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FERTILIZING OF YOUNG RUBBER IN THE CAMEROONS [1])

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SUMMARY AND CONCLUSIONS

Growth responses of rubber trees, as measured by their girth increase, to nitrogen, phosphorus, potassium and their combinations were investigated in three experiments situated at the foot of the Cameroon Mountain in the Southeast at Missellele in the Tiko plain, in the east at Meanja in the Ekona area and in the north at Mukonje.

The soils in the three areas originated from the same parent material, but differed in depth owing to root impeding layers and in availability of nutrients owing to whether the areas were replanted with rubber or planted in virgin bush.

1 It was demonstrated that, even though these soils were poorly supplied with nutrients, lack of rooting depth had a far greater impact on growth than the availability of nutrients. Whereas an abundant nutrient supply was estimated to reduce the improductive period by half a year, shallow soils would reduce it by at least one year. The main conclusion was, that in a climate where the wet seasons are always too wet and the dry seasons always too dry, the production of rubber is primarily dependent on the profile characteristics of the soils.

2 Yield responses to different fertilizer treatments were a reflection of the observations made on growth, i.e. N and K being the major deficiencies and P having an effect only in combination with N and K. Balanced nutrition of the trees proved to be superior in respect of a more consistent high production under hazardous climatic conditions and of a larger productivity per unit length of bark, rather than in respect of maximum growth, i.e. total tappable bark, under favourable conditions. Given the prevailing climatic conditions, it was one of the main results of this study that annual fluctuations in yield could be reduced by fertilizing. Since in many tropical countries the cost of large fertilizer dressings is prohibitive, the possibility of obtaining more consistent yields by high levels of application, well known for other crops (10), must be excluded. It was shown, however, that small amounts of well balanced fertilizers could – at least to a certain extent – produce the same effect.

3 Possible means of further yield increases by NPK fertilizer applications were discussed in relation to seasonal fluctuations, i.e. by the use of a lower N – K ratio in applications made before the dry season and of a higher ratio before the rains, as well as in view of the addition of magnesium, particularly during the transitional period from the vegetative to the reproductive stage.

4 Fertilized trees, opened up at 18″ girth, yielded 430 lbs per acre in the first year whether dressed with balanced fertilizers or not, but owing to adverse climate conditions the latter are estimated to produce only 580 lbs in the second year against the former 700 lbs approximately.

1) Received for publication July 8, 1960.

Introduction

Development of rubber (*Hevea Brasiliensis* Muell.-Arg.) is greatly encouraged and is expanding rapidly in West Africa.

Information concerning the nutrient requirements of the rubber tree under West African conditions is, however, not abundant. If, therefore, a fertilizer policy were to be adopted one could either follow as a kind of insurance policy the recommendations based upon the extensive experience gained in the major rubber growing countries of Southeast Asia or apply fertilizers only when deficiency symptoms become apparent. In the latter case the quantity to be applied forms the major difficulty both from a viewpoint of curing the deficiency and of avoiding excessive dressings, which may induce deficiencies of other nutrients. Compared with other continents, Africa consists of very old soils (4) and the threat of multiple deficiencies and particularly of inducing deficiencies by curing the more obvious one (s) is more prevalent than elsewhere. It is, therefore, not surprising that, in studies related with fertility patterns in Africa, much stress has been laid on balanced fertilizing (3, 5, 7, 8, 9, 13).

As part of the investigations on the use capabilities of the land leased to the Cameroons Development Corporation, which is situated on the slopes of the Cameroon Mountain range, fertilizer trials were laid out in young rubber on non volcanic soils at Missellele in the Tiko plain, at Meanja in the Ekona area and at Mukonje. The soils are of Precambrian origin (granites, gneisses, schists) (12), in the former two areas they were transported and redeposited by the sea in recent geological history (6), but all are acid pH between 4.5 and 6).

The present study on the effect of the main plant nutrients nitrogen, phosphorus and potassium is based upon observations made on growth and yield of rubber trees up to the age of eight years.

Methods

The three fertilizer experiments at Missellele, Mukonje and Meanja were of a randomised block design with the following treatments: control (O), nitrogen (N), phosphorus (P), potassium (K) and their combinations NP, NK, PK and NPK, in three replications at Missellele and Meanja and in four replications at Mukonje.

