

12 DEC 1977

RP-36

## Multispecies Crop Combinations with Tree Crops for Increased Productivity in the Tropics

Kombinationen mehrerer Arten mit Baumkulturen zur Steigerung der Produktivität in den Tropen

P. K. R. Nair

(Central Plantation Crops Research Institute, Kasaragod 670 124, Kerala, India)

### Introduction

In bioenergetic terms, crop production can be viewed as conversion of visible spectrum of total electromagnetic radiation into chemical energy (protein, fat, and carbohydrates) through the photosynthesis of crop plants. In the tropics where the solar energy is in bountiful supply all through the year, the „photosynthetic factory“ can be kept operative at higher efficiency for longer periods by appropriate agronomic manoeuvres. With the realisation of this, the practice of multiple cropping is gaining popularity in the tropics (NAIR and SINGH, 1971; NAIR, 1972; NAIR et al., 1973). Multiple cropping in essence, represents a philosophy of maximum crop production per unit of land and time with minimum of soil deterioration (SINGH and NAIR, 1973). In the case of annuals and other short duration crops, this can be attained by sequential combination of crops i. e. by growing crops in quick succession within a calendar year or other relevant time span. But in the case of tree crops, where the land remains committed to the crop for decades, the strategy has to be one of parallel or simultaneous combination of crops. Based on these concepts, certain crop combinations

with coconut palm (*Cocos nucifera* L.) have been evolved and put to trial at the Central Plantation Crops Research Institute (CPCRI), Kasaragod, on the west coast of India. This paper briefly discusses the merits of such cropping systems on the basis of salient results obtained so far.

### Amenability of Coconut Palm to Crop Combination

#### Soil and Climatic Factors

Coconuts are grown under diverse soil conditions, ranging from littoral sands to heavy clays. However, typical coconut soils are characterised by a medium texture (sandy loam to loam), adequate supply of soil moisture, good drainage, and at least 1 m depth. As far as climatic requirements are concerned, coconut is essentially a crop of coastal areas of tropics, with good amount of rainfall (about 200 cm per year), mean annual temperature of about 27° C with a diurnal variation of 6—7° C and adequate sunshine (about 2000 sunshine hours per year). The average climatic parameters of Kasaragod, a typical coconut growing belt, are given in Table 1.

Table 1. Mean\* climatic parameters at CPCRI, Kasaragod†, India

Mittlere klimatische Angaben, Kasaragod, Indien

Months	Quantity (mm)	Rainfall		Air temperature (°C)		Relative Humidity %	Sunshine hours per day	Evaporation USWB pan) mm/day
		No. of rainy days		Maximum	Minimum			
January	0.8	0.1		31.8	20.3	85	9.2	4.5
February	—	—		32.1	21.3	87	9.8	4.8
March	3.1	1.0		32.5	23.3	88	9.5	5.1
April	43.6	2.1		33.3	25.1	82	9.2	5.2
May	281.9	9.3		32.3	25.0	84	7.5	5.0
June	965.9	20.2		29.7	23.4	92	3.9	3.6
July	1098.2	28.9		28.5	22.9	94	2.7	2.3
August	644.0	21.8		28.5	22.8	95	3.7	2.6
September	319.8	11.9		29.2	22.7	94	5.8	3.5
October	193.6	10.1		30.4	22.7	92	6.9	3.6
November	76.5	4.3		32.0	22.0	87	8.2	4.1
December	19.3	1.6		32.3	20.9	83	8.3	4.1

\* Average for 20 years 1956—1975

† Kasaragod: 10.7 m above MSL; 12°30' N and 75° E

### Pattern of Land Utilization by the Palm

Growth habits and crown shape of the coconut palm necessitate a spacing of  $7.5 \times 7.5$  m, giving a plant population of about 175 palms per hectare. However, a critical evaluation will indicate that the two basic resources of crop production *viz.* soil and solar energy are not being utilized to the fullest extent possible in a pure stand of coconut palms. The effective root zone of an adult bearing palm grown under normal management is confined laterally within a radius of 2 meters around the base of the palm and vertically within 30 till 120 cm depth from soil surface (KUSHWAH et al., 1973). This means that at a planting distance of  $7.5 \times 7.5$  m, about 77% of the total soil area in a pure stand of coconut is not effectively utilised by the coconut roots.

