GROWTH OF YOUNG COCONUT PLANT IN SAND CULTURE[1]

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The plants suffering from nitrogen deficiency were stunted and lacked succulence. The leaves were short, but well proportioned and the yellow leaflets were stiff. Along the midribs buff colored blotches were frequently noticed.

The minus-phosphate plants were stunted and rosetted. The dark-green leaves were usually not fully exerted from the stipules or "guinit". There was severe drying of old leaves.

The minus-potassium plants developed little dots along the margins of old leaves. In severe cases, they coalesced and gave the leaves the appearance of "firing."

The minus calcium plants were tall and slender with sparse leaves taking on a "tucked in" appearance. Petioles were deep yellow or orange, indicating that plants were rich in anthocyanin. Orange blotches along midribs were frequent.

The minus magnesium plants had elliptical water-soaked or translucent spots along the margins of old leaves. Old drying leaves assumed a "bronze" appearance. Plants were big and deceptively healthy.

The minus-sulfate plants became yellow much later than the minus-nitrogen plants. The mature leaves progressively lost their green color from the margins of the leaflets towards the midrib, so that the green seemed to form a haze on a yellow background. The rachis may be weak and pliant. Although the plant may be short and rosetted it may produce many leaves.

The plants in the minus-micro-nutrient treatment were similar to the plants receiving the complete solution until about the middle of 1958 or about 45 months of treatment. Then the plants produced thick, brittle young leaves. This was followed by leaves with malformed leaflets and eventually by leaves with no leaflets at all. This characteristic was ascertained to be caused by boron deficiency.

This is a report on the latter part of the experiment which was started in 1954 and covers the period from May, 1956 to August, 1959. The early part of the study was reported by Velasco and Fertig in 1956. The objects of the experiment were (1) to catalogue the de-

[1] Central Experiment Station Contribution No. 2031. Research Project 529.

ficiency symptoms on coconut of the different essential elements, (2) to note how immediate the symptoms appear after withdrawing the element and how soon plants recover their normal characteristics upon supplying it, and (3) to determine changes in the composition of the leaves of plants suffering from nutrient deficiency.

MATERIALS AND METHODS

The cultures. On May 9, 1956, 32 of the potted plants which were started in 1954 were transferred to tarred 55-gasoline drums, one plant to a drum. Each drum contained about 290 kilograms of acid-washed white sand. This came from the same stock being used by the San Miguel Brewery Co. in the manufacture of beer bottles and is reportedly mined in the shores of Palawan Island.

When feasible, the potted plants in the earlier treatments were given the same treatments in the drums. An exception was made in that plants held in reserve and maintained in the complete solution were used in the minus-nitrogen cultures instead of plants in the minus-nitrate or the minus-ammonium culture. There were eight cultures in all: the control or the culture receiving all the essential elements and the seven cultures deficient in nitrogen, phosphorus, potassium, sulfur, magnesium, calcium, and the minor elements (iron, boron, copper, manganese molybdenum, and zinc).

Method. Each plant received two liters of solution per week until December 1957, and four liters a week until August 31, 1959. Hoagland's solution No. 2 was modified in such a way that one element was eliminated at a time (table 1). To supplement the water

TABLE 1.—*Composition of Hooglands' modified solutions for the various deficiency treatments*

DEFICIENCY TREATMENT	PLANT NUMBERS	SALTS [a] KNO_3	$Ca(NO_3)_2$	$MgSO_4$	$NH_4H_2PO_4$
Complete	103, 122, 143, 156	√	√	√	√
Minus nitrogen	95, 105, 111, 121	(KCl)	($CaCl_2$)	√	(NaH_2PO_4)
Minus phosphate	100, 115, 117, 126	√	√	√	(NH_4Cl)
Minus potassium	96, 102, 137, 169	($NaNO_3$)	√	√	√
Minus calcium	99, 147, 162, 166	√	($NaNO_3$)	√	√
Minus magnesium	93, 98, 114, 171	√	√	(Na_2SO_4)	√
Minus sulfate	116, 129, 145, 165	√	√	($MgCl_2$)	√
Minus microelements	109, 161, 163, 173	√	√	√	√

[a] Potassium nitrate was 0.006 molar (M); calcium nitrate, 0.004 M; magnesium sulfate, 0.002 M and mono-ammonium phosphate, 0.001 M. When a salt was substituted for another, it was supplied in the same concentration as the displaced salt.

supplied in the culture solution, additional rain water or distilled water was supplied to the plants during sunny days. There were also a few instances during the dry season when, for lack of both rain and distilled water, tap water was used.

In cases where the growth of the plants was severely retarded, complete solution was temporarily supplied them so that they would not die. This treatment incidentally provided opportunity to observe the time it would take plants to recover their normal characteristics, and on being returned to the deficient culture, the time needed to develop the deficiency symptoms. Summary of these treatments is presented in table 2.

The plants were sprayed weekly with either dithane or parzate, to control a fungus disease which was tentatively diagnosed as caused by *Helminthosporium* sp. As an added control measure, some of the completely diseased leaves were cut off and burned. To control the scale insects, monthly sprayings of EPN were made.

Measurements of the height and diameter of the stem, together with leaf counts were recorded monthly. A representative plant from each treatment was photographed every two months during the early part of the experiment, but starting in 1958, the pictures were taken every six months.

Leaf samples were gathered beginning July 19, 1957 and every three months thereon until May, 1958; then, every six months until September, 1959. Every other leaflet on both sides of the rachis of the oldest functional leaf and from the youngest fully formed leaf was taken, and the samples from plants of the same treatment were pooled. The leaves from plant No. 173 of the November 29, 1958 sampling, were separated from the rest of the micro-nutrient-deficient samples because of the modified treatment given it.

The samples were placed immediately in a forced draft oven at a temperature of about 100°C. When dried, the midribs were removed and the remaining leafblades were ground in a Wiley mill with a 40 mesh sieve.

Total nitrogen was determined by the modified semi-micro Kjeldahl method. For phosphorus, potassium, calcium, and magnesium determinations, a sample was wet-ashed by the perchloricnitric acid method and aliquots of the extract were analyzed. In the analysis for each of these elements the methods of Wolf and Ichisaka (1947) were used.

TABLE 2.—*Summary of treatments*

TREATMENT	DATE COMPLETE SOLUTION APPLIED	APPROX. TIME TO RECOVER	DATE DEFICIENT SOLUTION APPLIED	DATE SYMPTOM FIRST NOTED	APPROX. TIME SYMPTOM APPEARED
N-deficient	December 6, 1956—all replications	60 days	March 6, 1957		
	August 31, 1958—all replications	52 days	October 22, 1958	November 8, 1958	16 days
P-deficient	October 17, 1956—No. 100 and 126 only	Not yet [a]	October 30, 1956		
	November 29, 1956—No. 100 and 126 only	152 days [b]	May 1, 1957		
	August 31, 1958	238 days [b]	April 29, 1959	June 11, 1959	42 days
K-deficient	October 17, 1956—No. 96, 102, and 137 only	Not yet [a]	October 30, 1956		
	December 6, 1956—No. 96, 102, and 137	149 days	April 30, 1957	January 19, 1958	259 days
Ca-deficient	October 17, 1956—No. 99 only	Not yet	October 30, 1956		
	December 28, 1956—all replications	122 days [b]	April 30, 1957	October 17, 1958 [c]	527 days
Mg-deficient	December 6, 1956—No. 114 only	27 days	January 3, 1957	March 9, 1958 [c]	429 days
S-deficient	October 17, 1956—No. 116 and 165 (replacement)	—	October 30, 1956—No. 116 only		
	December 19, 1956—No. 116, 129, 165 only	240 days	July 19, 1957	April 29, 1958	250 days
Micro-nutrient deficient	December 28, 1956—all replications	Not yet	February 1, 1957		
	October 17, 1958—No. 173 only	192 days	April 29, 1959	June 11, 1959	42 days

[a] When application of deficient solution was resumed, the plants have not yet recovered.
[b] Plants also recovered from Helminthosporium leaf spot.
[c] Slight deficiency symptoms.

The different forms of carbohydrates were determined according to the A.O.A.C. (1945).

