten cultivars or lines of mung beans or *Vigna mungo* were grown in pots at 100, 90 and 50% of normal light intensity. Pod number and root DW were decreased, and plant height increased, in mung beans grown at 90% of full sunlight. Seed yield and plant and leaf DW were decreased, and flowering date delayed at 50% light intensity. Seed yields were highest in mung beans cv. PSU 107-3 and PSU 1. Flowering and maturity dates of PSU 1 were least affected by shading, and this cultivar was recommended for intercropping between rows of young rubber trees. *V. mungo* cv. U-Thong 2 and BC 48 produced much higher seed yields than mung beans cv. KPS 1 and PSU 1 at 100 and 90% light intensity, but yields at 50% light intensity were similar..

Keywords: Light intensity; Mungbean; Shade; Thailand

(CAB Abstracts 1991-1992)

102. **Laosuwan, P; Sripana, P; Sirisongkram, P and Tongsomsri, A** (1987)

Potential of food legumes as intercrops with young rubber

Australian Centre for International Agricultural Research (ACIAR) Proceedings, 1987, Canberra, Australia, pp. 240.

In two experiments at Songkhla in 1981-85 mung beans, soyabeans, groundnuts or maize were sown between rows of rubber of differing ages. Crop yields tended were low mainly due to disease and soil variability. There was no obvious effect of shading by rubber on the yield of intercrops in successive years. In a second experiment intercrops of mung beans + groundnuts, maize + upland rice, pigeon peas, a legume cover or bananas with rubber over two years performed well in all cases. Groundnuts and mung beans yielded 1.8 t/ha. Mung beans + groundnuts and maize + upland rice intercrops gave the largest girth increments in rubber.

Keywords: Groundnut; Maize; Mungbean; Soyabean; Thailand

(CAB Abstracts 1984-89/May)

103. **Laosuwan, P; Yeedum, I; Sripana, P and Sirisongkram, P** (1988)

A study on intercropping of young rubber: 1 Yield potential of different intercrops.

Thai Journal of Agricultural Science, **21**(3): 179-188.

In a trial carried out during 1981-86, rubber was planted with a spacing of 7 m between rows and 3 m between trees within the rows and was then intercropped with a legume cover

crop mixture including *Calopogonium mucunoides, Centrosema pubescens* and *Pueraria phaseoloides*, or with mung beans [*Vigna radiata*], soyabeans, groundnuts, rice, maize, bananas or pineapples. Mung beans and groundnuts gave average yields of 0.59 and 1.15 t/ha, respectively, but soyabeans gave only low yields of 1.21 t/ha. Rice given 40 kg N and 21.5 kg P/ha yielded 2.14 t/ha, and maize given 93.8 kg N, 40.2 kg P and 75 kg K/ha yielded 2.96 t grain/ha. Bananas planted at 477 plants/ha began to yield early in the 2nd year and gave 2082 bunches/ha annually. Pineapples also began to yield in the 2nd year, and at 17 000 plants/ha gave 11 572 fruits/ha annually. The legume cover crop established rapidly and inter-row weeding was not needed.

Keywords: Banana; Economic aspect; Groundnut; Legume cover crop; Maize; Mungbean; Pineapple; Rice; Soyabean; Weed management; Yield; Thailand

(HORTCD 1989-2001/03)

104. **Lasminingsih, M; Wibawa, G; Boerhendhy and Suhaimi, A** (1998)

Evaluation of latex timber producing clones and integration of forest trees at plantation

Proceedings of the National Meeting on Rubber Breeding in 1998 and Discussion of Natural Rubber Prospect in 21st Century, 8-9 December 1998, Indonesia, pp. 73-91.

The development of agro forestry project (HTI) by Department of forestry and estate crops is one of several alternatives to anticipate the decrease of the natural forest as a source of timber production for wood industries. Rubber (*Hevea species*) is one of the recommended tree crops for HTI, where its timber has several advantages such as good quality and several clones have a good girth growth. The output of rubber based HTI determines the choice of technical practices to be adapted: starting with type of planting materials, clones, spacing, intercropping and harvesting systems. Various clones producing timber and latex, results of breeders in Indonesia or in other countries, can be developed in HTI. Rubber based perennial cropping system research projects, which is based on the objective to obtain latex and timber are currently tested in Indonesian Rubber Research Institute. The first, sengon and several latex timber-producing clones were planted as intercrops in between doubled row (4m x 2m) x 16m of main rubber BPM 24. The second is thinning out method of rubbers planted with high density (2000 trees/ha). The preliminary findings showed that no effect of intercrops on rubber growth is observed either in the first or the second experiments. More observations are still needed.

Keywords: Agroforestry; Forest tree; Perennial crop; Indonesia

105. **Lin W; Chen, Q; Zhou, Z and Huang, S** (1996)

Mixed farming in China's rubber plantations

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp.100-112.

Mixed farming has been practiced in rubber plantations in China since the late 1950s when China began, with great effort, to expand its rubber plantation industry. Many forms of mixed farming have been tried during the last four decades or more. Rubber trees have been

intercropped with tea bushes, sugar cane, pineapple, pepper, cinnamon etc apart from various cover crops. The mixed farming system is desirable in the context of economic returns and environmental effects, although it varies depending on the crop combinations and market demands as well as geographical locations and terrain. In general, mixed farming or intercropping in rubber plantations could fetch an average net economic return at around RMBV 1500/hectare in China. Intercropping in rubber plantations can increase the land use capacity by 30- 50% and create more job opportunities. The ecological and environmental effects are more pronounced from such mixed farming systems. This can be seen from reduced soil erosion, enhancement of soil nutrient status, better biodiversity compared with arable farming, decreased temperature by 1.2-7.0° C and increased humidity by 2-10% to create a situation similar to secondary tropical forests. Some interactions between rubber and intercrops and the new ecosystems in terms of fauna and flora are discussed. It is concluded that correct intercropping in rubber plantations is a sustainable farming system. Some existing intercropping problems in China are dealt with and recommendations for their solution are made.

Keywords: Cinnamon; Ecology; Economic aspect; Land utilization; Mixed farming; Pepper; Pineapple; Soil conservation; Sugar cane; Tea; China

106. Lisha, C (2005)

Competitive interactions in a rubber based agroecosystem with coffee and cocoa as intercrops MSc Disseration, Centre for Plantation Development Studies, University of Calicut, Calicut, India, 66 p.

A study on competitive interactions in a rubber based agro ecosytem with coffee and cocoa as intercrops was carried out in a smallholding in the central rubber-growing tract of India. The study revealed that coffee and cocoa could be grown as intercrops in mature rubber without adverse effect on growth and yield of rubber. Though competition existed between the component crops for above ground resources the soil fertility was improved under the intercropped situation compared to monoculture rubber.

Keyword: Cocoa; Coffee; Rubber based farming system; Kerala; India

107. Mak, C and Yap, T C (1985)

Soybean intercropping with rubber and oil palm

In: Soybean in Tropical and Subtropical Cropping Systems. (Eds. S. Shanmugasundaram *et al.*). Asian Vegetable Research and Development Center, Taiwan, pp. 61-65.

Systems for intercropping soyabeans with rubber (*Hevea brasiliensis*) or oil palm (*Elaeis guinaensis*) are discussed with recommendations for planting distances. Problems of soyabean cultivation and economic considerations are examined.

Keywrods: Economic aspect; Planting density; Soyabean; Taiwan

(CAB Abstracts 1984-89/May)

108. **Manurung, G and Burgers, P** (1999)

Innovative farmers: Bapak Kanijan. Reviving rattan in Sumatra is a booming business

Agroforestry Today, 11 (1-2): 16-18.

A short account is given of the efforts of one farmer (Bapak Kanijan) to use his knowledge of the forest environment and of propagation methods for rattan to boost the profitability of his land and rubber garden. Rattans are grown in the middle of alleys in between the rubber plants, which are planted at 4X3 m spacing. Since they are climbers, they are staked at a few years old to prevent damage to the rubber trees. The woody thorns of the rattans can be slashed of with a piece of wood so that rubber tapping is not impeded. The normal problem on smallholdings of pig and deer attacks on the rubber is averted because of the presence of the thorny rattans. The first rattan seeds were collected from the forest, but the seeds are now collected mainly from the farmer's own plants, and seedlings raised in his own nursery. Some of the seedlings are now contracted out to be grown, and some are raised for the Forestry Department.

Keywords: Economic aspect; Innovation adoption; Rattan; Sumatra; Indonesia

(HORTCD 1989-2001/03)

109. **Masae, A; Cramb, R A; Date, R A; Grundon; N J; Rayment, G E and Probert, M E** (1993)

Socio-economic aspects of rubber intercropping on acid soils in Southern Thailand

Plant Soil Interactions at Low pH, Principles and Management: Proceedings of the Third International Symposium, 12-16 September 1993, Brisbane, Australia, pp. 679-684.

Rubber is widely cultivated in acid soils in Southern Thailand. Many smallholders intercrop the young rubber with food crops. A project to study the management of soils under intercropping involved two on-farm experiments and a socioeconomic survey of sixty rubber smallholders in three villages. This paper discusses the results of the survey. The survey revealed a range of cropping practices, from repeated cropping of upland rice for subsistence to continuous cultivation of pineapples on a commercial basis. Farmers adopted intercropping if their rubber plots ere conveniently located and they had spare family labour. They adopted more intensive, commercial practices as an innovative response to market opportunities. The evolution of intercropping systems had taken place with little technical or economic support from the public sector. Research into alternative management practices needs to take account of the place of intercropping within the overall farming system and the trend towards greater commercialization of intercropping.

Keywords: Cropping system; Economic aspect; Pineapple; Rice; Socioeconomics; Survey; Thailand

110. **Mathew, J** (1984)

A new outlook on interplanting of tree crops in rubber plantations

Planters Seminar, 25 January 1984, Kottayam, India, pp. 25-29.

Author provides his personal opinions about the interplanting of trees like albezia, tea, anjili etc in both smallholdings and large plantations towards some extra benefit. Albezia and

mahogany, which are growing strong, have only limited foliar competition. The details of the experiment with anjili as avenue trees are also provided.

Keywords: Alzebia; Anjili; Mahogany; Teak; Tree crop; Kerala; India

111. **Mathew, M** (1974)

Plant association and competitions and intercropping

First Short-term Training Course on Rubber Cultivation, Processing and Estate Management, Lecture Notes, 4 November- 4 December 1974, Rubber Research Institute of India, Kottayam, India, pp.1-3.

The relative advantages and disadvantages of maintainining cover crops and intercrops centralized in rubber plantations are discussed.

Keywords: Cover crop; Economic aspect; India

112. **Mathew, M** (1990)

Intercrops (Malayalam)

In: Rubber: Vithu muthal Vipany vare, Rubber Board, Kottayam, India, 1990. pp. 51-54.

Keywords: Banana; Plantain; Rice; Tapioca; Turmeric; Kerala; India

113. **Mathew, M; Potty, S N; Punnoose, K I and George, C M** (1978)

Intercropping in rubber plantations

In: Agronomy Soils Physiology and Economics of Plantation Crops: Placrosym 1, 1978, Kottayam, India (Ed. E. V. Nelliat), Indian Society for Plantaion Crops, Kasaragod, India, pp. 431-437.

Economics of raising certain food crops as intercrops in the rubber plantations and the effect of such intercropping on the growth of rubber plants are discussed. Growing tapioca and bananas(nendran and non nendran) was found to fetch additional returns. Dry land paddy and green gram can be economical only when family labour is employed. Growth of rubber plants, as evaluated by the girth recorded at seventeen months after planting, was better in plots intercropped with nendran variety of banana than those with tapioca, non-nendran banana or legume ground cover. The possible reasons for the above observations are discussed.

Keywords: Banana; Dry land paddy; Green gram; Tapioca; India

114. **Mathewkutty, T** (2002)

Medicinal plants as ground cover in rubber plantations

In: Global Competitiveness of Indian Rubber Plantations Industry: Rubber Planters' Conference. India 2002 (Ed. C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, India. pp. 89-92.

The establishment and maintenance of legume ground cover to conserve soil and improve its fertility is a common practice in rubber plantations. Medicinal plants named in Malayalam as Tippali (*Piper longum*), Karimkurinji (*Sorbilanthus*

diffusa), Orila (*Desmodium gangeticum*) and Moovila (*Pseudarthria viscida*) can be cultivated in the interspace of rubber plantations in place of cover crops. Besides being ground cover their cultivation helps the farmer in generating subsidiary income. Being shade tolerant they can be cultivated even in mature rubber plantations. These plants are propogated vegetatively through seeds or rooted cuttings. Planting is done at a spacing of 75x 75 cm for Tippali and Karimkurinji, 60x60 cm for Thazhuthama and 45x 45 cm for Orila and Moovila. As the roots are of medicinal value in these crops, controlled harvesting by selectively pulling out the mature plants (not by digging) so as to minimize soil disturbance and root injury of rubber can be done. These plants effectively reduce run-off and soil, erosion increase the soil moisture content and suppress weed growth. They add large quantity of organic matter and improve soil physical, chemical and biological properties. Orila and Moovila are capable of fixing atmospheric nitrogen, since, these plants are of medicinal value, there is good market demand. The introduction of medicinal plants in rubber plantations, as ground cover will enhance the biodiversity and sustain our herbal wealth.

Keywords: Biodiversity; Karimkurinji; Medicinal plant; Moovila; Orila; Thazhuthama; Tippali; India

115. **Medina, B F and Leite, J A** (1985)

Effect of three soil management systems and two vegetative covers on water infiltration in a yellow latosol from Manaus, Amazonas, Brazil

Pesquisa Agropecuaria Brasileira, **20**(11): 1323-1331.

In a field experiment at Manaus, on a heavy clayey yellow Latosol, infiltration rates were much higher under rubber with tropical kudzu (*Pueraria phaseolides*) and under regenerated and virgin forests (28.5, 22.7 and 27.3 cm/ hour, respectively) than under rubber with grass (3.3 cm/hour), and rubber X coffee treatments (5.9 cm/hour). The higher infiltration rates under the first three systems were due to changes in soil physical conditions brought about by their respective covers. The comparatively low values of infiltration under rubber with grass and rubber X coffee systems were attributed in the first case to wheel-induced soil compaction as a result of excessive machinery traffic, and to lack of a vegetative cover to protect the soil and enhance good tilth in the rubber X coffee intercropping system.

Keywords: Coffee; Brazil

(CAB Abstracts 1984/89 May)

116. **Meng, Q Y; Wang, Z Q and Chen, X** (1999)

Analysis of energy flow of rubber-tea-chicken agroforestry system in tropical area of China

Journal of Zhejiang Agricultural University, **25**(5): 473-478.

Energy flow of rubber-tea-chicken eco-agricultural model - a typical tropical agro-forestry was studied in Wenchang Municipality of Hainan Province, China. Energy flow path, input and output structure and conversion efficiency of rubber, rubber-tea and rubber-tea-chicken gardens were analysed. The results showed that the efficiency of utilization of solar energy in the three gardens increased gradually. Their energy output/input ratios were 1.50, 1.88 and 0.20, respectively. The organic energy input/total input ratios were 0.138, 0.119, 0.997, and [illegible] input ratios were 0.862, 0.881, 0.023, respectively. In the rubber-tea-

chicken system, the artificial subsidiary energy input was decreased comparatively and the system's stability and energy output increased.

Keywords: Energy conversion; Poultry; Tea; China

(HORTCD 1989-2001/03)

117. **Meng, Q Y; Ye, X J; Yan, L J and Wang, Z Q** (1999)

Study on the ecological benefits of the rubber-tea-chicken agroforestry system in the tropical region of China.

Acta Agriculturae Zhejiangensis, 11 (4): 193-195.

A study in Wenchang, Hainan, China, showed that compared with monocropping and intercropping rubber [*Hevea brasiliensis*], a rubber-tea [*Camellia sinensis*]-chicken agroforestry system improved soil physical structure and fertility, which increased the yield of rubber and tea and the quality of the chicken.

Keywords: Agroforestry; Soil fertility; Soil property; Tea; China

(HORTCD 1989-2001/03)

118. **Menz, K M; Magcale, D M and Rusastra, I W** (1999)

Improving smallholder farming systems in *Imperata* areas of Southeast Asia: Alternatives to shifting cultivation

Australian Centre for International Agricultural Research (ACIAR) Monograph, 1999, 280 p.

The results of the research project 'Improving smallholder farming systems in *Imperata* areas of Southeast Asia: A bioeconomic modelling approach' is reported. The monograph is arranged in 5 sections. Out of these 5 sections, section 3 and 4 contain chapters in which various tree-based interventions (growing trees in fallows such as hedgerows (in alley cropping), and in other intercropping systems are modelled with and without animal component; the tree species used are multipurpose trees and rubber, and work with natural vegetation strips and napier grass hedgerows is also described. Some of these modelled farming systems are already in place in farmers' fields, and in these cases, possible management policy or policy interventions analysed with the models can point the way to productive and economic improvements. In other cases, the farming systems modelled are experimental in nature. Imperata grows on uplands of various slopes, but some special attention is given to Imperata on steeply sloping land where soil erosion is a particular problem.

Keywords: Economic aspect; Farming system; *Imperata cylindrica*; Smallholding; Weed management; South East Asia

(HORTCD 1989-2001/03)

9. **Mohd Yusof, M N; Mahmud, A W; Bachik, A T; Zainol, E; Norhayati, M; Mohd Johari, H and Grundon, N J** (1989)

Intercropping under young rubber

Proceedings of the Rubber Research Institute of Malaysia, Rubber Growers' Conference, 21-23 August 1989, Malacca, Malaysia, pp. 166-80.

Two experiments were conducted to assess the effects of liming to ameliorate soil acidity and on

the sustainability of intercropping in the interrows of young rubber on acid, highly weathered Oxisol (Munchong series) and Utisol (Rengam series). The possible effects of liming and intercropping on growth of rubber, were also monitored. Lime, in the form of ground magnesium limestone (GML), was applied at rates of 0, 0.5, 1 and 2 tonnes/ha, and these were rotovated into the soil at depths of 0-15 cm and 0-30 cm, at two weeks before planting of the first crop. The crops planted were groundnut and maize. Data indicated that yield as well as quality of both maize and groundnut improved with application of GML. However, the rate of application of GML needed to achieve maximum yield differed between sites, crop species and time. Generally, GML became less effective with continuous cropping, with only the higher rates of application of lime being able to sustain reasonable growth and yield with time. Application of GML did not appear to have any deleterious effects on girth of the rubber trees. Over a thirty-month period, the mean girth increment of rubber trees with intercropping was 28.2 cm compared to 24.3 cm for trees with normal legume covers, thus indicating that trees with intercropping generally grew better than those with normal legume covers. A comparative benefit-cost analysis indicated that groundnut performed better than sweet corn and grain corn. Subject to being substantiated by further indepth research, the improved girthing rate of rubber trees suggests prospects for earlier maturity and returns to investment.

Keywords: Groundnut; Maize; Soil property; Malaysia

120. **Mokhtaruddin, A M; Eusof, Z; Hashim, G M; Wahab, M A; Sudin, M N and Bachik, A T** (1991)

Effects of cultural practices on soil erosion under immature rubber.

Developments in Soil Research in Malaysia, pp. 183-193.

About 40, 000 ha on sloping ground in Malaysia are used for rubber planting often intercropped with maize, groundnuts, bananas and papaya. Many farmers' smallholdings are on oxisols and ultisols, which, due to continuous cultivation, are exposed to erosion and degradation. Soil erosion was monitored on erosion plots fitted with tipping buckets for runoff and a sedimentation pit. Results from 5 cultural practices tested on these plots showed that papaya intercropped with rubber gave the largest soil loss and runoff and a rapid decline of soil fertility. However, soil loss was reduced to 1 to 2 t/ha when rubber was intercropped with groundnuts. It was concluded that the average soil loss and runoff for one cropping cycle of groundnuts and maize was greatest from papaya and farmers' practices followed by legume and groundnut and papaya plus groundnuts/ maize treatments. Approximately six months after legume establishment soil erosion was minimal.