From the point of view of growth phases of the palm, during the early stages up to about 8 years after planting, the canopy size of the palm increases gradually, giving much open area for growing some short duration crops. During 8 to about 25 years of age, the shading of ground by the canopy is more or less complete and consequently the possibility of growing other crops is limited, if not nil. Later on, though there is little change in the size of the crown, the apparent coverage of ground by the canopy decreases because of the increase in height of trunk and the resultant increase in the amount of sunlight falling on the ground (NELLIAT et al., 1974). NAIR and BALAKRISHNAN (1976) have estimated that in a pure palm stand, an average of only about 44% of total available sunlight is intercepted by the canopy during the peak bright hours (10–14 h) of the day.

These conditions indicate that there are great possibilities for growing other compatible crops in coconut plantations, except probably during the period from about 8–25 years of age of the palms.

### Possible Cropping Systems

All such crop combinations envisage the cultivation of other crops in the interspaces between the palms. Such crops could be of shorter or longer durations. The practice of growing annuals or other relatively short duration crops in the interspaces of perennial crops is known as intercropping. On the other hand, the practice of growing other perennial crops in the interspaces is

known as mixed cropping. Still more intensive cropping is possible by having a multispecies combination of both long and short duration crops simultaneously.

### Salient Results of the Trials with Cropping Systems

#### Intercropping

A number of annuals and other short duration crops have been tried at CPCRI. These included tuber crops, rhizome spices, pulses, upland rice, banana, pine apple etc. (NAIR and VARGHESE, 1976).

Results of some trials are given in Table 2. Most promising among them were tubers and rhizome spices. Owing to the relative short duration, comparative ease of management, and high carbohydrate output, tubers have great potentialities as intercrops (NAIR and BAVAPPA, 1975). The pulses tried included green gram (*Phaseolus aureus*), black gram (*Phaseolus mungo*), horse gram (*Dolichos biflorus*), as well as soybean (*Glycine max*). However, their performance was not very satisfactory, probably because the diminished light conditions in the interspaces of plantations may not be sufficient for proper development of grain legumes. On the other hand, pine apple and bananas were very promising.

#### Mixed Cropping

Some of the tree crops and other perennials which require or tolerate shade such as cacao (*Theobroma cacao*), clove (*Eugenia caryophyllata*), nutmeg (*Myristica fragrans*), and black pepper (*Piper nigrum*) were grown successfully as mixed crops with coconut. The most promising among them was cacao. In a mixed cropping experiment of coconut and cacao at CPCRI, there was considerable increase in the yield of coconut over the pre-experimental yield (CPCRI Annual Reports for 1973, 1974, and 1975; NAIR et al., 1975). Increase in productivity from this crop combination of coconut and cacao is given in Table 3.

#### Multistoreyed Cropping

A combination of coconut + black pepper + cacao + pine apple is a typical example of a multistoreyed crop combination. Coconuts spaced 7.5 m apart and growing up to 30 m height with its crown shaped canopy functions as the top floor of this crop building. The second floor

Table 2. Yield of intercrops under coconuts (Average for 3 seasons, 1973–74 to 1975–76)  
Erträge der Unterkulturen unter Kokospalmen, Schnitt der 3 Jahre 73/74 bis 75/76

Intercrop	Variety	Scientific name	Yield (t/ha)		Net return per unit cost of cultivation	Energy equivalent of produce/ha* (m K cal)
			Gross area of coconut	Net area of inter crop		
Elephant yam	local	<i>Amorphophallus companulatus</i>	13.46	16.82	1.37	10.63
Cassava	H. 165	<i>Manihot utilissima</i>	14.82	16.78	1.52	23.27
Sweet potato	H. 42	<i>Ipomoea batatas</i>	8.38	11.96	0.93	10.08
Greater yam	local	<i>Dioscorea alata</i>	13.61	17.01	1.64	18.34
Lesser yam	local	<i>Dioscorea esculenta</i>	9.26	11.57	1.38	12.40
Chinese potato	local	<i>Coleus barbatus</i>	7.32	11.26	1.71	3.59
Ginger	Rio-de-Janeiro	<i>Zingiber officinarum</i>	8.61	13.25	1.92	5.77
Turmeric	Armoor	<i>Curcuma longa</i>	10.94	16.84	0.36	9.52

