A '2' CONFOUNDED DESIGN' FOR A MANURIAL EXPERIMENT ON COCONUT

By T. A. DAVIS

Indian Statistical Institute

SUMMARY. A micronutrient-manurial experiment on a factorial '2' confounded design' was started in 1953 on a 8-hectare coconut plantation at the Central Coconut Research Station, Kayangulam, Kerala State as an attempt to control the Root (wilt) disease affecting the palms. The micro-nutrients tried were Boron, Copper, Manganese, Iron, Molybdenum, Zinc, as well as Magnesium. Data on the fruit-yield and other morphological characters were recorded on the 384 experimental palms from the inception of the experiment. The fruit-yield data alone upto and inclusive of 1960 were considered for the Analysis of Covariance and the results reported. After 1960, the micro-nutrients were administered directly into the palms in liquid form by a different method.

Results of analysis have revealed that the healthy palms did not show any significant response to the application of any of the micro-nutrients. But palms in the early stage of the Root (wilt) disease responded favourably to the treatment combination of Boron and Iron. However, when applied alone or in combination with Copper, Iron depressed the nut-yield in this category of palms significantly. Severely diseased palms responded very favourably with Magnesium and Molybdenum when applied individually.

1. INTRODUCTION

The Root (wilt) is the most serious disease of the coconut palm in India affecting over ten per cent of the coconuts in Kerala which is roughly about seven per cent of the crop (0.64 million hectares) grown throughout India, and is responsible for an annual loss of over ten million rupees. The disease appears to be very complex in nature although indications of its viral nature are becoming more clear (Menon, 1951, 1961; Menon and Nair, 1951; Menon and Shanta, 1962; Nagaraj and Menon, 1955, 1956; Nagaraj *et al*, 1954; Radha and Menon, 1954; Shanta and Menon, 1960; Shanta *et al*, 1960). On account of its unknown origin, the Root (wilt) disease may be compared with similar major diseases of the coconut in other countries such as the Lethal Yellowing (or the Unknown Disease) in Central America and Jamaica; Kaincoope disease of Togoland; Bronze Leaf Wilt of British Guiana, West Indies and Nigeria, and the Cadang-Cadang of the Philippines. The Coconut Withering Disease making its early manifestation in two provinces of Ceylon may also fall under the above category.

2. HISTORY OF THE EXPERIMENT

At the Central Coconut Research Station, Kayangulam (South India) where the Root (wilt) disease of the coconut is being investigated, the effect of certain micro-nutrients in curing the disease or preventing healthy palms from contacting the disease is being investigated. An experiment with six micro-nutrients : Boron (B), Copper (C), Manganese (D), Iron (E), Molybdenum (F), Zinc (G) and also Magnesium (A) is in progress at this research centre from 1953.

The design of the experiment chosen is '2^7 confounded design'. There are 384 trees included in the experiment which are spread over a 8-hectare plantation along with several other coconut palms which are regarded as controls. All the palms received uniform macro-nutrients (Nitrogen, Phosphorus and Potash). Of the experimental

palms, a third (128) were apparently healthy at the beginning of the experiment, another 128 palms were moderately diseased, and the remaining 128 palms showed severe disease symptoms. Most of the severely diseased palms included in the experiment were producing some fruits (nuts) and/or flower-bunches even in 1960, and their condition at the time of selection was presumably within the scope of recovery. The yearly mean numbers of nuts produced by the trees of the three categories during the pre-treatment period were : healthy palms 45.97 nuts, palms showing early stage of disease 27.68 nuts, and those showing severe disease symptoms 18.75 nuts. Figure 1 explains this further.

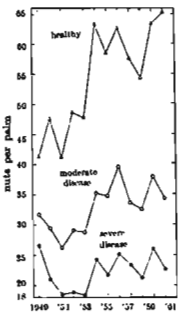

Fig. 1

Blocks and plots : There are 16 blocks under each category making a total of 48 blocks (vide Tables 2-4). Each block was divided into 8 plots (palms). Three blocks (one representing each category) comprising 24 palms may be regarded as one major block, and the trees of a major block are distributed more or less in one region. The 8-hectare experimental plantation consists of three almost contiguous fields as shown in Fig. 2. Field number one accommodated 3 major blocks comprising the first 24 healthy palms, 24 palms in early stage and 24 palms in late stage of disease.

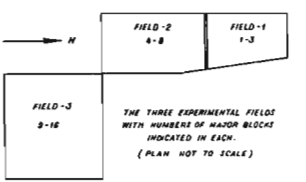

Fig. 2

Five major blocks were distributed in field two, and the remaining 8 were distributed in field three. Thus, the 48 blocks comprising the 384 plots do not form one composite population. Though the division of blocks within a field was arbitrary, differences between fields, and thus between blocks, were suspected on certain grounds such as the age and variety of palms, soil conditions, level of water table etc. In view of this, a confounding design was decided upon which is expected to eliminate the block-to-block variation and thereby eliminate the variation between fields.

The main treatments and all possible combinations (two to seven) amount to 128 (inclusive of one no-treatment), and a particular treatment was made on a set of three palms (plots) of which one is healthy, another with moderate disease and the third with severe disease. Securing very uniform experimental palms of the same age in large numbers was a difficult problem. Importance was, therefore, given to (1) the uniformity of the condition of the palms (healthy or diseased) under each category, and (2) the spacing between them (as far from each other as possible) so that the nutrients applied to a tree were least absorbed by the neighbouring palms. Even if the palms were planted with the maximum recommended spacing of 10m, there is bound to be root competition between palms since many roots of adult palms measure over 20 meters in length. Accordingly, sufficient consideration could not be given to the age of the palms, and they were from 15 to 65 years in 1953 as recorded in Tables 2-4.

Table 1 gives details on the form and quantity of the manurial salts used and the calculated amounts of micro-nutrient elements contained in them. These salts were applied in powder form in shallow basin trenches (diameter 2 metres) taken around the base of the stem and covered with a thin layer of soil. The application was made in September every year when the heavy South-West monsoon was just over. The experimental palms as well as the non-experimental ones standing in the experimental fields received a basal nutrient dose of 0.34 kg nitrogen as groundnut cake, 0.34 kg phosphoric acid as bonemeal and 0.68 kg of potash as murate of potash (KCl) per tree per year. The pH of the soil was generally acidic, becoming strongly acidic during

TABLE 1. TREATMENTS AND DOSES OF INDIVIDUAL MICRONUTRIENTS

symbol	salts applied	dose per tree per year (gm)	quantity of micro-nutrient element present in the dose (gm)
A	Magnesium Sulphate ($MgSO_4.7H_2O$)	454	45.4 (Magnesium)
B	Borax ($Na_2B_4O_7.10H_2O$)	227	25.9 (Boron)
C	Copper Sulphate ($CuSO_4.5H_2O$)	227	58.1 (Copper)
D	Manganese Sulphate ($MnSO_4.4H_2O$)	227	55.8 (Manganese)
E	Ferrous Sulphate ($FeSO_4.7H_2O$)	227	45.4 (Iron)
F	Ammonium Molybdate ($(NH_4)_6Mo_7O_{24}.4H_2O$	2	1.0 (Molybdenum)
G	Zinc Sulphate ($ZnSO_4.7H_2O$)	227	51.3 (Zinc)

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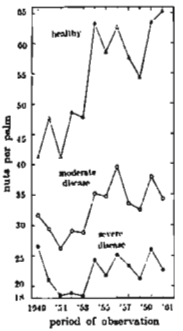

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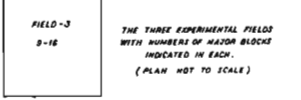

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monsoon, and to ameliorate this condition, about 100 kg of slaked lime per acre was spread over the soil and worked in with hand spades. In addition, a green-manure crop of sunn hemp was raised every year in these fields and at the proper time the entire plants were ploughed into the soil *in situ*. The first application of the micro-nutrients was made in September 1953.