Fertilizers were applied at two levels (0 and 1) according to the following schedule (ounces per tree per annum):

Year	Sulphate of Ammonia	Rockphosphate (30 % P_2O_5)	Muriate of Potash (50 % K_2O)
Plant year	1	1	½
1st „	2	2	1
2nd „	4	4	2
3rd „	8	8	4
4th „	16	16	8
5th „	24	24	16
6th „	24	24	24
7th „	24	24	24

Two applications of fertilizer were made, one half during the period of the early rains (April) and the other during the period of the late rains

(October). It was a routine plantation practice to apply rockphosphate as a plant hole dressing, so that all the trees received a dressing of ¼ lb rockphosphate irrespective of the experimental treatments. Each plot of 15 trees, i.e. 3 rows of 5 trees, was surrounded by a single guard row, the planting density being 12 ft. by 24 ft. or approximately 151 trees per acre.

Every six months the girth of each tree was measured at 3 ftt. above the lowest point of the budding line and an average figure obtained for the 15 trees in each plot.

a Missellele

The area in which the experiment was situated was cleared from virgin forest, planted in 1949 and budded with the clones PB 5/37 and PB 60 in 1950. Apart from the planthole dressing of rockphosphate it had not received any fertilizer until the trial was laid out in September 1952, when it received half of the 3rd year's dressing.

The experiment was discontinued in April 1956.

The soil in the top 50 cm was a dark grey sandy clay (Munsell colour 1CYR 4/2) containing many lateritic concretions and was well drained. Below 50 cm the concretions increased in numbers and formed a solidified layer, difficult to be penetrated by roots and not well drained.

The average annual rainfall was approximately 95 inches with a dry season of 2½ to 3 months (less than 4 inches per month) extending from the end of November till the middle of February.

b Mukonje

This experiment was laid out on replanted rubber land amongst four year old rubber trees of clone PB 86 which as in Missellele were dressed with rockphosphate at planting in 1952, and were budded in 1953. It received its first experimental fertilizer application in April 1956. It was abandoned at the end of 1957 owing to serious losses sustained from winddamage and root disease.

The soil was derived from basement rocks (12) weathered in situ. The soil in the top 30 cm was a sandy clay (Munsell colour 7.5YR 5/4) rather well drained with some lateritic concretions, changing to a clay (Munsell 5YR 4/4) with many lateritic concretions, which between 40 and 45 cm became so abundant as to form a compact layer largely impeding rootgrowth and drainage. Below 50 cm the soil was poorly drained.

The average annual rainfall was approximately 105 inches with a dry season of 2½ months extending from December to the middle of February.

c Meanja

This experiment was laid out in April 1954 in an area planted in 1952 on replanted rubber land and budded with the clone PB/S 78 in 1953. At planting the trees had a planthole dressing of rockphosphate. The first experimental dressing was made in May 1954, i.e. two years after planting.

As at Missellele the soil is a marine deposited sandy clay, but without lateritic concretions and well drained. The soil in the top 10 cm was a dark grey (Munsell colour 10YR 4/1) loamy sand, gradually changing to a brown sandy to very sandy clay (Munsell 10YR 5/3) down to 120 cm, containing a few lateritic concretions between 40 and 70 cm. The soil was well drained.

The average annual rainfall was approximately 85 inches with a dry season of three months extending from the middle of November to the middle of February.

Trees which had a girth of 18″ in April 1958 were opened up and tapped in cycles of six weeks, i.e. 4 weeks tapping followed by 2 weeks resting (S/2, D/1, R2w/6, 133 %). At the beginning of March 1959, after 8 cycles of six weeks each, the trees were rested for four weeks during refoliation. During this period the stand was thinned out from approximately 151 to 113 trees per acre. Tapping was resumed on 31st March.

Tapping rounds were altered every day in order to compensate for the variations in latex flow. The experiment was tapped by one and the same tapper, who normally completed his task before 9 a.m.

Results and discussion

a Missellele

The mean increase in girth per tree per half year in the period from October 1952 to April 1956 is shown in table 1.

Table 1 Mean girth Missellele (area planted in 1949).