\* per hectare of gross area of coconut

Table 3. Total productivity of coconut and cacao in a mixed cropping experiment initiated in 1970  
*Gesamte Erzeugungsleistung von Kokospalme und Kakao im Mischkulturversuch, begonnen 1970*

Crop combination	Plant population per hectare		Annual yield of coconut (nuts per palm)			Annual increase in productivity per ha.	
	Coconut	Cacao	Before <sup>+</sup> planting Cacao	After* planting Cacao	Response	Coconut (no. of nuts)	Cacao (Kg dry beans)
Coconut alone	175	—	77.4	130.8	53.4	9345	—
Coconut + single hedge of Cacao	175	350	65.4	139.3	73.9	12932	300
Coconut + double hedge of Cacao	175	650	49.8	117.9	68.1	11917	400

<sup>+</sup> Average for 2 years (1968—69 and 1969—70)

\* Average for 4 years (1972—73 to 1975—76)

crop of black pepper develops the canopy on the coconut trunk at a height up to 8 m. Cacao which grows to 1.5—2.5 m height with its pruned canopy is the next canopy floor and pine apple constitutes the ground floor of this crop building (Fig. 1). Apart from enabling the interception and utilisation of light at various vertical intervals by different plants, such a crop mix also facilitates efficient „soil harvesting“ by root systems of different crops from distinct layers and columns (NELLIAT et al., 1974). This way, 600 cacao plants and 3500 pine apple plants could be accommodated in a hectare of coconut plantation, in addition to the black pepper vines trailed on to each coconut trunk (NAIR and VARGHESE, 1976). Productivity from one such experiment is given in Table 4.

#### Mixed Farming

The cropping programmes of inter and mixed cropping are usually concentrated around crop with human being as entrepreneurs, but an integrated plant — animal — human ecosystem involving human beings as the pivotal link of the whole unit has also been developed to suit the special conditions of diminishing farm size and surplus labour availability of the coconut farmers of India (NAIR et al., 1975). A farmer with a small holding of about 1/2 ha of coconut farm can maintain a few milch animals on the pasture legumes (eg. *Stylosanthes gracillis*) and grasses (eg. *Hybrid Napier*) grown in the interspaces of coconut, which in turn are benefitted by the barn wastes which could be added to the soil. A gas plant working with cow dung can meet a part of the energy requirement of the farmer's family and the slurry can be added to the soil. Thus an efficient organic recycling involving the whole ecosystem is possible. Results of 1974—75 and 1975—76 from one such project in progress since 1972 at CPCRI indicated that the yield of coconut palms of the experimental plot increased by 17%. Even without accounting for this, the input-output relationship worked out to 1 : 1.53. The employment potential generated by way of labour from farmer and his family worked out to about 1100 man hours per year

Fig. 1 (right). Photograph of a multistoreyed crop combination of coconut and black pepper and cacao and pineapple, initiated in 1972 when the coconut palms were 25 years old. „Mehrstöckige“ Kultur-Kombination von Kokospalme, Pfeffer, Kakao und Ananas, angelegt 1972, als die Palmen 25 Jahre alt waren. Fotografiert 1976.

Table 4. Total annual productivity from one hectare of multistoreyed crop combination

*Gesamte Jahresproduktivität je ha bei einer mehrstöckigen Kulturkombination*

Crops	No. of plants per hectare	Yield	
		Unit	Quantity
Coconut	175	No. of nuts	21000
Cacao	600	Dry beans (Kg)	400
Black pepper	175	Dry pepper (Kg)	100
Pine apple	3500	Fresh fruits (Kg)	5000



for one hectare in comparison to about 150 man hours for pure coconut plantations (CPCRI, 1975).