Keywords: Banana; Cropping system; Groundnut; Maize; Papaya; Smallholding; Soil fertility; Malaysia

(CAB Abstaracts 1995)

121. **Morales, J O; Bangham, W N and Barrus, M F** (1949)

Intercrops in *Hevea* plantations

Abstracts in Biological Information Colombia, 7: 12.

The value of various crops for planting as intercrops in young *Hevea* plantations was studied in areas with a temperature of 23-26° C and an annual rainfall of 254 cm. Yucca proved to be a

profitable crop but maize required too much labour. The cultivation of intercrops resulted in a better growth of the *Hevea*, and fewer replacements of trees.

Keywords: Yucca; Malaysia

(BPPM Abstract Bibliography of *Hevea* rubber: V 2, 1970.)

122. **Nair, P K R** (1980)

Agroforestry species: A crop sheets manual

In: Crop Sheets Manual, International Council for Research in Agroforestry, Nairobi, Kenya 336p.

Agroforestry is the growing of trees and crops intermixed on the same piece of land. It is a traditional farming practice in many ecological zones. This booklet is divided into three parts, ie General principles of agroforestry, crops sheets of some species of the major economic groups of crops and short notes on some underexploited and localized species. Most of the crops mentioned are horticultural, and include fruit, beverage, spice and other plants such as arecanut, cashew and rubber in part II, and cucurbitaceous crops, onion, several tree fruit, spice and condiment plants medicinal and aromatic plants, and miscellaneous plants (including *Orbignya martiana*, guayule and jojoba) in part III. There are several illustrations of interplanted crops. It is stressed that Agroforestry is only one of the farming systems, which are potentially useful in fragile environments It may be particularly applicable where labour is not a limiting factor.

Keywords: Agroforestry; Forest tree; Kenya

(HORTCD 1973-1988)

123. **Nayar, T V R and Suja, G** (2004)

Production potential of root and tubers in multiple cropping systems involving plantation crops

Journal of Root Crops, **30**(2): 93-100.

In India, tropical root and tuber crops namely cassava, greater yam, lesser yam, elephant foot yam, taro, tannia and arrowroot are mostly cultivated in association with plantation crops like coconut, arecanut, coffee, rubber and banana. Intercropping the root and tubers with tree crops both at the immature and mature phases is a common practice, especially in small and medium sized land holdings, to augment the net income and employment opportunities. In such farms, the produce from the perennials generates the cash income, while the starchy root and tubers partially meet the food requirements of the farm family and the feed needs of farm animals. Research during the past two decades in India had brought out the agronomic and economic advantages of the cropping systems involving tropical root and tubers and the plantation crops. In this paper, the opportunities, challenges and future research needs of cropping/farming systems involving tropical tuber crops and perennials are critically evaluated.

Keywords: Economic aspect; Multiple cropping; Plantation crop; Root-crop; Yield; India

(CAB Abstracts 2005/01- 2005/09)

124. **Narong, S and Soonthorn, N** (1976)

Upland rice as an intercrop of rubber in Songkhla province

In: Progress and Development of Rubber Smallholders: Proceedings of the Third ANRPC Seminar, 24-30 November 1976, Hat Yai, Thailand, pp167-170.

This survey was conducted to determine the number and percentage of rubber smallholders who plant upland rice as an intercrop in Songkhla with a view to studying the problems involved and work out guidelines for further research and extension on intercropping. It shows that there are many kinds of intercrops such as upland rice, corn, groundnut, mungbean, pineapple and banana being planted. But of all the intercrops upland rice is the favourite. However, there are no data on appropriate rice varieties, fertilizer application, and weed control and rice diseases. It is suggested that more research on these areas be conducted for the benefit of the smallholders.

Keywords: Smallholding; Upland rice; Weed management; Thailand

125. **Neerakkal, I** (1998)

Intercropping of medicinal plants in rubber plantations: Light requirements and physiology of shade adaptation.

PhD Thesis, Mahatma Gandhi University, Kottayam, India, 160p.

Five species of medicinal plants viz *Plumbago rosea, Adhatoda beddomei Adhatoda vasica, Alpinia galanga and Strobilanthes heyneanus* were subjected to six treatments including five different shade levels of 30%, 40%, 50%, 60%, and 70%, along with open sunlight. Periodic observations on morphological, physiological, biochemical, anatomical and growth parameters were carried out. All the five species tended to enhance the dry matter production under shade inspite of a clear reduction in the photosynthesis per unit area of the leaf. The main mechanisms of adaptations are increase in the total leaf area, photosynthesis per leaf and chlorophyll contents and a decrease in leaf thickness.

Keywords: Light intensity; Medicinal plant; Shade; India

126. **Neerakkal, I; Thomas, V; Vijayakumar, K R and Sethuraj, M R** (1995)

Screening for shade tolerance of potential medicinal plants as intercrops in rubber plantation

International Conference on Medicinal and Aromatic Plants Research, 30 December 1994-1 January 1995, Calcutta, India.

Five commercially important shade adapted plants viz. *Adathoda beddomei, Adathoda vasica, Alpinia galanga, Plumbago rosea and Strobilanthus heyneanus* were elected to study the shade adaptation characteristics in order to intercrop them in rubber plantations. Observations on morphological, anatomical and physiological parameters were recorded in the plants grown under different light intensity. Plants grown under 70% shade showed better adaptation characteristics as reflected in plant height, internodal length, leaf area, total dry matter and photosynthetic rate per plant. Anatomically, shade leaves showed variation in palisade and spongy tissue organization over open leaves.

Keywords: Medicinal plant; Shade; Kerala; India

127. **Neerakkal, I; Thomas, V; Meenakumari, T; Vijayakumar, K R and Sethuraj, M R (2001)**

Leaf anatomy of five medicinal species grown under two light regimes

Phytomorphology, 51(2): 185-189.

The foliar anatomy of five species of medicinal plants viz., *Adathoda beddomei, A. vasica, Alpinia galanga, Plumbago rosea and Stobilanthes heyneanus* grown as intercrops in rubber plantations under direct sunlight and 70% shade was studied. A significant decrease in leaf thickness was observed under shade, which could be attributed to a decrease in intercellular spice and cell number in palisade layer.

Keywords: Leaf anatomy; Medicinal plant; Shade; Kerala; India

128. **Neerakkal, I; Dey, S K; Vijayakumar, K R and Sethuraj, M R (2002)**

Diurnal changes in photosynthetic characteristic of shade adapted medicinal plants grown under open sunlight and shade condition

Indian Journal of Plant Physiology, 7(3): 2002. 234-238.

Five commercially important medicinal plants viz. *Adatoda beddomei* C. B. Clark *Adathoda vasica* Nees, *Alpinia galanga* S.W., *Plumbago rosea* Linn. *Strobilanthus heyneanus* Nees were grown under open sunlight and 70% shade conditions. Diurnal variations in rates of photosynthesis, stomatal conductance and transpiration were observed in the field under open and shaded condition in nine-month-old plotted plants. Maximum Pn was observed for a short period in open sunlight for all the species around 9.00 or 10.00 h whereas peak Pn under shade continued for 3 to 4 hours even at midday. The adaptability of species to shade is also discussed.

Keywords: Diurnal change; Medicinal plant; Photosynthesis; India

129. **Neerakkal, I; Vijayakumar, K R and Sethuraj, M R (2005)**

Intercropping of medicinal plants in rubber plantations: Light requirements and mechanism of shade adaptation

International Natural Rubber Conference India 2005 : Preprints of Papers, 6-8 November 2005, Cochin, India, pp. 205-209.

Five species of medicinal plants were found to be best suited for intercropping in rubber plantations from the studies conducted by intercropping 48 species of medicinal plants in rubber plantations. The light requirements and physiology of shade adaptations of these five species of medicinal plants viz. *Plumbago rosea, Adhatoda beddomei Adhatoda vasica, Alpinia galanga and Strobilanthes heyneanus under* six shade treatments comprising 0%(open). 30%, 40%, 50%, 60% and 70% shade were suited. 70% shade was most favourable for growth of *A. vasica and P. rosea,* 60% for *A. beddomei* and 50% for *A. galanga* and *S. heyeneanus.* All the five species tended to enhance the dry matter production under shade inspite of a clear reduction in the photosynthesis per unit area of the leaf. The main mechanisms of adaptations are increase in the total leaf area, photosynthesis per leaf and chlorophyll contents and a decrease in leaf thickness

Keywords: Light intensity; Medicinal plant; Shade; Kerala; India

130. **Newman, S M** (1985)

A survey of interculture practices and research in Sri Lanka

Agroforestry Systems, 3(1): 25-36.

Details are given of species composition, spatial arrangement and justification for growing the crops as mixtures (soil conservation, generation of fuel and fodder, incentives for replanting, export diversification, microclimate modification and reduction of pest incidence). The systems include intercropping in tea, rubber and coconut plantations, spice gardens and alley cropping between leguminous tree crops.

Keywords: Alley cropping; Tea; Sri Lanka

131. **Ng, K F** (1980)

Suitable catchcrop in rubber smallholdings II. Ground nut production

Siaran Pekebun, 78: 36-42.

This article discusses mainly the planting techniquesof groundnut, which is recommended as a suitable catchcrop in rubber smallholdings. Problems faced by the smallholders are also included.

Keywords: Groundnut; Smallholding; Malaysia

(Publications of the R R I M, 1980.)

132. **Ng, K F and Abraham, P D** (1980)

Suitable catchcrop in rubber smallholdings I. Maize production

Siaran Pekebun, 78: 28-35.

Several experiments were carried out by the Rubber Research Institute of Malaysia (RRIM) with the aim of discovering the catchcrop that can be best grown and from which a profitable return could be obtained. This article features the planting of maize in smallholdings of immature rubber. It briefly outlines the breeding propogation, soil fertility, fertiliser and manuring, weed control and economic viability of maize production.

Keywords: Maize; Smallholding; Malaysia

(Publications of the R R I M, 1980.)

133. **Ng, K F; Mohd Yusof, M N and Abraham, P. D** (1980)

Suitable catchcrop in rubber smallholdings: 3. Soyabean production

Siaran Pekebun, 78: 43-52.

In this article, a brief explanation is presented on soil suitability, fertilization, plant protection, weed control, economic benefits snd problems faced by the smallholders who select soyabean as a means of additional income to immature rubber smallholdings.

Keywords: Economic aspect; Smallholding; Soil property; Soyabean; Malaysia

(Publications of the R R I M, 1980.)

134. **Ng, K F and Ismail, I** (1980)

Suitable catchcrop in rubber smallholdings: 4. Banana production

Siaran Pekebun, 78: 53-61.

Banana is common crop planted in rubber smallholdings in Malaysia. However production is less intensive if compared to the other catchcrops like maize or groundnut. This is due to certain factors. Marketing is on a much smaller scale and this problem can only be solved if the smallholder is in an area where the demand for bananas is likely to be high. Added to this, is the unstable price of bananas, as a fall in prices may have adverse effects on the income of the smallholders.

Keywords: Banana; Smallholding; Malaysia

(Publications of the R R I M, 1980.)

135. **Nguema, J; Hugot, N and Enjalric, F** (1996)

Rubber and associated food crops in a Central African Country

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp.1-9.

Hevea brasiliensis is a perennial species and provides a regular source of income during its exploitation, which usually begins about six years after planting. Within the context of rural plantation development, the association of food crops grown between rubber trees during their immature stage is a way of providing planters with a supplementary income or a degree of food self-sufficiency. The latter point was a deciding factor in the decision to introduce this new crop in Gabon. Since 1987, experimentation led by C.A.T.H (the local center for technical support to *Hevea* farming) has enabled us to publish some recommendations/suggested techniques that can improve traditional farm productivity. The association of food crops proved to have a positive influence on the growth of rubber trees. Among the species experimented with, the rice/groundnut rotation is satisfactory even when repeated several times; the banana-plantain tree offers the best income; and *Cassava*, a traditional Gabonese staple food, may be planted without damaging repercussions on *Hevea*. competitions for water, which might occur, are estimated and described.

Keywrods: Banana; Cassava; Economic aspect; Groundnut; Plantain; Rice; Gabon

136. **Nguyen, G Q et al.** (1998)

Effective utilization of idle land between rubber rows with incomplete canopies

Symposium on Natural Rubber (Hevea brasiliensis): 3. Rubber Smallholdings, NR Processing and Quality and Technology Sessions, 14-15 October 1997, Ho Chi Minh City, Vietnam. pp. 42-46.

Studies were made in 1991-95 in Vietnam on improved intercropping systems to effectively utilize the idle land between young rubber [*Hevea brasiliensis*] rows with incomplete canopies. These studies included continuously cropped rice and Coix lachrymal Jobi [*C. lacryma-jobi*], rotations including rice, black gram [*Vigna mungo*], maize, millet [*Pennisetum glaucum*],

soyabeans, sorghum, groundnuts and cowpeas [V. unguiculata], and cover crops, particularly legumes. Effects of fertilizers were analysed, as were returns of the various systems.

Keywords: Black gram; Cropping system; Groundnut; Maize; Rice; Soyabean; Vietnam

(HORTCD 1989-2001/03)

137. **Nguyen, V T** (2001)

Micro phytoclimatic conditions in coffee plantations under influence of the intercropping tree

Science and Technology Journal of Agriculture and Rural Develeopment, 9: 645-646.

A phytoclimatic investigation aiming at determining conditions of radiation, humidity and thermal status in number of coffee plantations under canopies of the trees was carried out some places in Daclac province. The results showed that trees such as rubber, cinnamon, cashew and durian could decrease more than 70 percent of the solar radiation coming to the coffee canopies, thus decreased strongly the coffee yields. In the coffee plantations with the intercropping trees, the wind speed was decreased between 41 percent-80 percent; the air temperature was between 2°C 4°C lower and the relative humidity was between 5 percent-15 percent higher in comparison with in pure standing coffee plantations.

Keywords: Agroclimate; Coffee; Vietnam

(AGRIS 1999-2002/09)

138. **Nilnond, C; Suthipradit, S; Nualsri, L; Edwards, D G; Myers, R J K and Grundon, N J** (1999)

Management of tropical acid upland soil for sustainable food crop production in southern Thailand

Thai Journal of Agricultural Science, 32(1): 19-30.

A field trial was conducted in Southern Thailand to develop and evaluate input technologies, which could be employed for an opportunistic food crop production system on a Typic Paleudults under rainfed conditions. The trial compared ten different input technologies for intercropping a rotation of groundnuts, upland rice, super sweet maize [sweet corn] and mungbean [*Vigna radiata*] between young rubber [*Hevea*] trees for a period of four years prior to canopy closure. Results indicated that the highest yields of all crops were obtained in the high input technology which included application of lime and inorganic fertilizers containing N, P, K and Mg sufficient to meet crop requirements. The low input technology which applied minimal rates of N, P, K, Ca and Mg resulted in a lower yield, but was economically sound. Green manure (slashed *Mucuna cochinchinensis*, which had received 500 kg/ha rock phosphate once at sowing) did not sustain yields of rice and super sweet maize. Technologies which did not receive any inorganic fertilizer, viz. usual farmers' practices and organic residues, resulted in comparatively low yields of groundnuts and rice and an extremely low yield of maize.

Keywords: Cropping system; Groundnut; Maize; Rice; Soil fertility; Sweet corn; Thailand

(CAB Abstracts 2000)

134. **Ng, K F and Ismail, I** (1980)

Suitable catchcrop in rubber smallholdings: 4. Banana production

Siaran Pekebun, 78: 53-61.

Banana is common crop planted in rubber smallholdings in Malaysia. However production is less intensive if compared to the other catchcrops like maize or groundnut. This is due to certain factors. Marketing is on a much smaller scale and this problem can only be solved if the smallholder is in an area where the demand for bananas is likely to be high. Added to this, is the unstable price of bananas, as a fall in prices may have adverse effects on the income of the smallholders.

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135. **Nguema, J; Hugot, N and Enjalric, F** (1996)

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(HORTCD 1989-2001/03)

137. **Nguyen, V T** (2001)

Micro phytoclimatic conditions in coffee plantations under influence of the intercropping tree

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Keywords: Agroclimate; Coffee; Vietnam

(AGRIS 1999-2002/09)

138. **Nilnond, C; Suthipradit, S; Nualsri, L; Edwards, D G; Myers, R J K and Grundon, N J** (1999)

Management of tropical acid upland soil for sustainable food crop production in southern Thailand

Thai Journal of Agricultural Science, 32(1): 19-30.

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Keywords: Cropping system; Groundnut; Maize; Rice; Soil fertility; Sweet corn; Thailand

(CAB Abstracts 2000)

139. **Nogueira, O L; De Conto, A J; Calzavara, B B G; Teixeira, L B; Kato, O R and De Oliveira, R F (1991)**

Recommendations for the cultivation of perennial species in mixed systems.

Documentos Centro de Pesquisa Agropecuaria do Tropico Umedo, No. 56, EMBRAPA, CPATU, Belem, Brazil, 61p.

The systems investigated in this Brazilian study are: rubber [*Hevea brasiliensis*], cocoa [*Theobroma cacao*] and bananas [*Musa*] intercropped with maize [*Zea mays*] and cowpeas [*Vigna unguiculata*]; rubber, black pepper [*Piper nigrum*] and cocoa with maize and cowpeas; rubber and urucu [*Bixa* orellana] (cocoa can be used as a substitute if the urucu fails) with maize and cowpeas; urucu and maracuja [passion fruit, *Passiflora edulis*] with maize and cowpeas; citrus fruits (orange, lemon or tangerine) and maracuja with maize and cowpeas; cupuacu [*Theobroma grandiflorum*], pupunha [*Bactris gasipaes*] and bananas with maize and cowpeas; and (7) cupuacu, acai [*Euterpe oleracea*] and bananas with maize. Details of cultural operations, management and yields are given.

Keywords: Cowpea; Food crop; Maize; Pepper; Urucu; Brazil

(HORTCD 1989-2001/03)

140. **Obouayeba, S (1992)**

Agro-economic importance of intercropping of rubber trees and food crops in peasant farming in Ivory Coast: Analysis of a plantation model

Agronomie Africaine, 4(1): 21-33.

The intercropping of young rubber trees with food crops was studied for two years on small farms in the southeast of the Ivory Coast. Food crop yields and the growth of rubber trees were satisfactory, and could be improved by simple cultivation measures. These include appropriate plant densities and sowing dates, fertilization of the food crop, and adequate maintenance. The introduction of food crops produces a slight decline in the initial soil fertility with no adverse effect on the rubber trees. A profit can be made through the sale of part of the food crops.

Keywords: Economic aspect; Food crop; Planting density; Smallholding; Ivory Coast

(ATA No. 92643, 1994.)

141. **Pathiratna, L S S (1997)**

Rattan: A potential intercrop under rubber in Sri Lanka

Bulletin of the Rubber Research Institute of Sri Lanka, 36: 30-33.

In Sri Lanka too it may be possible to grow the endemic species of *Calamus* under rubber. Smaller species may be more suitable as their shading and covering effect on rubber canopy and the ground space they occupy may be less than the larger species. The climatic requirements will be favourable for rattan in the main rubber growing districts as most of the endemic species are found in the two main rubber growing areas of Sabaragamuwa and Psadunkorele. Growing of these rattans in the reservations in estates is yet another possibility. Experiments are now being planned to start small scale trials with *C. zeylanicus C.ovoideus* and *C. psendotenuis*

to select the most suitable species of rattan as an intercrop under rubber, particularly those tolerate shade and least competitive with rubber.

