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PLANTING DENSITIES AND PLANTING SYSTEMS FOR COCONUT, *COCOS NUCIFERA L.* 2. STUDY OF YIELD CHARACTERS AND THE ECONOMICS OF PLANTING AT DIFFERENT DENSITIES

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ABSTRACT

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Data are presented on a coconut spacing trial using *Typica* x *Nana* form *Pumila* (CRIC 65) hybrids as the planting material. Analysis of yield data over a four year period indicates significant differences in the mean yield per palm both among between-row spacings and within-row spacings. As far as the yield per palm is concerned, its increase per unit increase in spacing is more pronounced at the narrow range of spacing than at the wider range of spacings. Further as far as yield per unit area is concerned, what really matters is not the 'rectangularity' of the system of planting but the plant density. We find that at a density of 175 palms/ha the mean yield per palm is of the same order of magnitude whether the system of planting is almost square (rectangularity of 1.04) or highly rectangular (2.67). The number of nuts/palm decreases with increasing density with 83 nuts/palm at a density of 128 palms/ha, 68 nuts/palm at a density of 175 palms/ha and 54 nuts/palm at a density of 239 palms/ha. The high density systems have given a high yield per unit area as well as high net profit in a fifteen year old plantation.

With the present emphasis on intercropping under coconut, a high density-rectangular system of planting would be recommended.

INTRODUCTION

Coconut in Sri Lanka has been regarded for a long time as a 'monoculture' crop, particularly on the larger plantations. In small holdings and home gardens, a somewhat disorganised system of mixed cropping has been practised, where, along with coconut, a multitude of annual and perennial crops of every-day use to the farmer have been cultivated. Therein it is not altogether uncommon for the coconut to take second place to the other crops. In the case of the smaller home gardens, coconut spacing and density are often largely determined by the degree to which they can be crowded in with other crops, particularly perennial tree crops such as jak, bread-fruit, mango and citrus. Coconut would then be planted in an almost disorderly fashion with irregular plant-to-plant spacings.

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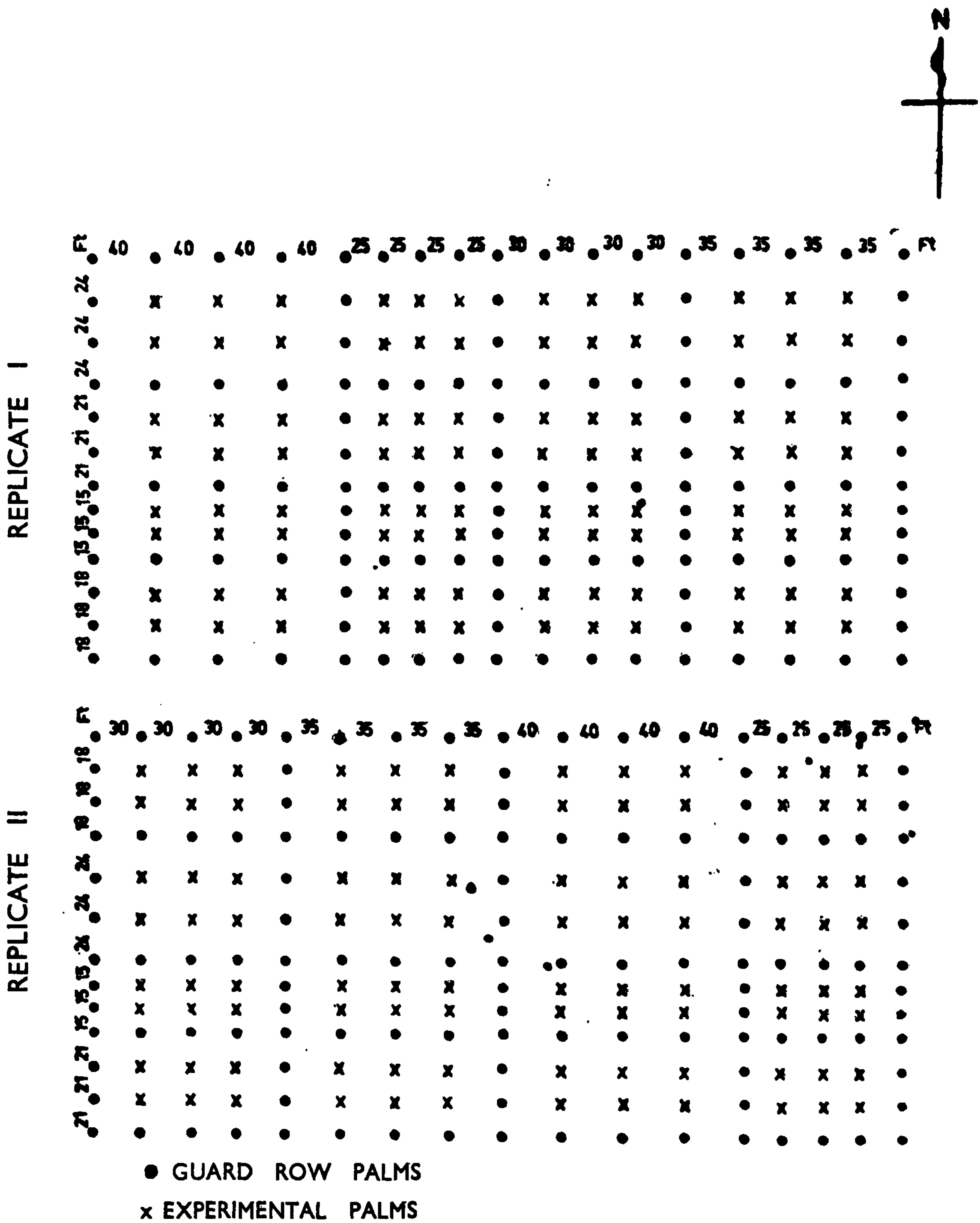