### Agronomic Features of Crop Combinations in Plantations

#### Competition

Such crop communities will essentially consist of a multi-layer canopy with the canopy of coconut palm at the higher level. Therefore, only such crops which require or tolerate shade to some extent can fit well in this programme. This would also mean that breeding programmes may have to be oriented to develop varieties adaptable to shady conditions. Moreover, the variety selected as an intercrop should not be a strong competitor with the main crop for environmental or management inputs.

#### Yield of a Crop in a Multispecies Community

Yield of a crop grown as an intercrop is likely to be less than that of a monocrop of the same. This is not necessarily a point against the success of the programme, because on unit area basis, the additional productivity obtained from the intercrop is a gain, provided the cost : benefit ratio is favourable.

#### Water Use Efficiency

The total water requirement of a crop at potential production level is decided primarily by the evaporative demand of the climate of the area. Therefore, irrespective of the number of crops grown in an area, the water requirement remains almost the same. Thus, the water use efficiency of a mixed community of crops is greatly enhanced over that of a pure palm stand.

#### Maintenance of Soil Fertility

Combination of compatible crops is likely to have beneficial effects on the soil fertility also. For example, beneficial microorganisms such as free N-fixers (*Beijerinckia* sp.), phosphate solubilisers (*Pseudomonas* sp. and *Aspergillus* sp.) and indole acetic acid synthesizers (*Escherichia* sp., *Aspergillus flavus* and *Aspergillus fumigatus*) were noticed in the rhizosphere of plants in the coconut + cacao combination (NAIR, 1974). The available nutrient status, particularly that of P was also better under this combination (NAIR and VARGHESE, 1977). Thus there are some 'non-monetary' inputs by appropriate crop combinations.

On the other hand, improper management of the crop mix will result in disastrous effects. When the accompanying intercrop is not adequately fertilized, it is likely to be a parasite on the main crop and the performance of both the main and inter crops would be detrimentally affected, as has been shown from earlier trails in CPCRI.

#### Microclimate

Evaporation from the moist soil surface will be much more in a pure crop of coconut as compared to a crop mix because the former shades the soil only about 50% whereas shading is more complete under the latter (NAIR and BALAKRISHNAN, 1976). Moreover, the canopies of the crop mixes are more closed and less ventilated and consequently offer greater aerodynamic roughness. Therefore, the air temperature within the crop mix will be cooler (BALAKRISHNAN et al., 1976). This modified microclimate will have great influence on the physical, chemical and biological processes taking place in the soil.