RESULTS

Visual Observations

General observations. In January, 1956, most plants were suffering from a fungus disease which, in the early stage, produced elliptical spots measuring from 3 to 5 mm. by 5 to 10 mm. They were burnt umber (Maerz and Rea-Paul, 1950: Pl 15, A-12)[2] on the upper surface of the leaf and sayal brown (Pl 13, G-9) on the lower surface. Each spot had a halo of water-soaked mustard color Pl 11 1-4). At this stage, the rest of the leaf was calla green (Pl 22, 1-4) on the lower surface and Lincoln green (Pl 23, 1-3) on the upper surface.

The old spots were 10 mm. or more in diameter. They were circular or irregular, especially when neighboring spots coalesced. The central portion were rose dust (Pl 6, A-2) with brown to black borders (Pl 48, L-12). The outlying areas which were in the early stage of degradation were orange (Pl 11, E-11) or chocolate brown (Pl 8, J-10). Fig. 1 shows representative leaflets in various degrees of spotting, and fig. 2 is a portion of a leaf with mild infection.

At first it was suspected to be a case of the bleeding disease of coconut (*Ceratostomella paradoxa*) on juvenile plants; but on closer study, the causal fungus was determined to be *Helminthosporium* sp.[1] The disease seemed to be most severe on plants maintained in potassium- and phosphate-deficient cultures. The lack of these nutrients *per se* brought about drying of the leaves; the apparent increase in susceptivity of these plants to the fungal infection aggravated it. The plants which seemed to suffer least from the disease were those in the minus-nitrogen treatment.

Another kind of spotting occurred during the dry months of February, March, April, and May of 1957. The older leaves of plants in almost all treatments developed elliptical specks of about one by two millimeters in size. The specks were at first yellow and translucent but they rapidly turned orange and ultimately brown (Pl 8,

[2] All subsequent designations of color plates refer to Maerz and Rea-Paul, 1958.

[3] Thanks is due Mr. Gil Divinagracia for identifying it.

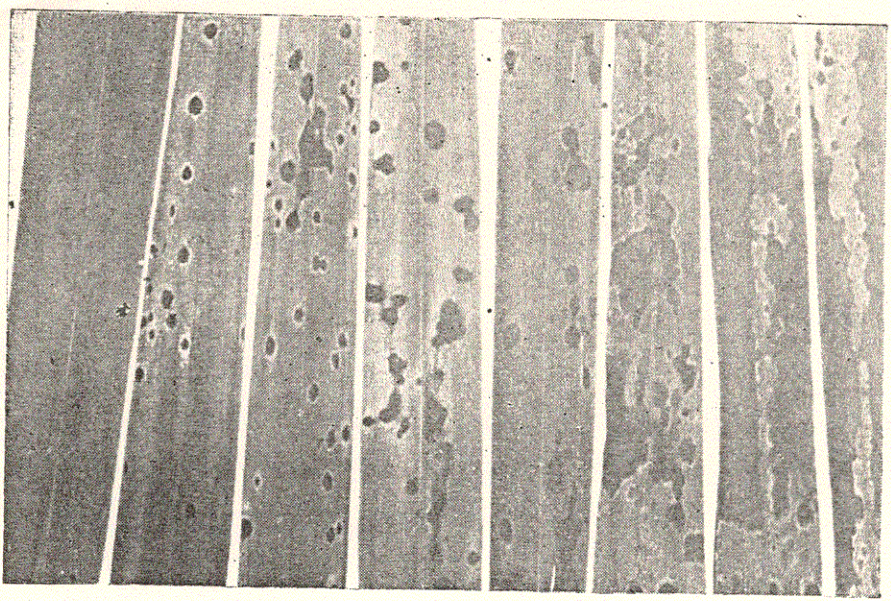

Fig. 1.—Leaflets of increasing severity of infection. Black spots or blotches with orange border.

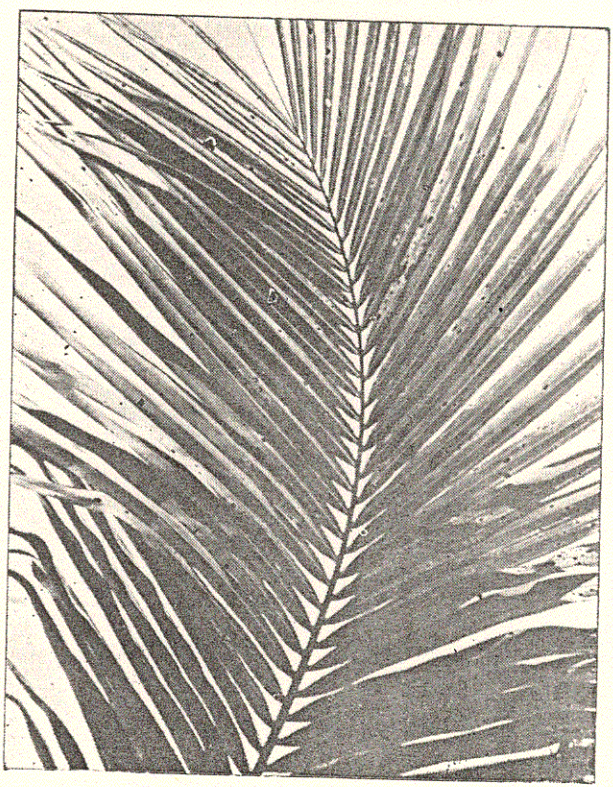

Fig. 2.—Portion of a leaf with spots of *Helminthosporium* sp.

E-12) on the upper surface and water-soaked vandyke brown (Pl 7, A-11) on the lower surface. They were most marked on plants treated with magnesium-deficient solution, hence the suspicion that they might be caused by magnesium deficiency. On the assumption that even the complete Hoagland's solution was not supplying the coconuts enough magnesium, the writers raised the level of magnesium in all solutions to twice its original level. This alleviated but little the malady. Late in 1958 when the writers were reviewing the observations of the previous two years, they became impressed with the recurrence of the abnormality during the dry season and decided that probably the spots were brought about by the accumulation of salts in the sand as a consequence of too rapid evaporation during these months, coupled with insufficient water used in flushing out the residual salt in the sand. During the dry months of 1959, the sand was flushed out with water every other week. The treatment seemed to have obviated the difficulty.

A third case of deterioration was the occasional yellow or orange blotch noticed around the midrib of the older leaves of some plants. The blotches seemed to be most prevalent on plants which were not receiving nitrogen The mosaic appearance tended to suggest that they were virus in nature. On the other hand, their occurrence on old leaves and especially on nitrogen-deficient plants gave ground to the suspicion that they might be one aspect of protoplasmic degradation.

Complete. In September, 1956, the Helminthosporium leaf spot was noticed to be quite heavy on plant No. 156. Plants 103, 122, and 143 had light infections. The plants were pruned in order to minimize the source of inoculum. The latter three plants were noticed to have improved considerably in February, 1957 and practically freed of the leafspot. The former was so set back by the infection that even in January, 1958 when it had almost recovered from this, it was still much smaller than the other three.

Fig. 3 shows the relative sizes of a plant in this treatment after one and four years in the complete culture. (The drum which is 57 cm. in diameter can serve as an internal scale in these pictures). The plant at right is much smaller than a corresponding five-year old plant grown in the soil. This is because the root of the plant is pot bound. Even as early as the second and third year of treatment, the roots had already reached the bottom of the drums.

