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GROWTH AND YIELD OF COCONUT–CACAO INTERCROPS

By I. MIALET-SERRA†*, X. BONNEAU‡, S. MOUCHET‡ *and* W. T. KITU§

†Programme Agronomie, CIRAD-AMIS, TA 40/01, Avenue Agropolis, 34398 Montpellier cedex 5, France, ‡Programme Cocotier, CIRAD-CP, TA 80/01, Avenue Agropolis, 34398 Montpellier cedex 5, France, and §PT Multi-Agro Corporation Ltd, Multi-Agro Plantation, Lampung, Sumatra, Indonesia

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SUMMARY

The study of interactions between cacao (*Theobroma cacao*) and coconut (*Cocos nucifera*) in Lampung, Indonesia, examined different combinations of age, plant lay-out, planting chronology and choice of planting material under changing environmental conditions. Four coconut-cacao intercropping trials were used to assess the performance of each intercrop under limiting or non-limiting environmental conditions. In intercropping experiments with young cacao trees and young coconut palms, delayed cacao tree development and reduced yields were observed. When coconut palms were aged five years or over, coconut and cacao growth were satisfactory under virtually normal environmental conditions; death rates remained reasonable and yield percentages differed little from those of the monocultures for each crop. The performance of both plants, however, changed when water became a limiting factor.

INTRODUCTION

In South East Asia, over the last 20 years, coconut (*Cocos nucifera*)-based farming systems have attracted increasing government attention. Very often this interest is linked to the fact that the coconut crop, although widespread and, moreover, traditional in this part of the world, is declining. The reasons have been pinpointed by Liyanage *et al*., (1986) in Sri Lanka, Darwis (1990), Godoy and Bennett (1991), Zainal and Akuba (1990) in Indonesia, José (1968) and Baliad (1994) in the Philippines, Denamamy *et al*. (1979) in Malaysia, and Dootson *et al*. (1987) in Thailand. The critical size of farms (very often are under 2 ha), the ageing coconut plantings (many over 60 years old), inefficient farming practices, the highly diverse and unselected planting material, and poor upkeep are the main causes of very low yields. Combine this with fluctuating copra prices and the very low gross incomes are explained. The stated intention is to return to acceptable production levels and to increase smallholder incomes. Given the drive to intensify, extend, rehabilitate and rejuvenate these coconut plantings, introducing intercrops seems to be one solution. Moreover, such farming systems

* Address for correspondence. E-mail: isabelle.mialet-serra@cirad.fr

are not without advantages including better control of weeds, fertility (Vandermeer, 1990; Zainal and Akuba, 1990) and soil erosion (Darwis, 1990), without any depressive effects on coconut yields (Godoy and Bennett, 1991; Barrant, 1978) and even higher yields in many cases (Zainal and Akuba, 1990; Baliad, 1994; Benjamin, 1968; Nair *et al*., 1975). They also have socio-economic merit in having a lower risk of natural catastrophes than that associated with monoculture (Godoy and Bennett, 1991), and having more stable prices. It is possible, therefore, to intensify cultivation and, thereby, to manage land and labour resources, notably family manpower, more effectively (Bhat, 1987; Denamamy *et al*., 1979. Introducing an intercrop helps to reduce the cost of crop upkeep (Barrant, 1978). The shade cast by cacao trees naturally reduces weed development enabling, in some cases, a 40% reduction in herbicide use in the first three years and up to 50% in subsequent years (Godoy and Bennett 1991). An increase in soil microflora linked to the introduction of cacao trees leads to corresponding fertilizer savings. Financial gains increase in the long term (Godoy and Bennett 1991; Zainal and Akuba, 1990; Baliad, 1994).

In view of the economic interest and the large area of intercropped cacao (*Theobroma cacao*)-coconut in South East Asia, it seemed necessary to study interactions of this intercropping system systematically, on a large scale and at different development stages. In general, knowledge acquired in the past, and that of coconut-cacao intercropping in particular, has come primarily from socio-economic studies that list the drawbacks and advantages involved in such farming practices depending on the geographical zones involved. Experimental results have been obtained but often under conditions that were not clearly defined and, mostly, are too specific to the study sites. They are therefore very difficult to interpret and cannot be extrapolated. Given these facts CIRAD, and its tree crops department (CIRAD-CP) in particular, undertook to develop a large experimental network on this subject. The four experiments described in this article are the most significant examples and were launched in 1988 at Gunung Batin, the commercial plantation of Multi-Agro Corporation Ltd, in central Lampung, Indonesia. They provided estimates of the combined effects of coconut-cacao intercropping on the growth, death rates and yields of both these tree crops, together with an idea of relevant advantages and limitations.