3. Observations recorded

Data on the production of nuts as well as female flowers were available on these experimental palms from 1949 onwards. In addition, data on the emergence and shedding of leaves, opening of spathes, measurements of leaves and leaflets as well as the numbers of leaflets, female flowers, nuts shed prematurely and those harvested as ripe ones, appearance and progress of disease symptoms as well as incidence of major pests were collected on these palms periodically from 1953. Colour sketches depicting the condition of their crowns were prepared at the time of first application of the micro-nutrients for later comparison.

In this paper data on the fruit-yield alone are considered, and that too, for a period upto and inclusive of 1960. After 1960, the micro-nutrients were administered directly into the palm as solution by a root-injection method (Davis *et al*, 1954) instead of applying them in the soil around the stem. The fruits produced by a palm have to be regarded as the ultimate criterion of the palm's response to a treatment, since the experiment was running for a fairly long period and since a great majority of the palms were in the productive stage. The author was in charge of this manurial experiment from its inception until 1960, and hence, the data relating to this period alone are considered in this paper.

4. Presentation of data

The fruit-yield data relating to the 384 palms for a 12-year period (1949-1960) are tabulated in Tables 2 to 4. This period has been split into a 6-year pre-treatment period and a 6-year post-treatment period. Since the first annual application of micro-nutrients was made in 1953, normally the years 1953 and 1954 should have been included under the post-treatment period. But the coconut palm is unique in effectively showing the benefit or adverse effect of a manurial treatment only after two years. A flower-primordium, which is most sensitive to a treatment, matures into a nut after about two years although during this two-year period a slight effect due to a higher or lower setting or shedding of the already developed flowers and young fruits may be noticeable.

Three palms gave no nuts at all during the 12 year and they were all diseased (late stage). Three healthy and three diseased palms died through lightning and disease between 1956 and 1959. For these trees the yield averages were based on the yields for the years before their deaths. The nuts were harvested 8 times every year, and partial yields in the year when a tree died were omitted. A few other trees only started producing fruits after 1949.

MANURIAL EXPERIMENT ON COCONUT

TABLE 2. EFFECT OF MICRO-NUTRIENTS ON THE FRUIT YIELD OF COCONUT PALMS: *HEALTHY PALMS*

plot no.	tree no.	age (1953)	spiral	treatment	pre-treatment yield						post-treatment yield					
					1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	58	40	L	A	36	46	11	53	12	85	16	89	5	98	45	85
	55	40	R	ABCDF	15	19	16	20	13	12	12	8	39	13	13	38
	120	55	R	ABCEG	92	42	46	70	80	61	60	44	54	47	48	39
1	104	55	L	ADEFG	108	91	61	121	50	117	91	55	69	99	74	63
	75	55	L	BDE	66	77	74	82	74	97	89	81	75	67	72	56
	79	55	R	BFG	41	14	19	24	38	32	28	25	21	7	5	6
	54	45	R	CEF	51	56	50	60	64	84	70	70	61	57	77	62
	154	45	L	CDG	88	100	62	129	107	114	104	124	116	113	132	94
	36	45	R	B	62	67	90	45	91	94	57	67	104	17	112	36
	19	40	R	ADE	70	46	43	66	50	47	49	57	62	56	54	55
	116	55	R	AFG	54	38	53	57	43	71	52	43	66	36	32	31
	52	40	L	CEG	38	17	43	39	35	59	55	38	43	4	57	42
2	33	45	R	CDF	66	71	29	94	54	115	26	141	3	134	35	121
	53	45	R	ABCEF	36	65	32	82	53	80	50	18	61	34	35	67
	63	40	L	ABCDG	27	74	13	94	44	63	103	36	69	82	87	69
	78	50	L	BDEFG	80	53	55	79	63	80	74	61	79	39	79	57
	66	45	R	AB	57	46	52	62	82	81	84	44	63	58	18	65
	46	45	R	DE	17	63	32	70	80	95	70	91	83	52	40	180
	81	55	R	FG	55	40	44	73	56	73	66	72	56	71	51	57
	48	45	R	ACEG	75	56	83	55	107	98	100	89	109	56	32	71
3	87	50	L	ACDF	81	50	64	80	78	87	79	62	74	39	117	62
	31	40	R	BCDG	48	64	50	75	65	93	63	97	72	78	70	89
	42	50	L	BCEF	55	47	53	61	56	60	56	69	68	76	71	63
	3	30	L	ABDEFG	22	22	27	25	29	42	52	40	62	14	84	45
	116	40	R	C	11	65	27	54	11	25	71	39	55	67	60	72
	48	25	R	ADG	nil	14	46	29	24	38	104	60	80	62	59	25
	95	55	R	AEF	78	63	84	69	64	99	72	73	59	57	67	100
	138	20	R	BDF	nil	nil	nil	6	20	82	14	78	29	81	59	66
4	89	50	R	BEG	73	74	57	88	115	111	105	88	83	91	93	132
	83	25	R	ABCDE	1	4	10	10	3	11	27	33	31	17	32	61
	114	25	R	ABCFG	nil	nil	nil	7	7	25	25	41	22	6	15	23
	129	50	R	CDEFG	43	54	40	36	25	80	51	69	53	63	65	48
	45	40	R	AG	5	52	18	20	34	43	63	58	42	51	62	115
	150	50	L	BF	61	64	46	64	32	62	30	41	17	54	17	48
	149	45	R	CD	98	nil	85	85	nil	64	75	81	63	58	73	58
5	99	55	R	ABCE	38	67	34	66	74	64	63	73	51	50	20	28
	118	45	R	ADEF	18	49	30	31	59	85	44	82	63	37	62	66
	91	55	R	BDEG	37	53	32	91	46	62	89	48	80	51	40	102
	133	60	L	CEFG	58	49	57	49	53	73	78	67	72	49	59	64
	90	55	R	ABCDFG	34	45	50	44	47	48	77	73	63	68	52	47
	270	50	R	D	42	30	95	56	57	114	48	92	77	63	81	52
	251	50	L	ABE	30	29	11	53	26	47	37	41	43	54	21	69
	232	50	L	BCF	59	42	48	52	54	94	48	101	55	67	78	75
6	322	55	L	ACG	91	72	84	98	118	111	115	117	99	127	136	108
	279	45	L	EFG	33	47	49	61	58	88	67	73	60	55	78	58
	254	50	L	ABDFG	76	61	59	65	87	95	82	85	102	94	82	118
	274	50	R	ACDEF	23	77	36	78	65	104	92	89	88	57	77	65
	285	50	L	BCDEG	37	20	28	36	26	36	35	42	33	32	31	46
	189	55	L	E	75	75	51	69	63	83	77	84	64	81	67	85
	210	50	L	ABD	6	88	21	69	71	60	64	71	44	81	57	138
	303	60	L	ACF	82	75	49	69	72	77	37	54	62	66	76	65
	302	60	R	BCG	34	44	34	45	26	41	37	54	44	24	60	56
	295	35	R	DFG	11	22	9	21	13	30	29	40	29	38	57	25
7	315	40	L	ACDEG	2	14	13	33	15	31	33	43	23	50	49	53
	208	55	L	ABEFG	17	43	21	13	41	52	26	67	7	60	45	81
	206	30	L	BCDEF	19	29	9	18	22	31	24	39	25	52	51	54
	405	50	R	AF	12	44	28	15	28	72	28	30	64	55	46	57
	330	45	R	BG	9	12	114	8	23	31	24	40	38	37	42	50
	380	25	L	CE	nil	nil	nil	53	116	46	127	81	86	173	90	180
	391	25	L	ABGD	nil	nil	nil	61	112	88	136	123	143	112	145	175
8	310	60	L	BDEF	66	50	51	66	39	72	64	79	63	81	69	74
	416	50	L	CDFG	30	15	13	17	8	29	8	15	36	26	23	35
	327	40	R	ADEG	40	32	51	60	56	67	56	53	45	47	52	54
	354	35	L	ABCEFG	4	38	22	24	31	21	72	42	79	35	85	45