Keywords: Shade; Rattan; Sri Lanka

142. **Pathiratna, L S S** (2001)

Possibilities for intercropping cinnamon under rubber (*Hevea*)

Sri Lanka Council for Agricultural Research Policy Project Report ,No. 12/378/285, pp.1-22.

Cinnamon was established along with rubber in the same season with different inter row spacing for rubber and the first harvest was taken after 2.5 yrs. Inter species competition at this stage was minimal and the per hectare intercropping yield of Cinnamon about 700 kg/ha. There is some evidence of intra species competition in cinnamon under the plant density used in this experiment. The growth of cinnamon established under mature rubber was badly reduced due to competition from rubber. There is some indication that the below ground competition from rubber can be reduced by the addition of high levels of fertilizer.

Keywords: Cinnamon; Smallholding; Sri Lanka

143. **Pathiratna, L S S and Perera, M K P** (1996)

Performance of cinnamon and forage grass + tree legume mixtures under rubber (*Hevea*)

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 41-45.

Two intercropping systems involving rubber/cinnamon and rubber/forage grasses/tree legumes were investigated. Cinnamon reached harvesting age 2½ years after establishment under immature rubber. Cinnamon also performed satisfactorily under mature rubber where light availability for cinnamon was ca. 53% daylight. The yields under immature rubber were a little low but comparable to that of monocrop cinnamon. Among the two species of grasses, the dry matter (DM) yield of *Panicum maximum* was almost double of that of *Brachiaria brizantha* during the first two years but the DM yields of both species declined with the growth of rubber trees. The growth and yield of both species of tree legumes were poor in all treatment combinations. The growth of rubber was not affected adversely by these intercrops during the period of study, ie, three and five years with cinnamon and grass respectively.

Keywords: Cinnamon; Forage grass; Tree legume; Sri Lanka

144. **Pathiratna, L S S and Perera, M K P** (1998)

Effect of shade on the bark yield components of Cinnamon (*Cinnamomum Verum* J. Pres) intercropped with rubber (*Hevea brasiliensis Muell. Arg.*)

Journal of Plantation Crops, **26** (1): 70-73.

In this study the effect of shade under rubber trees on the components of bark yield and their relationship to bark yield in six monthly coppiced (harvested) cinnamon plants (bushes) was investigated. The results show that though cinnamon is a full sunlight crop its growth and bark yield was not affected under moderate shade. It is also capable of adapting to still lower light levels (21% day light) to maintain higher bark yields. Yet the thickness of bark under this light level was poor, which may not be very attractive for commercial peeling and making good quality quills.

Keywords: Cinnamon; Shade; Yield; Sri Lanka

145. **Pathiratna, L S S and Perera, M K P (2002)**

Contour and east west row planting systems of rubber (*Hevea*) for intercropping: 1. Effects o growth and yield of component crops

Journal of the Rubber Research Institute of Sri Lanka, 85: 53-61.

Light availability in the inter-row is one of the main constraints to the productivity of intercrop East-West oriented rubber rows were expected to allow more light into the interrow and th planting system was compared with contour planted rubber in an experiment involving thre species of intercrops viz: coffee, cinnamon and a grass (*Brachiaria brizantha*). The yield of al intercrops declined with time with the increase of competition from rubber. Growth of rubbe was reduced in the presence of grass after the third year. The yield too was low in grass plots Growth and yield of rubber was favoured by the presence of cinnamon as the intercrop Reduction in the yield of intercrops was high and occurred at an early stage in rows closest to rubber whereas it took 2- 2* years for this to occur in the middle. Yield of cinnamon and coffee was better under planted in east-west rows than those under contour planted rubber in the 7th and 6th years after planting respectively.

Keywords: Cinnamon; Coffee; Grass; Light intensity; Planting density; Yield; Sri Lanka

146. **Pathiratna, L S S Perera, M K P and Wijesuriya, B W (2004)**

Performance of cinnamon (*Cinnamomum Verum* J. Pres.) intercropped at different spacings of rubber (*Hevea brasiliensis Muell. Arg.*)

Natural Rubber Research, 17(2): 150-158.

The suitability of interrow spacing wider than the standard 8.1 m for rubber in rubber/cinnamon intercropping was investigated. Eleven spacings ranging from 7.2 to 18.0 m were tested. The experimental design used was convenient and reduced the land requirement. Closure of rubber canopies in the 7.2 m and 8.4 m spacings by the sixth year limited the available light to 12 per cent even in the middle of the interrow. When the interrow spacing was 12 m or more, the middle of the interrow had more than 80 per cent light. The length density of fine roots of rubber (RLD) was high close to rubber trees and in treatments with narrow interrow spacings, whereas it significantly decreased with the increase in distance from rubber trees. Bark yield of cinnamon was highest in the first harvest compared to the next two. Reduction in yield in subsequent harvests was observed in treatments with narrow interrows. The yield in the third harvest was about 19 per cent of the first harvest in the 7.2 m interrow spacing. The cumulative bark yield for the three harvests increased with the increase of the interrow space. The interrow spacings of 12 m or more was found suitable for a sustainable rubber/ cinnamon intercropping. Growth of rubber was not affected significantly by the spacing treatments.

Keywords: Cinnamon; Light intensity; Root activity; Sri Lanka

147. **Penot, E and Wibawa, G (1996)**

Complex rubber agroforestry systems in Indonesia: An alternative to low productivity of jungle rubber conserving agro forestry practices and benefits

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 56-80.

A preliminary simple cost-benefit analysis of various rubber based cropping systems (based

partly on technical assumptions which should be confirmed by experimentation) gives an idea of the improved economic output which should result from using rubber clones instead of unselected seedlings in jungle rubber. Both NPV and return to labour are significantly improved in Rubber Agro forestry systems (RAS) and TCSDP systems with advantages to RAS in terms of income diversification, environmental benefits and return to labour as well as limited investment during the immature period as compared to TCSDP and for biodiversity conservation for RAS in particular.

Keywords: Agroforestry; Economic aspect; Rubber based farming system; Indonesia

148. **Pereira, A V; Pereira, E B C; Freitas Filho, J de F and Junqueira, N T V** (1997)

Rubber in agroforestry systems

Documentos Centro de Pesquisa Agropecuaeria dos Cerrados, No. 63, 45 p.

A review is made of agroforestry systems Brazil in which rubber is intercropped with coffee, cocoa, citrus species, peppers (pimenteira [*Piper nigrum*]), palmyra palm and other plants requiring little light, and guarana. The role of rubber in rural agroforestry is discussed briefly.

Keywords: Agroforestry; Cocoa; Coffee; Brazil

(HORTCD 1989-2001/03)

149. **Perera, M B A and Fonseka, J P** (1991)

Assessment of tea in Sri Lanka

Sri Lanka Journal of Tea Science, 59(1): 37-48.

The land use planning project using remote sensing techniques produced district land use maps at the scale of 1:100 000 showing tea and other major land use areas in Sri Lanka. The actual tea growing area covers 201 630 ha but small tea stands (<4ha) are included under 'homesteads', and areas in which tea is interplanted with cocoa, coffee, peppers, coconuts, rubber and bananas are mapped under 'Mixed Tea and other Perennial Crops'.

Keywords: Survey; Tea; Sri Lanka

(CAB Abstarcts 1991-1992)

150. **Potty, S N; Kothandaraman, R and Mathew, M** (1980)

Field upkeep

In: Handbook of Natural Rubber Production in India (Ed. P N Radhakrishna Pillai). Rubber Research Institute of India, Kottayam, India, pp. 145-148.

Chapter nine provides a short account of raising annual food or cash crops alongwith rubber during the initial years among smallholders in India. Economic aspects and soil properties are also discussed. Among the intercrops, 'nendran' banana was recommended as the most suitable intercrop besides tapioca, paddy, ginger and green gram.

Keywords: Banana; Ginger; Green gram; Paddy; Tapioca; India

151. **Punnoose, K I** (1990)

Banana intercropping (Malayalam)

Rubber, 296: 13-14.

Keywords: Banana; Kerala; India

152. **Punnoose, K I** (2003)

An update of agromanagement in rubber cultivation

In: Global competitiveness of Indian Rubber Plantations Industry: Rubber Planters' Conference India 2002 (Ed. C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, India pp. 65-76.

In a tree crop like rubber (*Hevea brasiliensis*) with a long gestation period, adoption of appropriate crop management practices is necessary for achieving a uniform stand of trees ready for tapping in the minimum possible period. The potential of high yielding clones can be realized only through scientific field management. An attempt is made to update and consolidate the scientific practices in various agromanagement aspects *viz.* planting materials, density of planting, soil conservation, fertilizer and weed management, intercropping, irrigation and farm mechanization.

Keywords: Agromanagement; Banana; Medicinal plant; Pineapple; India

153. **Punnoose, K I; Kothandaraman, R; Philip, V and Jessy, M D** (2000)

Field upkeep and intercropping

In: Natural Rubber: Agromanagement and Crop Processing (Ed. P J George and C Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, India, pp. 164-167.

Chapter ten gives an overview of intercropping banana, ginger, turmeric, vegetables, pineapple, coffee, medicinal plants, fodder grass and other crops along with rubber. The importance of inter-row management in rubber based intercropping systems is also discussed. Priority may be given to these crops, which need only less disturbance. Timber yielding trees like teak, mahogany etc. can also be given along the boundaries of rubber plantations.

Keywords: Banana; Cocoa; Cardamom; Coffee; Ginger; Mahogany; Medicinal plant; Paddy; Pepper; Pineapple; Sesamum; Tapioca; Teak; Turmeric; Vegetable; India

154. **Pushparajah, E and Weng, W P** (1969)

Cultivation of groundnuts and maize as intercrops in rubber

Proceeding of Crop Diversification in Malaysia Conference, 1969, Kuala Lumpur, Malaysia

Keywords: Groundnut; Maize; Malaysia

(Cited by Mohd Yusoff, M N *et al.*)

155. **Rajasekharan, P** (1989)

Pineapple intercropping in the first three years of rubber planting in smallholdings: An economic analysis

Indian Journal of Natural Rubber Research, 2(2): 118-124.

A study on pineapple intercropping in rubber holdings was conducted during July-August 1989 in Kottayam district of Kerala. Fifty-one rubber smallholders, having pineapple intercropping, were interviewed and an analysis was done using ABC cost concept. Sensitivity analysis was done at 10 per cent variation of output prices. The

discounted net income for the first three years was worked out at Rs. 22443.48 per hectare. The average pineapple plant population in the first year of planting was 4565 per hectare and the total yield for the first three years amounted to 31 tonnes. The cost of production worked out to Rs. 0.57 per kilogramme of pineapple on cost C basis. The BCR of the discounted cash flow was 2.27. Even though the BCR indicates the economic feasibility of investment, this crop lacks definite policy content. More and more pineapple processing industries need to be set up in Kerala so as to have much greater value addition within the state itself, resulting in price stability and a fair share of consumer's rupee to the growers.

Keywords: Economic aspect; Family labour; Pineapple; Kottayam; Kerala; India

156. **Rajasekharan, P and Veeraputhran, S** (1998)

Multiobjective land use planning model for intercropping in small rubber holdings: A compromise programming approach

Indian Journal of Natural Rubber Research, **11**(1/2): 31-37.

A multi objective land use-planning model for one-hectare farm was developed using the compromise programming approach. Maximization of gross margin and family labour employment as well as minimization of hired labour and capital borrowing were the objectives used and the activities (crops) included were banana, tapioca, yam, colocasia, turmeric, ginger and cowpea. The compromise set of farm plans showed gross margins ranging from Rs.15691 to Rs.21250 per ha where different weights were assigned to the four objectives.

Keywords: Family labour; Land utilization; Smallholding; Kerala; India

157. **Rajasekharan, P and Veeraputhran, S** (2002)

Adoption of intercropping in rubber smallholdings in Kerala, India: A tobit analysis

Agroforestry Systems, 56(1): 1-11.

Natural rubber (*Hevea brasiliensis*) is one of the major plantation crops of the state of Kerala in India and intercropping is practiced during the initial gestation period of the crop. In this paper a tobit model was used to study the decision making behaviour of farmers in adoption and extent of adoption of intercropping in three regions of Kerala. The availability of family labour and the type of intercrops were found significant in explaining the adoption behaviour in all three regions. The perception of profitability of intercropping was also found to influence decision on adoption. The probability of adoption of intercropping was highest for three intercrops, banana (*Musa spp.*), cassava (*Manihot esculenta*) and pineapple (*Ananas comosus*). Targeting extension efforts to groups of farmers with available family labour and popularising selected intercrops may result in higher rates of adoption of intercropping in all three regions of the state.

Keywords: Banana; Cassava; Family labour; Pineapple; Smallholding; Kerala; India

158. **Ridwan and Khatib, W** (1999)

Effect of genotype growth and yield of upland rice as an intercropping in rubber planting strip

Jurnal Stigma, 7(2): 21-24.

Yield of upland rice in rubber depend on variety and cultural practices technologies. The experiment was carried out at farmer's rubber plantation Sitiung, West Sumatra in the rainy

season 1998/1999 (from November, 1998 to March, 1999). Two factors of experiment was arranged in randomized block design in a factorial with four replications. Three varieties/lines of upland rice (Jatiluhur, Laut Tawar and GH-Pasaman) as the first factor and two rates of KCl fertilizer application (0 and 75 kg/ha) as the second factor. Objectives of the experiment were to observe the effect of varieties/lines and KCl fertilizer application on growth and yield of upland rice as an intercropping in rubber planting strip. The results showed that Jatiluhur variety and Pasaman line gave better plant growth, the higher number of panicle/hill, number of grain/panicle and yield than Laut Tawar upland rice variety. Application of 75 kg KCl/ha significantly increased number of grain/panicle, filled grain percentage and yield of upland rice as an intercropping in rubber planting strip. Yield of upland rice 14.1 percent increased due to application of 75 kg KCl/ha.

Keywords: Growth; Upland rice; Yield; Indonesia

(AGRIS 1999-2002/09)

159. **Rodrigo, L** (1989)

Cultivation of banana as an intercrop of rubber plantations

Bulletin of the Rubber Research Institute of Sri Lanka, 26:1-2.

Banana is one of the most popular fruit crops in Sri Lanka. There is a ready market for it throughout the year. A good income can be obtained with this crop, when grown as an intercrop during the immature period in a rubber plantation. However, to obtain an economical return, good cultural practices should be adopted. This article discusses some of the cultural aspects that are not been given much attention by most growers.

Keywords: Banana; Economic aspect; Sri Lanka

160. **Rodrigo, V H L** (2000)

Population density effects on light and water use of rubber/banana interculture systems of Sri Lanka

PhD Thesis, University of Wales, UK.

Keywrods: Banana; Light intensity; Water use; Sri Lanka

161. **Rodrigo, V H L** (2001)

Rubber-based intercropping systems

In: Handbook of Rubber: 1. *Agronomy* (Ed. L M K Tillekeratne and A Nugawela), Rubber Research Institute of Sri Lanka, Sri Lanka, pp.139-155.

The recognized advantages associated with mixed cropping systems also apply to rubber intercropping. The major advantages of intercrops over sole crops can be summarized as: improved total yield and economic return; greater variety of produce and seasonal spread of income; reduced susceptibility to market crashes; reduced crop losses due to pests and diseases; reduced dependency on fertilizer inputs due to more efficient use of nutrients; perennial intercrops such as banana help bind the soil and so reduce land degradation; presence of rubber offers physical protection to weaker crops; increased demand for labour provides an improved opportunity cost for labour in the smallholder sector. Biophysical factors relate to

the agronomic feasibility of growing a certain crop given the soil and climatic conditions of a particular location (i.e. soil depth, structure and texture, soil pH, nutrient availability, rainfall, erosion, relative humidity, wind and elevation/temperature) and crop-related factors (i.e root and canopy architecture, susceptibility/tolerance to pests and diseases, demand for nutrients, light requirement, allelopathy and life cycle). Important socioeconomic factors comprise demand for produce, marketing/price, capital and maintenance cost, availability of subsidies and loan schemes, security, labour availability and its requirement, availability of planting materials and other inputs such as local knowledge and skill. The most common crops grown during the immature phase of rubber are banana, pineapple, passion fruit, sugar cane and different kinds of vegetables.

Keywords: Banana; Economic aspect; Family labour; Passion fruit; Pineapple; Sugar cane; Vegetable; Sri Lanka

162. **Rodrigo, V H L** (2002)

Rubber-based intercrops for improved productivity: The best available today

In: Global Competitiveness of Indian Rubber Plantations Industry: Rubber Planters' Conference, India 2002 (Ed. C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, India, pp. 24-25.

Suitability of crops for intercropping on rubber lands depends not only on agronomic, but also socio-economic factors. Therefore, this paper aims to discuss the practicality of different rubber based intercropping systems under Sri Lankan conditions. Most sun-loving short-term crops are suitable for initial 3-4 years of rubber with banana being the most popular intercrop. Pineapple, passion fruit, sugarcane and different types of vegetables are grown, should socio-economic conditions be conductive. Crops that could be established under mature rubber are limited, eg. cardamom and vanilla. However, shade tolerant crops such as coffee and cocoa could be grown throughout the lifespan of rubber provided that temporary shades is given during the early stages. Should economically important sun-loving perennial crops such as tea and cinnamon, be grown with rubber, the spatial arrangement of planting rubber has to be alterated compromising the planting density for improved light penetration. However, use of such systems may depend on the size of the holding. In addition to the growing of crops between rubber rows, land use optimization could be achieved by introducing suitable crops to the boundary of rubber clearing where competition for resources will be minimal. Except for few, most intercrops facilitated improved growth of rubber and also contributed to social benefits.

Keywords: Banana; Economic aspect; Land utilization; Passion fruit; Pineapple; Socioeconomics; Sugar cane; Vegetable; Sri Lanka

163. **Rodrigo, V H L; Nugawela, A; Kariyawasam, L S and Aluthhewage** (1988)

Field performance of young coffee seedlings and cuttings intercropped with rubber

Journal of the Rubber Research Institute of Sri Lanka, 68: 45-51.

In this study seedlings and cuttings of *Coffea canephora* intercropped with rubber were compared for their field establishment and growth. It is evident that there is no difference in the success of their field establishment. The dry matter yields determinants of plants, ie. light interception,

conversion efficiency and rate of loss of dry matter, estimated by total leaf area, CO_2 assimilation rate and dark respiratory rate respectively, are also similar in both seedlings and cuttings. This is confirmed by the similar mean total dry weight of a seedling and a cutting. The partitioning of assimilates is more towards root development in the cuttings and is evident by the significantly high root dry weight and the root/shoot ratio. The percentage of assimilates partitioning towards the growth of aerial parts is less in the cuttings, i.e.52 and 67% for cuttings and seedlings respectively. Despite of similar light levels, the CO_2 assimilation rates are lower in the afternoon in both seedlings and cuttings. The percentage decline is 23.5 and 18.6% for seedlings and cuttings respectively.

Keywords: Coffee; Light intensity; Sri Lanka

164 **Rodrigo, V H L; Stirling, C M; Teklehaimanot, Z and Nugawela, A** (1997)

Effect of planting density on growth and development of component crops in rubber/banana intercropping systems

Field Crops Research, 52 (1/2): 95-108.