Date	Mean girth per tree (cm)	A Mean girth increase per tree per ½ year		B Mean girth increase per tree during period October '52—April '56	
		(cm)	ratio $\frac{\text{wet season}}{\text{dry season}}$	treatment	girth increase (cm)
October '52	15.4	—		O	32.6
April '53	19.9	4.5	1.64	N	32.3
October '53	27.3	7.4		P	34.2
April '54	30.9	3.6	2.31	K	33.9
October '54	39.2	8.3		NP	32.6
April '55	41.3	2.1	2.48	NK	31.9
October '55	46.5	5.2		PK	32.2
April '56	48.1	1.6		NPK	33.1

It will be seen from table 1 A that the greater increase occurred in the wet season, approximately 7 cm against only 3 cm on the average for the dry season.

The absence of an effect of fertilizing (table 1 B) could not have been due to the inherent fertility of the soil, since large responses from fertilizers were obtained on similar soils in current banana, oil palm (5) and rubber (cf. Meanja sub c) trials. It was considered to be due to the shallowness of the soil and the supply of nutrients from decaying forest litter. The adverse effect of the former and the decreasing supply of the latter source became particularly apparent in the dry season. For, the increase in girth in successive dry seasons decreased more rapidly i.e. from 4.5 cm via 3.6, 2.1, to 1.6 cm, than in the rainy season i.e. successively 7.4, 8.3 and 5.2 cm. The ratio between girth increase in the wet and the dry season increased from 1.64 to 2.31 to 2.48 (table 1 A). The area was taken into production in October 1956 when the trees had reached a circumference of approximately 51 cm (20″), i.e. more than 7 years after planting.

Owing to the poor soils in this area, growth of the rubber trees in the dry season virtually came to a standstill. In the young rubber a dense cover crop was being maintained, leading inevitably to serious competition for moisture in the dry season. Under such conditions, it might be considered desirable to open up rather wide black-weeded strips along the lines, combined with mulching in the dry season.

b Mukonje

The mean increase in girth per tree per half year in the period from April 1956 to October 1957 is summarised in table 3.

Table 3 Mean girth – Mukonje (area planted in 1952).

Date	Mean girth per tree (cm)	Mean girth increase per tree per ½ year (cm)
April '56	18.4	–
October '56	27.3	8.9
April '57	28.3	1.0
October '57	36.6	8.3

The difference in growth rate between the dry and rainy half of the year was even more pronounced than in Missellele. It would seem, however, that the smaller girth increase in the dry season in Mukonje was to a certain extent made up for by a larger increase in the rainy reason (cf. girth of 4½ year old trees in Missellele and Mukonje in October 1953 and 1956 respectively).

As in Missellele, the poor growth in Mukonje in the dry season was attributed to the shallow soil, but was probably aggravated initially by the absence of a moisture conserving layer of decaying forest litter and of its derivated humus, with its large water retaining capacity.

The effect of the difference in virgin fertility between the two experimental areas was demonstrated also by the observation that fertilizers had an effect on growth in Mukonje (table 4).

Table 4 Mean girth increase per tree during period April '56–October '57.

Treatment	Mean girth increase (cm)
O	15.9
N	18.7 **
P	18.5 *
K	18.4 *
NP	18.7 **
NK	18.8 **
PK	18.5 *
NPK	19.0 **

* Significant difference at P 0.05 : 2.06 cm.
** „ „ „ P 0.01 : 2.80 cm.

It will be seen from table 4 that the girth of the trees was significantly increased by fertilizing. Neither the main effects nor the interactions between the different nutrients attained significant levels. The soil was apparantly so deficient in all of the three main nutrients, that during the short period under consideration girth increases of between 15 and 20% were obtained from dressings of any of the three nutrients, whether applied alone or combined.

c Meanja

1 Girth

The mean increase in girth per tree per half year in the period from October 1954 to April 1958 in shown in table 5.

Table 5 Mean girth – Meanja (area planted in 1952).