MATERIALS AND METHODS

The site

The plantation covers 10 000 ha in Lampung province in southern Sumatra (4°38′S, 105°15′E). There are two seasons, a rainy season from November to April and a dry season from May to October. The dry season varies in intensity. Water deficits vary in degree from one season to another and can be very severe, as in 1991 and 1994 (Table 1).

Called locally ‘red-yellow podzolic’, the soil is of a ferrallitic type with a podzolic tendency. Superior horizons have a sandy-clayey texture with an increase of clay

Table 1. Monthly climatic data for Gunung Batin in 1991 and 1994.

	Precipitation (mm)		Evaporation (mm)		Water deficit (mm)	
Month	1991	1994	1991	1994	1991	1994
January	367	392	140	146	0	0
February	211	262	130	119	0	0
March	280	511	128	154	0	0
April	399	316	118	132	0	0
May	99	26	109	132	0	−6
June	35	61	103	127	0	−66
July	5	1	143	159	−116	−158
August	0	0	184	203	−184	−203
September	18	58	184	212	−166	−154
October	15	9	215	196	−200	−187
November	313	79	134	147	0	−68
December	292	316	130	147	0	0
Total	2034	2028	1718	1873	−666	−842

Evaporation measured with an open pan, Type A
Water deficit = [Precipitation + Soil Water Reserve] − Evaporation
Maximum soil water reserve = 100 mm

with depth. The organic matter in the topsoil is normally satisfactory (>2%) and the C:N ratio is low, indicating a good rate of mineralization. The pH is slightly acid. Exchangeable P content is low. The cation exchange capacity is low, with a high proportion of exchangeable Al (without danger for the coconut crop in this type of soil). Exchangeable K content is low but the K:Mg ratio is satisfactory. These chemical properties of the soil are suitable for coconut and cacao farming. The limiting factor is physical; a highly compacted and very strongly cemented accumulation, locally called 'hardpan', which appears between 100 and 150 cm depth and strongly limits the soil water reserve.

Planting material

The planting material involved was:

- coconut hybrids Malayan Yellow Dwarf × West African Tall (Port Bouët 121) and Cameroon Red Dwarf × West African Tall (Port Bouët 111); and
- a mixture of different cacao hybrids.

Experimental designs

Experiment 1. A planting density trial varying both the cacao and coconut planting densities and their layout, to find the best combination in terms of income per hectare. It covered 34 ha with six replications of eight treatments, three of which were mono-crops and five intercropping systems (Table 2). The coconut palms were planted in October 1986, the cacao trees in February 1988. This experiment was carried out during 1990 and 1991 and stopped after the severe dry season of 1991.

Table 2. Characteristics of the treatments in Experiment 1.

	CACAO				COCONUT		
			Spacing (m):			Spacing (m):	
Treatment	Plants ha^{-1}	No. of rows	between rows	in rows	Plants ha^{-1}	between rows	in rows
A	1176	2	2.5	2.0	131	8.50	9.0
B	1212	2	4.0	1.5	107	11.00	8.5
C	1186	3	2.5	2.3	107	11.00	8.5
D	1186	3	2.5	2.3	87	11.00	10.5
E	1185	4	2.5	2.5	71	13.50	10.5
T2-1	1176	2	2.5	2.0	—	—	—
T2-2	1333	—	3.0	2.5	—	—	—
T1	—	—	—	—	160	7.36	8.5

No. of rows = Number of cacao rows in the coconut inter-row.
T2-1 and T2-2 = Cacao monoculture, respectively 'fruit hedge' and random
T1 = Coconut monoculture

The data recorded for coconut were girth, percentage of palms having flowered and the number of nuts produced per palm. Following the 1991 drought, the number of fronds remaining on each palm and the percentage of dead palms were also recorded. A leaf analysis was carried out in April 1991, just before the beginning of the 1991 drought. The data recorded for cacao were the canopy percentage (i.e. the proportion of cacao trees with a pseudo-whorl of lateral branches) in the first year and the number of healthy pods per hectare. Following the 1991 drought, the death rate percentage was also recorded.