In a field trial in Sri Lanka, rubber (*Hevea brasiliensis*) trees, clone RRIC 100 (R), and bananas (*Musa spp*) cv. Kolikuttu (B) were each grown as sole crops and in three intercropping treatments consisting of an additive series of 1 (BR), 2 (BBR) and 3 (BBBR) rows of bananas to one row of rubber. Planting density of bananas was 500, 1000, 1500 and 1700 plants ha^{-1} in the BR, BBR, BBBR and B treatments and planting density of rubber was 500 plants ha^{-1} in all treatments. Growth analysis commenced at eight months after planting. At the start of the experiment, rubber plants were four months old. Density had significant effects on both leaf area index and total dry matter (TDM) of the stand, with the highest values in the most dense treatment, BBBR. TDM, leaf area and dry matter partitioning to above-ground components of bananas were significantly greater in the BBR and BBBR treatments than in the BR treatment. Dry matter yield and the crop performance ratio (CPR) of rubber also increased with increasing banana planting density. Plant weight, stem girth and plant height of rubber were greater in the intercropping treatments than the sole crop treatment. Treatments had little affect on bunch yield per banana plant, harvested percentage and CPR, with mean values of 6.2 kg, 65.3% and 0.95, respectively. Since yield per plant was similar across treatments, yield/ha increased significantly with increasing banana density. Amongst intercrops, the highest density BBBR treatment always performed best in terms of both stand parameters and performance of individual component crops. It was concluded that increasing the density of bananas from a single row to three rows increased biomass production per unit area, with no adverse effects on the growth or yield of either component crops.

Keywords: Banana; Growth; Planting density; Yield; Sri Lanka

165. **Rodrigo, V H L; Nugawela, A; Sivanathan, A; Witharama, W R G and Jayasinghe, W K** (2000)

Rubber cum sugarcane intercropping: A suitable cropping system for farmers in the intermediate zone of Sri Lanka

Journal of the Rubber Research Institute of Sri Lanka, 83: 62-74.

In the process of expanding rubber cultivation to the nontraditional areas with drier climate, it is extremely important to find remedies for both biophysical and socio-economic limitations for it.

In this regard, intercropping sugarcane with rubber was used as a tool in the present study. Sugarcane was planted in two densities together with immature rubber crop under on-farm conditions in the intermediate zone of Sri Lanka and growth and yield parameters were assessed. The planting density of sugarcane did not affect sugarcane yield per unit length of planting, hence the highest density tested gave the greatest yield per hectare. Either density of sugarcane had no adverse effect on the growth of rubber, instead intercropped rubber showed an improved performance over the sole crop. Alleviation of radiation stress on photosynthesis by the partial shading given by sugarcane was identified as the factor, which governed the better growth of intercropped rubber. Social implications of the rubber/sugarcane intercrop are discussed.

Keywords: Agroclimate; Planting density; Sugar cane; Yield; Sri Lanka

166. **Rodrigo, V H L; Stirling, C M; Silva, T U K and Pathirana, P D** (2000)

High density intercropping with banana reduces the length of the immature period of rubber and increases latex yield

Proceedings of the Indonesian Rubber Conference and IRRDB Symposium, 12-14 September 2000, Bogor, Indonesia, pp. 490-500.

The research conducted in Sri Lanka and elsewhere has shown that intercropping does not affect the growth of rubber, indeed growth of young rubber trees is often improved. Few, if any studies however have evaluated the long-term effects of intercropping during the immature phase on growth of rubber. Intensive intercropping of rubber with banana results in a sustained increase in growth and yield of rubber trees, as well as reducing the length of the unproductive immature period. The study was an extension of the intercrop experiment described by Rodrigo et al. (1997) in which rubber was grown either as a sole crop (R), or intercrop comprising an additive series of one (BR), two (BBR) or three (BBBR) rows of banana to one row of rubber. Intercropping had a positive effect on the growth of rubber throughout the six years of the study, with the result that trees in the intercrop treatment were ready for tapping six months earlier than in the sole crop. Whilst girth and height were greater in the intercrops, bark thickness was similar to that of the sole crop. Treatments had no affect on latex yield per plant, but yield per hectare was greater in the intercrop than sole crop treatments due to a greater number of tappable trees. Results are discussed in terms of the socioeconomic implications for smallholder rubber growers.

Keywords: Banana; Economic aspect; Socioeconomics; Smallholding; Yield; Sri Lanka

167. **Rodrigo, V H L; Stirling, C M; Samarasekera; Kariyawasam, L S and Pathirana, P D** (2000)

Agronomic and economic benefits of high-density banana intercropping during the immature period of rubber with particular emphasis on smallholders

Journal of the Rubber Research Institute of Srl Lanka, 83: 30-48.

Intercropping with short duration crops alleviates the problem of no income during the immature period of the rubber crop. Banana is an important crop in this context and its present recommendations in Sri Lanka in planting density appear to be suboptimal for rubber/banana intercropping. This study evaluates the effects of planting of banana with respect to resource use and productivity on immature rubber lands. Field trials were conducted at two

locations with a large-scale experiment (5 ha) and a small scale trial (1ha). There were five treatments comprising sole crops rubber (R) and banana (B) and three intercrops consisting of an additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Biomass productivity and leaf area index showed a steady increase with increasing planting density in the rubber/banana intercrop. There was no identification of any negative effect of mutual shading on either crop: indeed growth was enhanced, resulting in a 25 and 36 % increase in biomass per plant of rubber and banana respectively, in the high density BBBR relative to the single row BR intercrop. As a result, the Land equivalent ratio (LER) for biomass increased by 76% from the BR to BBBR intercrop. Because treatments had no significant effect on bunch yield per banana plant or harvested percentage, yield per hectare increased three-fold from the current recommended BR to BBBR intercrop resulting in an estimated 350% increase in profits from the banana crop. An increase in resource capture was the principal cause of the increased productivity in high density intercrops and on average, radiation and water use in the BBBR intercrop increased by 73% and 140%, respectively, over the BR intercrop. Neither photosynthesis nor respiration was affected by the increase in mutual shading at the leaf level. Therefore, increased whole plant photosynthesis and hence light-use efficiency resulted from the increase in leaf area per plant. The increase in girth of intercropped rubber was maintained throughout the immature phase resulting in an earlier onset of tapping in the intercrop than in the sole crop rubber. The social implications of these findings are discussed.

Keywords: Banana; Economic aspect; Light intensity; Planting density; Socioeconomics; Sri Lanka

168. **Rodrigo, V H L; Stirling, C M; Naranpanawa, R M A K B and Herath, P H M U** (2001)

Intercropping of immature rubber in Sri Lanka: Present status and financial analysis of intercrops planted at three densities of banana

Agroforestry Systems, 51: 35-48.

Intercropping during the unproductive immature stage of rubber provides one means of addressing the gap in income suffered by smallholders after replanting or new planting of rubber. A survey of small-holder rubber plantations was undertaken to determine the current status of intercropping in Sri Lanka. A total of 587 smallholders were included in the survey that encompassed the four major rubber growing regions: Kalutura, Kegalle, Colombo and Rathnapura. Intercropping was practiced on relatively few farms with the percentage of smallholders engaged in intercropping ranging from 23 to 54%. Banana was the most common companion crop of rubber with a current extension recommendation for a single row of banana planted between rubber rows. A financial appraisal, based on data from an agronomic experiment, revealed the potential to raise profits by more than 350% if planting density of banana was increased threefold over current recommendations. Profitability of banana intercrops was governed by four major components: yield expected in the third year, fertilizer costs, labour costs and market value of banana fruit. The influence of planting density of banana on each component is discussed. The survey indicated that most farmers grew banana without chemical fertilizer. If high density banana intercropping is to be widely adopted as a means of raising income on immature rubber lands then current

recommendations for chemical inputs need to be addressed in order to bring initial costs down to a sustainable level for smallholders.

Keywords: Banana; Planting density; Smallholding; Socioeconomics; Survey; Sri Lanka

169. **Rodrigo, V H L; Stirling, C M; Teklehaimanot, Z and Nugawela, A** (2001)

Intercropping with banana to improve fractional interception and radiation use efficiency of immature rubber plantations

Field Crops Research, 69: 237-249.

To evaluate current recommendations for intercropping rubber in Sri Lanka, the effects of a range of planting densities of banana were assessed. In this paper, the hypothesis that rubber/banana intercropping, even at high densities of banana, results in an increase in biomass per unit land area and per crop plant due to an increase in both radiation capture and radiation-use efficiency was tested. Five treatments were imposed: sole crop rubber (R); sole crop banana (B); and three intercrop treatments comprising and additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Dry matter production in the rubber-based treatments was directly related to planting density, being least in the sole rubber and greatest in BBBR intercrop. A more than four-fold increase in dry matter across treatments derived from an increase not only in light capture (270) but also radiation-use coefficiency (RUE, 230). Neither R nor BR treatment, which is currently recommended for intercropping in Sri Lanka, achieved full ground cover with fractional interception remaining below 40 and 50, respectively. Fractional interception was greatest in BBBR treatment and by the end of the measurement period, total intercepted radiation was 23 and 73 greater than that in the BBR and BR intercrops, respectively. Shade did not limit either photosynthesis or growth of component crops in the intercrops, even when planting density of banana was increased three-fold. Intercropping increased growth of both rubber and banana components suggesting that shade associated with the denser intercrop canopies, moderated that microclimate and alleviated plant stress. These results highlight the potential gains that can be made by intercropping and optimizing planting density for improved resource capture in immature rubber plantations.

Keywords: Banana; Light intensity; Planting density; Sri Lanka

170. **Rodrigo, V H L; Thenakoon, S and Stirling, C M** (2001)

Priorities and objectives of smallholder rubber growers and the contribution of intercropping to livelihood strategies: A case study from Sri Lanka

Outlook on Agriculture, 30 (4): 261-266.

A case study is used to illustrate the agronomic and socioeconomic complexity of smallholder cropping systems in Sri Lanka and how rubber, and in particular the intercropping of immature rubber, has contributed to improving rural livelihoods through raising household income and capital assets. Smallholder cropping systems are extremely diverse and what appeared initially as random planting was seen to be anything but, with planting arrangements based on a thorough knowledge of local soil and microclimate conditions, as well as on the specific needs of the household. The potential benefits of intercropping immature rubber are discussed and the authors show how the more liberal

attitude towards intercropping within the rubber extension service has impacted positively on the livelihoods of smallholder farmers. A cash flow was constructed for the household, indicating that over two-thirds of annual household income was derived from on farm activities, with 70 of this from intercropping on immature rubber land. The benefits of rubber intercropping to income generation, land tenure and upkeep of immature rubber lands are discussed within the context not only of the smallholder, but also in terms of the estate sector.

Keywords: Case study; Cropping system; Economic aspect; Smallholding; Land utilization; Sri Lanka

171. **Rodrigo, V H L; Silva, T U K; Kariyawasam, L S and Munasinghe, E S** (2002)

Rubber/timber intercropping systems and their impact on the performance of rubber

Journal of the Rubber Research Institute of Sri Lanka, 85: 10-26.

Current low productivity levels of rubber cultivations could practically be addressed by intercropping techniques. Obviously, there is an increasing demand for timber; hence this study aimed to investigate the feasibility of growing timber crops with rubber under three different systems. i.e timber species are grown, in between rubber rows; on the boundary; and; in vacant patches of rubber clearings (as a means of infilling). Four different timber species and two different spatial arrangements of planting rubber were tested to assess the system 'A' and *in situ* assessments were done for the rest. Alstonia could be established together with rubber comprising the growth and yield of rubber crop. Also, Alstonia could not be established properly under the shade given by five-year old rubber planted in the traditional single row system. The shade provided by the rubber canopy has mitigated the stem borer attack on Mahogany, hence the establishment of Mahogany was successful with five year old rubber. Paired row planting system of rubber was preferred over the traditional single row planting system for the better establishment of both Alstonia and Mahogany with five year old rubber. Timber trees could be planted along the boundaries and in the vacant patches of rubber clearings with no adverse effects on growth and yield of rubber.

Keywords: Alstonia; Mahogany; Planting density; Timber plantation; Sri Lanka

172. **Rodrigo, V H L; Silva, T U K and Munasinghe, E S** (2002)

Feasibility of growing rubber/ timber intercropping systems

Proceedings of Eleventh International Workshop of BIO-REFER, 8-12 October 2002, Seoul, Korea, pp.172-178.

Intercropping on rubber lands increases the land productivity and diversifies the income of farmers. Also, intercropping on rubber lands increases the land productivity and diversifies the income of farmers. Natural forests are under threat with increase in demand for timber, therefore this study-aimed to investigate the feasibility of growing three different rubber/timber intercropping systems. Systems where timber crops grown in between rubber rows, on the boundary and in vacant patches of rubber clearings (as a means of infilling) were assessed under two different spatial arrangements of planting rubber, i.e. single and paired row systems. A rapid appraisal was conducted on existing sites to evaluate other systems. In the inter-row planting system,

despite the advantage of having the highest establishment rate, Alstonia showed a competitive effect on growth and yield of rubber if both crops are planted together. Establishment of Mahogany was successful under the shade of rubber, however it was not the case for Alstonia. In order to minimize competition on rubber, it is suggested to plant timber crops allowing first 2-3 years for the establishment of rubber. The paired row system of planting facilitated the establishment timber crops even at later stage, however this system must be improved in order to minimize the inter-specific competition of rubber. No clear competitive effect on rubber was found, if timber trees are grown either along the boundaries or in the vacant patches of mature rubber clearings indicating why growers in their own have established these systems.

Keywords: Alstonia; Mahogany; Planting density; Timber plantation; Sri Lanka

173. **Rodrigo, V H L; Stirling, C M; Thenakoon, S; Senevirathna, A M W K and Pathirana, P D** (2003)

Technology refinement of rubber/ banana intercropping using a farmer participatory approach

Tropical Agricultural Research and Extension, 6: 77-84.

On-farm adoption of the technologies developed under on-station conditions has been below expectations, demanding technology refinement in accordance with the requirements of end-user farmers. However, assessment of farmers' needs and subsequent adjustment of the technology are time consuming compared with that of direct recommendations, which have often been practiced. The study reported here was on the technology refinement of rubber/banana intercropping and identification of issues related to rubber cultivation at the smallholder level in Sri Lanka. Planting of a single row of banana between two rubber rows had initially been recommended in rubber/banana intercropping, however, an on-station experiment showed that planting density of banana with rubber could be increased threefold without any deleterious effect on either crop. Based on some preliminary observations on farmers' needs, a series of on-farm experiments were set up in four villages in both the wet and intermediate zones of Sri Lanka. Both biophysical factors on plant growth and socio-cultural effects in the rural context were also taken into consideration. Finally, the observations made by scientists were verified through a farmer participated central workshop. Selection of rubber by the smallholders was driven by two main benefits, firstly as a long-term income source and secondly to secure land ownership. Intercropping was a practical measure to generate income during the early stage of rubber cultivation, particularly in the intermediate zone where farmers depend more on on-farm than off-farm activities. The extension services on rubber were not up to expectations of the farmers. In addition to the market factors, crop selection of intercropping was based on the income level of farmers and availability of family labour. Among the systems tested, two-row planting system for banana with rubber was found to be the most suitable system for smallholders.

Keywords: Banana; Economic aspect; Family labour; Planting density; Smallholding; Sri Lanka

174. **Rodrigo, V H L; Silva, T U K and Munasinghe, E S** (2004)

Improving the spatial arrangement of planting rubber (*Hevea brasiliensis* Muell. Arg.) for long-term intercropping

Field Crops Research, 89: 327-335.

Fluctuation in rubber prices has been a serious problem to grower's land intercropping with economically important crops offers a practical solution to this issue whilst increasing overall

productivity. However, shade given by the rubber canopy limits possibilities of incorporating other sun-liking crops into rubber-based systems. Therefore, the present study aimed to determine suitable spatial arrangements for planting rubber in order to facilitate long-term rubber-based intercropping systems. A field experiment was established in a commercial estate in the Kalutara district of Sri Lanka with five systems of spatial arrangement comprising, single row; double row; three row systems; as well as, three plant triangular; four plant square cluster systems of planting. Planting density of rubber remained constant across the treatments and systems were assessed for a period of nine years. Plants in single row alleys and in cluster systems performed better than those in other systems with respect to three row systems provided the highest unshaded area and hence light penetration. Both double row and three row systems provided the highest unshaded area and hence light penetration. Considering overall performance, the double row system was identified as the best system for long-term intercropping. In view of improving the plant growth in the double row system and further facilitating long-term intercropping, a revised version of the double row system was proposed reducing the planting density of rubber.

Keywords: Cropping system; Planting density; Shade; Sri Lanka

175. **Rodrigo, V H L; Iqbal, S M M and Pathiratna, L S S** (2004)

Intercropping: A way to maximize the land productivity and to obtain economic stability

Bulletin of the Rubber Research Institute of Sri Lanka, 45: 55-59.

The article provides an overview of intercropping practices followed in Sri Lanka with major research findings of research in intercropping, suitable intercrops (sugarcane, pineapple, passionfruit, banana etc) based on climatic adaptability and socio-cultural acceptability. Perennial crops could be planted with rubber if they can tolerate the shade under the rubber crop. Crops such as coffee and cocoa are intolerant to the root competition given by the rubber if planted under mature rubber, hence should be established during the immature phase provided with temporary shades. Should sun loving long-term crops like tea, cinnamon etc. be grown with rubber, planting density of rubber needs to be compromised. Any form of successful intercropping with combinations of perennial crops, facilitates pricing mechanism protecting the growers from market crashes. Price of either tea or rubber has been attractive throughout the history hence the rubber/tea intercropping assures the continuous income to the growers. In the estate sector, intercropping could practically be promoted as a part of poverty alleviation programme of estate workers and a cost saving mechanism of immature upkeep.

Keywords: Agroclimate; Banana; Economic aspect; Passion fruit; Pineapple; Sugar cane; Land utilization; Sri Lanka

176. **Rodrigo, V H L; Stirling, C M; Silva, T U K and Pathirana, P D** (2005)

The growth and yield of rubber at maturity is improved by intercropping with banana during the early stage of rubber cultivation

Field Crops Research, 91(1): 23-33.

Intercropping with short-term crops provides a significant additional income during the long immature period of rubber tree growth when no latex is produced. Much previous evidence

has demonstrated that the growth of young rubber trees is unaffected by the presence of an intercrop. This study demonstrates for the first time that intensive intercropping of young rubber with banana may result not only in a sustained increase in growth and yield of rubber trees but also a reduction in the length of the unproductive immature phase. Rubber was grown either as a sole crop, or intercropped for the first four years with banana. The intercrop comprised an additive series of one, two or three rows of banana to one row of rubber. Growth of rubber was monitored for six years. i.e. up to the time that tapping of rubber latex began and logistic growth function was fitted to girth data in order to assess growth. Intercropping had a positive effect on the growth of rubber throughout the six years of the study, with the result that tree in the intercrop treatment were ready for tapping four months earlier than in the sole crop. Whilst girth and height were greater in the intercrops, bark thickness was similar to that of the sole crops. Intercrop treatments had no effect on latex yield per plant, but yield per hectare was greater in the intercrop than sole crop intercrop treatment

Keywords: Banana; Growth; Yield; Sri Lanka

177. **Rodrigo, V H L; Stirling, C M; Teklehaimanot, Z; Samarasekera, R K and Pathirana, P D** (2005)

Interplanting banana at high densities with immature rubber crop for improved water use

Agronomy for Sustainable Development, 25(1): 45-54.

Consumptive water use of the rubber (*Hevea brasiliensis*)/banana intercropping systems was assessed in Ratnapura, Sri Lanka. Five systems were tested; sole rubber (R) and banana (B) crops and three intercrops comprising additive series of one (BR), two (BBR) and three (BBBR) rows of banana to one row of rubber. Planting density of rubber remained constant across the treatments, hence the rate of transpiration associated closely with the planting density of banana with ca. 140% increased from banana-rubber to banana-banana-banana-rubber intercrops. Although water use efficiency (WUE) at whole stand basis was comparable among treatments, WUE component rubber during the latter part of the experiment increased by 118% in intercrops compared to that of the sole crop. Amount of water transpired even in the banana-banana-banana-rubber intercrops was small by comparison to the water received from rainfall, hence in wet tropics with heavy rainfall, agricultural systems should be designed to enhance the productivity through increase water use with less emphasis on WUE.