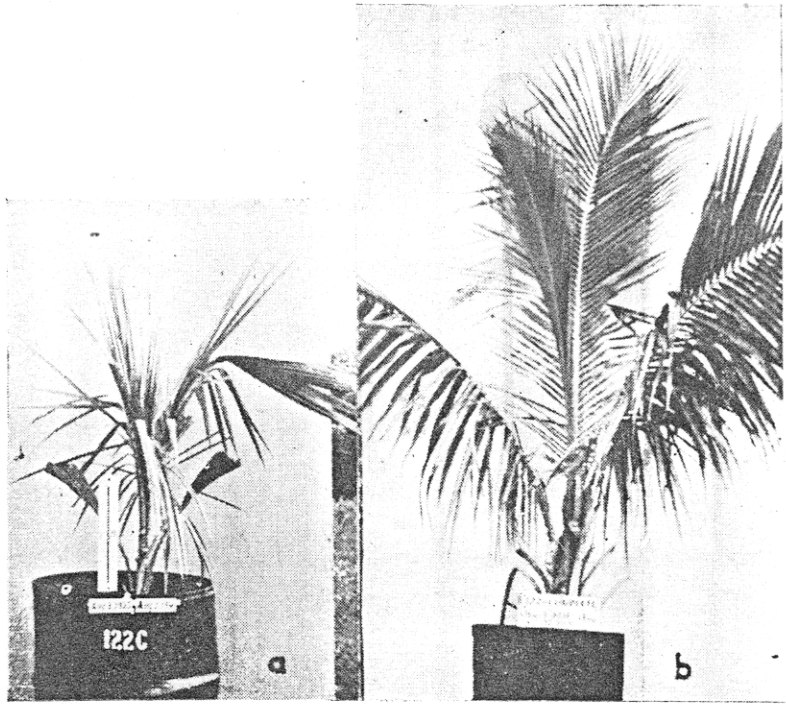

Fig. 3.—A plant receiving the complete solution after one and four years of treatment. Plant (a) is approximately two years of age. Note that the distal pinnae of the youngest leaf are still webbed.

The youngest leaf of this plant (fig. 4) is gracefully arched and the leaflets ascend at an angle of 45 degrees with the rachis. They are fairly long and pliant.

The following are the descriptions of the plants as they appeared on August 6, 1959:

Plant 122 had five exserted leaves; oldest leaf showed stubs of leaflets sampled for chemical analysis; distal leaflets, dried to almost lead grey (Pl 55, A-1); they had brown spots (Pl 1, C-9 to J-10) 3 by 5 mm., more or less grouped in colonies; basal leaflets, green. Next oldest leaf also showed stubs of leaflets sampled for analysis; similar to oldest leaf except that extent of drying was less. Third leaf, uniformly green (Pl 22, H-8 to L-9); some leaflets had dried patches, apparently attacked by leaf miner; rachis gracefully arched. Fourth leaf, lighter green than third (Pl 22, K-3 to L-5),

Fifth leaf, not fully expanded and leaflets still coherent at tips; leaflets even lighter green than fourth and the unexpanded ones almost yellow (Pl 19, E-4 to D-7).

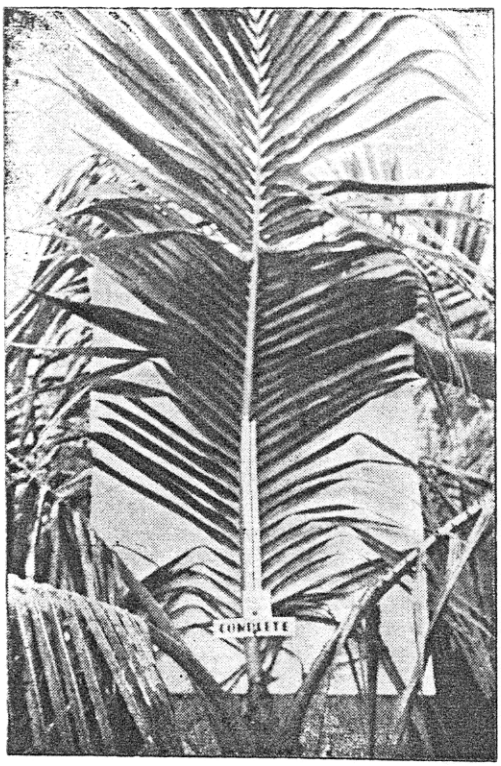

Fig. 4.—Close-up of the youngest fully exserted leaf of plant with complete solution. Pinnae at 45° angle with rachis.

Plant 103 showed no marked differences from plant 122.

Plant 143 had profuse brown specks (Pl 7, C-10 to C-12), 1 by 2 mm.; specks tended to concentrate along margins of leaflets; even petioles had specks along the edges, which coalesce and form virtual stripes.

In general, the plants were well proportioned (fig. 3 and 4) and except for the drying old leaves, they may be considered of a normal green color. Fig. 17 indicates how the leaflets of the complete culture compare with homologous leaflets in the other treatments.

Plant 111, also similar to plant 121 except that the leaves were darker green (Pl 20, L-4).

Minos phosphate. Right at the start (August, 1956), plants No. 100 and 126 were unthrifty and heavily attacked by Helminthosporium leaf spot. Even the youngest unexpanded leaf had big disease spots . Plant 126 ultimately died and was replaced on November 21. 1956 with plant 170, which had hitherto been maintained in complete solution.

Although, in general the plants were stunted, they remained darker green than those in the complete culture. The old leaves died of severe drying and the leafspot disease; but unlike the other plants which underwent changes in shades of color from yellow to brown, they remained essentially dark-green until they ultimately and almost abruptly turned brown. Yellowing of the margins of leaflets in old deteriorating leaves was observed only during the dry months of March to May.

In the early stage, the plants were not distinctly different from those receiving the complete solution (cf. fig. 3 and 7). But in the later stages, there was much rosetting in the phosphate-deficient plants. The young leaf came out with difficulty, oftentimes remaining not fully exserted (fig. 8) while the succeeding one was already half-way out and its distal leaflets unfolded.

At the last observation, plant 117 had six exserted leaves; in general, petiole was short and leaflets closely set together. Oldest leaf was severely drying (firing) at distal end; heavily attacked by Helminthosporium disease; leaflets remained dark-green and hardly turned yellow before drying; basal leaflets dark green (Pl 22, I-6). Next leaf, more severely attacked by the disease so that leaflets appeared tattered. Third oldest leaf was previously sampled; distal leaflets, with disease spots and starting to dry; middle leaflets, dark green (Pl 24, J-8) with occasional disease spots.

Plant 100 had five exserted leaves; bases, closely encased in "guinit" or stipule; severely attacked by Helminhtosporium disease. Oldest and next oldest leaves, drying; leaflets, very short.

Plant 115 seemed to be more vigorous than plant 117; about the same color of leaves; almost free from disease; petioles tended to be short and leaflets closely set.

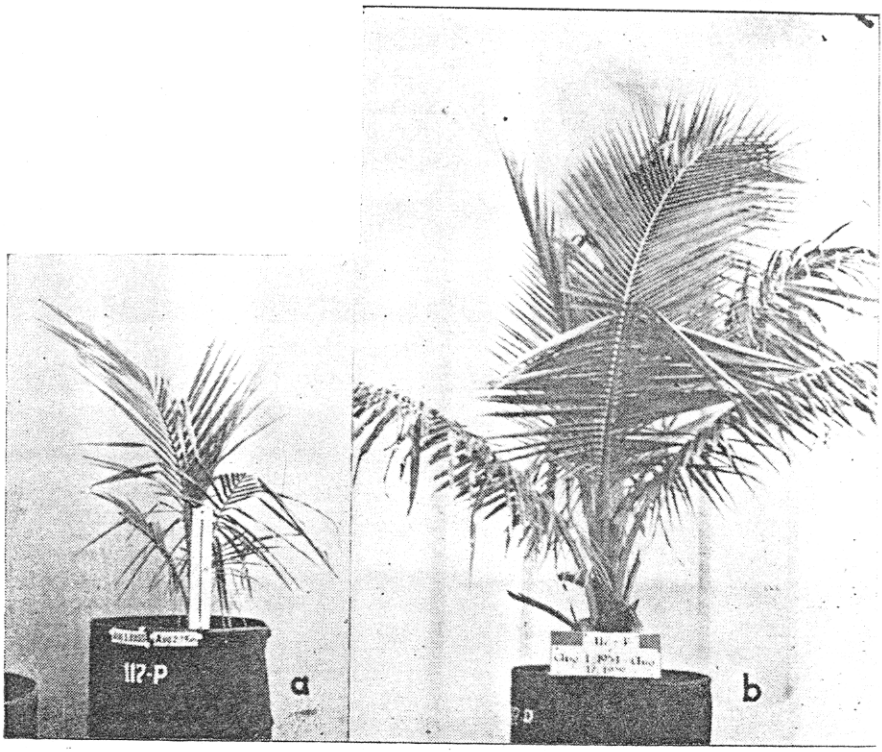

Fig. 7.—Plant receiving no phosphate. Note the severe drying of old leaves and tendency of leaves (a) to form rosette.

