COCOS, (1985) 3, 22-28
Printed in Sri Lanka.

The Sulphur Nutrition of Coconut*

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SUMMARY

The sulphur content in the sixth leaf from the apex of coconut palms was found to be the most sensitive index to sulphur treatments. Although the S concentration in this leaf correlated negatively with applied levels of S, the response curve was concave. Sulphur treatments increased the total yield of fruits and weight of copra, but decreased the weight of kernel per nut. The derived curve for yield versus S concentration in the tissue was C-shaped, attributed to growth dilution effects caused by enhanced initial growth following the restoration of a nutrient in minimum.

As for most other crops, investigations of the sulphur nutrition of coconut has lagged behind in research on mineral nutrition. Velasco *et al.* (1960) described symptoms of S deficiency in young coconut plants grown in sand cultures, but the first report of field observations on sulphur deficiency in coconut was probably from Papua-New Guinea (Southern, 1969), where young and adult coconut palms showing severe symptoms of sulphur deficiency were identified and successfully treated. Bioassay studies of soils in Sri Lanka, using grasses and legumes as indicator plants, have shown that at least some soils in the coconut growing areas could be deficient in sulphur (Paltridge and Santhirasegaram, 1957; Santhirasegaram *et al.*, 1966), but several decades of cropping have so far produced no visible symptoms of deficiency, and apparently caused no significant drop in yields due to deficiency of sulphur.

Pressure on maximizing production through high-yielding hybrid varieties, and the use of increasing levels of fertilizers, consisting usually of ammonium sulphate, muriate of potash and saphos phosphate, is likely to lead to a higher demand for other essential nutrients. Against this background there is the possibility of urea replacing ammonium sulphate as a source of nitrogen for plantation crops in Sri Lanka, with the likelihood that nutrients such as sulphur may rapidly reach limiting levels. A project was therefore initiated to study the S nutrition of coconut, to assess the optimum requirements of this nutrient to maintain high levels of production. This paper describes preliminary work on sampling techniques to evaluate the sulphur status of coconut palms, and the effects of sulphur on fruit production.

EXPERIMENTAL

Field experiment and yield records

A fertilizer experiment, laid down in October 1966 at Ratgama in Sri Lanka, was the source from which plant materials and yield data were obtained for this study. The object of the experiment was to determine yield response curves of adult coconut palms

*Reprinted from the Journal of Experimental Agriculture 13, 265-271(1977) by courtesy of the Editors and the Cambridge University Press.

to the application of sulphur, zinc and boron, to assess optimum levels for their application under the soil (lateritic gravelly) and climatic (low country, wet zone) conditions typical of the Southern Province of Sri Lanka.

The experimental layout was a central composite rotatable second order design, with 15 plots of 18 trees each. All plots were given an annual basal treatment of 700g potassium as muriate of potash, 170g phosphorus as saphos phosphate and 650g of nitrogen as urea per tree, applied uniformly in a circle 1.5m radius round the base of each palm, and turned into the soil.

Each of the factors, sulphur (as elemental sulphur), zinc (as zinc oxide) and boron (as sodium borate) was tested at five annual levels per tree, namely

Sulphur—0, 1125, 2250, 3375 and 4500g S,
Zinc—0, 110, 220, 330 and 440g Zn, and
Boron—0, 35, 70, 105 and 140g B.

The first differential manuring was in June 1968 and annually thereafter, but application of zinc had to be suspended in 1970 and 1972 because zinc oxide was not available. The soil pH dropped from an initial range of 5·1–5·3 to 4·8–4·9 in the sulphur-treated plots but there was no correlation between soil pH and the applied levels of sulphur. Ripe fruits were harvested at two-monthly intervals, and at each pick two or three bunches mature fruits were harvested, stored on the plot for 30 days, and then dehusked to record weights of nuts. The copra equivalent of yield was determined by multiplying the husk-free nut weights by a factor of 0.32.

Plant samples

To evaluate the merits of different leaf positions in nutritional studies on S, samples from the first, sixth, tenth, fourteenth and seventeenth leaves were taken in January 1973 from the fertilizer experiment described above, considering the youngest fully opened leaf as number one, and the others in increasing order of maturity. In each plot ten healthy palms were selected, and in each leaf category six leaflets were taken from each side of the rachis near mid-point on the leaf. The 60 leaflets thus collected from each leaf category of a plot were combined to form a sample, which was collected within three consecutive days, between 7.30 and 11.00 a.m. each day.

In the laboratory the leaflets were washed in distilled water and then stripped into laminae and midribs, the latter discarded, and the middle third of the lamina strips dried overnight at 90°C and powdered to pass a 1·0 mm sieve. One gram of the oven-dried leaf material was used to determine total S.