Date	Mean girth per tree (cm)	Mean girth increase per tree per ½ year	
		cm	ratio $\frac{\text{wet season}}{\text{dry season}}$
October '54	11.5	–	
April '55	14.6	3.1	3.39
October '55	25.1	10.5	
April '56	28.6	3.5	2.31
October '56	36.7	8.1	
April '57	38.7	2.0	2.95
October '57	44.6	5.9	
April '58	47.5	2.9	

The girth of six year old trees at Meanja in April 1958 was approximately the same as that of seven year old trees at Missellele, i.e. in April 1956 (table 1 A). This difference of one year was less the younger the trees. It would appear, therefore, that the difference in the rooting depth of the soils in the two areas and the difference between their initial fertility level (the land in Meanja was replanted with rubber and in Missellele it was cleared from virgin bush) exerted a progressively increasing and decreasing influence respectively with increasing age of the trees. The opposite trend with increasing age of the trees of the ratios between girth increase in the rainy and the dry season at Missellele (cf. table 1 A) and Meanja (cf. table 5) indicated that the initially richer but shallower soil at Missellele reduced the adverse effects of the dry season on early growth but, owing to the poorer drainage conditions, affected growth unfavourably during the generally better growing conditions of the rainy half the year.

It will be seen from tables 3 and 5 that the trees at Meanja were also one year ahead in growth of those at Mukonje. In respect of Missellele this difference was attained when the trees at Meanja were six years old, but at Mukonje it was already reached when the trees at Meanja were only four years old. For, in April 1956 the girth at Meanja was 28.6 cm compared with only 18.4 cm for trees of the same age at Mukonje and 28.3 cm for trees at Mukonje one year older than in Meanja. From this it may be concluded that the depth of a soil was of major importance and had a far greater impact on the rate of growth and consequently, by earlier maturity, on the production of rubber than the chemical fertility of a soil. Trees growing on a soil cleared from virgin forest were estimated to reach the productive stage half a year earlier while at least one year was gained in the case of rubber growing on a deep soil, i.e. without root impeding layers.

Mean girth increments (expressed as a percentage of the control) per half year and the cumulative increment over the entire period of observation are shown in table 6. It will be seen from the table that in the first two measurements after the first fertilizer application large growth responses, as measured by the increase in girth of the trees, were obtained from all the fertilizer treatments, except P and NP, treatments N, K, NK and NPK being significantly different from the control. The main effects of N and K, and the interaction N $\times$ P $\times$ K were positive and significant while the negative interaction N $\times$ P was nearly significant in the rainy half of the period.

The trend in the second year was principally the same as in the previous year, although the differences between the treatments were smaller and did not attain a significant level.

Growth in the third year, however, was adversely affected by fertilizing except perhaps by treatments PK and NPK, which were not significantly lower than control. In the last half yearly period before the trees were taken into production, i.e. in the dry season of 1957/'58, the responses to the different treatments were more in line with those of the first two years. From the cumulative girth increments shown in table 6 it will be seen, that the large responses obtained from fertilizing gradually levelled off, so that measured over the entire period of observation from October 1954 to April 1958, only NPK fertilizing produced a significant increase in girth i.e. of 6%. The main effects of N and K were still large but not significant, while P $\times$ K was the only significant (positive) interaction left.

It was evident from these results that there was a shortage in the supply of both N and K, but that when applied together they did not interact positively but somewhat negatively. This and the positive interaction between N, P and K in the first half yearly measurement emphasized the importance of P in enabling the plant to make full use of NK dressings. Such a response to P was further supported by the interaction P $\times$ K, which was found to be consistently positive, though not significant, in the individual half yearly measurements. The cumulative effect after three years of fertilizing, however, produced a significant interaction P $\times$ K, which suggested that it was in the P – K relationship that P played its role rather than in the N – P balance. Similar observations were made in current banana trials and in a fertilizer trial with oil palms situated in the same area (5).

The striking difference between these results and those obtained in Malaya was the absence of an effect of dressings of P alone and the marked effect of K. With regard to P, it was shown that it was effective only when the plant's requirements of N and K had been met. With regard to K it will be seen from table 6 that its favourable effect both as a treatment and its main effect, was seasonal and was almost entirely confined to the dry season. K – dressed trees were apparently more tolerant to periods of drought, a phenomenon well known in other crops (11), by regulating the water content of the plant.

A similar but opposite trend was noticed in respect of N, in which case the larger responses were obtained in the rainy season.

Table 6 Girth increase – Meanja (expressed as a percentage of control).