A-Mg; B-B; C-Cu; D-Mn; E-Fe; F-Mo; G-Zn.
L-plam having left-handed foliar spiral
R-palm having right-handed foliar spiral

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plot no.	tree no.	age (1953)	spiral	treatment	pre-treatment yield					post-treatment yield					
					1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	408	40	L	AE	82	51	31	28	48	58	47	43	53	20	Died	
	358	60	L	BD	45	48	50	44	43	55	68	78	67	81	40	27
	178	55	R	CF	8	21	17	28	11	34	28	38	32	25	53	18
	200	45	R	ABCG	33	19	25	28	17	22	24	50	24	40	31	28
9	288	65	L	BEFG	44	49	39	34	30	31	36	44	33	38	36	31
	421	45	L	ADFG	45	64	30	54	35	79	22	110	10	89	21	58
	404	50	R	CDEG	51	32	29	35	37	38	39	28	22	17	Died	
	276	40	L	ABCDEF	15	41	35	72	58	56	77	80	69	69	93	47
	323	55	R	AC	40	58	56	54	52	41	43	70	57	65	75	69
	190	50	R	DG	52	58	38	54	62	50	50	44	46	43	54	51
	345	45	L	EF	37	35	34	27	44	48	57	55	40	84	51	48
10	463	35	L	BCFG	4	4	12	13	33	17	126	76	116	96	142	102
	191	60	L	BCDE	55	58	71	45	70	68	72	68	46	46	76	62
	307	25	R	ABDF	43	28	19	28	34	40	42	54	11	14	15	3
	438	50	L	ABEG	73	50	51	43	70	55	58	69	65	65	50	54
	344	40	R	ACDEFG	30	74	60	32	50	68	65	50	54	61	82	nil
	398	30	R	AD	13	50	35	nil	nil	46	38	47	21	66	34	73
	388	50	L	CG	37	28	20	23	22	40	27	37	23	24	42	27
11	272	20	R	BE	13	20	40	14	37	58	68	65	59	48	91	61
	240	25	R	ABCF	nil	nil	nil	nil	1	13	25	35	27	27	49	59
	392	40	R	CDEF	12	25	15	28	11	64	30	66	32	57	90	69
	232	60	L	AEFG	6	3	7	42	41	34	53	53	43	46	29	21
	240	50	R	BDFG	56	62	36	24	50	20	37	11		Died		
	254	20	L	ABCDEG	11	16	14	36	31	108	78	50	107	67	109	74
	289	25	L	BC	48	25	41	43	45	112	63	81	65	21	69	54
	299	35	R	EG	17	36	55	41	42	63	70	91	83	75	93	92
	282	35	L	DF	19	28	37	47	53	69	62	73	65	60	80	72
12	292	60	L	ACDE	32	36	20	48	45	53	54	51	44	50	38	21
	291	45	R	ACFG	37	63	58	27	68	101	36	109	55	56	84	81
	15	50	L	ABEF	49	79	70	64	71	83	83	78	76	67	101	76
	189	55	R	ABDG	21	40	31	38	37	60	38	31	50	43	49	44
	298	45	L	BCDEFG	7	12	21	nil	9	32	35	6	41	1	32	17
	362	60	L	F	40	50	55	44	62	68	52	50	62	51	94	69
	367	50	R	ACE	33	31	15	23	26	53	39	45	42	22	56	47
	359	65	R	ABG	40	50	32	42	36	54	35	43	44	29	54	36
13	361	60	R	DEG	63	63	45	61	57	70	54	66	64	68	56	41
	354	55	R	BCD	74	40	36	55	62	37	65	108	49	90	69	62
	110	30	L	BCEFG	nil	nil	nil	20	5	100	68	33	94	13	91	72
	96	55	R	ACDFG	17	35	48	22	47	67	63	60	78	30	52	85
	305	55	R	ABDEF	nil	nil	nil	11	31	57	38	93	45	69	82	57
	241	35	L	G	nil	nil	nil	nil	rail	12	21	38	56	49	52	59
	211	45	R	ACD	86	100	94	61	98	123	80	95	104	76	106	70
	218	45	R	DEF	37	53	48	48	44	45	56	45	40	40	48	48
	188	25	R	BCE	1	22	32	31	17	40	30	36	1	4	nil	nil
14	186	25	R	ABF	4	6	15	28	41	29	20	34	26	28	22	24
	4	55	L	ACEFG	44	39	33	29	37	41	43	46	38	30	47	36
	192	25	L	ABDEG	nil	nil	nil	30	85	99	88	107	102	98	112	85
	199	50	R	BCDFG	39	52	32	28	21	29	36	40	45	47	51	34
	94	55	R	ABC	27	48	45	43	47	62	53	54	56	13	62	34
	125	30	R	ADF	42	63	55	40	36	72	67	37	74	33	65	60
	113	45	L	ABCDEFG	60	80	64	105	49	121	126	118	114	53	127	100
15	70	30	L	AEG	6	36	15	46	85	101	80	87	66	77	86	121
	102	35	R	BDG	22	81	60	69	89	102	94	112	116	40	110	93
	105	25	L	BEF	6	62	15	80	35	84	86	94	76	108	78	99
	79	30	R	CDE	58	34	30	91	131	127	167	131	126	73	123	114
	126	40	R	CFG	63	71	62	47	54	78	75	62	82	68	84	75
	133	50	R	I	60	65	52	60	41	58	55	65	80	40	60	91
	44	45	L	ABDE	66	58	40	62	58	76	61	71	51	69	60	39
	48	30	R	BCEG	nil	nil	nil	nil	1	9	20	4	15	nil	nil	nil
	28	35	L	ABFG	34	71	14	60	21	84	69	105	43	80	65	86
16	148	50	L	ACEF	56	63	41	62	52	83	76	71	84	89	90	103
	3	25	R	ACDG	66	85	40	45	59	86	54	49	33	32	46	nil
	136	50	L	DEFG	33	67	41	27	46	44	45	49	40	23	41	46
	141	45	R	BCDF	30	64	41	57	34	24	60	53	49	20	48	133