Keywords: Banana; Planting density; Water use; Sri Lanka

(CAB Abstarcts 2005/01-2005/09)

178. **Rodriguez, F A and Hernandez, P L** (1998)

Evaluation of planting distance for Chamaedorea palm under rubber trees

Scientific Technological Agricultural, Forestry and Husbandry Meeting: Proceedings, 3-4 December 1998, Huimanguillo, Mexico, 399p.

Keywords: Chamaedorea palm; Mexico

(AGRIS 1999-2002/09)

179. **Rosyid, M J; Wibawa, G and Gunawan, A** (1996)

Rubber based farming systems development for increasing smallholder income in Indonesia

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 17-24.

Natural rubber is one of the more important commodities in Indonesia and is a source of both foreign exchange and also income for more than twelve million people who depend on the rubber industry for their livelihood. The rubber planters in Indonesia are predominately smallholders and therefore the quantity and quality of Indonesian rubber depends mainly on the conditions used by these rubber smallholders. As a result of their low productivity (less than 1000kg drc/ha), smallholder income, national production and foreign exchange earnings are also low. Hence, it is essential that the productivity of smallholders is improved through improvements in the technology of their farming systems. Sembawa Research Station has utilized three steps in the development of rubber based farming systems: by providing recommended planting materials through farmer groups; by developing a technological package of intercropping during immature periods and by investigating the optimum scale for rubber based farming systems. The results showed that farmers could gain cheaper planting material (clones PR 261 and BPM 24) through farmer groups of 10-15 farmers. Both food and horticulture crops could be intercropped between immature rubber with no effect on rubber growth. The optimum rubber-based farming systems can be achieved by planting 1.4 ha of rubber (PR 261), 0.5ha of food crops and rearing 3.0 cattle. This farming system needs 630 man days/year and generates an income of Rp 4,751.291/year (US$ 2000/year).

Keywords: Economic aspect; Food crop; Horticultural crop; Rubber based farming system; Indonesia

180. **Roy, S; Raj, S; Dey, S K; Choudhury, M; Deka, H K; Alam, B; Sudhasowmyalatha, M K; Das, G; Varghese, Y A and Nazeer, M A** (1999)

Rubber based farming system: A preliminary report

National Seminar on Strategies for Agricultural Research in the North East, 10-12 November 1999, National Academy of Sciences, ICAR Research Complex for the NEH Region, Umiam, Meghalaya, India, pp.52.

A field trial was conducted during Kharif season of 1999 to identify suitable annual crops to be grown as intercrop with immature rubber. Four crops viz. pigeon pea, groundnut, sesame and chilli were tried for this study. All the intercrops produced high yield except chilli, which suffered several severe viral attack. Pigen pea, groundnut and sesame yield, as intercrop was equal to their sole crop yield. Integration of intercrops resulted in higher growth rate of main crop, rubber compared to rubber without intercrop. Increment in girth and height was highest in rubber when chilli was intercropped. The leguminous intercropping with pigeonpea and groundnut reasonable increased the girth and height of rubber. Intercropping in rubber increased organic carbon content, whereas available phosphorous and potassium content decreased in soil. It appears that intercropping of annual crops in rubber can produce a substantial return and better growth of main crop too.

Keywords: Chilli; Economic aspect; Groundnut; Rubber based farming system; Sesamum; Tripura; India

181. **Roy, S; Raj, S; Choudhury, M; Dey, S K and Nazeer, M A** (2001)

Intercropping of banana and pineapple in rubber plantations in Tripura

Indian Journal of Natural Rubber Research, 14(2): 152-158.

The effect of two cropping systems involving two intercrops, banana and pineapple, on soil chemical properties, growth of rubber, biomass production, nutrient recycling, productivity and returns was investigated during the first four years (1996-97 to 1999-2000) growth period of rubber in North-Eastern India, Agartala, Tripura. In the first system (Model I), intercrop strip consisting of five rows of pineapple and two rows of banana was planted in between four strips of rubber with a stand of 550 rubber plants per ha and in the second system (Model II), one of banana and two rows of pineapple were planted in alternate gaps with 470 rubber plants per ha. Continued fertilizer use under these two systems showed increase in available phosphorus and calcium. The growth of rubber was better and biomass production as well as nutrient recycling was higher in Model I. High yield and benefit: cost ratio of banana and pineapple established the economic feasibility of growing these intercrops. The maximization of yield and returns from the intercrops was possible by increasing the plant density (as in Model I) without adversely affecting the soil properties.

Keywords: Banana; Economic aspect; Non traditional region; Pineapple; Tripura; India

182. **Roy, S; Choudhury, M; Dey, S K and Pal, T K** (2001)

A preliminary study on kharif crop cultivation under rubber based cropping system in Tripura

National Seminar on Approaches for Increasing Agricultural Productivity in Hill and Mountain Ecosystem, 2001, Umiam, Meghalya, India

Keywords: Kharif crop; Non traditional region; North eastern region; Tripura; India

183. **Roy, S; Choudhury, M; Dey, S K and Pal, T K** (2004)

Intercropping of arable crops for higher monetary returns from an immature rubber plantation in Tripura

Natural Rubber Research, 17(1): 91-94.

Among five intercrops tried in a rubber plantation in Tripura, net return was maximum for ginger, though it required higher initial investment. Groundnut generated low net return considering the initial investment but the employment requirement was very high and may be suitable only for farms maintained on family labour. The pulse crop, pigeon pea, required less investment with high returns and can suit low to moderate input situations. Sesamum with less initial investment also suits local low-input situations. Turmeric intercropping required high investment but the profit was low. While organic carbon content in soil increased under ginger, sesamum and turmeric intercropping, available P and K increased only with ginger.

Keywords: Economic aspect; Ginger; Groundnut; Pigeon pea; Sesamum; Turmeric; Tripura; India

184. **Roysid, M J and Wibawa, G** (1996)

Farmers experience in integrated rubber farming system with *Uncaria gambir* in South Sumatra and West Sumatra (Indonesia)

Warta Pusat Penelitian Karet, 15(1): 48-56.

Keywords: Farming system; *Uncaria gambir*; Sumatra; Indonesia

(AGRIS 1999-2002/09)

185. **RRIC** (1941)

Cultivation of food crops in young rubber areas

Advisory Circular Ceylon Rubber Research Scheme, 15: 2.

In order to make full use of young rubber areas up to 2 years old for food crop growing, the authorities recommend a regular cropping rotation for which they advise 24 named plants, stipulating that no food plant shall be grown within 4 feet of any rubber plant and that certain other named soil-conserving operations shall be carried out.

Keywords: Food crop; Ceylon

(BPPM Abstract Bibliography of *Hevea* rubber: V2, 1970)

186. **RRIM** (1967)

A new look at intercropping

Planters' Bulletin, 89: 53-54.

Keywords: Cash crop; Economic aspect; Malaysia

187. **RRIM** (1972)

Banana and tapioca as intercrops in immature rubber

Planters' Bulletin, 123: 203-212.

This article attempts to focus on the prospects of intercropping rubber with bananas and tapioca, two popular perennial crops associated with intercropping in rubber. Banana is more widely grown throughout the country while tapioca is centered around tapioca factories and in regions where pig rearing is an occupation. The fact that rubber growth under banana intercropping compares favourably with that under estate practices of maintaining pure legume covers is of practical importance. Although intercropping tapioca may be profitable on a short-term basis, the heavy nutrient drainage and the adverse effect on rubber growth by tapioca, particularly on a long-term basis cannot be ignored. Intercropping rubber with tapioca therefore cannot be recommended generally.

Keywords: Banana; Tapioca; Malaysia

188. **RRIM** (1973)

Intercropping with annual crops in immature rubber

Planters' Bulletin, 126: 85-92.

This paper discussed the information obtained from intercropping experiments with groundnuts and maize. Such intercropping is feasible on flat or gently undulating land, and the rubber

should be planted east- west to minimize its shading effect. A spacing of 30x 10 or 30 x 9 ft is recommended and fertilizer programmes are suggested. When three year intercrop rotations of cereals to cereals, legumes to legumes, and legumes to cereals were compared with a control of leguminous covers for their effect on the girth of young rubber the average girth in intercropped plots was slightly greater and the best growth was recorded in the legume rotation sequence (soyabeans to groundnuts). Crop rotation in intercropping would result in the advantages of maintaining soil fertility as well as reducing pests and diseases. A crop rotation sequence from legumes to legumes (soya bean to groundnut) or from legumes to cereals (groundnut to maize) would be an appropriate combination. Both groundnut and maize are suitable for intercropping between rubber during the immature period and give a welcome cash relief before the rubber starts to yield. Successful implementation of intercropping would be of particular importance to the smallholdings with regard to replanting.

Keywords: Cropping system; Groundnut; Maize; Smallholding; Soyabean; Land utilization; Malaysia

189. RRIM (1975)

Cajanus cajan: New legume cover crop

Planters' Bulletin, 137: 51-52.

A new legume crop- *Cajanus cajan* (L) has been introduced in Malaysia. It can be used as a dual purpose crop either as a cover crop or an intercrop for rubber plantaions. Twenty-one varieties of *Cajanus cajan* (L) were evaluated at the RRIM Experiment Station, Sungei Buloh. Preliminary results show that this crop has great potential in Malaysia. The leaves and stem tops can provide excellent fodder for farm animals. The leaves have a protein content of 23%. Further development of this crop is being conducted.

Keywords: *Cajanus cajan;* Cover crop; Malaysia

190. RRISL (2001)

Rubber based intercrops

DFIDAdvisory Circular, No. 2001/01, Plant Sciences Research Programme, Rubber Research Institute of Sri Lanka,13 p.

The recognized advantages associated with mixed cropping systems apply intercropping in rubber also. The major advantages of intercropping over sole cropping can be summarized as: improved total yield and economic return; greater variety of produce and seasonal spread of income; reduced susceptibility to market crashes; reduced crop losses due to pests and diseases and reduced dependency on fertilizer inputs due to more efficient use of nutrients. Intercropping in rubber plantation generate additional income during the immature unproductive period of rubber, and improve growth of rubber. Selection of crops for intercropping should be based on plant factors like root and canopy architecture, complete for resource and factors such as soil type, rainfall etc and socio-economic factors like demand for production, marketability, labour availability etc. A variety of crops like banana, pineapple, sugarcane, etc. can be grown during the immature phase. Cardamom, vanilla,

rattan, coffee and cocoa can be grown during mature phase. By sending the planting density of rubber, crops like tea, cinnamon and pepper can also be accommodated as intercrops

Keywords: Banana; Cardamom; Cinnamon; Cocoa; Coffee; Passion fruit; Pepper; Pineapple; Rattan; Rubber based farming system; Sugar cane; Tea; Vanila; Sri Lanka

191. **RRIT** (1974)

Report on a survey of intercropping in immature rubber preliminary table: Part II, Rubber Research Centre, Hat Yai, Thailand, Document. 48. 25p.

This preliminary report outlines the results of a survey of intercropping in immature rubber replantings conducted during 1970-1971. Data on the extent and economics of intercropping in immature rubber on smallholdings in Thailand were collected. The holdings visited were selected on the basis of the intercrop grown, the area intercropped, whether grown for sale or home consumption and date of harvest. The crops found to be of major importance in preliminary studies are upland rice, pineapples, banana, peanuts, maize, tobacco, sweet potatoes, chillies and watermelon. In the final analysis no holdings growing chillies or watermelon are included in the tabulations. Thus the report summarizes the tabulated data of yield, labour and inputs and incomes.

Keywords: Economic aspect; Family labour; Food crop; Yield; Thailand

192. **RRIT** (2000)

Planting cardamom as an intercrop in rubber plantation

RRIT, Department of Agriculture, Document, No. 3, Thailand

Keywords: Cardamom; Thailand

(Cited by Buranatham, W.)

193. **RRIT** (2000)

Planting *Calamus caesius* as intercrop in rubber plantation

RRIT, Department of Agriculture, Document, No. 5, Thailand

Keywords: *Calamus caesius*; Thailand

(Cited by Buranatham, W.)

194. **Rubber Mithram** (2001)

Intercrops, Multicrops. Part II (Malayalam)

Rubber Mithram, 3(2): 24-26.

Keywords: Multiple cropping; India

195. **Saint Pierre, C** (1991)

Evolution of agroforestry in the Xishuangbanna region of tropical China.

Agroforestry Systems, 13(2): 159-176.

This paper is based on a two-month survey made in Xishuangbanna, Yunnan, China, during 1989-1990. Descriptions are given of agroforestry practices and trials on the rubber farms,

and in a low land Dai village and a highland Jinuo village. Agroforestry practices on the state rubber farms have not been developed as much as in the other main rubber producing area in China (Hainan); the main practices undertaken are (private) planting of pineapple and tea (*Camellia sinensis* var. assamica) under the rubber trees. The Dai community has several farming systems: staple crops (mainly rice in flat valley paddy fields); rubber plantations (grown by 50% of families) which are underplanted with pineapple and tea and used for grazing by water buffaloes; the medicinal cash crop *Amomum villosum*, which is cultivated in talwegs [areas cleared of undergrowth] in the forest; multi-layered home gardens; taungya (which develops into woodlots) with *Cassia siamea* for fuelwood production; pure bamboo plots; protected sacred forest; and collective forest where timber cutting is regulated. The cultivation cycle is long (three year of rice as staple crop, 1 of corn as cash crop, or more in fertile plots) and the fallow period has dropped from 13-20 year in 1960 to seven year (in 1989-90). There are very small areas of paddy fields. Tea is planted in the forest and talwegs are planted with *A. villosum*. A table is given showing indigenous woody species under cultivation in agroforestry systems in Xishuangbanna, and their uses. The traditional Dai and Jinuo agroforestry systems are under threat because of an extension of the monetary economy of the area based on rubber tapping and the harvesting of *A. villosum*. Various outcomes of this situation are possible and these are briefly discussed; they include the development of new agroforestry systems, and an extension of agroforestry systems under rubber and of the cultivation of *A. villosum* in the forest.

Keywords: Agroforestry; Medicinal plant; Pineapple; Survey; Tea; Yunnan; China

196. **Salgado, J S and Marques, P C** (1984)

Selection of legumes for intercropping with rubber

Pesquisa em Andamento, 22: 6.

In a field trial in 1983-84 at Fundao, (a) *Cajanus cajan* (b) *Leucaena leucocephalia* cv. Peru (c) Tephrosia sp., (d) *Canavalia paraguayense* and (e) *Calopogonium mucunoides* were sown between rows of *Hevea brasiliensis*. The details such as the number of days from sowing to flowering, plant height four months after sowing, and above ground fresh weight are presented. Data on root density (cm/cm3) and apparent density (g/cm3) at 0-29 and 20-50 cm are similar for all spp.

Keywords: *Cajanus cajan*; Legume; Brazil

(HORTCD 1973-1988)

197. **Salleh, M N and Aminuddin, M** (1986)

Rattan as a supplementary crop in rubber plantations

Proceedings of the Rubber Research Institute of Malaysia: Rubber Growers' Conference, 20-22 October 1986, Parak, Malaysia, pp. 261-273.

The most important species of rattan, are *Calamus manan* (Rotan manau), a large cane of >18 mm diameter, and *C caesius* (Rotan sega) a small cane of <18 mm diameter are facing depletion due to over-exploitation in their natural habitat. Trial plantings on a commercial scale are being initiated and such plantings are carried out in logged-over forests and in secondary forests. Another approach is to establish Rotan manau in rubber plantations, between rows of rubber trees. The main objective of planting Rotan manau under rubber is to increase the income of rubber smallholders through greater utilization of their land resource. Rattan in its

natural state requires tree crops for shelter and support, which can be provided by rubber trees. Indeed, the land area under mature rubber is currently under-utilized for any economic crop, and rattan offers the opportunity to utilize this area for economic gain. Experimental trials in Dengkil, Selangor were established in 1980 by planting nine month-old seedlings of Rotan manau in between mature rubber trees (thirteen years' old). Survival and growth of the plants have been encouraging. Five years after planting, survival was 76.2% and the mean stem length was about 150 cm. The growth rate of 30 cm per year for the early establishment phase was better than growth figures obtained from trials in forest areas. Based upon other research, Rotan manau can grow at an average rate of 1-3 m per year. Taking the lower conservative growth limit of 1 m per year, it can reach harvestable age after twelve years, at which time it could produce three mature sticks of cane each of 3 m in length. It is estimated that the top 25% of the plant would be immature and cannot be utilized. Assuming an average final density of 300 plants per hectare, the expected yield would be 900 sticks of cane. The current price of a 3 m cane of Rotan manau is 3-ringgit ex-farm. Harvesting is planned to take place during felling of rubber trees for re-planting. The advantages for the smallholder are that establishment cost is low, care and maintenance requirement is low, RISDA has accepted rattan as an intercrop with rubber, return on investment of rattan plantation under forest conditions is estimated to be 16% IRR, and, smallholders could be involved in secondary and tertiary processing of rattan. It is also envisaged that the plantation sector can profit from the cultivation of rattan. The establishment of about 500 000 h of rattan can be of economic benefit to Malaysia.

Keywords: Economic aspect; Land utilization; Rattan; Malaysia

198. **Samarappuli, L; Yogaratnam, N; Karunadasa, P and Mitrasena, U** (1997)

Management of tree legumes towards higher productivity in rubber plantations

Proceedings of the Ninth Workshop on Multipurpose Trees for Environmental Conservation, 1997, Kandy, Sri Lanka, pp. 85-98.

The value of tree legumes in enhancing the soil nutrient status and organic carbon content of the soil was clearly shown by the experimental data. Higher porosity, lower bulk density and penetrometer resistance were also found in tree legume plots. Soil moisture content was generally higher in tree legume plots and root growth measurements made, indicate that the root density was improved by mulching with tree legume loppings. Furthermore, among the different soil management practices tested, tree legumes (mulched) exhibited the highest growth and yield of rubber plants in comparison with other practices such as growing leguminous covers or naturals. *Flemingia congesta*, *Crotolaria anagyroides* and *Tephrosia vogellie* were identified as tree legume species that can be grown successfully between the rows of rubber plants and which would provide sufficient biomass for mulching. Although the growth rate of *Flemingia congesta* during the early stages appeared to be slow, this tree legume species provided sufficient biomass thereafter. It was also observed that the first lopping of *Crotolaria anagyroides* may be done four months after planting and it may be posiisble to do 2-3 loppings during the first six months after establishment if climatic conditions remain favourable.

Keywords: *Crotolaria anagyroides*; *Flemingia congesta*; *Tephrosia vogellie*; Soil management; Tree legume; Sri Lanka

199. **Santosa, E; Sugiyama, N; Hikosaka, S; Takano, T and Kubota, N (2005)**

Intercropping practices in cacao, rubber and timber plantations in West Java, Indonesia

Japanese Journal of Tropical Agriculture, 49(1): 21-22.