Treatment	1954/'55				1955/'56				1956/'57				1957/'58	
	Dry season		Rainy season		Dry season		Rainy season		Dry season		Rainy season		Dry season	
	G°	M.E.°	G	M.E.	G	M.E.	G	M.E.	G	M.E.	G	M.E.	G	M.E.
O	100 (= 2.7 cm)°°		100 (= 10.0 cm)		100 (= 3.4 cm)		100 (= 7.8 cm)		100 (= 2.1 cm)		100 (= 6.6 cm)		100 (= 2.7 cm)	
N	130**	9	111*	69*	105	2	109*	75**	92	– 29	85*	– 6	106	– 10
P	107	– 25	102	– 13	98	8	94	1	88	5	86*	– 10	104	8
K	131**	53**	102	27	108	28	102	3	92	3	88*	– 12	104	18
NP	90	– 13	105	– 55	96	16	111*	25	84	– 1	92	44	98	– 20
NK	115	– 11	112*	– 11	96	– 4	104	– 45*	78	– 15	90	30	104	– 10
PK	116	27	107	11	106	30	103	17	109	31	88*	18	117	16
NPK	131**	63**	106	– 7	117	30	107	– 15	89	– 7	92	– 36	105	0
	Significant differences (G) and levels (M.E.)													
P = 0.05	19.0	30.7	9.4	56.2	27.1	55.6	8.0	37.8	31.1	39.8	11.3	44.6	18.9	30.6
P = 0.01	26.3	42.6	13.0	78.0	37.6	77.2	11.1	52.4	43.1	55.2	15.7	62.0	26.2	42.5

Treatment	October 1954–October 1955		October 1954–October 1956		October 1954–October 1957		October 1954–April 1958	
	G	M.E.	G	M.E.	G	M.E.	G	M.E.
O	100 (= 12.7 cm)		100 (= 23.9 cm)		100 (= 32.7 cm)		100 (= 35.2 cm)	
N	115**	78*	111**	155**	105	120*	105	110
P	103	– 38	99	– 29	96	– 34	97	– 26
K	108	80*	106	111*	101	102	102	120
NP	102	– 68	104	– 27	100	16	100	– 4
NK	112**	– 22	107	– 71	102	– 56	102	– 66
PK	109	38	106	85	103	134*	104	150*
NPK	112**	56	111**	71	106*	28	106*	28
	Significant differences (G) and levels (M.E.)							
P = 0.05	9.7	73.6	7.7	110.6	6.0	117.1	6.4	136.0
P = 0.01	11.8	102.1	10.7	153.6	8.3	162.6	8.9	188.6

° G = Girth increase (% of control); M.E. = Main effects and interactions.
°° = Absolute girth increase.
* = Significant at probability of 5 %.
** = Significant at probability of 1 %.

It was evident that fertilizers with an unbalanced ratio between N and K would adversely affect the growth of rubber, notwithstanding that both might be in short supply. Furthermore, it appeared that the requirements of both nutrients over a period of one year should preferably be split into amounts which differ in their N : K ratio depending on whether they are applied at the beginning or at the end of the dry season.

The abnormal trend in the period 1956/'57 was related to the effect of magnesium deficiency, since well marked deficiency symptoms as described by BOLLE JONES (1), were observed during the rainy season of 1957. In the years before and after 1957, the deficiency was absent or mild respectively, which would concur with the absence of conspicuous adverse effects on the increase in girth in 1954, 1955 and 1956 and the dry season of 1957/'58 respectively. Hence, it would seem reasonable to assume that the treatments which produced the larger growth response, would have been affected most by the deficiency of magnesium.

It would have been borne out by the comparison between the control and the treated plots, but for the P and NP plots, which were similarly affected by a large retardation in growth. In view of the latter observation and in analogy with the results obtained in a nearby oil palm experiment, situated on a similar soil, it was tempting to relate the abnormal trend with a critical period in the plant's life, i.e. during the transitional period from the vegetative to the reproductive stage. The first inflorescences in this experiment were indeed observed in 1957, whilst the following was concluded from the results obtained in the nearby oil palm experiment (5):

"Vegetative oil palms, when they enter the reproductive stage, had a greatly increased need for Mg, in the absence of which an adverse effect on growth was noticeable" and further: "it has been demonstrated that Mg deficiency resulting from increased Mg requirements of oil palms flowering for the first time, increased the incidence of Crown Disease and at the same time suppressed growth of reproductive palms".