Fig. 1. Spaeing trial (Pothukulama) (Strip plot design)

In contrast, on larger holdings of a few hectares or more it has been the common planting practice to locate the planting sites on the corners of a square or triangle, less often on a rectangle. It would appear that past experience and traditions largely determine the spacings and the system of planting and it is not surprising therefore that different plant-to-plant spacings are used in different coconut growing countries. For example, in Jamaica, the "Jamaica Tall", variety of coconuts has always been planted at 10 m (33 feet) on the square giving 98 palms/ha, (40 palms/acre), a density that is now considered to be far below the optimum, (Smith, 1972). In Malaysia most of the larger plantations are spaced 9.1 m x 9.1 m (30 feet x 30 feet) on the square system giving a stand of approximately 123 palms/ha or 50 palms/acre - again a sub-optimal density for coconut in monoculture, but probably well suited for intercropping particularly with permanent tree crops such as cocoa. At the other end of the scale, due to ever increasing pressure on cultivatable land, coconuts are sometimes planted at very high densities either in the belief that this may lead to high yield or where the monetary value of the land is based not on its area, but on the number of coconut palms that it carries. It is generally recognised that a spacing of about 7.5 m (25 ft.) approaches the optimum, although here too opinion is divided as to whether the same yardstick can be used irrespective of soil types, soil fertility, land terrain and water retention capacity. The range of palm density normally found in Sri Lanka for the commercial tall variety of coconuts (Variety *Typica* form *typica*) varies from 123 to 210 palms/ha, (50 to 85 palms/acre), with even higher densities in the coastal areas. Different systems of planting - square, rectangular, and triangular – as well as spacing, would combine to give the range of densities mentioned earlier.

With the current emphasis on permanent intercropping with crops such as coffee, cocoa and pepper, a re-assessment must necessarily be made on hitherto accepted planting distances and densities. In view of the scant information on this subject a planting distance and density trial was planted in 1964 at the Pothukulama Research Station (Chilaw District) where the effect of spacing (density) on vegetative growth, initial flower production and yield are being studied. The degree of shade cast by the palms at the different densities was indirectly assessed by the vegetative growth and yield of an annual, *Vigna catiang Burm* Walp. Var. MI 35 (Karunaratne *et al.* 1976).

An interim analysis of the data from the coconut spacing trial indicated that (a) spacing had no significant influence on total leaf production (b) spacing had a significant effect on the length of leaves and the girth of the trunk and (c) it had no significant effect on the period taken for the emergence of the first inflorescence, popularly referred to as initial flowering, (Manthriratna, 1976). The yield patterns and the economics of planting at the different densities as shown in this experiment are discussed in this paper.

MATERIAL AND METHOD

Material: Selected hand pollinated F_1 seedlings of *typica* x *pumila* (CRIC 65 hybrids) were used as planting material. The *pumila* pollen parent was common to all the hybrids.

Soil type and rainfall: Sandy loam (regosol) with 1370 mm of rain per annum.

Design: The experiment is a 4 x 4 strip plot design where within each replicate the columns are allotted the between row spacing and the rows are allotted the within-row spacings. There were two replicates with 6 palms per plot. The design is shown in Figure 1 and spacings and number of palms are given in Table 1. The crop yields of individual palms were recorded for two four-year periods, 1969–1972 and 1973–1976. Only the yield data gathered for the second four-year period are considered in this paper, as during the earlier period all the palms were not in reasonably full bearing as they had been transplanted only five years previously.