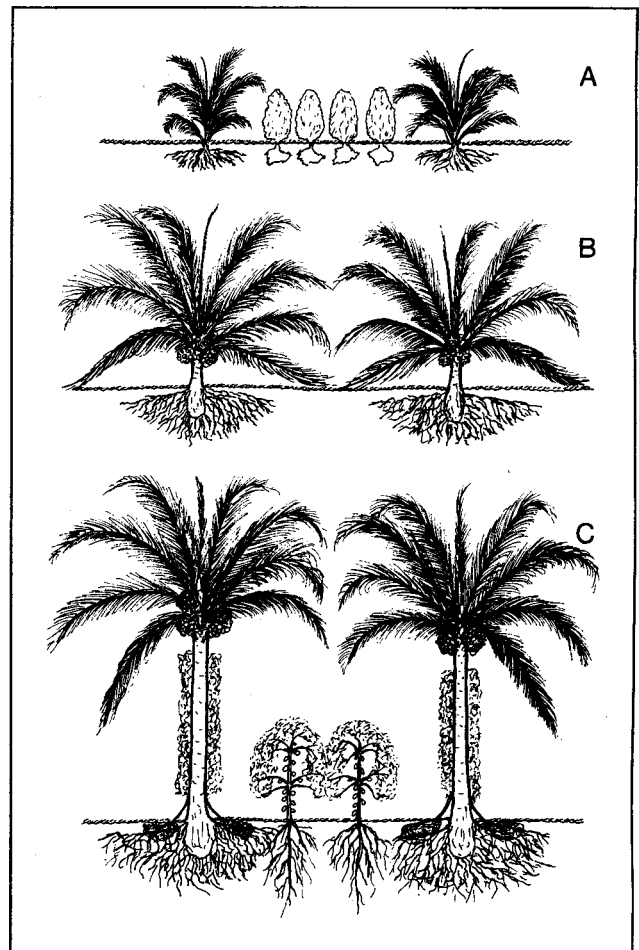


Fig. 2. Schematic presentation of the growth phases of coconut palm indicating the possibilities for intercropping  
A — Early phase (up to about 8 years after planting) — Canopy of the palm develops gradually, much scope for intercropping

B — Second phase (about 8—25 years) — Greater coverage of the ground by canopy, very limited scope for intercropping  
C — Third phase (after about 25 years) — As the trunk height increases, the coverage of ground by canopy is reduced, mixed cropping possible.

A multistoreyed crop combination consisting of coconut and black pepper and cacao is depicted.

*Schematische Darstellung der Wachstumsphasen der Kokospalme mit Hinweis auf die Möglichkeit einer Zwischennutzung.*

*A Frühe Phase (bis 8 J. n. d. Pflanzung)*

*B Zweite Phase (8—25 J.)*

*C Dritte Phase (nach 25 J.)*

*Mit zunehmenden Stammhöhen ist die Beschattung des Bodens wieder verringert, dadurch wird Mischbau möglich.*

*Eine mehrstufige Kulturkombination von Kokospalme und Pfeffer und Kakao wird gezeigt.*

#### Weed Control

Considering that weeds are also plants with physical and physiological requirements, the growth of weeds will be made increasingly difficult in such intensive cropping systems.

#### Possibilities in other Tree Crops

In general, the growth pattern of all tree crops can be considered to consist of three phases:

1. an initial phase from planting till full development when the canopy volume and root development gradually increase.
2. an adult bearing stage when canopy volume and root proliferation remain almost constant, and
3. a period of decline in growth, when the apparent coverage of ground by canopy decreases.

Depending upon the duration of each phase and characteristics of each crop during the different phases, appropriate crop combinations can be thought of during one or more of these phases. A possible model is given in Fig. 2. Intercropping with relatively short duration crops is possible during phase I. In phase II, crop mixes are not generally possible because of the intensity of shading by the main crop. Towards the end of phase II, other perennial crops could be planted in the inter-spaces. In phase III, short duration crops can also be brought in, thus making a multistoreyed combination.

Multiplespecies crop combinations with tree crops and integration of tree crops and livestock production are possible only with those tree crops below which or between which other crop species or forages can grow and be utilised. These include coconuts, oil palms, rubber, spice trees and fruit trees. PAYNE (1976) has estimated that the humid tropical climates extend over approximately 12% of world's land area and that the total area of coconut, oil palms and rubber in the humid tropics is approximately 46 million ha, 80% of this total area being in Asia. Even if only 25% of this total area under these tree crops could be brought under intensive cropping, that would go a long way in increasing the agricultural production from these parts of the world.

### Problems and Prospects

From the present state of subsistence farming in the tree crops areas of humid tropics to the high intensity cropping programmes is a great leap forward. The constraints in the adoption of these programmes could be many; to mention a few: small size of holdings, unavailability or high cost of inputs, difficulties in marketing the produce, lack of technical knowhow on the part of the farmers etc.

On the other hand, the potentialities offered by the system are tremendous. Under the conditions of exploding rate of population increase and increasing pressure on arable land, such cropping programmes look very promising.

This article was prepared during the tenure of my stay in the Federal Republic of Germany on a Senior Research Fellowship awarded by Alexander von Humboldt Foundation.