Samples of coconut kernel were also examined to compare leaf and kernel S with treatments, and relations between S concentration in kernel and yield. Samples of mature fruits were collected from each plot on 1 August 1973, taking 25 uniform fruits (17·5cm short axis and similar maturity). These fruits were seasoned for 30 days and clean-husked for recording individual weights, then split and the kernel carefully removed and weighed. Uniform strips of kernel from each fruit of each plot were combined to form samples for chemical analysis, using 2g to determine total S.

Analytical procedure

The plant sub-sample was subjected to wet digestion with a mixture of nitric acid (20ml) and perchloric acid (5ml), finally made up to 25ml, with 10ml transferred to a flask and sufficient 2N NaOH added to give a yellow colour with thymol blue indicator, followed by adding 1 ml 5N HCl and 15 ml 96% ethanol. The solution was then boiled and S precipitated as sulphate with 2 ml of 2.4% barium chloride solution, allowed to stand overnight and filtered through a Jena glass crucible of porosity number four. The precipitate was washed thrice with 10 ml portions of cold water, and dissolved in a solution of 10 ml hot 0.02M EDTA

Table 1. *t values for significance of regression for effects of applied S on the S concentration of different leaves*

Factor	Leaf position: 1st	6th	10th	14th	17th
B ...	—2.02	—3.13*	0.24	—1.29	—0.25
Zn ...	—0.23	0.27	—2.74*	0.63	—0.83
S ...	—0.86	—3.64*	—1.65	0.37	0.25
B^2 ...	—0.05	4.46**	8.31***	3.20*	—2.65*
Zn^2 ...	—2.95*	3.46*	7.34***	0.73	—4.01*
S^2 ...	1.58	13.22***	6.93***	9.14**	4.87**
B × Zn ...	0.51	—0.57	—2.88*	—1.07	—0.67
B × S ...	0.33	2.82*	0.98	0.61	0.22
Zn × S ...	—0.33	0.44	0.55	—1.26	0.68
Multiple correlation coefficient ...	0.7518	0.9455	0.9045	0.8615	0.7607

*, **, *** significant at P = 0.05, 0.01 and 0.001.

and 5 ml 9N ammonia. Finally the excess EDTA was titrated with 0.02M solution magnesium sulphate to evaluate barium and hence the S. This method gave good recoveries and had reproducible results.

RESULTS AND DISCUSSION

The data (Table 1), representing '*t*' values for significance of regression for the effects of S treatments on leaf S, show that different leaf categories gave different responses to treatments. However, the multiple correlation coefficients show a characteristic pattern, reaching a peak value in the sixth leaf. Both the number of significant factors, and the dimensions of the multiple correlation coefficients, suggest that the sixth and tenth leaves are more sensitive than others. It is also evident that the sixth leaf is more sensitive than the tenth for factors involving S treatments, and it was therefore decided to select the sixth leaf for nutritional investigations on S in adult coconut palms.

In the sixth leaf, as also for most others, S concentrations in the leaf tissue were negatively correlated with the applied levels of sulphur. However, the positive correlation of the quadratic effect of sulphur indicated that the response curve could in fact be concave, as was clear from the data presented (Fig. 1) for the effects of treatments on the concentration of S in leaf tissue. It is interesting to note that both the total *content* of sulphur per nut, and also the sulphur *concentration* in the fresh kernel, followed identical patterns (of Figs. 1 and 2). In both tissues the minimal concentration of sulphur was associated with a relatively higher level of sulphur supply.

To explain this phenomenon Steenbjerg and Jakobsen (1963) introduced the concept of the 'quotient of utilization', which was defined as the reciprocal of concentration, low concentrations being associated with high quotients. It may accordingly be assumed that a resumption of the supply of sulphur probably generated a rapid increase in growth and production, causing in effect a 'diluting' effect on S levels in the plant tissues (see later section).

The data summarised in Tables 2 and 3 show yield responses in 1972 to sulphur treatments, from which it is evident that both the weight of husked fruit and of fresh kernel decreased gradually with increasing levels of applied S. The ratio of the weight of kernel to the weight of husked nut also significantly decreased with sulphur treatments (P = 0.05).

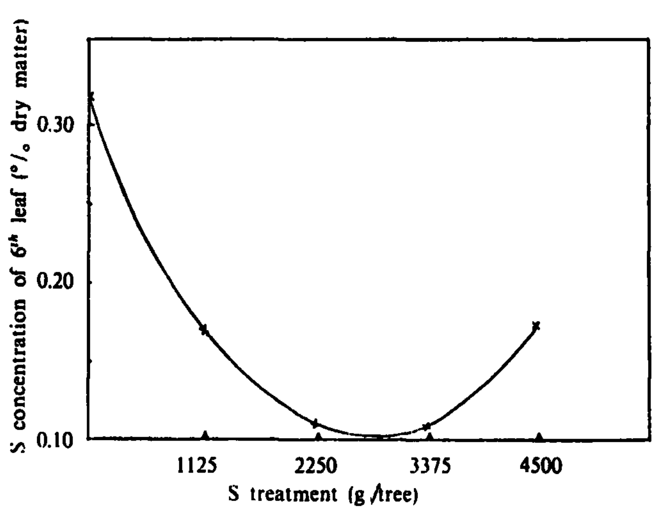

Fig. 1. Effects of applied S on S concentration of sixth leaf. (N.B. In all figures S concentrations, yields, etc., are estimated from the production functions.)