MANURIAL EXPERIMENT ON COCONUT

TABLE 3. EFFECT OF MICRO-NUTRIENTS ON THE FRUIT YIELD OF COCONUT PALMS : *DISEASED PALMS* (Early Stage)

plot no.	tree no.	age (1953)	spiral	treatment	pre-treatment yield						post-treatment yield					
					1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	153	45	L	A	11	8	13	31	30	24	42	51	38	53	43	49
	61	40	R	ABCDF	19	26	46	28	43	50	40	27	44	28	18	60
	145	45	R	ABCEG	60	26	15	54	29	38	17	12	13	4	1	nil
	38	50	R	ADEFG	71	44	68	61	59	75	88	69	82	87	90	72
1	76	50	R	BDE	7	13	8	7	12	8	11	14	9	7	12	16
	59	45	L	BFG	5	3	nil	nil	nil	nil	nil	nil	1	1	nil	nil
	144	55	L	CEF	50	39	37	40	42	52	44	41	34	21	26	25
	117	40	R	CDG	49	26	14	31	21	44	38	27	28	22	35	35
	77	55	R	B	9	17	12	16	18	31	15	5	13	7	13	nil
	108	50	R	ADE	18	11	13	21	19	18	19	28	16	1	15	14
	122	55	L	AFG	36	21	26	44	51	44	34	68	45	43	34	27
2	41	45	R	CEG	55	47	66	29	20	nil	4	3	2	nil	1	nil
	39	45	L	CDF	12	73	18	62	52	18	117	21	58	45	30	97
	91	40	L	ABCEF	16	5	22	11	9	15	27	27	18	26	23	17
	113	55	R	ABCDG	34	24	17	20	38	35	23	35	26	25	16	16
	34	45	L	BDEFG	15	23	14	21	24	48	38	30	32	39	25	23
	16	45	R	AB	12	24	21	27	4	53	11	28	31	17	14	20
	32	45	R	DE	52	35	27	68	44	43	55	50	52	48	40	47
	47	35	R	FG	26	28	13	26	30	41	30	36	29	31	32	31
3	17	45	R	ACEG	20	15	7	21	17	30	19	29	21	13	13	17
	99	45	R	ACDF	77	68	31	89	101	81	110	84	126	45	133	36
	98	45	R	BCDG	19	8	17	16	11	21	25	20	17	20	16	9
	14	45	R	BCEF	39	24	12	32	16	37	33	11	11	3	6	2
	83	50	L	ABDEFG	63	37	42	67	56	76	72	71	51	57	20	77
	93	40	L	C	84	38	48	74	55	53	47	54	50	56	48	58
	15	30	R	ADG	74	48	39	66	24	60	38	67	63	55	58	47
	123	45	R	AEF	17	5	2	11	3	2	27	21	15	15	5	10
	125	50	R	BDF	29	21	19	38	31	23	33	42	27	20	27	32
4	80	20	L	BEG	nil	5	10	nil	nil	2	1	2	3	nil	nil	nil
	29	35	L	ABCDE	35	25	12	47	7	48	38	49	34	61	38	58
	72	45	R	ABCFG	44	16	36	52	4	26	77	29	63	44	82	51
	13	40	L	CDEFG	43	21	31	45	15	35	63	41	37	57	50	64
	44	40	R	AG	44	46	33	48	16	40	52	49	47	57	61	46
	57	50	R	BF	13	22	11	46	29	41	36	14	40	16	47	15
	166	45	L	CD	6	18	8	26	48	54	32	68	15	10	48	40
5	31	40	R	ABCE	30	13	13	20	22	20	28	33	27	31	34	58
	165	60	L	ADEF	24	29	18	8	34	23	29	20	52	26	48	40
	58	40	L	BDEG	26	38	11	48	35	38	59	58	40	53	50	54
	42	45	L	CEFG	90	82	73	77	76	79	48	40	37	28	32	25
	103	55	L	ABCDFG	29	39	29	34	48	57	32	35	44	22	24	14
	255	50	R	D	48	27	29	10	58	25	52	45	25	42	34	2
	286	55	R	ABE	40	27	56	37	47	62	61	40	54	54	60	43
	281	55	R	BCF	6	50	15	52	16	58	29	58	33	38	46	41
	285	55	L	ACG	13	36	17	25	25	33	41	34	31	27	36	27
6	282	35	R	EFG	53	50	47	43	53	70	56	123	48	74	76	84
	224	35	L	ABDFG	20	24	20	31	27	49	33	37	32	37	25	35
	227	50	L	ACDEF	11	29	5	19	24	29	3	22	11	15	24	13
	289	50	R	BCDEG	50	15	19	30	39	40	14	15	8	1	12	34
	216	45	L	E	3	4	5	8	8	21	21	14	7	11	22	18
	223	50	L	ABD	14	30	17	46	37	36	27	47	42	40	54	58
	217	50	L	ACF	10	20	16	19	22	37	34	51	33	35	47	37
	293	35	L	BCG	1	3	1	1	nil	17	21	29	51	49	36	62
7	219	50	L	DFG	10	40	12	34	48	62	18	62	62	2	56	47
	290	60	L	ACDEG	24	44	33	25	33	44	39	42	21	52	32	45
	22	35	L	ABEFG	10	6	3	20	27	33	18	34	26	44	25	38
	218	50	L	BCDEF	18	30	29	27	37	27	24	51	32	46	36	39
	382	30	R	AF	47	3	15	8	8	32	24	36	16	14	51	29
	346	55	L	BG	46	35	44	35	32	32	25	32	32	25	23	11
8	319	60	R	CE	35	50	23	46	30	34	10	29	34	19	25	32
	328	45	L	ABCD	59	57	53	42	38	47	46	86	72	32	38	36
	383	55	R	BDEF	5	37	12	10	21	23	17	15	27	4	21	7
	402	55	R	CDFG	43	59	59	39	56	59	70	71	45	30	67	60
	321	55	R	ADEG	19	10	11	9	7	13	9	15	15	20	22	21
	320	55	L	ABCEFG	7	31	18	18	13	27	44	15	20	61	34	37