Table 1 *Between-row and within-row spacings and number of palms/acre (in bold type)*

Within-row spacing	Between-row spacing (feet) 25	30	35	40
15	**116**	**96**	**82**	**72**
18	**96**	**80**	**69**	**60**
21	**82**	**69**	**59**	**51**
24	**72**	**60**	**51**	**45**

Note – (All spacing in this and subsequent tables are in British units which were in use when this experiment was planted in 1964. Metric conversions have been used to discuss the results.)

RESULTS AND DISCUSSION

1. Influence of spacing on yield

Table 2. *Analysis of variance of mean yield/palm for the period* 1973–1976

Source of variation	DF	SS	MS	F
Replicates	1	2.44	2.44	—
Linear	1	2541.54	2541.54	53.55**
Bn Row Quadratic	1	4.33	4.33	—
Cubic	1	106.69	186.69	3.83
Error (1)	3	142.39	47.47	—
Linear	1	1710.54	1710.54	45.99**
Wn Row Quadratic	1	65.92	65.92	1.77
Cubic	1	5.53	5.53	—
Error (2)	3	111.58	37.19	—
Bn Row x Wn Row (Interaction)	9	1171.47	130.16	1.35
Error (3)	9	865.82	96.20	—

An analysis of variance of the mean yield per palm (Table 2) indicates significant differences in the mean yield per palm both among between-row spacings and within row spacings. Two noteworthy features brought out by this analysis are: (1) the increase in yield per palm is linear for both inter-row spacings and intra-row spacings and (2) there is no interaction between inter-row spacings and intra-row spacings.

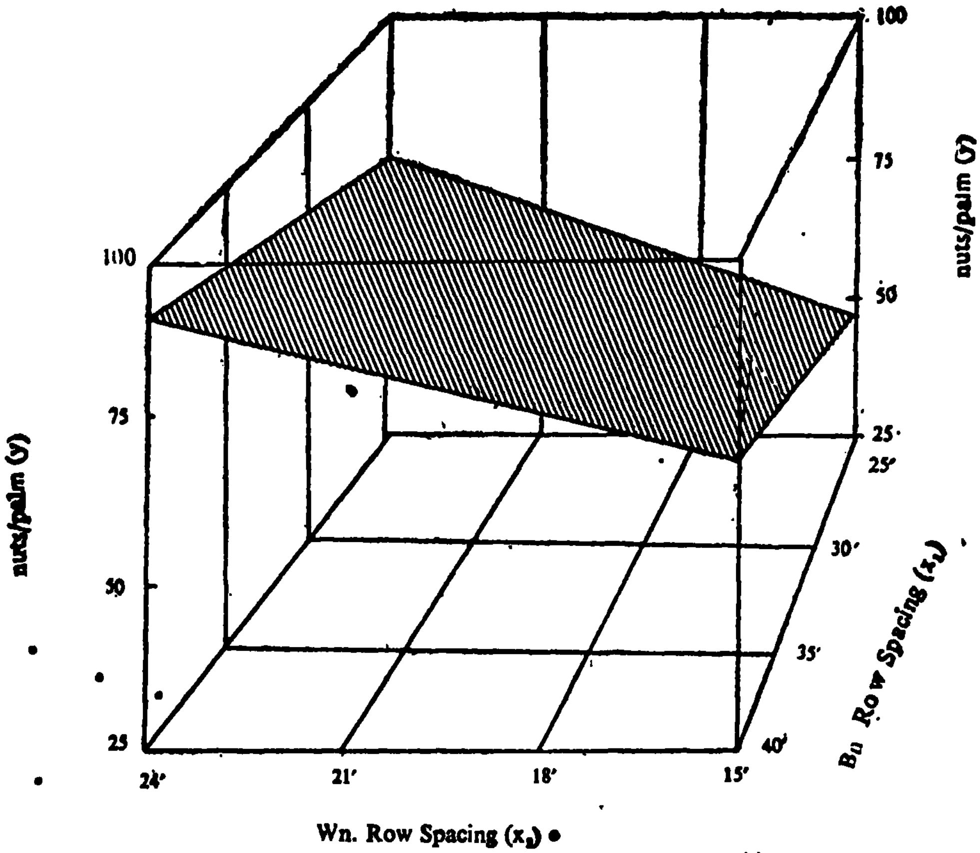
2. Response surface

A response surface fitted to the data gave rise to the following equation.

$$y = 24.32 + 1.48 X_1 + 2.28 X_2$$

multiple correlation $R = 0.906$

Where y = mean yield per palm
X_1 = inter-row spacing
and X_2 = intra-row spacing



$$y = -24.32 + 1.48x_1 + 2.28x_2$$

(multiple correlation $R = 0.906$

Fig. 2. Influence of spacing on yield (nuts palm).