Plant 126, had four exserted leaves; slightly better than plant 117 and almost like plant 115; showed attack of leaf-miner.

Because the leaves were dark green and in a rosette at this stage of severe phosphate deficiency, the symptoms were quite distinct from nitrogen deficiency. This is contrary to observations with corn or tomato where severe phosphate deficiency may be confused with severe nitrogen deficiency.

Minus potassium. In August, 1956, plant 102 was heavily attacked by Helminthosporium leaf spot. It was very small as a result of the continuous heavy pruning of infected parts. The deterioration was quite rapid and in October, only one leaf remained. The other three plants were normal at the start, but plants 96 and 137 became badly infected with Helminthosporium. They were given the complete solution for 149 days; this enabled them to recover con-

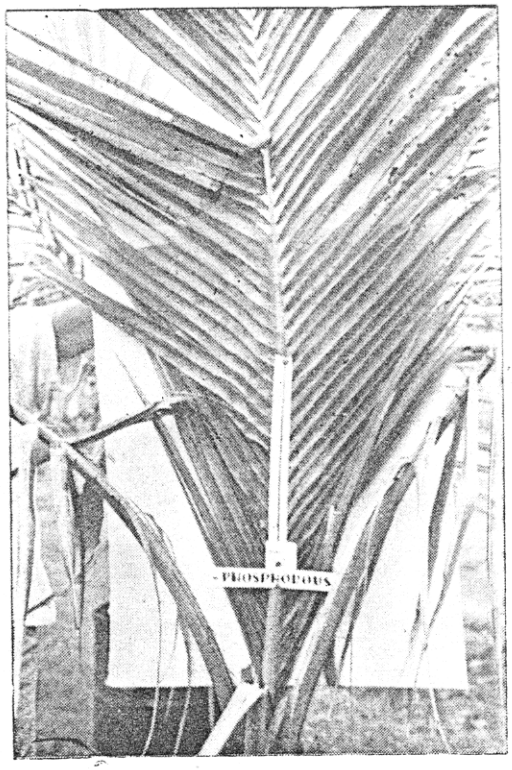

Fig. 8.—Close-up of youngest leaf. Note the crowding of pinnae and the short petiole. Exsertion is very much delayed

siderably. Plant 169 was not bothered by the disease but it exhibited the orange, brown, and black little spots along the margins (fig. 17) early in the experiment. However, it remained tall and comparable in size with those receiving the complete solution. It was only in August, 1959 when the older leaves dried very fast and the plant started to deteriorate (fig. 9b).

At the final observation, plant 169 had six exserted leaves; it was generally dark green and apparently normal like plants in the complete culture. Oldest leaf was severely drying at distal end; middle leaflets, green (Pl 24, L-8). Next leaf had dried or drying areas; drying started with the formation of brown areas (Pl 14, B-10) which developed into grey (Pl 6, A-7 on upper surface and D-6 on

lower surface). All the younger leaves were green (Pl 24, L-8) and without yellow or brown spots.

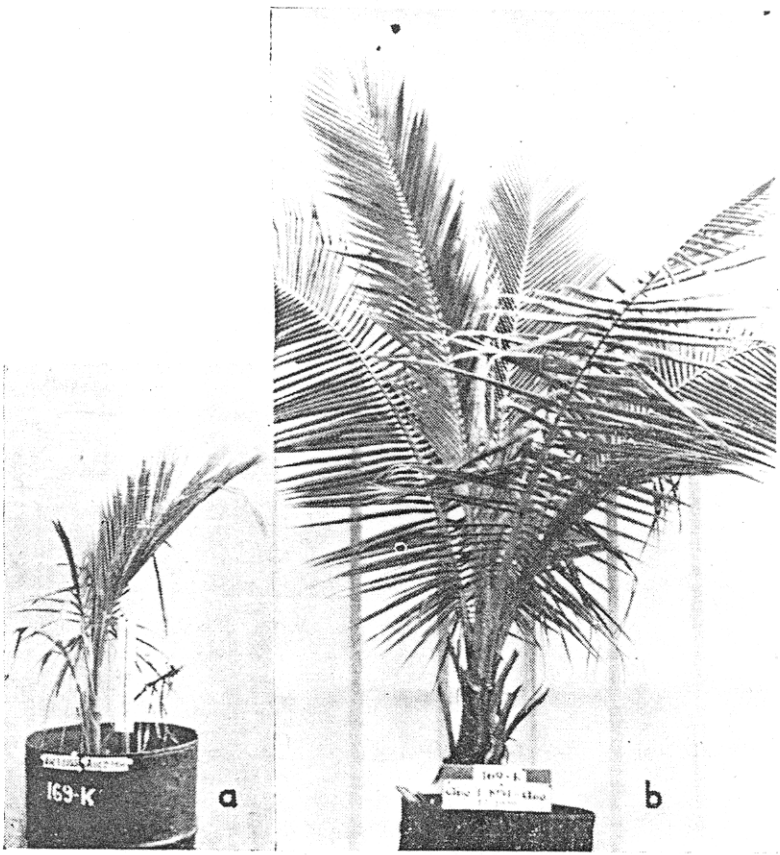

Fig. 9.—Plant receiving no potassium. Note drying (or firing) of old leaves.

Plants 96 and 102 were similar to plant 169; oldest leaf, also severely drying.

The oldest and next leaves of plant 137 were severely drying in extensive areas ("firing"); drying began as small and profuse pin-head-sized brown dots (Pl 7, E-12) which coalesced and formed dried brown areas (Pl 6, A-7). Third oldest leaf, had moderate Helminthosporium disease infection; middle leaflets, green (Pl 22, E-6). Youngest leaf had disease infection.

Minus calcium. In September, 1956, plant 99 was noticed to be attacked by Helminthosporium leaf spot. In addition, the leaflets tended to be narrow. The other plants of this treatment appeared normal. There was an imperceptible transformation of the plants into a tall slender form with rather sparse leaves. The irregular mosaic blotches along the midrib of leaflets were deep yellow to orange. They were more intensely colored than the blotches on the minus-nitrogen plants. Apparently anthocyanin is intensified with calcium deficiency. Except for the more rapid drying of older leaves, the plants seemed to remain normal up to the last observation (fig. 10b). Fig. 11 shows the slender and sparse young leaf, with leaflets ascending at an angle of almost 30 degrees with the rachis.

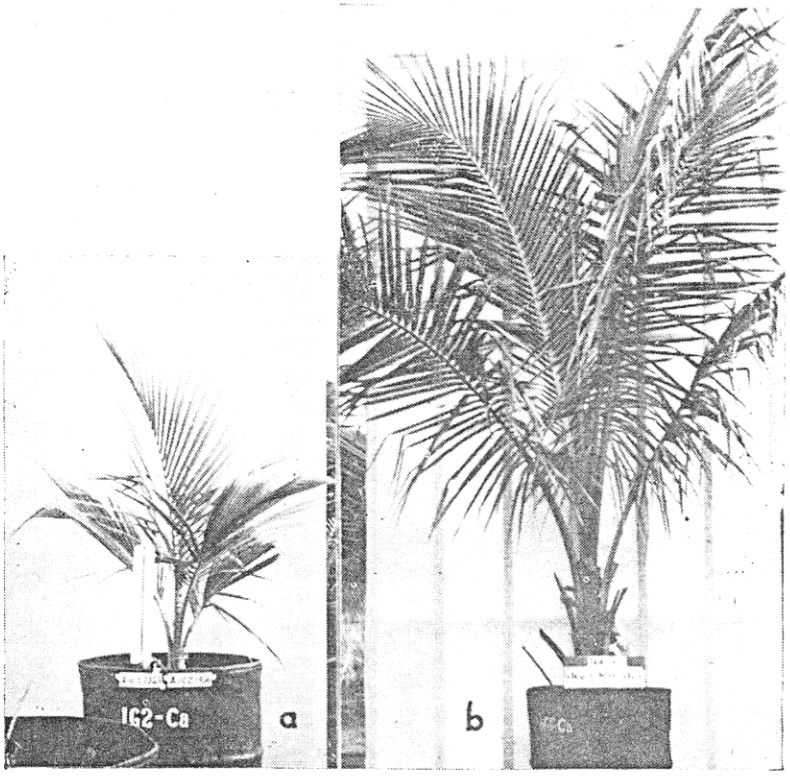

Fig. 10.—Plant receiving no calcium. Note long petiole and tucked-in leaves. Old leaves are drying.