Unfortunately, it was impossible to gather more conclusive evidence to support it, owing to the design of the experiment and the fact, that the trees were taken into production the following year.

2 Tapping

The trees with a circumference of at least 18″ were taken into production on the 1st April 1958 and their number in each plot was counted (table 7).

Table 7 Tappable trees.

Treatment	Percentage of available trees tapped	
	1-4-1958	16-9-1958
O	58	91
N	80	91
P	66	85
K	76	88
NP	69	92
NK	73	87
PK	75	91
NPK	91	96

Table 8 Weight of dry rubber (expressed as percentage of control) in lbs/acre.

Treatment	1st year (150 trees per acre)				2nd year todate (113 trees per acre)				Total to date	
	1-4-'58–15-9-'58	16-9-'58–2-3-'59	Total 1st year		31-3-'59–3-8-'59	4-8-'59–7-12-'59	2nd year todate		1-4-'58–7-12-'59	
	W°	W	W	M.E.°	W	W	W	M.E.	W	M.E.
O	100 (= 92 lbs)°°	100 (= 235 lbs)	100 (= 327 lbs)		100 (= 145 lbs)	100 (= 240 lbs)	100 (= 385 lbs)		100 (= 712 lbs)	
N	152	121	129*	110	97	102	100	– 228**	113	– 118
P	118	99	104	– 8	107	103	105	– 36	104	– 44
K	134	114	120	238	117	126	123**	244**	121*	482**
NP	103	99	100	– 80	86	93	90	26	95	– 54
NK	130	105	112	– 118	92	103	99	– 80	105	– 198
PK	146	116	124	220	116	110	113	16	118*	236
NPK	165	119	131*	220	105	108	107	170*	118*	390*
Significant differences (W) and levels (M.E.)		P 0.05	27.5	245.4			14.9	156.8	17.8	336.4
		P 0.01	38.2	340.6			20.7	217.6	24.0	466.8

° W = Weight (% of control); M.E. = Main effects and interactions.
°° = Absolute weight.
* = Significant at probability of 5 %.
** = Significant at probability of 1 %.

Analysing the results of the first colum of table 7 with the chi-square test, a significant departure from homogeneity was found. Checking the departure from the average percentage of tappable trees, it appeared that control was significantly inferior, whereas treatment NPK was highly significantly superior. Evidently, all fertilized trees had a larger percentage of tappable trees, treatment NPK being outstanding.

Analysis of the main effects and the interactions gave results similar to those demonstrated for girth increase, i.e. significant main effects for N and K and a positive interaction between N, P and K (significant at the 5% value for *).

Approximately nine months after tapping was commenced, all the trees had become available for tapping (cf. table 7, colum 2). It was obvious that the yield of dry rubber in the different treatments in the first year of tapping was related to the number of tappable trees. The yields in the first year of tapping and in the first 8 months of the second year, i.e. 6 cycles of 6 weeks (expressed as a percentage of the control) are shown in table 8.

The effect of fertilizing on the increase in growth was reflected in the yields obtained in the first year of tapping. In order to find out whether fertilizing had an effect on yield additional to that caused by earlier maturity as a result of improved vegetative growth, the production per cm girth was worked out for the first year during the period 16-9-'58 to 2-3-'59, when almost all the trees had reached the productive stage and for the second year todate after the stand had been thinned out from 151 to 113 trees/acre (table 9).

Table 9 Weight of dry rubber per cm girth in grams (expressed as percentage of control).

Treatment	1st year		2nd year		
	16-9-'58–2-3-'59		31-3-'59–4-8-'59	31-3-'59–8-12-'59	
	W°	M.E.°	W	W	M.E.
O	100 (= 14.5 g)°°		100 (= 9.8 g)	100 (= 26.8 g)	
N	119*	– 3	103	105	– 185
P	108	15	117	114	25
K	118*	97	116	121*	243
NP	105	– 53	90	94	– 351*
NK	104	– 139*	94	101	63
PK	117*	71	122	117*	– 27
NPK	115*	143*	103	105	61
Significant differences (W) and levels (M.E.).					
P = 0.05	14.9	130	–	17.0	275
P = 0.01	20.6	180	–	23.9	383

° W = Weight (% of control); M.E. = Main effects and interactions.
°° = Absolute weight per cm girth.
* = Significant at probability of 5%.
** = Significant at probability of 1%.