Experiment 2. A planting density trial varying the number of cacao tree rows in the coconut inter-row (Table 3). The aim was to determine the best cacao tree layout under adult hybrid coconut palms with a high production potential planted at standard density (160 palms ha^{-1}). The cacao trees were considered as an added value designed to optimize land use between the coconut palms. The trial covered 11 ha with 3 treatments replicated 12 times. The coconut palms were planted in January 1984, the cacao trees in February 1989. This experiment was followed up between 1989 and 1994 and stopped after the severe dry season of 1994. For the coconut palms, the number of nuts per hectare was recorded. For

Table 3. Characteristics of the treatments for cacao in Experiment 2.

			Spacing (m)	
Treatment	Plants ha^{-1}	No. of rows	between rows	within rows
A	543	1	—	2.5
B	1087	2	3.0	2.5
C	1359	3	2.0	3.0

the cacao trees, the death rate and canopy percentages were recorded along with the number of healthy pods per hectare once they started bearing.

Experiment 3. A cacao planting density trial under hybrid coconut palms planted at 160 palms ha^{-1} (standard density). There were always two rows of cacao trees but spacing along the row varied from 1.5 to 3.5 m depending on the treatment. The aim was to determine the best cacao tree layout under adult coconut palms with a high production potential and planted at standard density (160 palms ha^{-1}), as in Experiment 2. There were five treatments (Table 4) replicated six times. The coconut palms were planted in January 1984, the cacao trees in February 1989. This experiment was carried out between 1989 and 1991 and stopped after the severe dry season of 1991. Unlike in Experiments 1 and 2, only the cacao tree storey was taken into account. The canopy and death rates were recorded, along with the number of healthy pods per hectare in each treatment.

Experiment 4. This trial studied the interactions between coconut and cacao root systems. Two treatments with two rows of cacao trees in the inter-row (Table 5) were compared. One of the two treatments included a 1-m deep trench physically isolating the cacao trees from the coconut palms. Each treatment was replicated eight times. The coconut palms were planted in October 1988, the cacao trees in March 1994. The criteria involved were the cacao tree death rates and canopy percentages.

Fertilizer applications. Urea (46% N), triple superphosphate (46% P_2O_5), dolomite (19% MgO), NaCl (for coconut palms only, at 50% Cl) and KCl

Table 4. Characteristics of the treatments for cacao in Experiment 3.

			Spacing (m)	
Treatment	Plants ha^{-1}	No. of rows	between rows	within rows
A	1812	2	3	1.5
B	1359	2	3	2.0
C	1087	2	3	2.5
D	906	2	3	3.0
E	776	2	3	3.5

Table 5. Characteristics of the treatments for cacao in Experiment 4.

			Spacing (m)	
Treatment	Plants ha^{-1}	No. of rows	between rows	within rows
A	960	2	2	2.83
B	960	2 + trench	2	2.83

Table 6. Fertilizer applications on coconut and cacao in the four experiments (g per tree).

	Urea	Triple superphosphate	KCl	NaCl	Dolomite
		On coconut			
Year of planting	500	600	300	—	150
2nd year	600	—	600	—	—
3rd year	1000	—	800	—	—
4th year	1400	—	1400	—	2000
5th year	2000	—	1000	1500	3000
6th year	2000	—	1000	1500	1000
7th year	500	—	2500	1000	1500
8th year	500	—	1500	800	1500
9th year	—	—	1500	800	1500
		On cacao			
Year of planting	—	250	—	—	100
2nd year	—	150	—	—	200
3rd year	—	—	100	—	300
4th year	150	250	200	—	300
5th year	150	100	100	—	350

(60% K_2O) were applied twice or three times per year, in March or April and November during the first four years and then once per year in May. The applications were the same for each experiment (Table 6).

Analysis method. The analysis was based on a comparison of means between treatments. The discriminant test used was the *Student-Newman-Keuls* test, indicating whether these means differed significantly at the 5% probability level.

RESULTS

Coconut girth development

At 33 months in Experiment 1, significantly different girths were recorded between treatments D (triple row of cacao trees + 87 coconut palms ha^{-1}), E (four rows of cacao trees + 71 coconut palm ha^{-1}) and the control (coconut monoculture) of 125.8, 123.9 and 119.2 cm respectively. These differences subsequently disappeared completely.