At the last observation, plant 162 had four exserted leaves. Leaves tended to cluster together into a tuft giving the plant a tall

and slender appearance. Oldest leaf, drying at distal end; brown spots (Pl 15, A-8 to C-8), about 1 by 2 mm. in diameter, coalesced into extensive and irregular dried areas; petiole, green. Next leaf appeared brownish because of many spots, but background color was light green (Pl 14 J-2); leaflets seemed to lack water. Third leaf had three or four diseased spots; showed light green haze along midribs as if moderately infected; background color was green (Pl 22, H-7). Youngest leaf was apparently normal.

Plant 99 was similar to plant 162; petiole color, tuscan tan (Pl 13, D-8).

Plant 147 was similar to plant 162; petiole color, tan (Pl 12, B-1); young leaves, more pronouncely tucked in.

Plant 166 was the same as plant 162; oldest leaf had disease spots about 0.5 by 1 cm.

Minus magnesium. In August, 1956 and a few months after, plants 93, 98, and 114 were very healthy and tended to be bigger than the plants receiving the complete solution. However, plant 171 started with a heavy infection of Helminthosporium leaf spot. It died in September and was replaced with a new plant. The disease bothered the plants of this treatment but not as severely as those in the minus-phosphate and the minus-potassium cultures.

In October, 1956, water-soaked areas (fig. 17) appeared in the older leaves of all plants. This may be considered as one symptom of magnesium deficiency.

In May, 1958, the older leaves of all the plants in this treatment assumed bright color which soon turned brown (bronzing). They were very conspicuous and could be picked out from the rest of the plants even from a distance. This characteristic is reminiscent to that observed on coconuts in San Miguel Island, the supposed origin of cadang-cadang of coconuts.

At the last observation, they seemed to be normal, except for the drying of the older leaves (fig. 12b). Plant 114 had five exserted leaves. Oldest leaf, drying at distal end; drying started as profuse elliptical brown dots (cf. spotting due to salt accumulation); petiole color, cinnamon (Pl 12, E-7) next leaf, previously sampled for analysis; also drying and with profuse brown dots. Third oldest leaf had numerous spots; general color, garland green (Pl 22, H-7). Youngest leaf appeared normal, except for light blotches along mid-

rib; blotches probably related to those noted in nitrogen-deficient plants.

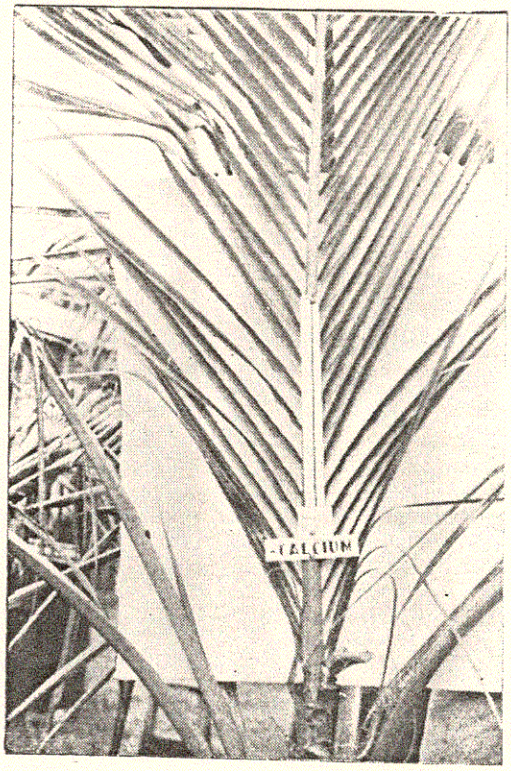

Fig. 11.—Close-up of youngest fully exserted leaf. Note pinnae ascending at 30° with rachis giving it a tucked-in appearance; also, relatively greater distance between pinnae.

Plants 93 and 98 were the same as plant 114, except that the petiole of the latter was lincoln green (Pl 23, J-4).

Minus sulfate. Even before the plants were transferred to the big drums, some plants in this treatment had turned chlorotic; the distal end of the leaves became greatly stunted so that the leaf approached the shape of a buri leaf (fig. 13a). The plants varied greatly in the time they responded to lack of sulfate. Plant 116 deteriorated rather fast and was replaced with a new plant on September 24, 1956. In December 1956, most of the plants had to be pruned heavily on account of the attack of Heltminthosporium leaf spot.

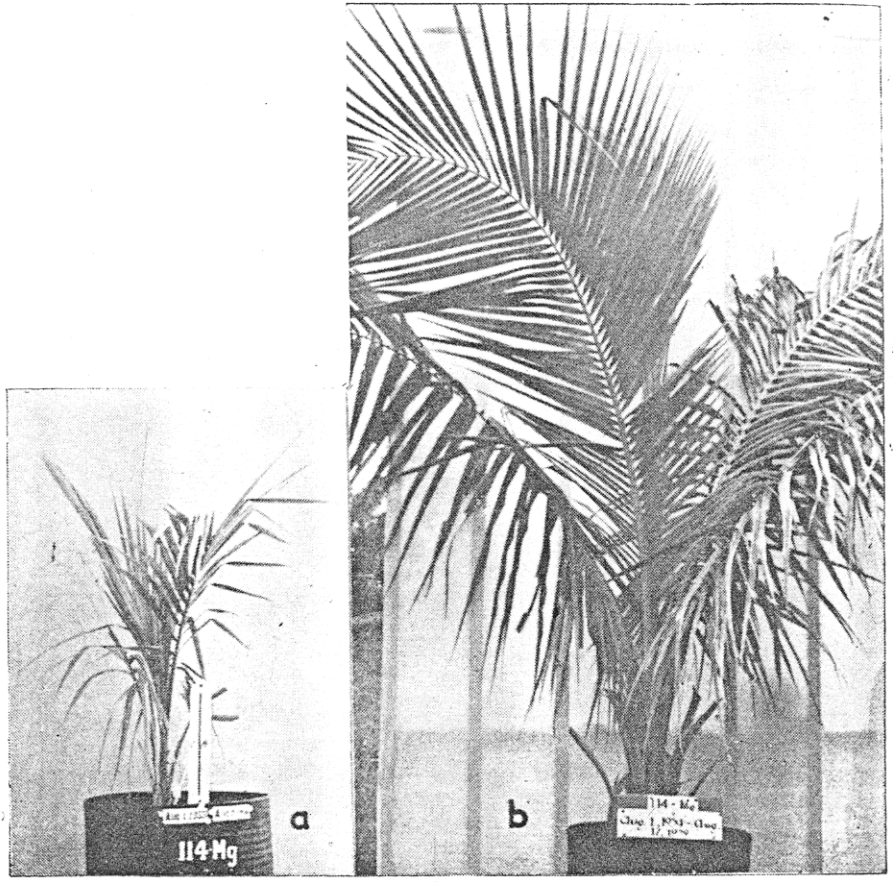

Fig. 12.—Plant receiving no magnesium. Except for the bright color of drying old leaves, the plant appears normal.

Yellowing developed imperceptibly. There was a tendency for the second and third youngest leaves to turn yellowish ahead of the others. It was a dirty yellow in which a green haze or mottling (especially along the midrib) was set on a yellow background. This is quite distinct from the clear yellow in nitrogen deficiency. By November, 1958, all the plants had turned yellow.

The leaves had short petioles and presented a rosette appearance (fig. 13b). Plants 116 and 145, however, differed from the other two replicates in that they produced slender, weak rachis which bent almost in a semi-circle (fig. 14).