It appeared, that in the first year the trees dressed with N, K, PK or NPK had a larger productivity per cm girth. Treatment NPK was, however, not markedly better than the other significant treatments, probably owing to the negative interaction N × K, which was only just offset by the addition of P resulting in a positive interaction N × P × K. It would seem therefore, that in respect of the production per cm girth of the latter half of the first year the amounts of N, P and K in treatment NPK were not balanced in the most favourable way.

The trend in the production for the first eight months of the second year was entirely different from the first year (table 8). Only treatment K attained a significant level whereas the main effect of N changed from + 110 in the first year to a significant negative level of – 228. It was caused by the damage sustained from heavy windstorms, which occurred in March 1959 at the end of the dry season. The percentage canopy lost was estimated and the results analysed with the chi-square test (table 10).

Table 10 Winddamage – March 1959.

Treatment	Percentage of trees affected by winddamage		
	A	B	C
O	25	20	6
N	20	14	14
P	6	3	3
K	14	14	0
NP	27	27	9
NK	28	28	14
PK	31	17	6
NPK	25	22	11

A = More than 25 % of canopy damaged.
B = More than 50 % of canopy damaged.
C = More than 75 % of canopy damaged.

It appeared that the number of trees with more than a quarter of their canopy damaged (colum A) was significantly lower for treatment P. The interaction N × P × K was also found to be significantly lower. In colum B, the positive main effect of N became also significant. Finally, treatment K was nearly significantly lower and the main effect of N again significantly higher in respect of the trees with more than 75 % of their canopy lost.

Dressings of N, particulary those combined with P or K, apparently lowered the resistance of the trees considerably. The adverse effect of these unbalanced fertilizer dressings was to some extent counteracted by the addition of either K or P to NPK. Trees dressed with K were more tolerant of wind but not as much as those dressed with P alone. The difference might, at least partly, have been due to the smaller canopy of the trees in treatment P, the effect of which on susceptibility to winddamage could not be assessed.

The aftereffect of the winddamage was clearly noticeable in the production in the second year, especially in the first three cycles (table 8). It would seem that thereafter in the period from 3rd August to 7th December 1959, the damage was gradually being overcome, since the treatments known to have stimulated the yield in the first year, such as N, NK and NPK, improved proportionally more than the control, whereas a poor treatment like P was beginning to loose some of its lead.

The latter trend was also noticed in the production per cm girth (table 9), indicating that it was rather due to the recovery of the productivity of the trees than to differences in total tappable panel area, resulting from differences in girth.

These results were in line with the interpretation given by BOLLE JONES and MALLIKERJUNESWARA (2) viz. that "the effect of mineral nutrient status on rubber formation was an indirect one and was concerned with the role of the nutrient elements in the formation of either carbohydrates, proteins or plant dry matter".

Increasing the productivity of these soils by means of fertilizing involved firstly applications of either N or K alone. A further increase could not be obtained from dressings of both N and K, unless P was added, thus NPK. The favourable effects of N, P and K dressings on growth attained their maximum two to three years after the first fertilizer applications, whereafter no more significant increases in girth were obtained and the unbalanced fertilizers, N, P, K, NP and NK even had an adverse effect. Whether it was due to the maximum level of increase that could be obtained from N-P-K fertilizing under the mitigating circumstances, or to the inducement of other deficiencies, in particular Mg-deficiency, could not be definitely established. The observation, however, that it did coincide with the onset of flowering of the trees, i.e. during the transitional period from the vegetative to the reproductive stage, which had been demonstrated to be a critical period in respect of the Mg requirements of oil palms growing under the same conditions on similar soils, and the indication that it seemed to be confined to this period, suggested a complex relationship of a physiological nature.

Subsequent yield responses to the different treatments were in line with the observed growth responses and provided further evidence in favour of balanced fertilizing. Growth responses obtained from unbalanced fertilizing reduced the plant's adaptability to climatical hazards, such as drought and windstorms, which, given such adverse conditions, would – at least temporarily – result in a suboptimal output of latex of the enlarged productive mechanism of the tree.

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