Intercropping practices in cacao (*Theobroma cacao*) (Rajamandala plantation in Bandung district), rubber (Cikkumpay plantation in Purwakarta district) and teak (Purwakarta and Sumedang plantations) plantations in West Java, Indonesia, were studied in 2003. Interviews with managers and farmers revealed that plantation companies allowed farmers to cultivate crops for three-four years after tree cutting (such as in the Purwakarta plantation where mahogany (Swietenia sp.) and pine seedlings intercropped with banana and pineapple were grown, and in the Sumedang plantation where teak trees were intercropped with tobacco). Thus, the farmers changed lands every three-four years. Each farmer managed 0.23 and 0.06 ha in the Cikumpay and Rajamandala plantations, respectively. In the Sumedang and Purwakarta plantations, larger farm areas (0.44 and 0.65 ha per farmer) were cultivated. After burning, the farmers ploughed the land, built terraces and furrows, and mulched the soil with plant residues. The companies usually planted tree seedlings either in the same year as cutting or one year after cutting. Most farmers decided which crops to grow based on crop profitability and marketability. However, in the Rajamandala plantaion, crop selection was mainly based on company regulations or the farmer's preferences for daily consumption. Farmers earned 57-72% of their income through intercropping activities. In the Sumedang plantation, farmers stayed in the farm for 7-20 day per month in temporary huts. In the Purwakarta plantaion, farmers visited their farms only 1-4 times during the growing season until ethephon application, after which subsequent visits were 1-4 times per month.

Keywords: Cocoa; Economic aspect; Timber plantation; Java; Indonesia

(CAB Abstracts)

200. **Sathik, M B M; Panikkar, P K S; Vijayakumar, K R and Sethuraj, M R (1994)**

Intercropping of medicinal plants in mature rubber: Possibilities

Seminar on Possibilities of Intercropping Medicinal Plants in Mature Rubber, 20 December 1994, Kottayam, India.

Possibilities were explored in 1987-88 for growing medicinal plants as intercrops in the mature plantations. Out of the 41 species tried six commercially important species, *Strobilanthus haenianus* (Karimkurinji), *Adatoda vasica* (Valia adalodakam), *Adatoda hedomei* (Cheirya adalodakam), *Plumbago rosea* (Chethikoduveli), *Alpinia galanga* (Aratha), and *Kaemferria rotunda* (Chengazhuneerkizhangu) were identified to be suitable for intercropping in the rubber plantations. Many of the medicinal herbs may not grow well under rubber shade, whereas shrub species perform better. Most of the medicinal plants that are accustomed to shade conditions propagate vegetatively. Seeds seldom germinate. The soil should have good structure with good drainage to avoid water logging. Plants with deeper root system could survive the sudden exposure to sunlight during wintering period. As both planting and harvesting of medicinal plants could cause soil disturbance, the planting programme should be limited to flat or gentle slope areas. In plantations with steeper slopes, medicinal plants could only be grown, if the land is terraced and strengthened with stonewalls. In gentle slope areas biological bund may be made below the interplantings across the slope. Cuttings of *Strobilanthes* may be planted on the bund in two staggered rows (15x 15 cm). intercropping

Plumbago rosea, *Adatoda vasica* and *Strobilanthus haenianus* in mature rubber plantations is recommended. The procedures for intercropping these species are also given.

Keywords: Aratha; Chengazhuneerkizhangu; Cheirya adalodakam Economic aspect; Karimkurinji; Medicinal plant; Valia adalodakam; Kerala; India

201. **Sathik, M B M; Panikkar, P K S; Vijayakumar, K R and Sethuraj, M R** (1995)

Intercropping of medicinal plants in mature rubber plantations

International Conference on Medicinal and Aromatic Plants, 30 December 1994 - 1 January 1995, Calcutta, India

Keywords: Economic aspect; Medicinal plant; Kerala; India

202. **Senanayake, Y D A** (1968)

Intercropping, supplementary cropping and crop substitution on rubber land: A viewpoint

RRIC Bulletin, 3(4): 99-113.

Keywords: Food crop; Pineapple; Sri Lanka

203. **Senanayake, Y D A** (1976)

Winged bean- *Psophocarpus tetragonolobus* (L) DC: A multirole second crop for rubber smallholdings.

Rubber Research Institute of Sri Lanka Bulletin, 11: 16-23.

Winged bean, *Psophocarpus tetragonolobus*, has been identified as an important crop of the future because of its nutritive value. It is a high protein crop, in which the protein and amino acid composition seeds, compared favourably with soya bean. In order to introduce this crop in to rubber smallholdings, the author urges experimentation with this crop as a substitute for the traditional cover crops, as an intercrop or even as a supplementary crop in rubber plantings.

Keywords: Cover crop; Smallholding; Winged bean; Sri Lanka

204. **Senevirathna, A M W K; Stirling, C M; Rodrigo, V H L; Karunathilake, P K W and Pathirana, P D** (2002)

Is shade important to rubber based cropping systems? Part 1. Effect of shade on growth, dry matter partitioning and adaptation of rubber and banana

Journal of the Rubber Research Institute of Sri Lanka, 85: 27-38.

An on-station experiment to determine the effects of shade on growth and shade adaptation of rubber (*Hevea brasiliensis*) and banana (Musa sp.) was established using an existing mature rubber plantation to provide a natural shade canopy. Four treatments were imposed consisting of an unshaded control and three levels of shade with 33.55 and 77% reduction in incoming radiation. Plant girth, height and dry matter of both rubber and banana decreased with increasing shade. Both rubber and banana showed clear adaptations to shade with an increase in specific leaf area and/ or decrease in leaf weight ratio, and partitioning of chlorophyll to the

light harvesting complexes (as indicated by the decline in chlorophyll a/b ratio). These shade adaptations of both crops would account, in part, for the improved growth of banana and rubber when intercropped.

Keywords: Banana; Dry matter partitioning; Growth; Shade; Sri Lanka

205. **Senevirathna, A M W K; Stirling, C M; Rodrigo, V H L; Karunathilake, P K W and Pathirana, P D** (2002)

Is shade important to rubber based cropping systems? Part 2. Photosynthetic performance of rubber and banana under natural shade

Journal of the Rubber Research Institute of Sri Lanka, 85: 39-52.

Shade effects on photosynthetic performance of rubber and banana were studied under natural shade established in an existing mature rubber plantation. Four treatments were imposed consisting of an unshaded control and three levels of shade with a 33, 55 and 77% reduction in incoming radiation. Chlorophyll fluorescence revealed no evidence of sustained protoninhibitory damage to photosynthesis under high light conditions in either banana or rubber. Short-term dynamic photoinhibition resulted in a reduction in photosynthetic efficiency during the central hours of the day in unshaded plants of both crops. Dynamic photoinhibition of both rubber and banana decreased with increasing shade, with the greatest depression in F/Fm occurring during the central hours of day. Although shade levels given were large enough to reduce the rate of CO_2 assimilation of both rubber and banana, reduced incidence of dynamic photoinhibition in both crops under shade would account, in part, for the improved growth of banana and rubber when intercropped.

Keywords: Banana; CO_2 assimilation; Photoinhibition; Photosynthesis; Shade; Sri Lanka

206. **Simon, P C** (1992)

Studies on intercropping in rubber plantation with ginger, plantain and gingelly in Taliparamba Taluk

Dissertation, P G in Natural Rubber Production, Kerala Agricultural University, Thrissur, India, 37p.

The study investigates the economics of intercropping of plantain, ginger and gingelly in rubber smallholdings in Taliparamba taluk of Kerala, India. Among the three intercrops, plantain was the best followed by gingelly and ginger. Plantain gave the maximum profit as intercrop. Poovan was found suitable in rainfed areas whereas nenedran in irrigated areas. Among the three intercrops, gingelly has the least cost of production and prevents soil erosion considerably. Eventhough ginger intercrop gave no profit, growth of rubber plantation found to be encouraged by ginger intercropping.

Keywrods: Economic aspect; Gingelly; Ginger; Plantain; Taliparamba; Kerala; India

207. **Singh, K A** (1999)

Resource management and productivity enhancement through agroforestry in the eastern hilly agro-ecosystems of India

Indian Journal of Agroforestry, 1(1): 63-72.

An unbalanced and unsustainable form of short-cycle shifting cultivation (jhuming) and limited opportunity to expand arable lands and their mechanized cultivation on the hill slopes

necessitates a greater intervention through agro forestry and horticulture in the northeastern hills of India. Both will enhance bio-productivity and lead to sustainability in the hills. Recent access to global market for various non-conventional products (edible fruits, herbal aromatics, cosmetics and medicines, spices, etc.) and bamboo, rattans and other palm group of trees of industrial importance will also provide opportunity to develop agro forestry-based land use systems. There are many traditional agro forestry practices existing in this region, which are economically viable but need in depth understanding for agronomic improvements to enlarge the area under agro forestry systems. Innovative practices already used by farmers in Arunachal Pradesh and in the hills of Meghalaya should be considered. In the last twenty years, a number of research agencies have contributed significantly to develop and improve many agro forestry techniques and systems, including silvi pastoral systems, sericulture, tree fodder production systems, aqua forestry and micro watershed approach to develop fodder, fuel and timber production systems, self regenerative forestry, feasibility of rubber and tea plantations in the low hills of Tripura and other states. Besides the improvement of jhum fallow through agro forestry and contour hedge intercropping, it can also optimize integrated land use capacity. There is a need to encourage product diversification on a unit of land through agro forestry in order to increase land capacity to produce its full potential. The products should be linked to assured marketing channels by identifying demands and outlets. In this context, government policy to strengthen land tenure systems and other legal aspects in relation to property rights and rights to use will have a positive bearing on agro forestry development.

Keywords: Agroforestry; Ecology; Land utilization; Resource management; North eastern region; Tripura; India

(CAB Abstracts 2002)

208. **Singh, R S; Bhattacharya, T K; Dutta, A K; Das, P K and Nag, D** (1998)

Production potential in the intercropping sequence of medicinal yam (*Dioscorea floribunda*) with pigeonpea (*Cajanus cajan*) and rubber (*Hevea brasiliensis*)

Indian Journal of Agricultural Sciences, **68**(4): 231-232.

A three year experiment with perennial plants sp., *viz.* medicinal yam (*Dioscorea floribunda* Mart. And Gal.), rubber (*Hevea brasiliensis* Mull. Arg.) and pigeon pea (*Cajanus cajan* (L.) Millsp.) was undertaken at the Tripura Forest Development and Plantation Corporation farm, Agarthala in 1990-93. Productivity of medicinal yam, pigeonpea, rubber in pure stands and medicinal yam-pigeonpea, and medicinal yam-rubber cropping system were compared for higher yield under intercropping than sole. Generally, intercropping medicinal yam with rubber or pigeonpea enhanced the Land Equivalent Ratio(LER).

Keywords: Pigeon pea; Yam; Yield; Tripura; India

209. **Sivadasan, C R and Nair, C K** (1989)

Rubber cardamom intercropping

Rubber Board Bulletin, **24**(4): 21-22.

A survey was conducted in areas where cardamom has been introduced as an intercrop in rubber plantations in Idukki (Marykulam). Wynad (Kalpetta and Sultan's Battery) and Palghat (Palakkuzhy) districts. The plantations were of small holders extending from 1 to 8 acres. The

survey indicated that rubber-cardamom intercropping can be adopted to areas suitable for this cropping system. For conducting economic and large-scale cultivation of cardamom as an intercrop in rubber plantations the following points are to be taken into consideration. Identify suitable areas where cardamom can be grown economically under rubber. Evolve cardamom types adaptable to lower elevation (cardamom normally grows at altitudes ranging from 700-1500 M) Evolve rubber clones adoptable to higher elevation. Standardize the age of rubber plantation that cardamom can be introduced without affecting the yield of rubber. Adopt scientific cultivation practices and pest and disease control measures to cardamom to reduce the cost of production.

Keywords: Cardamom; Kerala; India

210. **Soetardi, W** (1965)

Intercropping of rubber

Warta Karet, 1(8): 6-9.

The pros and cons of catch-cropping of young rubber by interplanting with rice, maize or other foodcrops are discussed on the basis of results obtained on a rubber plantation in Java (Indonesia). Intercropping not only give a highly valuable production of rice, thus saving foreign exchange for rice imports, but also results in a quicker growth of the young rubber treess, thus shortening the unproductive period prior to tapping.

Keywords: Food crop; Maize; Rice; Java; Indonesia

(BPPM Abstract Bibliography of *Hevea* rubber: V 2, 1970.)

211. **Sreenivasan, K G; Ipe, V C; Haridasan, V and Mathew, M** (1987)

Economics of intercropping in the first three years among new/replanted rubber

Rubber Board Bulletin, 23(1): 13-17.

Though rubber should ideally be grown in association with a legume cover, rubber growers are found raising different crops like banana, ginger, turmeric and elephant-foot yam (*Amorphophallus*) as intercrops, during the first three years after planting rubber. The present analysis is an attempt to probe into the economics of these intercrops and their relative profitability. The study was based on the data collected from a sample of 80 rubber growers, randomly selected, having new/replanted rubber in Kottayam district. The analysis brings out clearly the effects of changing market prices on the relative profitability of the three intercrops. Banana which is traded mostly in the domestic market showed less variations in net income. At 1984-85 prices, turmeric turned out to be more profitable than banana and ginger. Notably, at 1984-85 prices ginger earned profit of Rs. 5714 per hectare the benefit; cost ratio was 1.3617. At 1983-84 prices, ginger turned out to be highly profitable than the other two crops, followed by turmeric. The above analysis shows that prices affect considerably the profitability of both ginger and turmeric. Thus the risk associated with price changes is more pronounced in the case of ginger. It also reveals that the price risk is less with the cultivation of banana which is consumed domestically.

Keywords: Banana; Economic aspect; Ginger; Turmeric; Kottayam; Kerala; India

212. **Stirling, C M; Rodrigo, V H L; Janowski, M and Gray, A** (2000)

High density banana/rubber intercrops: Productivity, Livelihood/Stakeholder and market analysis

Final Technical Report, Department for International Development Plant Science Programme, UK, 41p.

Keywords: Banana; Economic aspect

(Cited by Rodrigo, V H L.)

213. **Stirling, C M; Rodrigo, V H L; Marzano, M; Thenakoon, S; Sillitoe, P; Senevirathna, A M W K and Sinclair, F L** (2001)

Intercropping boosts latex yield

Rubber Asia, 15(1): 53-54.

Intercropping of immature rubber, even at high densities, can have major benefits in terms of both income generations from the land and enhanced growth of rubber. One of the most common crops interplanted with immature rubber is banana. By raising planting density from one to three rows of banana, a 350% increase in profit can be achieved. Intercropping also has the potential to promote vigorous growth of rubber, thereby reducing the length of immaturity. Latex yield per hectare was also significantly improved due to the presence of a higher number of tappable trees. Intercropping offers a very practical and acceptable means of raising productivity, not only of rubber but also of the land in great, in a sustainable and environment friendly way.

Keywords: Banana; Latex yield; Smallholding; Sri Lanka

214. **Stirling, C M; Rodrigo, V H L; Sinclair, F L; Thenakoon, T M S P K and Senivirathna, A M W K** (2002)

Incorporating local and scientific knowledge in the adaptation of intercropping practice for smallholder rubber lands

Final Technical Report on a Research Project, Department for International Development Plant Science Research Programme, UK, 55p.

This report presents the results of a study to assess the potential for adoption of intensified banana/rubber intercropping on smallholdings in Sri Lanka. High density intercropping of rubber offers a win scenario: rubber can be successfully integrated with traditional cropping systems to provide many benefits to smallholders including earlier and greater latex yield, an additional income from the intercrop and better security of subsidy payments and property rights. Indirect benefits to soil fertility and stability will also accrue from the introduction of trees to traditional annual and perennial cropping systems.

Keywords: Banana; Cropping system; Smallholding; Sri Lanka

215. **Stirling, C M; Rodrigo, V H L; Marzano, M; Thenakoon, S; Sillitoe, P; Senevirathna, A M W K and Sinclair, F L** (2001)

Developing rubber-based cropping systems

The Rubber International Magazine, 3(25): 83-39.

Rubber cultivation offers many potential benefits to smallholders particularly the land poor in

developing countries. The experience in Sri Lanka has shown that whilst there may be reluctance to replant rubber in traditional rubber growing areas because of current low prices, in non-traditional regions farmers are very keen to introduce a perennial tree crop such as rubber into their present annual cropping systems. The introduction of rubber offers many of these poorer farmers security of property rights with respect to their land, which is an important step on the road to encouraging more efficient and sustainable agricultural practice. As a long-term perennial crop that can be grown on soils of low fertility and which sheds its leaves during winter, rubber also has the advantage of helping farmers maintain soil fertility and structure.

Keywords: Cropping system; Smallholding; Rural development; Socioeconomics; Sri Lanka

216. **Subadi** (1960)

Rice as a catch-crop in rubber

Warta Pusat Perkebunan Negara. **10**(6): 102-105.

With a view to the shortage of rice in Indonesia it is strongly recommended to grow rice as a catch-crop in young plantings of rubber (and of oil palm, etc.). For estates, which are equipped with tractors and agricultural implements, the interplanting with rice is fairly easy; but with only manual labour available the system in question is also attractive. It is claimed that besides the advantages of the rice product itself (about 1, 000 kg of dry paddy/hectare) and a decrease in weeding costs there is also a favourable effect on the growth of the rubber trees.

Keywords: Oil palm; Rice; Indonesia

(BPPM Abstract Bibliography of *Hevea* rubber: V 2.)

217. **Suhardi; Sulistyono, E; Sopandie, D; Chozin, M A; Sastrosumardjo, S and Suwarno** (1999)

Shade tolerance evaluation of upland rice lines/varieties

Proceedings of the Seminar on Increasing National Rice Production Through Tabela (direct sowing) System of Lowland Rice and Utilization of Unproductive Land, 9-10 December 1998, Peragi, Indonesia, pp. 481-487.

Evaluation for tolerance to shade of 200 upland rice lines/ varieties was initiated during December 1997 to April 1998 at PTPN VIII Cikumpay, West Java. Upland rice germplasms were grown as intercrop under rubber trees. Shading tolerance was determined by grain yield percentage and scoring value based on their growth performance in the field. The results showed that there were 25 lines/varieties classified as tolerant lines/varieties. Nine lines/varieties among them gave higher grain yield when were grown under 3-years old rubber canopies.

Keywords: Growth; Light intensity; Shade; Upland rice; Indonesia

(AGRIS 1999-2002/09)

218. **Sumarmadji; Sunarwidi; Koswara, J and Ismal, G** (1989)

Adaptation of two cardamom species and effects of organic matter application on rubber.

Bulletin Perkaretan, 7(3):66-74.

Rubber plantings (6, 10 or 23 years old) were intercropped, or not, with cardamom (*Elettaria cardamomum* and *Amomum* (local) sp.). Manure was applied at 0, 3 or 6 kg in each planting

hole. Data collected over 12 months are tabulated on microclimate (under the rubber shading), cardamom growth, flowering, leaf thickness and chlorophyll content and on rubber growth and yield. The three rubber plantings provided 12.2-47.4%, 34.8-51.0% and 35.5-63.0% shading, respectively, for the cardamom plants. Both cardamom species grew satisfactorily under even the oldest rubber trees; the local cardamom gave best results under six-year-old (newly tapped) trees. There was a significant interaction in effect on cardamom growth between shading and manure application rates.

Keywords: Agroclimate; Cardamom; Fertilizer application; Shade; Yield; Indonesia

(HORTCD 1989-2001/03)

219. **Sunarwidi and Hutagalung, O** (1978)

Residual effects of intercrop manuring on rubber growth

Bulletin Balai Penelitian Perkebunana Medan, 9(4): 185-191.

In a trial on soil deficient in P and Mg, rice and maize were grown as intercrops in the first year after planting rubber, and NPK and Mg fertilizers were applied, each at five different levels. Fifteen months after intercropping, rubber girths showed a positive response to P and Mg, but no response to N and K.

Keywords: Fertilizer application; Maize; Rice; Indonesia

220. **Sutrisno and Sastrosoedarjo, S** (1976)

Influence of upland rice (*Oryza sativa* L.) and corn (*Zea mays* L.) as catch crops on the growth of young rubber

Menara Perkebunan, 44 (2): 3-10.