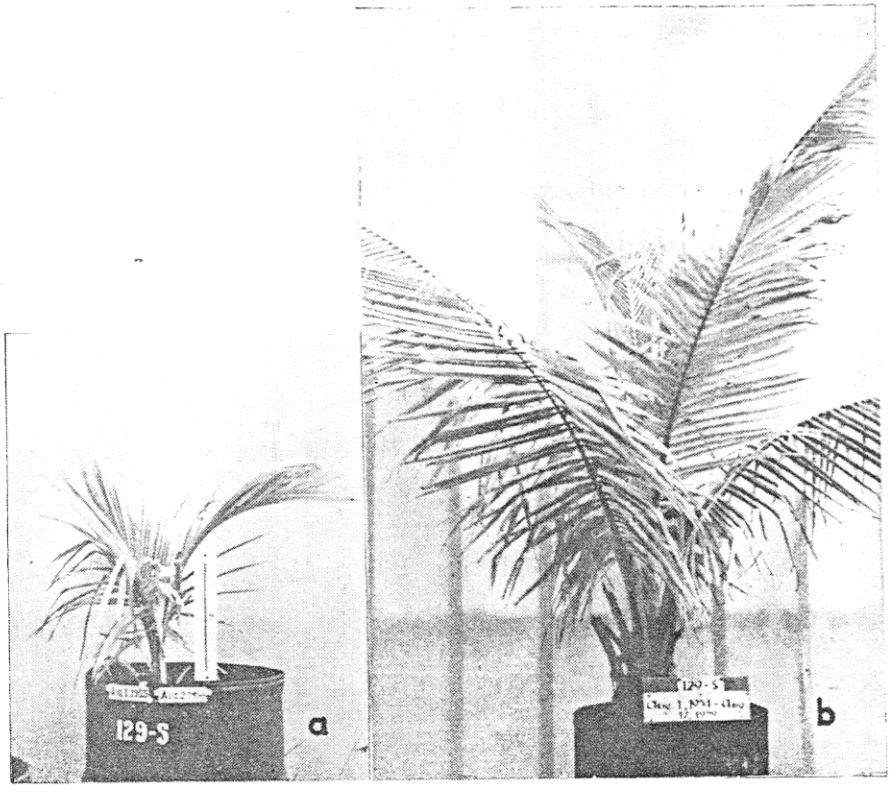

Fig. 13.—Plant receiving no sulfate. Leaves tend to form rosette.

Fig. 14.—Close-up of plant to show very weak young leaf arching in almost a semi-circle.

At the last observation, plant 129 had five exserted leaves. It appeared stunted; petiole, exserted only about 15 cm. beyond the stipule or "guinit"; grape green (Pl 21, K-1); leaflets, conspinuously short. Oldest leaf, silver green (Pl 21, H-3) at basal region and yellow ochre (Pl 11, L-7) at distal region; distal leaflets, drying. Next leaf, previously sampled for analysis; color similar to oldest leaf. Third leaf, slightly arched; midrib region had mosaic yellow coloration, which were more profuse on the basal leaflets than either the middle or distal leaflets; middle leaflets had brown patches due to attack of leaf-miners. Fourth leaf, oil yellow (Pl 12, L-1 to L-3); arched lightly like the third oldest; yellow mosaic pattern, visible in region of midribs.

Plant 116 had six exserted leaves. Oldest and next oldest leaves similar to those of plant 129. Third leaf arched to almost a semi-circle (fig. 14). Fourth, fifth, and sixth leaf appeared normal.

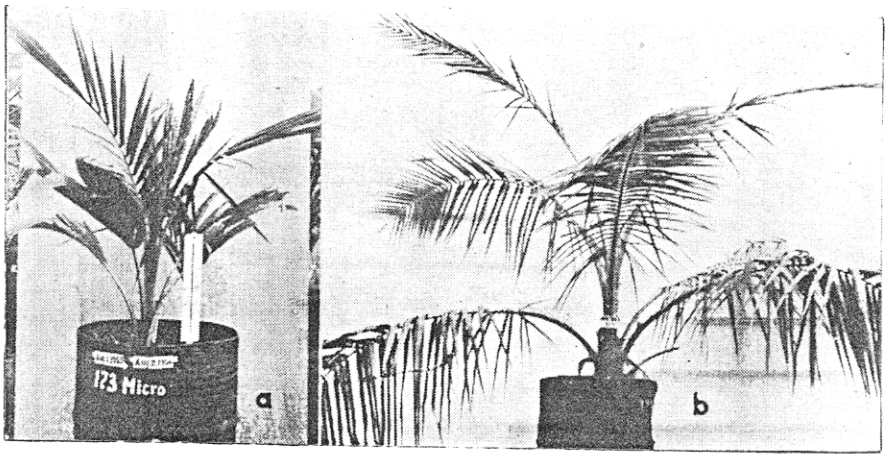

Fig. 15.—Plant receiving no micro-nutrients. Note horizontal position of old leaves and distorted young leaf at (b).

Plant 145 had five exserted leaves; similar to plant 129 except that third leaf was arched into a semi-circle; oldest and next oldest leaves dried in extensive brown areas (Pl 14, A-10).

Plant 165 had four exserted leaves; similar to plant 129; mosaic yellow pattern, very visible in third leaf; plant, stunted.

Minus micro-nutrients. In September 1956, the plants were generally big and very similar to those receiving the complete solution

(fig. 15a). They varied greatly in susceptibility to the Helminthosporium leaf spot.

On October 7, 1958, plant 173 produced a young leaf with frizzled leaflets (fig. 16). The succeeding leaves became more and more sparse until only the rachis remained. The old leaves were weak and projected from the base almost horizontally (fig. 15b).

Fig. 16.—Close-up of young leaf with frizzled and brittle leaflets.

Of the micro-nutrients (boron, copper, manganese, molybdenum, and zinc) boron-deficiency was suspected to have caused the distortion of the young leaves. To confirm this suspicion, a solution of borax (5 ppm boron) was applied on the clasping leaf-bases. The subsequent leaves recovered from the abnormality.

At the last observation, plant 173 had five fully opened leaves. Oldest leaf, previously sampled; leaflets, short especially at distal end of leaf; with profuse brown dots (Pl 16, A-9 to A-12 on upper

surface and Pl 15, E-11 on lower surface). Second oldest leaf, more spindling than first; leaflets, malformed and brittle. Third, fourth, and fifth leaf, apparently normal and dark green. This was probably brought about by sprays of 10 ppm boron as borax. Youngest leaf still unopened appeared malformed, with leaflets rather coherent at tips.

Plant 109 had normal looking three oldest leaves; the third, however, showed signs of brittleness. The two youngest leaves were almost without leaflets; rachis, swollen and weak.

Plant 161 had six exserted leaves; five eldest leaves, normal and dark green. The sixth leaf was slightly malformed. The seventh leaf yet unopened, brittle, and malformed.

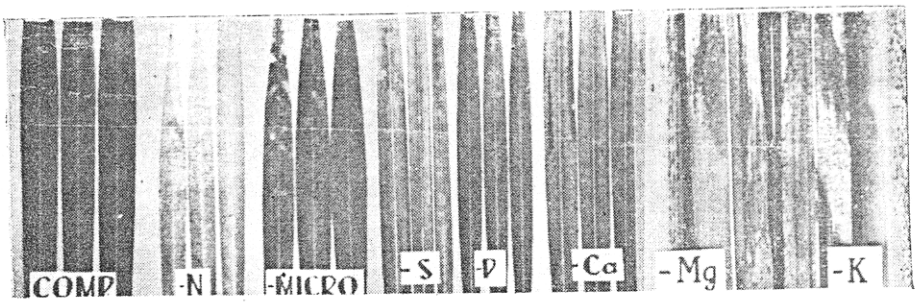

Fig. 17.—Comparative appearance of leaflets from third youngest leaves of the various treatments.

Plant 163 had four fully opened leaves. The fifth and sixth leaves still unopened but malformed; heavily attacked by Helminthosporium; almost dead.

Growth Measurement

Height. The heights of plants taken from the lid of the drum to the tip of the tallest leaf are graphically presented in figure 18. In general, the maximum height was attained some time in September, 1957. After this, the plants hardly grew and in the cases of minus-nitrogen, minus-phosphate, and minus-sulfate, the plants tended to decrease in height in 1959. The former period may be taken as the time when the roots were not yet bound, and the later period of hardly any growth probably indicates that the roots were pot bound. The decrease in height in some treatments at the end of observation

could mean that the deficiency of the particular nutrient was exerting marked adverse effect.