Number of green fronds at the end of the dry season

In Experiment 1, the mean number of green fronds still in place was significantly greater in treatment E (4.4 fronds $tree^{-1}$) than in the monoculture (2.3 fronds $tree^{-1}$). Intermediate values between these two extreme treatments (control and treatment E) were observed, with a gradual and linear decrease (Fig. 1) with increasing coconut planting densities combined with a decreasing number of cacao tree rows.

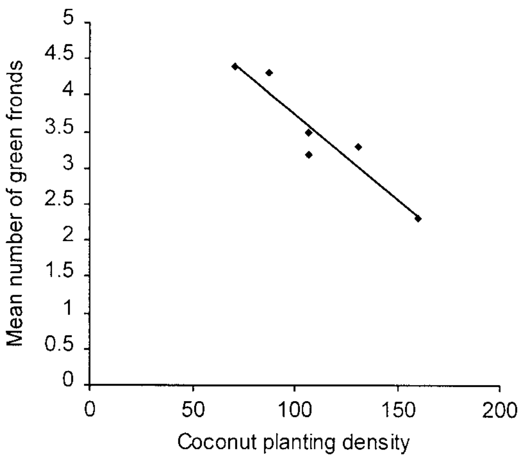

Fig. 1. Number of green fronds in place after the 1991 drought in relation to coconut planting density

Variation in cacao tree canopy percentage

In Experiment 1 the canopy percentage of the monoculture (T2-1 = double cacao tree rows, 1176 plants ha^{-1}) at 12 months was 75.3%. This was significantly greater than those of the other treatments that ranged from 63.6 to 49.7%. By 20 months the differences had completely disappeared. In Experiments 2 and 3 no significant difference was found between treatments. Treatments B of Experiment 2 and C of Experiment 3 had the same planting densities (160 palms ha^{-1} + 1087 cacao trees ha^{-1}) and their canopy percentages were comparable. In Experiment 4 in 1994, treatment B with the trench (92.5%) was significantly more precocious than treatment A without the trench (58.9%).

Variation in death rate percentage

The coconut death rate percentage in Experiment 1 was higher in the monoculture. No significant difference was found between the intercropped treatments (Table 7). In the case of cacao no significant difference was found between treatments. In Experiment 2 (Table 7) the coconut death rate percentages recorded after the 1991 and 1994 droughts were significantly higher in treatment C (a triple row of cacao trees). In 1990 and 1991 the cacao tree death rate percentages were low and not significantly different. In Experiment 3 (Table 7), one year after planting, the death rate percentages were not significantly different and remained low, as in Experiment 2. In 1991 they increased considerably though there were no significant differences linked to spacing along the planting. In Experiment 4, the death rate percentage in treatment B with the trench (10.4%) was significantly lower than that found in treatment A (37.0 %).

Percentages of flowered coconut palms

The percentage of coconut palms that flowered was only monitored in Experiment 1. At 33 months there was no significant difference between

Table 7. Coconut palm and cacao tree death rate percentages.

EXPERIMENT 1											
		Treatment	T2-1	T2-2	T1	A	B	C	D	E	*s.e.*
Year	Age (years)										
1991	5	Coconut	—	—	35.6	12.7	8.7	15.9	16.8	18.1	11.2
	3	Cacao	47.1	39.2	—	36.9	33.9	38.9	37.2	46.0	

EXPERIMENT 2							
		Treatment	T1	A	B	C	*s.e.*
1990	6	Coconut	—	—	—	—	
	1	Cacao	—	0.5	0.4	0.8	
1991	7	Coconut	0.0	0.0	1.2	3.0	2.1
	2	Cacao	—	26.6	24.2	19.1	
1994	9	Coconut	0.4	0.0	0.0	4.3	3.9
	4	Cacao	—	—	—	—	

EXPERIMENT 3							
		Treatment	A	B	C	D	E
1990	1	Cacao	0.8	1.4	0.5	0.5	0.6
1991	2	Cacao	60.6	64.8	60.3	57.7	65.6

treatments (Table 8). At 39 months the monoculture (T1) showed significantly lower percentages of flowered coconut palms than the intercropping treatments, particularly treatment D with a low planting density. By 46 months, the monoculture had still fewer flowered palms, whilst treatment B had the largest number of flowered palms.