TABLE 3. EFFECT OF MICRO-NUTRIENTS ON THE FRUIT YIELD OF COCONUT PALMS : *DISEASED PALMS* (Early Stage)—*contd.*

plot no.	tree no.	age (1953)	spiral	treatment	pre-treatment yield						post-treatment yield					
					1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	412	35	L	AE	14	18	14	1	nil	2	8	17	9	nil	5	3
	409	35	R	BD	17	13	8	29	35	36	36	66	44	55	64	53
	433	30	R	CF	nil	nil	1	1	1	14	34	34	60	39	76	75
9	453	45	R	ABCG	68	41	38	52	45	57	90	100	57	66	71	65
	434	25	L	BEFG	nil	nil	nil	nil	nil	15	37	10	54	15	94	20
	437	60	R	ADFG	4	1	7	nil	14	8	17	26	13	8	16	7
	407	35	R	CDEG	38	24	17	14	31	31	23	25	26	3	Died	
	439	50	L	ABCDEF	64	76	72	38	66	73	84	88	72	92	68	76
	231	60	R	AC	33	22	48	36	37	27	38	49	41	44	53	44
	458	35	L	DG	22	32	17	15	8	nil	11	53	43	66	42	27
	335	40	R	EF	21	32	26	11	3	8	10	9	23	15	18	28
	449	50	R	BCFG	5	8	8	1	1	20	10	18	14	31	15	17
10	456	55	R	BCDE	48	37	27	25	56	54	62	61	49	64	49	50
	352	65	L	ABDF	29	28	26	23	14	8	23	35	30	26	14	22
	446	40	L	ABEG	17	36	27	28	17	47	16	61	52	28	45	42
	450	30	L	ACDEFG	nil	nil	3	3	nil	39	22	9	nil	1	10	nil
	398	25	R	AD	nil	nil	nil	nil	nil	nil	5	25	1	nil	2	7
	231	25	R	CG	nil	4	12	4	8	7	23	11	19	nil	17	6
	391	30	L	BE	22	13	25	4	6	30	12	37	8	43	36	24
11	256	40	R	ABCF	68	79	72	43	85	79	68	81	55	59	98	68
	397	50	L	CDEF	27	56	47	51	53	59	33	56	41	42	53	58
	394	30	L	AEFG	24	36	34	24	3	28	13	31	25	nil	13	10
	395	45	R	BDFG	42	40	30	28	36	48	50	42	54	42	60	53
	387	35	L	ABCDEG	3	1	nil	1	3	1	11	7	1	3	4	2
	293	50	R	BC	50	38	13	5	1	9	12	21	16	13	18	14
	301	35	R	EG	21	44	26	11	27	27	34	38	42	59	38	38
	209	20	L	DF	nil	nil	nil	3	16	4	7	25	10	17	23	29
12	294	50	R	ACDE	26	33	49	23	33	20	40	66	27	45	31	24
	285	25	L	ACFG	nil	nil	nil	nil	nil	nil	nil	nil	nil	2	nil	2
	268	60	R	ABEF	46	46	35	36	43	54	34	56	45	45	50	32
	281	65	R	ABDG	16	21	13	18	25	17	26	25	12	14	27	16
	279	60	R	BCDEFG	33	24	35	23	24	40	20	41	13	20	28	1
	380	55	R	F	17	12	13	4	nil	17	13	17	5	3	12	4
	360	55	L	ACE	58	40	38	26	32	39	39	30	22	18	32	24
	371	55	R	ABG	19	21	4	7	6	11	8	21	5	5	8	3
13	348	35	L	DEG	20	34	34	7	45	53	29	26	49	57	35	93
	368	45	L	BCD	49	38	34	25	23	26	23	22	11	16	27	17
	370	30	L	BCEFG	nil	8	9	1	30	31	16	51	20	40	41	29
	351	35	R	ACDFG	14	23	41	41	24	33	39	150	46	25	52	15
	370	45	L	ABDEF	30	21	10	24	25	27	26	51	25	42	49	45
	206	40	L	G	28	24	21	32	12	26	35	38	36	39	41	42
	197	15	R	ACD	nil	nil	nil	nil	2	10	21	16	13	21	26	36
	187	25	R	DEF	4	10	14	2	7	16	12	29	21	10	18	8
	229	45	L	BCE	38	54	49	37	60	48	39	60	48	45	43	50
14	208	20	R	ABF	nil	nil	nil	nil	3	nil	3	nil	nil	nil	2	nil
	128	55	L	ACEFG	93	102	87	98	99	103	113	112	88	90	117	77
	304	35	R	ABDEG	3	12	4	3	5	1	9	20	10	25	5	7
	230	60	L	BCDFG	26	12	17	10	29	12	38	22	44	26	20	15
	121	50	L	ABC	35	30	54	17	20	18	28	36	29	32	34	20
	93	55	R	ADF	35	41	49	38	37	62	50	59	65	60	67	48
	153	40	L	ABCDEFG	26	13	12	26	18	18	41	53	46	48	54	47
15	98	55	R	AEG	36	16	36	29	30	15	28	16	30	17	43	22
	100	55	L	BDG	48	22	44	36	29	50	70	56	40	29	41	18
	90	50	L	BEF	17	26	36	23	13	39	27	34	31	28	28	29
	86	35	R	CDE	36	13	9	17	7	19	29	27	13	19	26	11
	124	25	R	CFG	nil	nil	nil	37	19	56	50	41	45	62	79	78
	27	30	R	I	7	13	15	4	9	12	23	45	25	25	51	23
	163	50	L	ABDE	42	48	41	53	50	49	56	65	57	68	73	41
	32	35	R	BCEG	16	4	10	15	4	12	6	8	12	9	16	9
	54	25	L	ABFG	nil	nil	nil	nil	nil	6	18	29	17	9	38	27
16	146	35	L	ACEF	66	58	40	43	59	95	113	81	98	37	130	25
	39	30	R	ACDG	97	95	53	90	84	93	105	108	112	103	111	118
	134	60	R	DEFG	38	28	8	20	21	12	14	17	11	7	23	8
	35	30	L	BCDF	nil	nil	nil	23	19	31	39	61	30	14	36	40

MANURIAL EXPERIMENT ON COCONUT

TABLE 4. EFFECT OF MICRO-NUTRIENTS ON THE FRUIT YIELD OF COCONUT PALMS: *DISEASED PALMS* (Late Stage)