### Summary

The rationale for crop combinations with tree crops in the humid tropics is that in pure stands of these crops, soil and solar energy — the two basic resources of crop production — are not being utilised to the fullest extent possible; on the other hand, in compatible crop combinations, the crop canopies intercept and utilize solar energy at different strata and the root systems forage soil mass in distinct zones. The results of trials on crop combinations involving coconut as the pivotal crop and short duration crops (intercropping), long duration crops (mixed cropping) and multiplespecies crop community (multistoreyed cropping) are presented. Feasibility of

integration of livestock and coconut production (mixed farming) is also envisaged. Some special agronomic features of interaction of crop communities such as competition, water use efficiency, maintenance of soil fertility, microclimate etc. are discussed based on experience and experimental results. Possibilities of extending the practice to other tree crops of the humid tropics are also indicated.

### Zusammenfassung

Die Begründung für die Kombination von Unterkulturen mit Baumkulturen in den humiden Tropen liegt darin, daß in reinen Beständen der Boden und die Sonnenenergie — die beiden Grundbedingungen für die Stoffproduktion — nicht im größtmöglichen Ausmaß genutzt werden. Andererseits fangen in zusammenpassenden Mischkulturen die Kronen die Sonnenenergie in verschiedenen Höhenschichten ein und die Wurzelsysteme ernähren die Pflanze aus verschiedenen Bereichen des Bodens. Die Versuchsergebnisse zur Misch- und Unterkultur enthalten Kombinationen der Kokospalme als Leitkultur und kurzfristige Zwischenkulturen, längerfristige Mischkulturen und eine aus mehreren Arten bestehende Pflanzengemeinschaft verschiedener Wuchshöhen. Die Möglichkeiten einer Einbeziehung des Vieheintriebes in eine Kokosnußplantage werden auch erörtert. Einige spezielle pflanzenbauliche Fragen der Wechselwirkungen innerhalb einer angebauten Pflanzengemeinschaft, wie z. B. Konkurrenz, Effizienz der Wassernutzung, Aufrechterhaltung der Bodenfruchtbarkeit, Mikroklima etc. werden auf der Grundlage bisheriger Erfahrungen und Versuchsergebnisse besprochen. Ferner werden Möglichkeiten der Übertragung auf andere Gehölzkulturen der humiden Tropen angesprochen.

### Résumé

*La combinaison de plusieurs espèces avec des arboricultures pour l'augmentation de la productivité dans les zones tropicales*

Le motif pour la combinaison de cultures sous couverture avec des arboricultures dans les zones tropicales humides est que le sol et l'énergie solaire — les deux facteurs essentiels pour la production de matière — ne sont pas assez mis à profit par les monocultures. De l'autre côté, les couronnes absorbent l'énergie solaire à différentes hauteurs et les systèmes racinaires approvisionnent la plante à partir de différentes zones du sol dans les cultures mixtes appropriées. Les résultats des expérimentations sur les cultures mixtes et les cultures sous couverture contiennent des combinaisons du cocotier avec des cultures intermédiaires courtes, des cultures mixtes à long terme et une association de plantes d'une ou de plusieurs espèces à différentes hauteurs de croissance. Les possibilités de laisser pâturer le bétail dans les plantations de cocotier sont également discutées. Quelques questions de culture spéciales des actions réciproques à l'intérieur d'une association de plantes, comme p.ex. la concurrence, l'efficacité de la jouissance de l'eau, la conservation de la fertilité du sol, le micro-climat . . ., sont discutées sur la base d'expériences et de résultats d'expérimentations faites jusqu'à présent. En plus, on envisage les possibilités de transmettre les résultats sur d'autres arboricultures dans les zones tropicales humides.

### Резюме

*Комбинация нескольких видов древесных культур для повышения продуктивности в тропиках*

П. К. Р. Найр

Мотивировка для комбинации подсевных культур с

древесными культурами во влажных тропиках обосновывается тем, что в чистых древонасаждениях почва и солнечная энергия — основные предпосылки для продукции веществ — не могут максимально быть использованы. С другой стороны, в сочетающихся смешанных культурах, кроны поглощают солнечную энергию в различных слоях стратосферы и корневые системы питают растение из различных зон почвы. Подопытные результаты смешанных и подсевных культур содержат комбинации кокосовой пальмы в качестве характерной культуры и краткосрочных промежуточных культур, более длительных смешанных культур и комбинацию растительного сообщества различной высоты, состоящую из нескольких видов. Обсуждаются также возможности включения загона скота на плантацию кокосовых орехов. На основе полученных до сих пор опытов и результатов исследований обсуждаются некоторые специальные вопросы взаимодействия внутри разведенного растительного сообщества, как напр. конкуренция, эффективность водопользования, обеспечение плодородия почвы, микроклимат и т.д. Помимо того затрагивались вопросы относительно возможности переноса на другие древесные культуры влажных тропиков.