Upland rice or maize was planted at distances of 25- 150 cm from two-year-old rubber trees. Distances of less than 100 cm had deletrious effects on both rubber growth (measured as girth increment) and the catch crop yield. Maize affected rubber growth more seriously than did rice.

Keywords: Maize; Upland rice; Indonesia

(HORTCD 1973-1988)

221. **Tan, H T** (1960)

Some aspects of the question of intercropping

Menara Perkebunan, 29: 203-211.

As a result of experiments on intercropping rice in rubber and oil palm plantations the following recommendations are made; the rice should be planted in strips 1-1 ° m from the main crop, the remaining area being clean weeded; adequate fertilizers for both main and food crops are needed; intercropping should only be practised for three years, including the year of planting the main crop; subsequently a permanent cover crop should be established.

Keywords: Rice

(BPPM Abstract Bibliography of *Hevea* rubber: V 2, 1970.)

222. **Thomas; Grist, P and Menz, K** (1995)

Modelling rubber growth as a function of climate and soils

Imperata Project Paper Improving Smallholder Farming Systems in Imperata Areas of Southeast Asia, No. 6, Indonesian Rubber Research Institute, Indonesia, 20 p.

Site indices are derived for rubber (*Hevea brasiliensis*) in Indonesia (where it is a promising tree for use on *Imperata cylindrica* infested grasslands) to represent separately growth (wood production) and latex yield (which respond differently to soil moisture content). The relationships for the climate component of the index (which includes moisture, thermal and light components) are based on the GROWEST classification system, and the soil component is based on the work of Y. Sugianto. Both components are modified to be specific to rubber in Indonesia and combined to give the overall site index for growth. This is used to estimate rubber growth in different areas of Indonesia. It will help to predict growth of the rubber GT1 clone (widely used in Indonesian plantations), and could be adapted to other clones. A particular application of the site index is in relation to improvement of the BEAM rubber yield prediction model RRYIELD, a rubber based agroforestry model involving bioclimatic, topographic and silvicultural variables which can incorporate latex and wood production and rice intercropping. Appendices to the paper use the improved site index developed here to replace the original one in the BEAM RRYIELD model, but it also has applications outside this one.

Keywords: Agroclimate; Agroforestry; Rice; Indonesia

(CAB Abstract 1996-1998/07)

223. **Thomas, J and Kuruvilla, K M** (2005)

Rubber as a shade tree for cardamom: A case study

International Natural Rubber Conference India 2005: Preprints of Papers, 6-8 November 2005, Cochin, India, pp. 149-152.

A survey was undertaken by Indian Cardamom Research Institute, Spices Board, Myladumpara to evaluate the performance of cardamom cultivated under rubber in the fringe areas of Cardamom Hill Reserve including Marykulam, Kanchiyar, Kozhimala and Thovarayar of Idukky District. Studies revealed that the canopy development in fully-grown 20-year-old rubber tree grown in these areas was only half of that grown in the traditional belt. The shade level under rubber canopy is 14349 lux compared to 13668 lux under natural shade in the cardamom tract. The growth and yield performance of cardamom with regard to number of tillers, number of panicles, number of capsules per racemes and yield were similar to those grown in conventional areas. The girth of rubber tree increased over 22 percent when intercropped with cardamom. The net returns from cardamom cultivation under rubber increased to the tune of 20 percent.

Keywords: Cardamom; Economic aspect; Idukky; Kerala; India

224. **Townsend, C H H *et al.*** (1964)

Cultivation of rubber inter planted in coffee fields

Boletim Tecnico Instituto Provincial Agropecuario, 6: 1-6.

Owners of coffee farms in Guatemala at altitudes up to 750 m are recommended to replace their shade trees with rubber trees planted on the contour at a spacing of 10 x 2.3 m; coffee

bushes less than 0.9 m from the rubber rows should be removed, those between 0.9 and 1.8 m from the rubber should be pruned back. In order to render the coffee more tolerant of the change, it is recommended to apply 56 g urea per bush to the soil in May-September and 85g in November, and to spray four times a year with a mixture of urea. M_nSO_4, $AnSO_4$ and borax. Farmers wishing to plant rubber may apply for a credit from a special fund managed by the Banco de Guatemala.

Keywords: Coffee; Guatemala

(BPPM Abstract Bibliography of *Hevea* rubber: V 2, 1970.)

225. **Van Brandt, H; Siahan, M and Sunarwidi** (1976)

Prospects for intercropping young rubber with *Pueraria Thumbergiana* for fodder and proposals for further research

UNDP/FAO Project, INS/72/004 Note No. 107

Keywords: *Pueraria Thumbergiana*; Indonesia

(BPPM Abstract Bibliography of *Hevea* rubber, 1975.)

226. **Vijayakumari, P R** (1993)

Economic feasibility of betelvine as an intercrop in rubber holdings of Mavelikkara Taluk

Dissertation, P G Diploma in Natural Rubber Production, Kerala Agricultural University. Thrissur, India, 48p.

This study analyses the economic feasibility of betelvine as an intercrop in the rubber holdings of Mavelikkara taluk of Kerala, India. Even though the cost of cultivation was very high for betelvine, it could be recommended as an intercrop in the rubber holdings where there is availability of water throughout the year since it ensures ssubstantial weekly income.

Keywords: Betelvine; Economic aspect; Smallholding; Mavelikkara; Kerala; India

227. **Vimalakumari, T G; Joseph, K; Jessy, M D; Kothandaraman, R; Mathew, J and Punnoose, K I** (2001)

Influence of intercropping on the rhizosphere microflora of *Hevea*

Indian Journal of Natural Rubber Research, 14(1): 55-59.

A comparative study of the rhizosphere microbial population of *Hevea* grown either as monocrop or along with other intercrops was carried out. Enumeration of soil samples for bacteria, fungi, actinomycetes and phosphobacteria indicated higher total microbial populations in rhizosphere of *Hevea* under intercropping but the count varied with the type of intercrop. The VAM colonization and the number of phosphobacteria harboured were more in the roots of *Hevea* under intercropping.

Keywords: Monocropping; Rhizosphere microflora; India

228. **Virgens Filho, A de C; Alvim, R; and De Araujo A C** (1988)

Cocoa planting in mature rubber groves in Southern Bahia

Proceedings of the Tenth Internatinal Cocoa Research Conference, 17-23 May 1987, Santo Domingo, Dominican Republic, pp. 33-38.

In Southern Bahia there is an area of approximately 30,000 ha planted with rubber trees, nearly all of which are situated in areas with a high incidence of fungal diseases. One plot containing the oldest *Heveas,* notably those consisting of clones most susceptible to *Microcyclus ulei,* has suffered repeated attacks by this pathogen, with the result that, together with the seasonal appearances of Erinnyis ello, it only had plants with little foliage and consequently low productivity. Because of this, approximately 4000 ha of cocoa have been planted under the rubber trees, which were considered to be in decline. Several designs were adopted, the most common being to plant the cocoa in single rows intercropped with the rubber, with 3 m spacing within the rows and at a distance of 3.5 m from the rows of rubber trees. In a double row combination, the cocoa trees were grown with 3x3 m spacing and at a distance of 2m from the rubber trees, which had 7x3 m spacing. In plantations with high mortality cocoa was planted throughout with 3x3 m spacing and it was sometimes necessary to plant banana for additional shade. During 1983-1985, data on mean annual productivity of trees planted alone or in combination were compiled in seven estates. Results show that an area of 2.45 ha of monocrop cocoa or rubber is needed to obtain a yield equivalent to 1 ha of mixed cropping.

Keywords: Cocoa; Bahia; Brazil

(HORTCD 1973-1988)

229. **Wahjudjati, B and Sumana** (1981)

The best intercrop rotation system for smallholders in Labuhan Batu

Bulletin Balai Penelitian Perkebunana Medan, 12(1): 35-42.

Intercropping in young rubber may yield additional income to the farmer. The highest income can be obtained with the rotation rice- -mung bean. Applying the rotation system to a ha rubber holding gives an income of Rp 495 857 per year, which means that an expenditure of Rp 441 160 per year can be covered.

Keywords: Economic aspect; Mungbean; Rice; Crop rotation; Smallholding; Indonesia

(HORTCD 1973-1988)

230. **Wan Mohamed, W E** (1978)

The concept of potentials of integrated farming with rubber

Seminar on Integration of Animals with Plantation Crops, 13-15 April 1978, Penang, Malaysia.

Integrated farming has been shown to maximize land and resource utilization. The concept and potential of animal integration with rubber are discussed. In rubber plantations particularly smallholdings, the potential is based on the availability of surplus family labour; cheap and nutritious animal feed; land for animals and cultivation of crops for feed and feed supplement such as soya bean, groundnut, maize, pigeon pea and good environment for animals. Results

obtained from trials carried out in rubber estates and smallholdings, as well as from a review of literature are presented. They highlight the feasibility of growing feed and feed supplements in the rubber inter rows, performance of some types and breeds of animals, and problems associated with animal integration with rubber. Suggestions for future research and work plan are also discussed.

Keywords: Groundnut; Integrated farming; Maize; Pigeon pea; Soyabean; Malaysia

(Publications of the RRIM, 1979.)

231. **Wan Mohamad, W E and Chee, Y K** (1976)

Maximising returns in immature rubber smallholdings

Proceedings of the Rubber Research Institute of Malaysia Planters' Conference, 1976, Kuala Lumpur, Malaysia, pp. 34-43.

Methods of modifying the farming systems of rubber smallholders by the introduction of intercropping and livestock to maximize land usage and economic returns are highlighted. Annual crops such as groundnut, soyabean and maize when grown as intercrops in rotation have been shown to be beneficial. Suitable varieties of these crops and the technical know-how of growing them economically are reviewed. A supplementary income of about $507, $707 and $406 per hectare per year can be obtained from goundnut, maize and soyabean respectively. The perennial crop, banana was also found to be a suitable intercrop in smallholdings in certain locations. Returns between $872 and $1743 were obtained from four varieties of bananas per hectare over two years. When intercropping became uneconomical due to shading in the interrow, caused by a full canopy, poultry rearing was introduced to provide income during the remaining period of immaturity of rubber. Poultry rearing with broiler birds under rubber was shown to be feasible and economically viable in teo locations. A family income of between $308.75 and $1746.55 from five batches were obtained depending on the number, type of birds, location of the project and prices received. Besides providing additional income to the small farmer, the birds contributed to the growth of the rubber trees by helping to weed the holding and providing manure via their droppings.

Keywords: Banana; Economic aspect; Groundnut; Integrated farming; Maize; Soyabean; Smallholding; Malaysia

232. **Wan Rasidah, K; Aminuddin, M; Ahmad Sahali, M; Zaharah A, R** (1997)

Rotan manau intercropped with rubber: Rate of root growth between three and four years after planting

Journal of Tropical Forest Science, **10**(1): 86-93.

Efficient fertilizer management depends partly on understanding the active root distribution. In this study, the active root distribution of three and four year old plantation grown rotan manau (*Calamus manan*) was assessed using isotope tracer technique. For the 3-y-old rotan manau, three distances from the plant base (0.5, 1.0 and 1.5 m) at 5 and 30-cm depths were examined. For the four-y-old plants, two distances, *viz-a-viz* at a centre between two rattan plants and another in the middle between two rattan plants and two rubber trees were studied. The isotope used was ^{32}P, applied as a solution with KH_2PO_4. The rotan manau plants had

been established under mature rubber plantation. High proportions of feeder roots were found at 0.5 and 1.0 m distances at the surface (5cm depth) for the 3-y-old plants. Uptake of ^{32}P was also observed for the application at 1.5 m distance for both depths but the counts were small. Statistical analysis gave a highly significant difference within the distances and within the different depths. For a better synchronization between fertilizer application and plant uptake, it seems that application at approximately between 0.5 and 1.0m distance around the plant is most appropriate at this age. At four years after planting, important uptake was obtained only for the two plants located near the application area. Anyhow, to some extent it reflected that roots had already extended for another 1 m compared to the 3-y-old plants.

Keywords: Rotan manau; Root activity; Fertilizer application; Malaysia

233. **Wanpen Prukwiwat** (2005)

Rubber based crops integration: Recommendation for smallholder in Thailand

In: Progress and Development of Rubber Smallholders: Proceedings of the Ninth ANRPC Seminar, 9-11 November 2005, Cochin, India, pp.16-17

Rubber plantation area in Thailand is approximately 5.04 million acres, mostly are smallholders around 95 percentage. Over one million of them own only 6 acres by average; yield per year is 700 kg/acre. Their income mainly depend on rubber performance, thus the inter-row supplementary income is essential to these smallholders. The suitable intercrops recommended by the Rubber Research Insttitute of Thailand (RRIT) are upland rice, maize, groundnut, mungbean, vegetables, banana, papaya, pineapple and some forage crop such as Ruzi grass and Cario grass. The consideration of appropriate crop for rubber intercrop or under rubber shade growing is due to the soil profile, fertilization, local climates, market potential and demand, water source, available labour including smallholders budget, experience, information and knowledge sources. After four years of plantation until mature period, the shade tolerant plants are significant. In Southern Thailand, the suitable plants for integration with tapped rubber are *Salacca sp.*, Rattan Calamus caesius Bl.,) Thiem (*Azadirachta excelsa* Jacobs), some native vegetables (*Gnetum gnemon* var. *tenerum* and *Glochidion wallichianum* Muell.,) Cardamom (*Amomum sp.*,) and some varieties of cut flowers as Anthurium sp., Curcuma sp., Heliconia sp.

Keywords: Banana; Cardamom; Groundnut; Maize; Mungbean; Papaya; Pineapple; Rattan; Upland rice; Vegetable; Thiem; Thailand

234. **Watanabe, H; Sahunalu, P and Khemnark, C** (1988)

Combinations of trees and crops in the taungya method as applied in Thailand

Agroforestry Systems, 6(2): 169-177.

In Thailand the taungya reforestration method has been practiced primarily in order to rehabilitate wasteland, particularly under the government forest village programme. The paper describes the crop combinations used in different regions, The major combinations discussed in this paper are para-rubber (*Hevea brasiliensis*) or fast growing trees (*M. azedarach L. leusocephalia, Diptocarpus alatus and Casuarina junquiana (C. junhuunnianna)* with fruit trees/ crops (coffee, cashewnut, banana and pineapple). The different crop combinations relate to differences in climatic conditions, mainly the duration of the rainy season.

Keywords: Agroclimate; Banana; Cashew; Coffee; Pineapple; Thailand

(CAB Abstracts 1984-89/May)

235. **Wibawa, G** (2000)

Rubber based agro forestry research in Indonesia

Proceedings of the Indonesian Rubber Conference and IRRDB Symposium, 12-14 September 2000, Bogor, Indonesia, pp. 247-265.

Several rubber based multi-strata experiments were carried out in Indonesia to respond farmers' short, medium and long-term goals. The principal component of the systems such as rubber planting material, intercropping practices, types of intercrops could be modified to increase the productivity, to conserve a certain level of biodiversity and respond farmers' needs. Various annual intercrops planted during immature periods could compensate the short-term needs. Types of intercrops planted by farmers were markets driven. Several multi purpose fruit timber trees, and latex-timber rubber clones may be able to respond medium-term goals. The latex-timber clones play an important role in long-term goals. Water was detected as the main limiting factor of growth of the system. To avoid the slow growth of rubber due to competition with perennial intercrops, the best planting time in which the rubber girth is between 15 and 20 cm. This time correspond to the end of the optimal period of annual intercrops. Rubber trees reach tappable size six years after planting and perennial intercrops may start to be harvested. Various results on other experiments related to rubber agro forestry systems developed in Indonesia were also presented. By considering both plant yield productivity and biodiversity benefits, rubber based agroforestry systems are very perspective in the near future where the availability of tropical rain forest will be very limited.

Keywords: Agroforestry; Fruit crop; Rubber based Farming system; Smallholding; Timber plantation; Indonesia

236. **Wibawa, G and Thomas** (2002)

Effects of soil moisture on rubber growth in rubber based inter cropping systems

IRRDB Joint Workshop on Plant Breeding, Agronomy and Socio- economics, 28 August-6 September 2002, Malaysia/Indonesia, pp.1-7.

The research was carried out at Sembawa Research Station (on-station research) and at farmers' lands (on-farm trial) around the station (latitude 3°C8' and longitude of 104° 18'), commencing in 1993. The objective of the on-station research was to analyze quantitatively the effect of intercrops on the growth rubber. The treatments comprise Rubber +: clean weeded interrow (A), Legume Cover Crops (LCC) (B), Upland rice-fallow (C), pineapples (D), pineapple+ banana (E) and alang-alang (*Imperata cylindrica*)(I:). Results showed that the growth of rubber depend on the types of intercrop. The stem diameter of rubber, until thirty months, of treatments rubber-: clean weeded soil (A), pineapple (D), pineapple+banana (E), were comparable, but there was a tendency of rubber growth of these last two treatments were slower than that of treatment A since 15 months. Upland rice-fallow (C) and CC(B), were intermediate. The treatments E,C,B and D,E were 10.5,7.5 and 3.3 months slower in diameter growth than that of treatment A. That stem growth variation was due principally to soil moisture than the mineral nutrient factors.

Keywords: Banana; Ecology; Pineapple; Soil property; Upland rice; Indonesia

237. **Wibawa, G; Thomas, W; Rosyid, M J; Tambunan, D and Gunawan, A** (1996)

Study of the component interactions in *Hevea*-based intercropping systems

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp 25-40.

Research was carried out at Sembawa Research Station (on-station research) and at farms (on-farm trial) around the station (latitude 3°8' and longitude 104°18') during 1993. The objective of the on-station research was to analyze quantitatively the effect of intercrops on the growth of rubber. The treatments were comprised of Rubber + clean weeded interrows (A), Legume Cover Crops (LCC) (B), Upland rice-fallow (C); pineapple (D); pineapple + banana (E) and alang-alang *(Imperata cylindrica)* (F). The on-farm trial was carried out to cover the variability at the farmers' level. The factors considered in choosing 16 farmer participants were the origin of the land; the farmers' profession, the accessibility to farmers' land and labour availability; upland rice was grown for at least the first year as the rubber intercrop. Two types of plot were made: *A farmers' plot,* where the farmers were free to decide what they did with their interrows, and *A clean weeded plot,* where the plot was kept free from weeds throughout the research period. Station results showed that the growth of rubber depended on the types of intercrop. The stem diameter of rubber (until 30 months) of the treatment rubber+: the clean weeded soil (A), pineapple (D), pineapple+ banana (E), were comparable, but there was a tendency for the rubber growth of these last two treatments to be slower than in treatment A from 15 months. The slowest growth of rubber was found in the alang-alang treatment (F). The two other treatments, Upland rice-fallow (C) and LCC (B), were intermediate. The growth in diameter of treatments F, C, B and D and E were 10.5, 7.5 and 3.3 months, respectively, slower than that of treatment A. The stem growth variation was principally due to soil moisture rather than due to mineral nutrient factors. On farm research results showed that many farmers stopped planting upland rice after the first harvest. Maintenance of other intercrops, such as banana, pineapple, katu and perennial fruit trees was continued with. Chilli was the best intercrop in terms of both agronomic and economic aspects. After two years, when the intensity of intercropping decreased, the intensity of weeds increased and rubber growth was affected. The management of interrows was very important in that period to avoid water competition.

Keywords: Economic aspect; Fruit crop; Mixed farming; Pineapple; Soil property; Upland rice; Yield; Indonesia

238. **Widodo, S E** (1999)

The uses of intercrop spaces of fruit crops for upland rice plant

Proceedings of the Seminar on Increasing National Rice production Through Tabela (direct sowing) System of Lowland Rice and Utilization of Unproductive Land, 9-10 December 1998, Peragi, Indonesia, pp. 444-448.