Yields

In Experiment 1 in 1990, the intercropped treatments produced significantly more nuts per hectare than did the control treatment (Fig. 2). In 1991 these data were somewhat modified. Coconut yields per hectare in the intercropped treatments tended to decrease gradually as their planting density decreased. The yields in the control treatment and treatment A were comparable. In the second harvesting year, 1990, cacao production increased considerably then decreased in 1991 (Fig. 3). Over those two years the monocultures produced significantly more than the intercropped treatments. All in all, the higher the coconut planting density the lower the cacao yields irrespective of the number of cacao tree rows in the coconut inter-row.

No significant differences occurred over time between the treatments in Experiment 2 (Fig. 4). Over the first four years the triple row of cacao trees gave significantly higher yields per ha than did the single and double rows of cacao trees

Table 8. Variation in flowered coconut palm percentages in Experiment 1.

Treatment		T1	A	B	C	D	E	
		Planting density (coconut + cacao)						
Year	Age	160 (control)	131 + 1176 (2)*	107 + 1212 (2)	107 + 1186 (3)	87 + 1186 (3)	71 + 1185 (4)	*s.e.*
1989	33 months	4.7	17.2	21.9	16.2	18.7	18.3	
	39 months	49.4	67.6	67.4	64.1	83.3	58.8	12.1
1990	46 months	94.0	99.3	99.8	96.0	99.0	97.6	4.5

* (Number of cacao rows in the coconut inter-row).

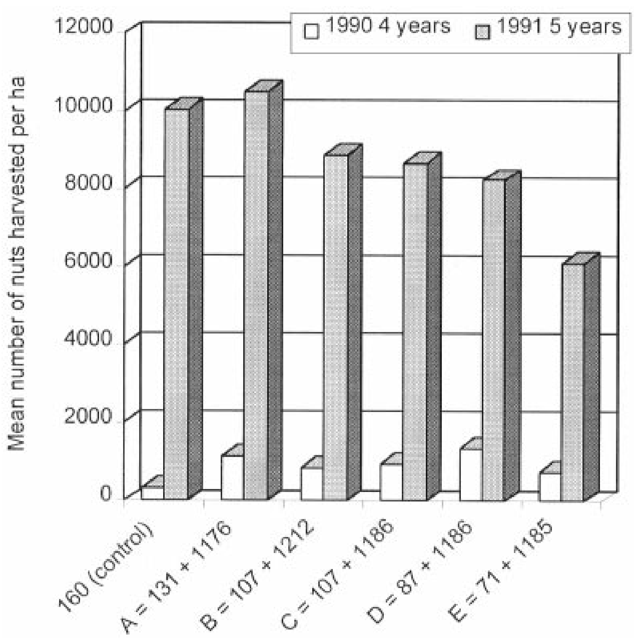

Fig. 2. Mean number of nuts harvested per hectare in 1990 and 1991, in Experiment 1.

(Fig. 5). Despite the 1991 drought the harvest in 1992 increased on average by 6700 pods ha^{-1} in the triple and double rows, but only by 400 pods ha^{-1} in the single row. In Experiment 3 (Fig. 6), there was no significant difference between the treatments. At the same planting densities and design, Treatment C of Experiment 3 outyielded treatment B of Experiment 2 by 2713 pods ha^{-1}.

Coconut leaf analysis

The analyses carried out on coconut leaves in Experiment 1 revealed significantly more phosphorus and chlorine in the intercropped coconut palms (Table 9). The phosphorus levels were high and the chlorine levels low (0.296% on average for a critical level at 0.5%). The reverse was seen for potassium, with

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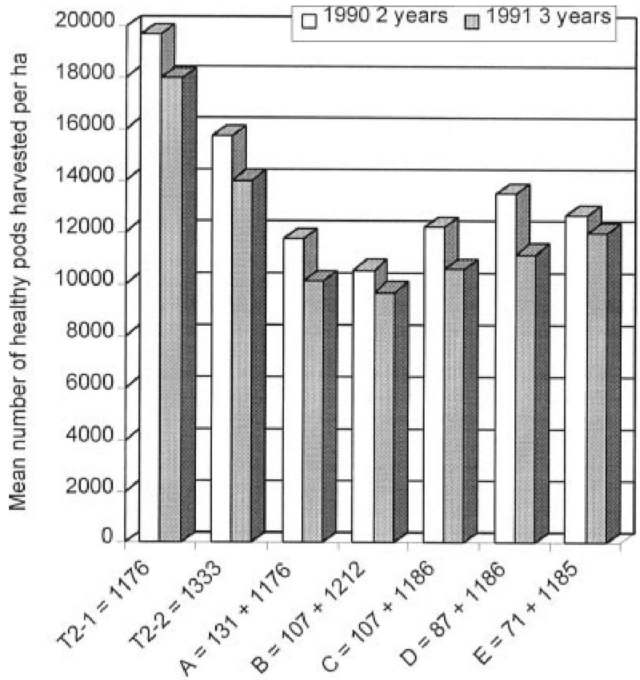

Fig. 3. Mean number of healthy pods harvested per hectare in 1990 and 1991, in Experiment 1.