#### Literature

- ANNUAL REPORT, Central Plantation Crops Research Institute, Kasaragod, India for the years 1973 (pp. 24—28), 1974 (pp. 24—27) and 1975 (pp. 25—32).
- BALAKRISHNAN, T. K., P. K. R. NAIR and E. V. NELLIAT 1976: Microclimate of coconut varieties and cacao and cinnamon grown as mixed crops with coconut. *Indian J. Met. Hydrol. Geophys.* 27, 71—74.
- KUSHWAH, B. L., E. V. NELLIAT, V. T. MARKOSE and A. F. SUNNY, 1973: Rooting pattern of coconut (*Cocos nucifera* L.). *Indian J. Agron.* 18, 71—74.
- NAIR, P. K. R., 1972: Potentialities of rice based multiple cropping systems in terms of harvesting of protein, carbohydrates and energy. *J. Fd. Sci. Technol. (India)* 9, 193—195.
- NAIR, P. K. R. and T. K. BALAKRISHNAN, 1976: Pattern of light interception by canopies in a coconut — cacao crop combination. *Indian J. agric. Sci.* 46, 453—461.
- NAIR, P. K. R. and K. V. A. BAVAPPA, 1975: Tubers as intercrops in plantations. First National Symposium on Tuber Crops, Trivandrum, India (under publication).
- NAIR, P. K. R., K. V. A. BAVAPPA and E. V. NELLIAT 1975: Intensive farming programmes for small-sized coconut plantations. IV FAO Working Party on Coconut Production, Protection and Processing. Jamaica.
- NAIR, P. K. R. and A. SINGH, 1971: Production potential, economic feasibility, and input requirements of five high intensity crop rotations with rice. *Indian J. agric. Sci.* 41, 807—815.
- NAIR, P. K. R., A. SINGH and S. C. MODGAL, 1973: Harvest of solar energy through intensive multiple cropping. *Indian J. agric. Sci.* 43, 983—988.
- NAIR, P. K. R. and P. T. VARGHESE, 1976: Crop diversification in coconut plantations. *Indian Farming.* 25 (2), 17—21.
- NAIR, P. K. R. and P. T. VARGHESE, 1977: Soil fertility management for coconut — cacao crop combination on the west coast of India. *J. Plantation Crops* (In Press).
- NAIR, P. K. R., R. VARMA, K. V. A. BAVAPPA and E. V. NELLIAT, 1975: Beneficial effects of crop combination of coconut and cacao. *Indian J. agric. Sci.* 45, 165 bis 171.
- NAIR, S. K., 1974: Studies on the Microflora of the Root Region of Plantation Crops — Coconut and Cacao. Ph. D. Thesis, Indian Agricultural Research Institute, New Delhi.
- NELLIAT, E. V., K. V. A. BAVAPPA and P. K. R. NAIR, 1974: Multistoreyed cropping — New dimension of multiple cropping in coconut plantations. *World Crops.* 26, 262—266.
- PAYNE, W. J. A., 1976: Possibilities for the integration of tree crops and livestock production in the wet tropics. Abstract in *J. Sci. Fd. Agric.* 27, 888.
- SINGH, A. and P. K. R. NAIR, 1973: Concepts of multiple cropping. In: *Multiple Cropping*, pp 25—31, Indian Society of Agronomy, New Delhi.

Eingegangen: 28. 12. 1976.

Anschrift des Verfassers: Dr. P. K. R. Nair, Institut für Bodenkunde und Waldernährung der Universität Göttingen, Büsingenweg 2, 3400 Göttingen, Federal Republic of Germany.