This indicates that with every one foot increase in the inter-row spacing, the yield increases by 1.48 nuts/palm and with every one foot increase in the intra-row spacing the yield increase by 2.28 nuts/palm. It would therefore appear that the intra-row spacing (distance between two palms on the same row) is more critical than the inter-row spacing (distance between two rows). This is not to be interpreted as if the coconut palm recognises "Intra-row" and "Inter-row" spacings. The inter-row spacings used in this experiment ranged from a spacing of 7.62 m (25 feet) to a spacing of 12.19 m (40 feet), and the lowest spacing (which is the spacing commonly met with on coconut lands) is probably good enough. On the other hand the range of spacings within a row varied from 4.57 m to 7.31 m (15 feet to 24 feet), and obviously the latter is more critical. Figure 2 shows the response surface indicating the influence of spacing on yield in terms of nuts/palm. The actual mean yields (nuts/palm/year) for the different treatments are given in table 3.

Table 3 *Mean yield (nuts/palm/year)*

intra-row (feet)	*inter-row* (feet) 40	35	30	25
15	70.88	51.22	48.82	48.64
18	75.88	79.79	70.12	55.98
21	86.21	73.00	67.09	57.22
24	91.89	75.47	71.62	71.36

Following a re-grouping of the different combinations of inter-row and intra-row spacings, such that similar densities are considered together (Table 4), an important deduction can be made – namely that as far as the yield per palm is concerned it is not the rectangularity of the system of planting that really matters but the plant density.

Table 4. *Yield per palm as influenced by density and rectangularity*

Group	*Inter-row spacing (ft)*	*Intra-row spacing (ft)*	*Rectangularity Inter-row/ Intra-row*	*Density palms/ha*	*Mean yield nuts/palm*
A ..	30	15	2.00	239	54.46
	25	18	1.39	239	53.89
B ..	35	15	2.33	205	61.88
	30	18	1.67	199	61.31
	25	21	1.19	205	60.75
C ..	40	15	2.67	179	69.30
	35	18	1.94	171	68.73
	30	21	1.43	171	68.17
	25	24	1.04	179	67.60
D ..	40	18	2.22	150	76.15
	35	21	1.67	146	75.59
	30	24	1.25	150	75.02
E ..	40	21	1.90	128	83.01
	25	24	1.04	128	82.44

We thus find that in Group C (Table 4), with a density of approximately 175 palms/ha, the mean yield per palm is of the same order of magnitude whether the system of planting is almost square (rectangularity of 1.04) or highly rectangular (2.67). The yield pattern follows a similar trend in the other groups as well (Table 4).

By far the commonest planting system in the plantation sector in Sri Lanka is the *square system* with distance between planting sites varying from 7.3, 7.6, 7.9 (24, 25, 26 feet) to rarely 8.5 or 9.1 m (28 or 30 feet). For intercropping, particularly with permanent tree crops, a rectangular system with a wide between-row spacing has many advantages over the square system. Thus if we consider Group C (Table 4), 12.19 m x 4.57 m (40 feet x 15 feet) and 7.62 m x 7.59 m (25 feet x 24 feet) gives the same density and the same yield per palm, but the more rectangular system would certainly be superior for intercropping. The number of nuts/palm decreases with increasing density, with 83 nuts/palm at a density of 128 palms/ha, 68 nuts at a density of 175 palms/ha and 54 nuts per palm at a density of 239 palms/ha. Coomans (1974) has found a similar trend in Ivory Coast, where the number of nuts/tree, copra/nut and copra/tree decrease with increasing density. This aspect will be studied in the planting distance trial reported in this communication when sufficient data on weight of husked nuts are available. Coomans further states that "the competition factor, which represents the fall in yield per tree when the density of a unit is increased, is mainly a function of the water supply!" He further recommends that the choice of planting density should be made taking into consideration the mean water deficit for the region under consideration. In this regard it would be extremely difficult to partition the effects of various factors, such as light intensity, water availability and nutrient supply whose combined effect would manifest itself in the growth and yield of the palms at the different densities of planting. In Sri Lanka, in those regions where serious water deficits are not encountered, it would appear that competition for light may be the decisive factor which determines the success or failure of coconut holdings planted at the different densities.