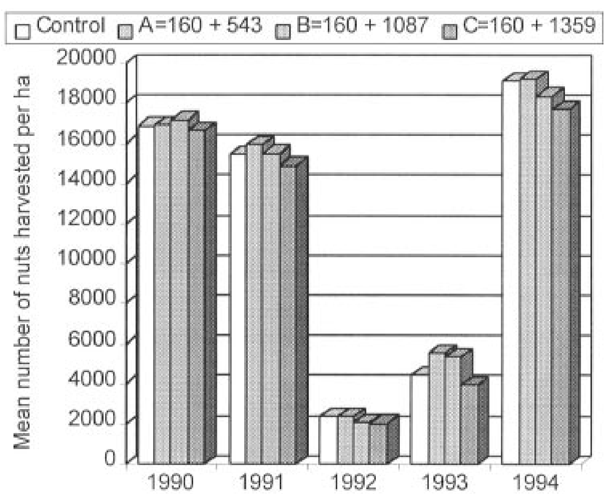

Fig. 4. Mean number of nuts harvested per hectare in 1990 and 1994, in Experiment 2.

significantly more in the coconut monoculture and a low level compared with the critical level of 1.4%. The magnesium percentages were not significantly different from one treatment to the other but its high level (0.291% on average) was rare for the Gunung Batin site.

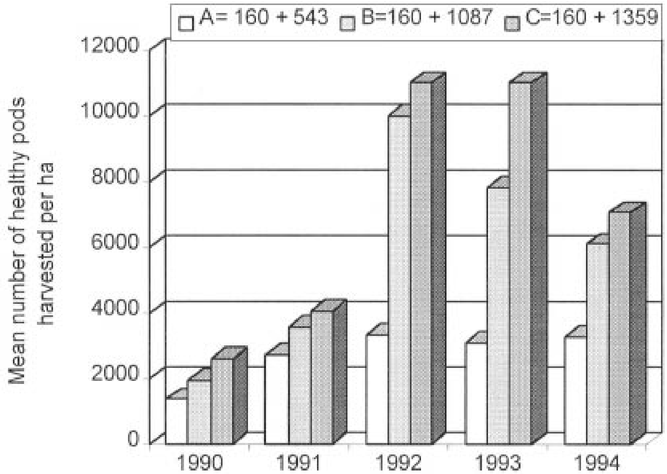

Fig. 5. Mean number of healthy pods harvested per hectare between 1990 and 1994, in Experiment 2.

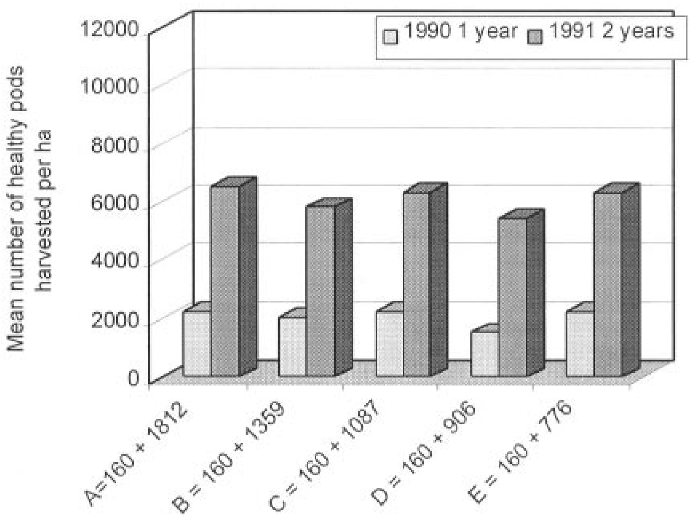

Fig. 6. Mean number of healthy pods harvested per hectare in Experiment 3.