plot no.	tree no.	age (1953)	spiral	treatment	pre-treatment yield						post-treatment yield					
					1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	23	45	R	A	38	52	54	59	60	57	44	48	54	37	48	50
	103	50	R	ABCDF	45	7	10	21	17	29	29	30	26	28	36	23
	152	45	R	ABCEG	29	21	25	40	41	32	41	40	38	26	33	25
1	146	50	L	ADEFG	11	nil	nil	2	5	3	5	22	13	10	17	9
	123	55	R	BDE	50	22	20	19	34	26	16	11	6	11	5	6
	118	45	L	BFG	18	6	11	8	15	23	nil	4	16	2	1	nil
	140	55	R	CEF	24	39	12	37	13	34	17	20	8	18	9	10
	124	40	R	CDG	4	nil	nil	2	5	5	8	6	4	2	4	1
	114	60	L	B	78	11	36	24	27	36	39	31	24	13	22	23
	138	65	R	ADE	40	14	14	18	17	32	29	32	40	33	34	31
	40	45	L	AFG	22	19	26	30	24	35	29	27	32	28	27	42
	51	60	R	CEG	21	19	5	16	2	11	13	2	17	5	19	5
2	21	40	L	CDF	5	nil	nil	nil	1	nil	10	11	3	nil	6	nil
	35	45	L	ABCEF	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
	93	50	R	ABCDG	20	16	9	37	17	33	11	9	15	7	16	9
	139	40	R	BDEFG	83	16	32	25	18	33	36	43	36	45	50	54
	82	50	L	AB	41	27	26	40	34	51	40	25	38	33	25	24
	109	50	L	DE	27	4	14	17	8	16	8	7	6	7	2	nil
	129	40	R	FG	42	39	38	47	40	84	56	67	75	17	84	50
	111	65	L	ACEG	102	28	26	51	70	82	39	73	67	40	16	22
3	20	45	R	ACDF	nil	nil	1	3	1	4	2	1	1	1	7	4
	18	55	R	BCDG	nil	1	nil	1	nil	nil	nil	nil	nil	2	nil	nil
	28	55	R	BCEF	2	2	2	2	1	17	1	6	nil	nil	nil	nil
	135	60	L	ABDEFG	48	18	21	48	50	24	29	24	33	42	43	40
	140	45	L	C	31	47	47	49	41	54	70	59	51	44	41	40
	147	35	L	ADG	5	17	10	23	10	32	10	42	12	42	30	4
	12	40	R	AEF	75	44	35	57	54	49	53	50	55	47	48	42
4	122	55	L	BDF	15	9	10	25	32	12	30	47	22	28	31	19
	25	45	L	BEG	18	2	4	18	12	13	12	11	12	24	32	35
	141	35	R	ABCDE	6	7	nil	2	7	17	7	26	9	19	42	21
	128	50	L	ABCFG	5	11	nil	6	7	10	3	10	8	7	1	7
	26	35	R	CDEFG	30	14	13	22	18	25	23	36	40	36	55	26
	119	65	R	AG	15	14	5	8	14	20	14	24	24	15	29	26
	43	45	R	BF	28	29	8	50	38	68	53	21	44	67	64	71
	158	60	L	CD	14	47	5	29	49	41	61	14	40	9	49	8
	162	55	R	ABCE	25	25	10	27	23	23	36	34	39	25	18	30
5	9	40	L	ADEF	53	37	30	40	40	42	47	52	48	48	61	55
	134	65	R	BDEG	22	17	18	21	16	37	22	28	35	36	29	29
	165	55	R	CEFG	16	14	7	9	36	20	13	8	26	12	3	14
	77	50	L	ABCDFG	12	18	14	13	13	26	26	31	23	37	27	36
	266	50	R	D	6	2	nil	1	1	3	Died					
	231	50	L	ABE	25	22	18	14	19	33	16	32	7	25	25	12
	244	50	L	BCF	2	5	1	7	19	11	17	24	26	14	20	41
	246	60	L	ACG	6	10	8	9	5	13	3	15	12	9	17	11
6	205	30	R	EFG	nil	6	1	4	2	4	1	6	nil	4	5	nil
	248	65	R	ABDFG	51	54	50	28	32	35	18	36	13	nil	13	31
	246	60	R	ACDEF	5	14	16	18	2	17	24	19	12	23	7	20
	253	35	L	BCDE	5	nil	5	12	11	13	7	3	15	11	6	4
	187	55	L	E	16	26	20	33	28	48	25	31	21	31	22	22
	190	65	L	ABD	27	29	15	22	2	58	14	29	43	21	42	60
	236	65	L	ACF	6	19	16	16	19	25	22	20	12	14	28	24
7	222	50	R	BCG	10	9	11	2	16	15	15	18	3	20	14	26
	226	50	R	DFG	40	49	36	29	31	17	12	39	1	2	7	4
	197	50	R	ACDEG	25	19	15	7	31	26	28	39	17	16	20	14
	195	50	R	ABEFG	3	9	nil	nil	1	8	3	10	11	10	4	7
	220	50	R	BCDE	11	8	7	12	17	19	10	12	15	17	22	13
	417	30	R	AF	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
	347	65	R	BG	42	20	24	10	14	37	27	19	2	13	20	nil
	311	60	R	CE	34	12	16	nil	1	16	nil	nil	nil	nil	1	2
8	358	35	L	ABCD	77	90	100	37	27	65	55	79	67	73	91	71
	375	25	L	BDEF	nil	nil	nil	nil	nil	6	11	11	4	7	1	6
	372	25	R	CDFG	nil	nil	nil	nil	nil	5	3	1	4	3	nil	nil
	329	35	R	ADEG	nil	4	3	4	2	5	9	11	10	10	8	nil
	363	65	R	ABCEFG	30	26	30	15	27	41	23	32	11	22	33	19

TABLE 4. EFFECT OF MICRO-NUTRIENTS ON THE FRUIT YIELD OF COCONUT PALMS : *DISEASED PALMS* (Late Stage)—*contd.*

plot no.	tree no.	age (1953)	spiral	treatment	pre-treatment yield						post-treatment yield					
					1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
	431	45	R	AE	43	32	28	21	16	23	28	41	32	13	21	23
	415	65	L	BD	16	2	nil	1	nil	3	nil		Died			
	425	65	R	CF	53	11	5	5	6	10	8	5	14	9	4	5
9	428	55	L	ABCG	38	6	4	5	2	16	8	15	14	11	10	7
	445	55	L	BEFG	18	23	3	5	5	10	14	28	33	12	22	16
	430	50	L	ADFG	16	11	19	3	nil	7	21	14	27	13	16	15
	434	55	R	CDEG	16	14	7	7	2	1	8	25	15	9	12	15
	437	65	L	ABCDEF	31	58	21	45	55	55	81	112	72	66	78	64
	455	30	R	AC	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	Died	
	462	55	L	DG	9	16	11	11	1	4	10	5	8	7	7	4
10	444	40	L	EF	37	28	32	13	30	21	38	31	30	39	40	17
	338	40	R	BCFG	9	4	9	10	nil	1	3	16	18	12	9	5
	457	45	L	BCDE	27	33	19	13	11	27	21	23	22	21	28	28
	343	50	R	ABDF	40	58	25	60	20	36	28	47	48	40	61	31
	340	50	L	ABEG	28	34	34	23	9	13	10	24	26	33	34	37
	336	45	R	ACDEFG	32	59	45	73	55	31	72	67	48	59	94	98
	389	55	L	AD	49	32	37	29	35	31	39	30	36	56	34	25
	394	50	L	CG	40	22	7	nil	1	nil	8	19	25	18	36	14
	288	55	L	BE	1	1	nil	nil	nil	nil	nil	1	nil	1	7	nil
	382	50	R	ABCF	65	56	39	45	30	39	48	42	43	39	51	39
11	252	50	L	CDEF	16	15	9	5	nil	9	10	8	9	9	8	12
	281	60	L	AEFG	36	15	14	27	20	26	27	31	31	29	43	28
	386	55	L	BDFG	22	20	7	9	11	12	12	15	16	4	8	2
	386	50	R	ABCDEG	27	14	23	9	4	18	38	41	2	10	28	14
	259	45	L	BC	6	30	11	5	2	nil	2	4	7	1	nil	1
	274	30	R	EG	70	9	29	13	5	18	2	14	13	16	16	17
	280	45	R	DF	22	28	36	21	10	9	26	48	26	32	27	26
	283	50	L	ACDE	67	36	42	16	12	28	37	34	39	28	46	31
	287	55	L	ACFG	16	14	4	8	nil	4	24	13	15	10	8	9
12	296	55	L	ABEF	40	56	35	11	7	26	28	27	36	40	32	23
	290	45	L	ABDG	58	49	49	53	32	39	49	54	52	57	67	52
	278	65	R	BCDEFG	50	42	46	7	15	21	3	11	26	8	13	17
	355	50	L	F	7	6	9	11	nil	nil	3	3	Died			
	372	50	L	ACE	24	7	18	24	24	23	11	22	6	6	28	nil
	366	50	R	ABG	2	3	10	1	1	7	4	15	6	11	14	3
13	419	40	L	DEG	10	6	10	8	2	7	14	17	2	nil	4	1
	373	50	R	BCD	45	25	22	28	36	33	28	24	24	19	40	17
	406	50	R	BCEFG	13	15	18	6	14	14	7	18	16	9	11	7
	363	45	R	ACDFG	1	1	nil	13	15	27	16	22	34	21	45	41
	374	45	R	ABDEF	26	15	18	20	11	60	20	34	19	18	28	11
	202	45	R	G	4	10	4	10	4	4	7	3	3	1	4	4
	243	40	R	ACD	36	43	17	11	3	18	10	4	13	1	nil	nil
	200	15	R	DEF	nil	8	7	nil	nil	nil	nil	nil	nil	nil	nil	nil
14	221	45	L	BCE	1	21	2	11	nil	2	3	6	11	nil	9	1
	185	45	L	ABF	18	22	8	9	20	37	32	32	36	17	36	27
	217	45	L	ACEFG	5	8	2	4	nil	9	16	7	13	21	45	11
	204	40	R	ABDEG	4	7	4	4	nil	nil	3	2	3	nil	1	1
	225	55	R	BCDFG	27	21	12	22	16	22	20	32	35	17	40	24
	60	60	R	ABC	22	14	22	13	7	15	24	31	39	17	37	nil
	68	55	R	ADF	1	4	1	nil	nil	nil	nil	nil	nil	nil	nil	nil
	107	60	R	ABCDEFG	10	15	20	6	13	13	11	28	12	5	11	6
15	82	35	R	AEG	1	4	12	18	1	37	11	31	3	21	16	15
	111	35	L	BDG	nil	nil	nil	7	6	29	16	19	9	7	31	11
	85	55	L	BEF	2	8	1	1	nil	2	3	3	Died			
	62	55	L	CDE	20	8	19	4	11	12	21	22	15	7	19	6
	84	60	R	CFG	16	3	6	16	18	28	25	22	23	18	13	8
	138	60	R	I	24	18	10	3	3	nil			Died			
	34	20	R	ABDE	nil	nil	nil	nil	5	6	18	18	11	13	21	8
	36	55	R	BCEG	21	12	24	19	9	20	16	19	23	7	13	14
16	38	25	L	ABFG	nil	nil	nil	6	17	23	29	26	17	29	57	70
	147	45	L	ACEF	83	66	45	60	66	54	50	60	50	52	78	76
	142	45	R	ACDG	50	32	17	17	26	23	40	51	34	38	33	43
	154	55	R	DEFG	9	8	15	4	12	17	4	14	15	24	15	nil
	11	50	R	BCDF	18	29	10	9	15	25	22	10	12	nil	15	5