Studies on the uses of intercrop spaces are frequently directed to those for woody plants, particularly industrial crops such as rubber, coconut, cocoa, and pepper. The uses of intercrop space for fruit crops however, have not been well studied although fruit culture usually employes wide intercrop spaces. These wide intercrop spaces, especially during a young-juvenile phase, offer better income for farmers if proper intercrops are planted. Economic studies on them suggest that they can be promising. Moreover, rice cultivars adapted to shading are available. Some aspects on intercropping rice into fruit crops, however, need to be studied further, as the

intercrops and the main crops may be interacted to affect flowering, yield, and fruit qualities of the main crops.

Keywords: Fruit crop; Land utilization; Upland rice; Indonesia

239. **Wijesuriya, W and Thattil, R O** (2001)

Methods of data analysis for intercropping systems under rubber

Journal of the Rubber Research Institute of Sri Lanka, 84: 39-49.

Analysis and interpretation of intercropping experiments are complex due to inclusion of two or more crops. Moreover, various types of experiments are involved in intercropping systems. Therefore, it is not to be expected that a single statistical approach suit all kinds of problems. The basic objective in all intercrop experiments is to assess biological or agronomic advantage in any intercrop system. This paper suggests possible ways of analyses for combined benefit of rubber based intercropping systems during the immature stages of rubber by employing the proxy variables girth and girth increment to substitute for rubber yield. Moreover, several other indices viz. income equivalent ration (IER) and monetary advantage (MA) have been modified to suit intercropping systems under rubber. For the rubber-tea intercropping system, bivariate analysis and diagrams were made using rubber girth and tea yield. The proposed analyses can be employed to assess the beneficial/deleterious effect of intercropping in rubber based farming systems.

Keywords: Economic aspect; Tea; Sri Lanka

240. **Wijesuriya, W; Thattil, R O; Yogaratnam, N and Iqbal, S M M** (1996)

Analysis of intercropping systems under rubber

IRRDB Symposium on Farming System Aspects of the Cultivation of Natural Rubber (Hevea brasiliensis), 6 November 1996, Beruwela, Sri Lanka, pp. 90-95.

Analysis and interpretation of intercropping experiments are complex due to inclusion of two or more crops. Moreover, various types of experiments are involved in intercropping systems. Therefore, it is not to be expected that a single statistical approach suit all kinds of problems. The basic objective in all intercrop experiments is to assess biological or agronomic advantage accruing in any intercropping system. This paper therefore attempts to quantify the beneficial effects of intercropping with respect to the growth and yield of rubber using the available indices with some modifications to suit intercropping systems under rubber. Design, analysis and interpretation of intercrop experiments under rubber are also discussed.

Keywords: Rubber based farming system; Sri Lanka

241. **Winardi** (1999)

Upland rice planting under young rubber: Some cases in Sitiung, West Sumatra (Indonesia)

Proceedings of the Seminar on Increasing National Rice production Through Tabela (direct sowing) System of Lowland Rice and Utilization of Unproductive Land, 9-10 December 1998, Peragi, Indonesia, pp. 439-443.

To study some aspects of intercropping of upland rice under young rubber, a study was done in October 1998 using RRA (Rapid Rural Appraisal) method in Sitiung and its surroundings

in Sawahlunto Sijunjung, West Sumatra. There are about 40, 000 ha smallholder rubbers and 7,500 ha of upland rice planting areas in the area. Although intercropping of upland rice is common to farmers, the level of yield of upland rice is still low. This is because of some factors such as lack of knowledge, lack of capital, low soil fertility, unsuitable crop cultivars, and pest (especially wild pigs) or diseases incidence.

Keywords: Smallholding; Socioeconomics; Upland rice; Indonesia

(AGRIS 1998-2002/09)

242. **Wongsukon, P and Templeton, J K** (1974)

Sweet and Glutinous corn as intercrops of rubber

RRC Document No. 28, Rubber Research Centre, Hat yai, Thailand

Maize, sold as fresh cobs, is one of the crops under study for its suitability as an intercrop of young rubber. In intercropping experiments over two years on rubber stations, sweet and glutinous cobs/ha of planted area, equivalent to 270 to 960kg and 3500 to 8000 per rai of intercropped rubber, according to soil and other conditions. Over a range of selling prices of 10 to 25 baht per 100 cobs and estimated costs of production of 680 baht/rai of rubber with labour charges and 400 baht without charging labour, the breakeven point for yields moved from 1500 to nearly 7000 cobs per rai of rubber. Maize thus has a good profit potential and the conclusion is that is a promising crop for use as an intercrop in the rubber growing regions.

Keywords: Maize; Thailand

243. **Wongsukon, P; Kongthon, A and Templeton, J K** (1974)

Yields of corn, sorghum, mungbean and sunflower in plots in South Thailand

RRC Document No. 24, Rubber Research Centre, Hat Yai, Thailand.

Field trials were conducted at various locations to study the possibility of intercropping young rubber with various varieties of maize, sorghum, mungbean and sunflower. Yields obtained are discussed. It is concluded that sorghum, mungbean and possibly sunflower all grew and yielded sufficiently well in the South to warrant their further consideration for intercropping.

Keywords: Corn; Mungbean; Sorghum; Sunflower; Thailand

(BPPM Abstract Bibliography of *Hevea* rubber, 1975.)

244. **Wongsukon, P; Buranatham, W and Templeton, J K** (1975)

Girth growth of rubber and interrow management

RRC Document No. 56, Rubber Research Centre, Hat Yai, Thailand.

Interim results from an intercropping experiment with budded rubber show that intercropping did not harm the growth in girth of the rubber trees. In one of the two clonal blocks under study growth was significantly promised, as compared to that with legume covers in some treatments. The importance of crop rotation and the use of fertilizers for the intercrops are emphasized.

Keywords: Crop rotation; Fertilizer application; Thailand

245. **Wongsukon, P; Buranatham, W and Jewtragoon, P** (1976)

Potential intercrops for smallholders in Thailand

In: Progress and Development of Rubber Smallholders: Proceedings of the Second Seminar, 18-23 October 1976, Hat Yai, Thailand, pp.167-170.

During the first 3-4 years after felling the old trees, the interrow area can be used for intercropping as an alternative source of income for smallholders. The intercrops which give the highest to the lowest net profits are sweet corn, ground nut, soyabean, mungbean, and upland rice. The provisions for intercropping are that family labour must be utilized. The intercrops must be fertilized and be planted in rotation with legume crops. Other advantages of intercropping are to control weeds in the interrows and to ameliorate soil property. Lastly, the smallholders will give more care and attention to the immature rubber trees.

Keywords: Economic aspect; Family labour; Groundnut; Mungbean; Soyabean; Sweet corn; Upland rice; Weed management; Thailand

246. **Wright, H** (1998)

Cultivation of para rubber trees

In: Para Rubber or Hevea Brasiliensis: Its Botany, Cultivation, Chemistry and Diseases, Biotech book, Delhi, pp. 30-32.

This book originally published in 1912, gives a comprehensive documentation of rubber cultivation, preprocessing, properties of latex etc. during the early days of plantation rubber. In chapter three on cultivation of para rubber trees, a session of intercropping of rubber with catch crops such as, banana, cacao, coffee, chillies, groundnut, lemongrass, pepper, gingelly, tobacco aand cotton is provided. Cocoa and coffee considered as the best intercrops are cultivated extensively in the major rubber growing countries like India, Ceylon, Samoa and Straits. Intercropping of lemon-grass is practised in Ceylon and Straits, groundnut in Ceylon, cassava in Straits. Intercropping of tea and coffee in association with rubber is followed in Ceylon and in India.

Keywords: Cocoa; Cassava; Coffee; Groundnut; Lemon-grass; Tea; India; Samoa; Sri Lanka; Straits

247. **Yang, Z J; Zheng, H S and Zhou, Z Z** (1996)

Impacts of rubber plantation intercropping on litter, humus and soil properties

Forest Research, 9(4): 354-358.

Results of intercropping rubber (*Hevea brasiliensis*) with coffee (*Coffea arabica*) or *Alpinia villosum* are presented.

Keywords: Agroforestry; Alpinia; Coffee; China

(CAB Abstracts 1996-1998/07)

248. **Yogaratnam, N and Iqbal, S M M** (1995)

Multicropping of rubber lands with tea

Journal of the National Institute of Plantation Management, 1-9.

During the first 2 or 3 years after the initial planting of rubber trees, before the trees have

grown sufficiently to extend their canopy fully, a wide inter-row area is left open. This area could be used for growing other crops. In the areas of Sri Lanka where rubber is grown, particularly in the South-West, there is great pressure for land and unemployment is high. This paper describes experiments carried out by the Rubber Research Institute in collaboration with the Tea Research Institute, which indicate that these two crops are ideally suited to intercropping, although it would require some adjustment of the spacing of the rubber plants to allow for the permanent growth of perennial crops. The inter-row space would generate an income during the first few unproductive years of the rubber trees, and also during wet periods when rubber tapping is not possible. This would increase the overall productivity of the estates and employment opportunities.

Keywords: Family labour; Planting density; Tea; Sri Lanka

(HORTCD 1989-2001/03)

249. **Yogaratnam, N and Iqbal, S M M** (1998)

Interplanting of rubber with tea: A technology appropriate for rubber smallholdings.

Bulletin of the Rubber Research Institute of Sri Lanka, **38**: 1-10.

A system to generate income and reduce unemployment by intercropping tea with rubber in Sri Lanka is presented and discussed. This system allows the generation of income from tea during the unproductive period (5-6 years) in young rubber plantations, and during periods when tapping cant take place. Results from experiments set up in 1985 and 1990 indicated that rubber should be planted at a spacing of 12 X 2.4 m (341 plants/ha, 75% of monoculture), with 7 rows of tea planted in between 2 rows of rubber at a spacing of 1.2 X 0.6 m (9375 plants/ha, 70% of monoculture), or at a spacing of 18 X 2.4 m with 12 rows of tea in between 2 rows of rubber. These planting systems reduce the limiting effect of shade on tea yield. It was calculated that costs would be recovered after 5-7 years, with the economic lifespan of the plantation being 25 years.

Keywords: Economic aspect; Shade; Smallholding; Tea; Yield; Sri Lanka

250. **Yogaratnam, N; Iqbal, S M M and Samarappuli, I N** (1995)

Intercropping of rubber with tea feasible

Rubber Asia, 9(5): 75-79.

Two plantation crops, tea and rubber, that were never grown in the same plot of land can now co-exist on the same land. This is an epoch-making discovery made through the research efforts of the Rubber Research Institute of Sri Lanka in collaboration with the Tea Research Institute of Sri Lanka. Experimental results very clearly show that there will be no adverse effects on either rubber or tea when rubber lands are intercropped with tea in a manner acceptable to both the crops. Initial results and its economics are fairly attractive to start this programme of interplanting rubber with tea, at least on a limited scale.

Keywords: Economic aspect; Tea; Sri Lanka

251. **Yogaratnam, N; Samarappuli, I N and Iqbal, S M M** (1995)

Economics of interplanting rubber with tea in the low country wet zone

Journal of the Rubber Research Institute of Sri Lanka, 76: 72-89.

This study examines the economic viability of interplanting rubber with tea in the low country wet zone, where cultivation of both these crops is agronomically feasible. In the analysis, apart from Net Present Value (NPV), other measurements of project worth have also been used to determine the return on investment. Economic lifespan of a 25-years is considered for discounted cash flow analysis. The results reveal the profitability of this integrated farm activity, which generates a NPV nearly Rs 162,000 at 15% discount rate. The B/C Ratio, Net Benefit Investment Ratio and IRR are 1.24, 3.73 and 31% respectively. The pay Back Period of 5 years also emphasizes the economic feasibility of the investment. Sensitivity Analysis on certain parameters has been done to ascertain the economic viability. The conclusion is that commencement of interplanting rubber with tea in the low country wet zone, at least on a limited scale is economically desirable.

Keywords: Agroclimate; Economic aspect; Family labour; Land utilization; Tea; Sri Lanka

252. **Zainol, E** (2002)

Advances and challenges in *Hevea* farming systems

Proceedings of the Indonesian Rubber Conference and IRRDB Symposium, 12-14 September 2000, Bogor, Indonesia, pp. 1-27.

This paper aims to present the experience gathered from studies conducted by the Malaysian Rubber Board in particular research on soil acidity amelioration and on- farm evaluation of soil management practices, and related crop production. Some experience on evaluation of smallholders' process of adopting *Hevea* farming systems are also outlined. The experience on farming systems in the Malaysian smallholding sector showed that a wealth of information has been generated especially in the field of crop production. Soil management techniques have been recommended to overcome the problem of aluminium toxicity. Favourable production levels were obtained in on-farm trial and farmer-managed projects. The agro management inputs in the interrows do not pose any deleterious effect on the growth of *Hevea*. However, to realize the potential of food production, the farming systems have to be enhanced to generate commercial yields. Policies and management approaches have to be innovative to achieve this. From the small holders perspective, steps have to be taken to underpin the research-extension-smallholder linkage. An integrated approach is essential to develop the existing smallholdings to be a modern and a productive entity.

Keywords: Farming system; Smallholding; Soil property; Malaysia

253. **Zainol, E and Mokhtaruddin, A M** (1993)

Effects of intercropping systems on surface processes in an acid ultisol 1. Short term changes in soil physical properties

Journal of Natural Rubber Research, 8(1): 57-67.

Changes in soil physical properties were detected after three years of intercropping in immature

rubber. Intercropping activities generally affected the degree of aggregation and its stability. The soils under legumes contained larger-sized aggregates and exhibited better water retention and transmission characteristics. Aggregates of finer size were recorded in cleanly cultivated pineapple plot indicating that the larger aggregates were being progressively broken down due to the direct impact of rain. The high input treatments consisting of frequently tilled corn-peanut plots showed a high degree of similarity in the size-distribution of water-stable aggregates, but the plots differed in water retention and transmission properties as a result of variability arising from management inputs. The redistribution of fine particles in the tilted plots accounted for its higher penetration resistance compared with the non-tilted plots. The study suggests that on-site soil degradation can be minimal under conditions of tillage provided less crops are planted and steps taken to have a mulch cover during the fallow period.

Keywords: Acid utisol; Corn; Peanut; Soil property; Malaysia

254. **Zainol, E; Mahmud, A W and Sudin, M N** (1993)

Effects of intercropping systems on surface processes in an acid ultisol 2. Changes in soil chemical properties and their influence on crop performance

Journal of Natural Rubber Research, 8(2): 124-136.

The chemical changes in an acid ultisol under intercropping, were monitored over thirty-three months. The systems of intercropping under immature rubber were designed on the basis of conservation-oriented surface vegetative cover. The lower input systems include interrows under naturals, and legumes; while the intercropped plots represent the high input treatments comprising peanut and corn rotation, pineapple, and combination of peanut-corn and pineapple. The use of fertilisers and the corrective input of lime influence the soil fertility dynamics. Towards the later croppings, the *pH* declined in all interrow systems, with a marked decrease in the highest input plots. The intercropped treatments showed significant residual amounts of phosphorus, calcium and magnesium. Over several croppings, the effective cation exchange capacity remains high and the soils have low aluminium saturation. Intercropping has an overall beneficial effect on growth of *Hevea* due to the combined effect of added fertilisers and lime.

Keywords: Acid utisol; Corn; Fertilizer application; Peanut; Pine apple; Soil property; Malaysia

255. **Zainol, E; Mahmud, A W; Sajjapongse, A and Elliott, C R** (1994)

The management of sloping lands for sustainable agriculture in Malaysia

Report of the Annual Review Meeting on Asialand Management of Sloping Lands in Asia, 2-8 September 1993, Guiyang, China, pp. 123-149.

This paper discusses the sustainability of intercropping annual crops under rubber, the changes in soil fertility as affected by different soil and crop management systems, and the practicability of high-input technology.

Keywords: Annual crop; Soil fertility; Malaysia

(HORTCD 1989-2001/03)

256. **Zhou, Z Z; Zheng, H S; Yang, Z J; Yin, G T and Chen, K T** (1997)

Research on biological cycle of nutrient elements in plantation of rubber intercropped with *Amomum longiligulare*

Forest Research, 10(5): 464-471.

Biomass and nutrients (N, P, K, Ca, Mg) of each component (trees, intercrops and litter) were determined in a 30-yr-old pure rubber (*Hevea brasiliensis*) plantation, and a plantation intercropped with *Amomum longiligulare* in [Guangdong] China. Net accumulation and cycling of nutrients were compared in the two plantations. Annual accumulation and uptake of the five nutrients in the intercropped plantation were 3447.07 and 1083.43 kg/hm2, 2.53 and 2.1 times greater, respectively, than the values in the pure plantation. Annual nutrient return in the intercropped plantation was 363.26 kg/hm2, of which values for N, P, K, Ca and Mg were 1.9, 2.54, 1.42, 1.05 and 1.16 times greater, respectively, those in the pure plantation. The results showed that the cycling coefficient in the intercropped plantation was less than that in the pure plantation, but the absorption coefficient was higher, indicating that intercropping can improve nutrient uptake from the soil.

Keywords: Agroforestry; *Amomum longiligulare*; Soil fertility; China

(HORTCD 1989-2001/03)

KEYWORD INDEX

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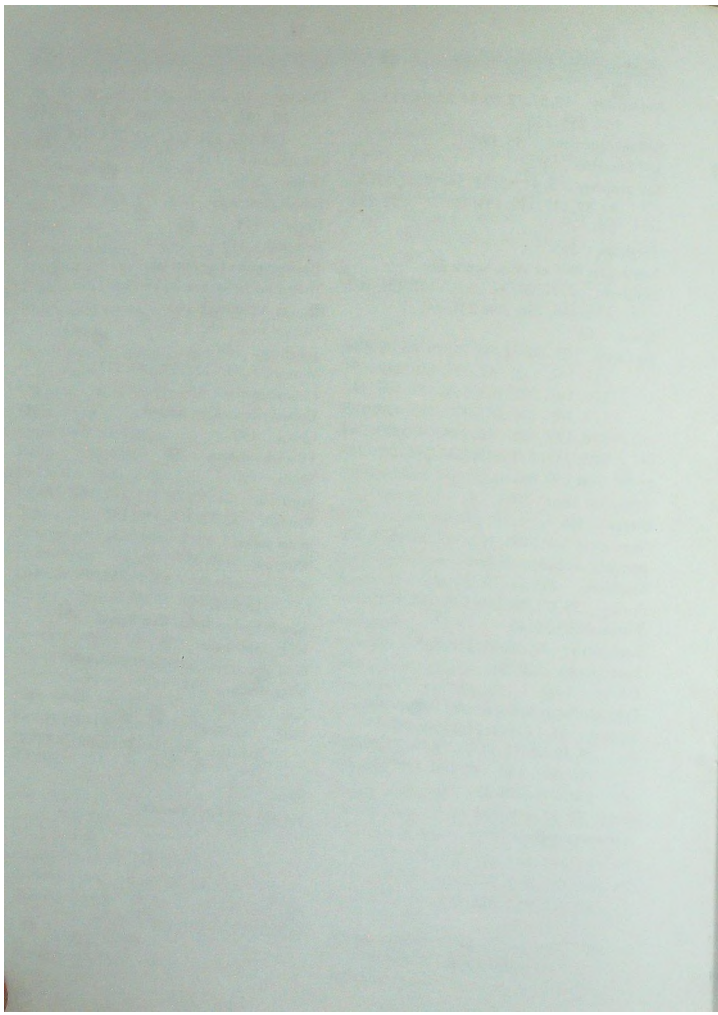

AUTHOR INDEX