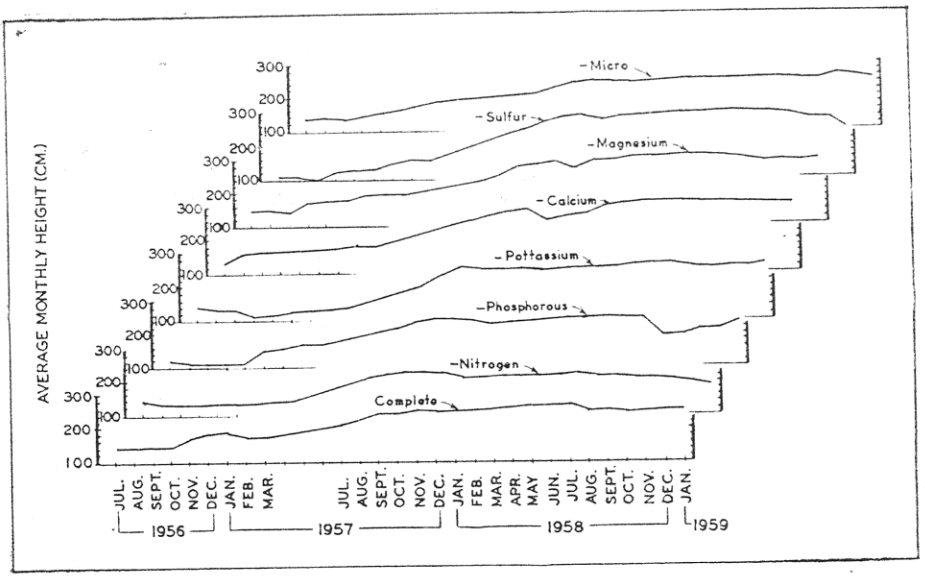

Fig. 18.—Average monthly height from the lid of the drum to the tip of the longest leaf

The minus-calcium and minus-magnesium plants were taller than those in the complete solution (control). Those in the minus-nitrogen, minus-phosphate, and minus-sulfate were shorter than the control.

Diameter of stem. Figure 19 indicates that there was, in general, a fairly rapid increase in stem diameter up to September 1957. Thereafter, the increase was slow but steady. With the exception of minus-nitrogen, there seemed to be little or no effect of treatment on this character.

Number of leaves. The number of leaves (fig. 20) assumed an approximately similar trend as the height of plants. The maximum number was attained in July to September, 1957. The number remained fairly steady up to November, 1958. Apparently, the number of new leaves produced just balanced the leaves which dried up. After this period, however, all treatments decreased in leaf number, except minus-phosphate.

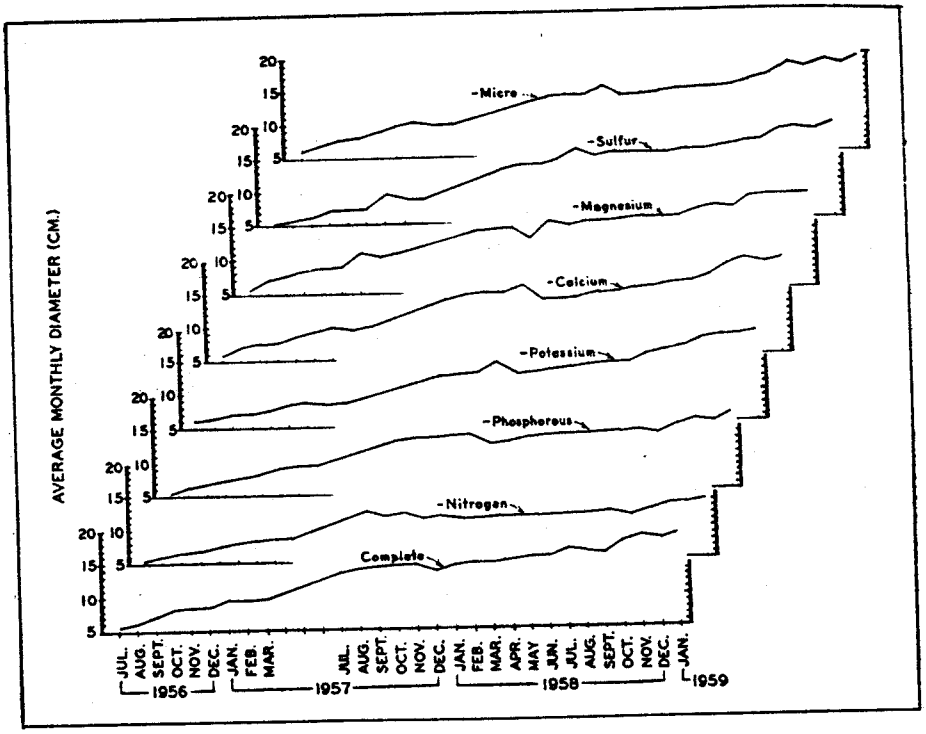

Fig. 19.—Average monthly diameter of stem at the ground surface.

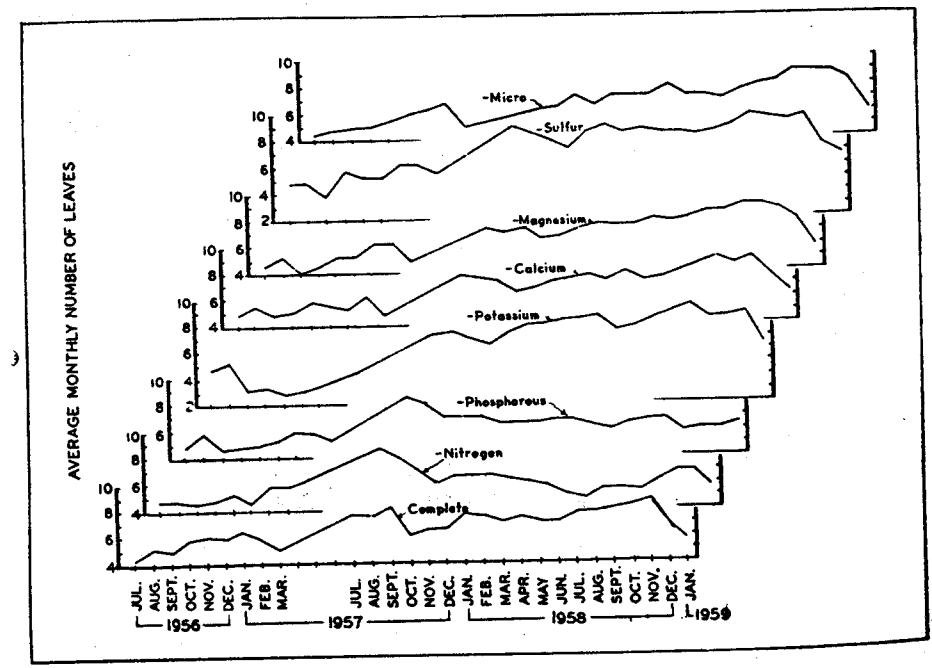

Fig. 20.—Average number of leaves in the different deficiency treatments.

The minus-nitrogen and minus-phosphate cultures had generally less leaves than the other treatments. On the other hand, the minus-sulfate plants ended to produce the most leaves.

Chemical Composition

Inorganic constituents. The analysis for total nitrogen, phosphorus, potassium, calcium, and magnesium are presented in table 3.

Total nitrogen was conspicuously low in the leaves of plants not receiving nitrogen (0.91 per cent). It was less than half of those receiving the complete solution. The minus-calcium plants tended to have less total nitrogen (1.54 per cent) than most other treatments. This may be a reflection of the part played by calcium in nitrogen utilization. Prevot and Ollagnier as cited by Baseden and Southern (1959) placed the critical nitrogen of leaves at 1.70 per cent. It is important to note that the average per cent nitrogen in these two cultures are below the critical level.