Data on the main effects and two-factor interactions are given in Tables 5 and 6. For the statistical analysis, the main effects and the two-factor interactions only were considered, the higher interactions being included in the error. The following interactions were confounded. ABC, ADF, AEG; BDG, BEF; CDE, CFG; ABDE, ABFG, ACDG, ACEF; BCDF, BCEG; DEFG and ABCDEFG.

TABLE 5. MAIN EFFECTS
(corrected for x)

treatment	effect		
	healthy palms	diseased palms	
		early stage	late stage
A	— 127	518	1476
B	898	— 157	246
C	1563	— 848	202
D	634	569	864
E	— 568	—2055*	34
F	—1148	1191	1242*
G	— 308	— 88	724

* significant treatments

TABLE 6. TWO-FACTOR INTERACTIONS
(corrected for x)
Effect

treatment	effect		
	healthy palms	diseased palms	
		early stage	late stage
AB	2007	49	— 154
AC	— 768	844	— 192
BC	1401	585	— 26
AD	1978	— 231	690
BD	1971	— 411	— 720
CD	— 152	— 2	964
AE	— 385	1089	424
BE	— 604	2506*	118
CE	— 808	—2168*	— 338
DE	— 176	1282	1160
AF	— 284	— 325	— 212
BF	2003	357	— 342
CF	1846	1289	103
DF	914	— 698	— 276
EF	150	159	— 162
AG	1114	— 466	— 370
BG	1380	814	—1138
CG	—1128	— 826	136
DG	—2105	— 840	— 450
EG	—1034	— 283	— 12
FG	— 344	381	— 640

* significant treatments

A correction for the yield difference between palms having left- and right-handed foliar spirals was made. Although this foliar asymmetry is non-inherited (Davis, 1962a), the left-handers have been observed to yield significantly more number of nuts than their counterparts (Davis, 1962b, 1963). Figure 3 shows the left-right yield differences of the healthy and diseased palms for the twelve-year period. Having

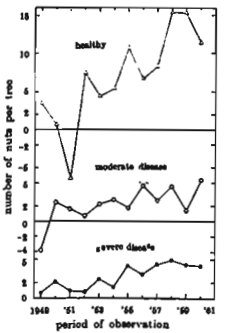

Fig. 3

noticed the difference in the yield between the left-spiralled and right-spiralled palms, it was very essential to make the correction because at the time of choosing the palms no consideration was made on the foliar spirality of the palms. 177 of the 384 palms were left-spiralled. The expectation on a basis of equality is 192 ± 9.8. The excess of rights is not significant at the 5 per cent level. Each of the 48 blocks contained 8 trees (plots), all healthy or all in the early or late stage of the disease. The numbers of blocks containing a given number of lefts are given in Table 7.

TABLE 7

lefts	0	1	2	3	4	5	6	7	8	total
blocks found	1	1	6	14	14	8	3	0	1	48
blocks expected	0.34	2.34	7.01	11.08	12.80	8.76	3.75	0.92	0.10	

The number of blocks expected with n lefts is $\binom{8}{n}\frac{48.59^n.69^{8-n}}{128^8}$. It is a little unexpected that even one block was found with 8 lefts, however, the variance of the number of lefts is 1.969, the expected value being $\frac{8.177.207}{384^2} = 1.988$.

With regard to treatments also, disparity occurs regarding the number of the lefts and rights receiving a particular treatment. With regard to treatment with Iron (E), the difference is significant, χ^2 being 8.0709 as seen below.

	L	R	L+R
E	37	27	64
•	21	43	64

$\chi^2 = 8.0709$.

Thus, because of the uneven distribution of the lefts and rights, it was decided to perform the Analysis of Covariance with the spirality as the concomitant variable.

Since the 48 blocks are distributed in a 8-hectare estate, block differences are bound to occur as may be seen from the block totals given in Table 8. The block differences were taken into account and the Analysis of Covariance done for each replication separately.

TABLE 8. NUT-YIELD OF COCONUT PALMS: BLOCK TOTALS

blocks	healthy palms		diseased—moderate		diseased—severe	
	pre-treatment	post-treatment	pre-treatment	post-treatment	pre-treatment	post-treatment
1	2849	2809	1437	1475	1086	914
2	2809	2785	1269	1246	921	956
3	2886	3288	1720	1772	1200	1057
4	1783	2782	1416	1857	928	1203
5	2376	2824	1721	1824	1186	1559
6	2871	3433	1648	1784	637	604
7	1897	2554	1060	1767	908	910
8	1772	3310	1455	1525	828	749
9	1876	2148	1084	2029	808	1059
10	2124	2802	1030	1491	1048	1287
11	1257	2266	1236	1413	927	1045
12	2129	2794	1033	1189	1220	1188
13	1885	2809	1150	1334	696	709
14	1730	2394	1220	1560	493	515
15	2878	4038	1304	1874	466	618
16	2185	2551	1482	2177	932	1179
total	35310	46587	21255	26317	14284	15532

5. STATISTICAL ANALYSIS PROCEDURE

Under this heading, the various steps used in arriving at the conclusions are described briefly.