Table 5. *Economics of different planting systems*

Planting system (ft)		*Palms/ha*	*Yield/ha annum*	*Income/ha* annum*	*Cost of** fertilizer (Rs.)*	*Cost of*** picking (Rs.)*	*Profit (Rs.)*
40 x 21	..	128	10589	6353	448.00	61.44	5843.56
35 x 24							
40 x 18	..	150	11237	6742	525.00	72.00	6145.00
35 x 21							
30 x 24							
40 x 15	..	175	11979	7187	612.50	84.00	6490.50
35 x 18							
30 x 21							
25 x 24							
35 x 15	..	200	12447	7468	700.00	96.00	6672.00
30 x 18							
25 x 21							
30 x 15	..	239	12948	7769	836.50	114.00	6818.50
25 x 18							

* Calculated at the rate of Rs. 600/- per 1000 nuts

** Calculated at the rate 3.50 per palm (3 kg per palm + cost of application)

*** Picking and collecting charges 8 cents per palm per pick

The yield of nuts and/or copra, per unit area, and the profitability would be a good yardstick to assess planting systems and densites. The economics of the different planting systems are presented in Table 5, where the different planting systems giving the same plant densities are grouped together. Yield of nuts/ha/annum and the profit indicates that the high density systems give a high yield as well as high net profit. The margin of profit between the standard density (150 palms/ha, 64 palms/acre) and the highest density experimented with (239 palms/ha, 97 palms/acre) is Rs. 673/– taking into account the cost of fertilizer, its application cost and picking charges. The choice would therefore appear to be between 9.14 mx4.57 m (30 feet x, 15 feet) and 7.62 m x 5.48 m (25 feet x 18 feet) and if we give weightage for intercropping needs, the former would be our choice.

Although these results directed us to the obvious choice of a high density planting with a wider inter-row spacing and narrow intra-row spacing in order to accommodate intercropping, a question was posed to the co-author (Pethiyagoda - personal communication) as to whether the narrower intra-row spacing would encourage more root growth in the inter-row space and thereby interfere with the intercrops. In order to verify this, we dug in the inter-row space pits of dimension 0.61 m wide, 0.61 m deep and 1.52 m long (2′ x 2′ x 5′) commencing 1.52m (5 feet) away from the bole of the palm and stretching across the inter-row space. The roots within these pits were weighted. This was repeated for each plot in the experiment. A statistical analysis of the data showed no tendency for the quantum of roots to increase in the the inter-row space as a result of a decrease of the intra-row spacing. Perhaps the lowest intra-row spacing of 4.57 m (15 feet) adopted in this trial is not narrow enough to induce the roots to find alternative feeding areas.

When coconut is grown in monoculture it may be an advantage to plant at reasonably high densities for two reasons - namely (1) the shading effect produced by the coconut conopy at higher densities would result in less weed growth leading to a reduction in maintenance costs. Whitehead and Smith (1968) report that few weeds grow and no control is needed at 22 and 25 feet spacings; frequent weed control is needed at 30 feet spacing and weed growth was extremely vigorous at the 35feet spacing. Thus if a 9.14 m x 4.57 m (30 feet x 15 feet) coconut plantation is inctercropped, the intercrop would be planted to occupy the wider between-row spacing and probably little weed would establish itself at the narrower within-row spacing and (2) loss of palms due to natural causes and the difficulty of bringing up supplies to the point of bearing would result in appreciable loss in total crop from a widely spaced plantation, whereas such loss in total crop would be minimal with high density planting.

In the case of a catch crop as opposed to a permanent intercrop, it is generally agreed that the density of coconuts should not be modified in order to accommodate a catch crop, for catch cropping is normally resorted to only in the early years of the plantation, *ie*, from time of planting until onset of flowering, usually 5-8 years. The field should contain an optimal population of coconut plams after removal of the catch crop, Smith (1972). In the case of permanent intercrops such as coffee and cocoa, unless the planting distance of the existing plantation is wide, say 9.14 m (30 feet x 30 feet) it may not be possible to successfully intercrop. As available land is getting scarce in Sri Lanka, it is now necessary to make the fullest utilization of available land by intercropping as opposed to the practice of growing one crop, say coconut, in monoculture. It may therefore be necessary to change hitherto accepted planting distances and densities when the time comes for underplanting or replanting of senile unproductive coconut lands.

The planting material described in this paper is CRIC 65 hybrids and it is only 15 years old. The plantation has since been intercropped with cocoa. It may be necessary to observe the performance of the palms and the intercrop for at least a few years more before any firm recommendations can be given, although the high density systems appear to be more profitable on the early yield data.

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