DISCUSSION

The results described above reveal differences in the performance of one or other of the two crops. An explanation is provided partly by the layout of the plants in relation to each other (they differed substantially from one experiment to the other) but also, sometimes primarily, by the planting chronology. Two cases were involved:

- slightly staggered plantings (Experiment 1) in which the cacao and coconut plantings were separated by only two years.
- staggered plantings in which five years separated the cacao and coconut plantings (Experiments 2, 3 and 4).

Table 9. Results of leaf analyses carried out on coconut palms in Experiment 1 (April 1991, before dry season, leaf 14).

Treatment	T1	A	B	C	D	E	
	Planting density (coconut and cacao)						
	160 (control)	131 + 1176 (2)	107 + 1212 (2)	107 + 1186 (3)	87 + 1186 (3)	71 + 1185 (4)	*s.e.*
Phosphorus	0.135	0.153	0.151	0.155	0.150	0.151	0.012
Potassium	1.121	0.850	0.995	0.861	0.998	0.926	0.152
Chlorine	0.238	0.316	0.319	0.298	0.307	0.299	0.055
Magnesium	0.264	0.303	0.287	0.304	0.284	0.304	

Slightly staggered plantings

Young coconut palms grew more slowly in monoculture. At the outset there was, therefore, significant competition between the palms during their establishment phase. Logically, introducing cacao trees was bound to exacerbate the situation. Yet the results were better in the intercropped treatments. This could be explained by a reduction in coconut palm planting density and stimulated vegetative growth due to added fertilizer. All intercropped coconut planting densities were lower than in the monoculture and, in addition to their own fertilizer applications, intercropped coconut palms benefited from fertilizer applied to the cacao. The increase in girth was then significant. The advantage did not persist, however, though subsequent coconut palm growth was not found to be retarded by the presence of intercropped cacao trees. It is important to emphasize that while the two plants were becoming established in this type of planting situation, it was difficult to distinguish between an interaction between coconut palms and the effects of cacao trees on the coconut palms. This experiment did not provide a clear-cut answer.

On coconut palms entering their fifth year and faced with a limiting water supply, the average number of green fronds recorded revealed better resistance in the intercropped palms. Here again the lower planting densities have to be considered. Nevertheless, another factor may also have influenced the result. Leaf analyses carried out at that time revealed that chlorine contents were higher in the intercropped coconut palms by 0.24 to 0.30% (that is well under the critical level of 0.5%). Earlier studies (Bonneau *et al.*, 1993) revealed that chlorine is responsible for better drought resistance, whilst being a growth and production factor under low to moderate water stress conditions. The possible reasons for its increased assimilation were pinpointed by Nair and Subba Rao (1977a;b). In an intercropping system, microbiological activity in the coconut palm rhizosphere increases due to the existence of a larger number of microorganisms in the thick litter produced by the cacao trees. This varied microbial and fungal fauna would seem to induce more effective solubilization and mobilization of certain nutrients by limiting their leaching.

While the coconut palms were developing, the intercropped cacao trees grew more slowly, resulting in late canopy formation. Reducing the coconut planting density did not increase cacao tree growth rate; neither did a reduction in the number of intercropped cacao rows with a standard coconut planting density (160 palms ha^{-1}). Increasing the spacing between cacao trees along the planting row did not give any better results. In all cases, cacao tree growth was fastest in the monoculture treatment, particularly in a fruit hedge design with two intermediate rows of cacao trees.

Following the 1991 drought, the death rates for both crops were high. For coconut, they were greatest in monoculture. The responses were greater the more the water supply conditions became limiting. As previously during the establishment phase of young monocultured coconut palms, competition caused by water stress doubtless increased in line with their planting density. In the intercrops, the small age difference between the intercropped plants may have been to blame for the pressure exerted on the coconut palms by the cacao trees. Even so such an explanation is not enough to interpret certain results. Indeed, the coconut death rates increased with wider spacing between the palms and with an increase in the number of cacao rows in the inter-row. Cacao tree competition with the young coconut palms was already strong and was only slightly compensated for, if at all, by a reduction in coconut planting density.

At four years, yields and numbers of flowered palms of monocultured coconut were significantly lower than those found in the intercrops. The following year, intercropping treatments A and B continued to perform well (Figure 3). Monocultured cacao produced significantly more healthy pods per hectare than did intercropped treatments. Lowering the coconut planting density could reduce the competition pressure exerted by coconut on intercropped cacao trees.