As already stated, this experimental data corresponds to a 2^7 confounded factorial manurial experiment on three groups of coconut palms (1) healthy, (2) moderately diseased and (3) severely diseased with 16 blocks of 8 plots for each group,

one palm constituting one plot. Also, corresponding to each tree there is supplementary data regarding the spirality of the leaves. This spirality, is an environmental effect and does not depend on the treatments that are applied to the tree. A difference in the nut-yield due to right and left foliar spirality is observed, so it is necessary to take the spirality of the leaves into consideration. Thus, in the statistical analysis a concomitant variable X to represent the spirality of the leaves is introduced. For computations, X is taken as 1 if it is right, otherwise 2.

In the data it may be observed that some trees have died during the observation period. To account for this, some minor adjustments were made. If the palm died in the course of the pre- or post-treatment period, the yield for that period has been calculated on the basis of the yearly mean production for the period the palms survived.

The model $Y = \beta X +$ treatment-effect + block-effect is assumed where Y is the increment in yield, i.e. the sum of post-treatment yields minus the sum of pre-treatment yields.

Treatment totals are calculated for X and Y, and the sum of squares for main effects and two-factor interactions are obtained by Yates' procedure. These are however influenced by the concomitant variable. Adjustment for the concomitant variable is made through standard routines of Analysis of Covariance.

The results of the Analysis of Covariance are presented in Table 9.

As clearly seen from Table 9, there exists a significant correlation between the nut-yield and the foliar spirality of the palms of the healthy and severely diseased groups. However, the moderately diseased palms do not show this dependence significantly. The fact the fruit yield depends on the foliar spiral in the coconut has already been reported (Davis, 1963).

TABLE 9. RESULTS OF ANALYSIS OF COVARIANCE

y = yield $\qquad\qquad$ x = spirality

corrected sum of squares due to	degrees of freedom	xx	xy	yy
	(1) Healthy palms :			
block	15	4.72	147.27	329630.43
treatment	28	7.60	− 545.30	346243.53
error	84	19.34	−1254.20	1200580.80
total	127	31.72	−1662.23	1876454.30

Variance estimate $\hat{\sigma}^2 = 13485.08$ $\qquad$ Estimate of β $(\hat{\beta}) = -64.8376$

F-statistic to test $\beta = 0$ is $\frac{E^2 xy}{Exx}$ /Error ms = 6.03.

TABLE 9. RESULTS OF ANALYSIS OF COVARIANCE—*contd.*

y = yield $\qquad$ x = spirality

corrected sum of squares due to	degrees of freedom	xx	xy	yy
	(2) Early disease			
block	15	4.30	−305.89	158044.22
treatment	28	6.91	−142.11	210252.28
error	84	20.72	15.36	489287.17
total	127	31.93	−432.64	857583.72

Variance estimate $\hat{\sigma}^2 = 5899.10$ $\qquad$ Estimate of β $(\hat{\beta}) = 0.7413$

F-statistic to test $\beta = 0$ is $\dfrac{E^2xy/Exx}{\text{Error } ms} = .0019$

	(3) Late disease			
block	15	2.72	− 94.50	55497.75
treatment	28	9.53	62.88	80361.00
error	84	22.47	−517.38	240233.25
total	127	31.72	−549.00	376112.00

Variance estimate $\hat{\sigma}^2 = 2750.84$ $\qquad$ Estimate of β $(\hat{\beta}) = 23.0264$

F-statistic to test $\beta = 0$ is $\dfrac{E^2xy/Exx}{\text{Error } ms} = 4.33$

The effect x (due to foliar spirality) has been eliminated in order to find out the effect of the manurial treatment alone, and the significance or otherwise was tested by the F-test. The results are presented in Table 10.

TABLE 10. SIGNIFICANT TREATMENTS (AT 5% LEVEL, $F_{1,82} \geqslant 3.92$)
MAIN TREATMENTS AND TWO-FACTOR INTERACTIONS

treatment	effect	F-value
	(1) *Healthy palms*	
	None significant	
	(2) *Diseased—early stage*	
E	−2055	5.43153
BE	2508	8.30783
CE	−2168	6.20560
	(3) *Diseased—late stage*	
A	1476	6.17821
F	1242	4.37523

6. Discussion of the results

Of the seven micro-nutrients (including Mg) tried in the experiment, five showed significant response when applied singly and/or in combination in either improving or depressing the fruit-yield of the coconut palms. No micro-nutrient was found to have any significant effect on the number of nuts of healthy palms. Plams in the early stage of disease responded very favourably with a combination of Boron and Iron (BE). The beneficial effect of Boron on the diseased coconuts became obvious even at an early stage of this experiment (Davis and Pillai, 1966). However, its beneficial effect is not noticed among severely diseased palms. Copper in combination with Iron (CE) shows severe depressing effect on early disease palms. At an early period, Copper showed some beneficial effect on healthy palms and those showing severe disease symptoms. Iron behaved differently. When applied singly, this element had severe depressive effect on moderately diseased palms. Further, Iron, in combination with Boron, showed beneficial effect while with Copper it had a depressive effect on the same category palms. The role of Iron, therefore, requires to be studied through further experiments.

Palms of the severely diseased group showed favourable response to Magnesium and Molybdenum applied singly. Analysis of yield data upto 1957 showed that Magnesium increased the nut-yield of trees of all categories, the healthy as well as the severely diseased palms showing greater response. With the present data upto 1960, this element continued to show a favourable response on all groups of palms, but significantly with the severely diseased ones. Root exudations were collected from healthy and diseased palms and their contents analysed chemically. Magnesium was found to be deficient in the root exudates of the diseased palms compared to that of healthy ones (Davis and Pillai, 1969). It would imply that diseased palms are unable to absorb as much Magnesium as healthy ones are capable of, from soils containing very low concentrations of the element. For all practical purposes, Magnesium is a macro-nutrient which is required in large quantities by the cocoonut. The first visible response to the soil application (as well as foliar application) was noticed on palms showing severe yellowing of the fronds. These leaves turned green steadily which eventually enabled the palms producing more fruits. It may be mentioned that the palms showing symptoms of the Withering Disease in Ceylon also showed a striking favourable response to the soil application of Magnesium (Davis, 1966; Nethasinghe, 1959; 1961a, b; Salgado and Nethasinghe, 1960).

Molybdenum has also shown a very favourable response with the palms showing severe disease symptoms. Though the palms receiving treatment F received just one gram of Molybdenum, they started showing the beneficial effect even in 1957.

7. Limitation of the analysis

(1) The effect of the interactions higher than the two-factor level has not been worked out.

(2) The experimental palms, as mentioned, are of varying age-groups, and no correction was made to this effect.

(3) Though the experimental palms belonged to the same tall variety of coconut, they represent more than one form or colour group. No consideration was given to these differences.

(4) Field one (having the first 5 major blocks) was underplanted with coconut seedlings from the commencement of the experiment, whereas the other two fields were underplanted only in 1958-59.

8. Acknowledgement

I am obliged to my former colleague, A. P. Anandan for the valuable help received at the early stage of the experiment. Also I thank N. G. Pillai, V. G. Lilly, K. J. Michael and P. V. Kunjan of the Central Coconut Research Station, Kayangulam for assistance in the collection of data. J. Roy, K. R. Shah. K. R. Unni, V. V. Menon and N. Vijayaditya of this Institute helped in the analysis of the data. I am greatly indebted to the late Sir Ronald A. Fisher who scrutinized the data and suggested me to get them published in *Sankhyā*. The drawings were prepared by Mr. S. K. De.

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Paper received : April, 1967.
Revised : April, 1969.