The phosphorus content of leaves was high in the young plant and progressively decreased with age. Mild nitrogen deficiency had no effect on phosphorus content but acute deficiency had apparently a marked adverse effect. As expected, phosphorus deficiency was reflected in low percentage of phosphorus in the leaves but the reduction was not striking (0.13 per cent vs. 0.17 per cent for the control). The other deficiency treatments seemed to have not affected the phosphorus content. Baseden and Southern reported 0.13 per cent phosphorus in leaves of trees bearing 0-15 nuts.

The potassium-deficient plants had 0.86 per cent potassium, which was less than half of those in the plants receiving the complete solution (2.00 per cent). There was also a tendency for potassium to be low in the minus-calcium and minus-magnesium plants. This, however, may be just fortuitous. Nitrogen deficiency tended to increase the percentage of potassium (2.35 per cent). The total content of potassium may not have been necessarily higher than the control, because the plants in this treatment were very much smaller. According to Baseden and Southern, potassium deficiency symptoms may occur when leaf potassium is 0.8 per cent.

Per cent calcium tended to be higher in the minus-nitrogen and minus-micronutrient plants than in the control. The minus-calcium plants had the lowest calcium content among the treatments. It was about three-fourths as much as the control. The minus-sulfur plants

TABLE 3.—*Percentages of the different elements in recently matured leaves of coconut receiving the different treatments and taken at different times of the year*

ELEMENT	SAMPLING *	COMPLETE	—NITROGEN	—PHOSPHATE	—POTASSIUM	—CALCIUM	—MAGNESIUM	—SULFATE	—MICRO
Per cent Nitrogen	1	2.06	1.08	1.62	1.89	1.50	1.73	1.65	1.96
	2	1.78	0.74	1.49	1.53	1.33	1.62	1.66	1.79
	3	1.81	0.72	1.93	2.02	1.62	1.72	1.71	2.00
	4	1.68	0.68	1.63	2.03	1.64	—	1.48	1.98
	5	2.19	1.42	2.04	1.85	1.62	1.96	2.41	1.88
	6	2.02	0.83	1.91	1.84	1.54	1.82	2.04	1.97
	Ave.	1.93	0.91	1.77	1.86	1.54	1.77	1.83	1.93
Per cent Phosphorus	1	0.30	0.30	0.25	0.32	0.26	0.32	0.24	0.29
	2	0.14	0.18	0.12	0.22	0.20	0.19	0.25	0.17
	3	0.20	0.17	0.12	0.19	0.19	0.18	0.18	0.19
	4	0.12	0.18	0.12	0.18	0.21	—	0.17	0.15
	5	0.13	0.08	0.06	0.07	0.07	0.09	0.11	0.12
	6	0.14	0.08	0.12	0.14	0.12	0.13	0.13	0.13
	Ave.	0.17	0.16	0.13	0.18	0.17	0.18	0.18	0.17
Per cent Potassium	1	—	—	—	—	—	—	—	—
	2	2.11	2.10	1.91	0.79	1.90	2.42	1.97	1.96
	3	2.82	3.45	2.11	—	2.31	2.40	3.60	2.70
	4	3.24	2.34	3.00	1.40	1.61	—	—	3.51
	5	0.63	1.89	1.31	—	1.18	1.23	0.87	1.19
	6	1.21	1.97	1.66	0.39	1.41	1.52	1.59	1.34
	Ave.	2.00	2.35	1.99	0.86	1.68	1.89	2.01	2.14
Per cent Calcium	1	0.39	0.37	0.32	0.35	0.33	0.35	0.29	0.45
	2	0.33	0.44	0.36	0.30	0.29	0.35	0.30	0.36
	3	0.40	0.54	0.43	0.38	0.30	0.39	0.31	0.42
	4	0.36	0.49	0.37	0.38	0.22	—	0.34	0.43
	5	0.45	0.15	0.18	0.43	0.26	0.37	0.36	0.53
	6	0.44	0.72	0.54	0.62	0.32	0.60	0.46	0.59
	Ave.	0.39	0.45	0.37	0.41	0.28	0.42	0.34	0.46
Per cent Magnesium	1	0.27	0.17	0.16	0.26	0.25	0.16	0.20	0.28
	2	0.26	0.25	0.27	0.27	0.31	0.19	0.34	0.29
	3	0.25	0.31	0.27	0.31	0.33	0.09	1.19	0.24
	4	0.09	0.16	0.12	0.16	0.13	—	0.08	0.16
	5	0.06	0.26	0.17	0.08	0.07	—	0.29	0.05
	6	0.30	0.25	0.24	0.30	0.27	0.09	0.30	0.24
	Ave.	0.21	0.23	0.21	0.23	0.23	0.13	0.24	0.21

* 1—July 19, 1957 3—Feb. 6, 1958 5—Nov. 29, 1958
2—Oct. 16, 1957 4—May 20, 1958 6—Sept. 3, 1959

tended to have less calcium than the control. All the other treatments may be considered as having the same content of calcium as the control.

The minus-magnesium treatment had about one-half as much magnesium as the plants receiving the complete solution. All the other treatments did not bring about an appreciable change in the percentage of magnesium in the plant.

Carbohydrate content. The different forms of carbahydrates may serve as indicators of metabolic activity in the plant. For instance, a high percentage of simple sugar may mean rapid production or ineffective polymerization. This aspect is also of interest on account of the claim that trees suffering from cadang-cadang (yellow decline of coconut) had lower contents of simple sugar and starch than the healthy plants.

Table 4 indicates that the reducing sugars in the minus-nitrogen,

TABLE 4.—*Per cent reducing sugar, total sugar, and starch in recently matured leaves of coconut receiving different treatments taken at different times of the year*

CONSTITUENT	SAMPLING [a]	COMPLETE	—NITROGEN	—PHOSPHATE	—POTASSIUM	—CALCIUM	—MAGNESIUM	—SULFATE	—MICRO
Per cent Reducing sugar	1	3.20	2.68	3.85	3.56	3.42	2.82	3.59	2.07
	2	3.66	2.16	1.63	2.13	1.97	1.88	3.05	3.24
	3	2.57	2.15	2.26	3.27	2.86	2.27	2.15	2.81
	4	1.19	1.04	1.21	1.26	1.08	—	1.28	1.02
	Ave.	2.66	2.01	2.24	2.56	2.33	2.32	2.52	2.28
Per cent Non-reducing sugar	1	0.95	0.52	1.04	0.32	0.64	0.62	—	2.51
	2	2.14	1.78	1.74	1.10	—	0.47	1.63	3.36
	3	—	—	—	0.86	0.24	1.01	2.71	0.64
	4	3.11	1.36	1.20	3.46	2.27	—	1.86	3.26
	Ave.	2.06	1.22	1.33	1.44	1.05	0.70	2.06	2.44
Per cent Total sugar	1	4.15	3.20	4.89	3.88	4.06	3.44	4.87	4.58
	2	5.80	3.94	3.37	3.23	—	2.35	—	6.60
	3	—	—	—	4.13	3.10	3.28	3.78	3.45
	4	4.30	2.40	2.41	4.72	3.35	—	3.99	4.28
	Ave.	4.75	3.18	3.55	3.99	3.51	3.02	4.22	4.73
Per cent Starch	1	14.26	15.13	12.89	13.41	16.11	16.45	12.48	14.43
	2	16.35	17.38	15.04	18.47	14.98	12.75	14.80	15.45
	3	14.70	16.31	14.54	13.62	14.62	14.20	14.16	13.37
	4	13.69	17.76	12.03	11.39	12.89	—	12.53	11.49
	Ave.	14.75	16.64	13.63	14.22	14.65	14.46	13.49	13.68

[a] 1—July 19, 1957
2—October 16, 1957
3—February 6, 1958
4—May 20, 1958

minus-phosphate, minus-calcium, minus-magnesium, and minus-micro-nutrient treatments were less than in the control, minus-potassium, and minus-sulfate treatments.

The non-reducing sugars of the minus-sulfate and minus-micro-nutrients were about equal to the control. All the other treatments had less non-reducing sugars than the latter.

In percentage of starch, the minus-nitrogen had much more than the control. The minus-potassium, minus-calcium, and minus-magnesium treatments may be considered as having equal starch content as the control. All the other treatments had less starch.

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