Staggered plantings

Observations carried out on cacao trees planted five years after the coconut palms revealed differences from previous results. The cacao tree canopy developed more quickly, despite higher coconut planting densities. A marked difference in age between the intercrops seemed to benefit the young cacao trees. Earlier observations (Kannan and Nambiar, 1973) reported perfectly satisfactory cacao tree development under 50-year-old coconut palms. Those authors did not find that the number of cacao tree rows had any significantly depressive effect on cacao tree growth. As soon as the water supply became limiting or severely limiting, however, growth was found to be significantly retarded, especially in the first 12 months, and this was attributed to the existence of strong competition between the root systems of the intercropped plants (see Experiment 4). The competition was detrimental primarily to the cacao trees. There were no negative interactions between the root systems of intercropped coconut palms and cacao trees. Colas (1997) stated that these two root systems develop in perfect harmony, intertwining and elongating in contact with each other without any repulsion on either side. As soon as conditions became limiting, though, water uptake became a source of strong competition between the plants and, as a general rule, was largely more unfavourable to the underlying smaller plant, in this case cacao. The coconut palm root system is powerful and invasive, exploring a volume of soil much greater than a cacao tree root system could occupy. It is reasonable, therefore, to assume that coconut is more able to absorb a greater quantity of water.

The coconut palm death rates remained acceptable, and much lower than seen in the previous case, even under limiting water supply conditions. The cacao tree results were much less clear-cut. Under non-limiting conditions, the death rates were perfectly reasonable. Under limiting conditions, the death rate was high during the establishment phase, but much lower on two-year-old cacao trees. Cacao tree age, therefore, was an important criterion, more so than the presence of coconut palms.

Coconut yields were identical in the monoculture and intercropping treatments. These results tally with earlier results thereby proving that the presence of cacao trees is, in theory, not detrimental to coconut production (Godoy and Bennet, 1991; Barrant, 1978). In other, frequently reported cases, however, their presence would seem to induce an increase in the number of nuts produced, though without any increase in copra weight per nut (Zainal and Akuba, 1990; Baliad, 1994; Nair *et al.*, 1975). Contrary to the only slightly staggered plantings, the presence of coconut palms did not have any negative effects on cacao production. According to the authors' observations, the most productive design was a triple row of cacao trees under coconut palms planted at standard density (160 palms ha^{-1}). This tallies perfectly with the results obtained by Kannan and Nambiar (1973) in India, showing that cacao yields were better in multiple rows. In the present case, the coconut and young cacao tree yields were the same as in the monoculture. The recommendation made by José (1968) in the Philippines to plant intercropped cacao trees in single rows with 3 to 4 m between trees does not seem to be justified if the age difference between the crops is at least five years.

CONCLUSIONS

The four experiments described here covered more than 45 ha in total, thereby avoiding problems of significance. The coconut planting material used was primarily the PB 121 hybrid. Theoretically this is the most versatile type of coconut palm in the world, with a wide spectrum of adaptability (Nucé and Bénard, 1985). It is frequently grown in commercial plantations and, therefore, is not marginal material for a given geographical zone. A wide range of planting densities was tested for both coconut and cacao in order to ascertain the best coconut-cacao combination in agronomic terms. Planting chronology was also studied to choose the most suitable time to plant the intercrop. An original design with a trench to isolate coconut palms from cacao trees revealed severe competition for water during a long dry season. This is a major finding and can be used to set the limitations of such designs.

Although the environmental conditions of the experimental area were marginal for intercropping systems, the results obtained can be used to recommend combinations that can be extrapolated to other situations and which are intended to ensure rational land occupation and avoid excessive overloading of the system. For instance:

- If planting is staggered only slightly, there is strong competition from coconut palms on cacao tree growth and yields in the short term. It is difficult to assess the impact of cacao tree presence on coconut palms given that the competition within the coconut storey is already not inconsiderable. It is preferable, however, to wait until the coconut palms have completed their establishment phase before planting a perennial intercrop.
- If plantings are clearly staggered (by at least five years), for constant coconut planting densities the pressures exerted are less and cacao tree growth remains satisfactory with reasonable death rate percentages for both plants, and yields that vary little between the monoculture and intercrop. In this case, a system combining coconut palms with a high production potential (160 palms ha^{-1}) and a triple row of cacao trees in the inter-row can maintain a production potential for both plants that is identical to that found in the monocultures when the water supply is not limiting.

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