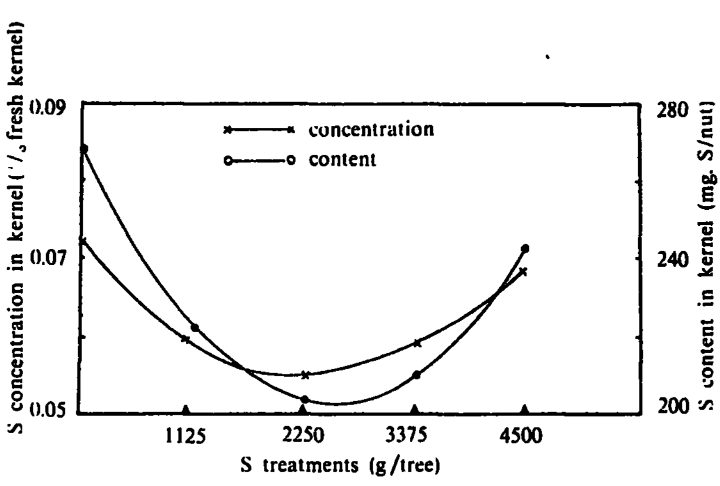

Fig. 2. Effects of applied S on content and concentration of S in the kernels.

On the other hand, yields of fruits and copra increased with treatments (Table 3), not significantly in 1972 (possibly on account of the unusually long dry spell from December 1971 to April 1972), but significantly (P = 0.05) in 1970. The effects of treatment on yield of copra (kg/ha) and the weight of kernel per nut (Fig. 3) suggest that sulphur had in effect reduced the size of fruits but increased overall yield. The data derived for copra out-turn (Table 3) confirm these assumptions, showing that to turn out one metric ton of copra at the highest supply level of sulphur (S_4), at least another 50 additional fruits would be required above the number required to turn out the same quantity of copra at the zero level of sulphur supply (So,), However, this is more than compensated by the overall increase in yield of fruits.

In Figure 4 the yield response curve is shown as a function of nutrient concentration in the leaf tissue. The form of the curve for yield *versus* S concentration in the kernel would be very similar. The concentration in the tissue initially decreases, whilst yield increases, as the level of S supply increases. This trend then changes sign, and takes the form (top part of curve) that has been described as 'normal'. Although the yield in this study refers to yield of fruits and not the yield of vegetative dry matter, the form of the curve is comparable to the C-shaped curve described by Steenbjerg and Jakobsen for a nutrient in minimum.

Table 2. *Effects of Streatmentson weights of husked nuts and kernels*

Applied S	Mean weight of husked nut		Mean weight of kernel per nut		Wt of kernel × 100*
(g/tree)	(g)	(—)	(g)	(—)	Wt of husked nut
Nil	704	100	385	100	55
1125	702	99.7	378	98.2	54
2250	697	99.0	370	96.1	53
3375	688	97.7	362	94.0	53
4500	679	96.4	354	91.9	52

*Linear responses significant at P = 0.05.

Table 3. *Effects of S treatments on yields of fruits and copra*

Applied S	Nuts/ha		Copra/ha		Copra out-turn
(g/tree)	(No.)	(—)	(kg)	(—)	(nuts/t of copra)
Nil	10,147	100	2292	100	4430
1125	10,789	106	2440	107	4420
2250	11,313	112	2559	112	4420
3375	11,737	116	2638	115	4450
4500	12,034	119	2687	117	4480

Bates (1971) states that plant analysis has very limited value for diagnostic purposes unless the C-shaped curve can be avoided. Ulrich and Hylton (1968) found that whereas the total and organic forms of plant sulphur gave C-shaped response curves in stems of ryegrass, the sulphate sulphur fraction gave a 'normal' curve and was thus considered superior to others. In their study the occurrence of a C-shaped curve has been attributed to the larger proportion of embryonic to non-embryonic, nodal to internodal tissue in stems of the highly deficient ryegrass plants. This would mean recognizing an internal disorder caused by the treatments and it would therefore remain debatable whether avoidance of a C-shaped curve by the use of different material or different nutrient fractions is to be considered a justifiable exercise.

In the present study S concentrations in two different tissue (leaf and kernel) followed a similar pattern with respect to treatments, and hence for yields. Furthermore, in the same tissue material (kernel), the concentration as well as the content per component of S followed similar trends with respect to treatment.

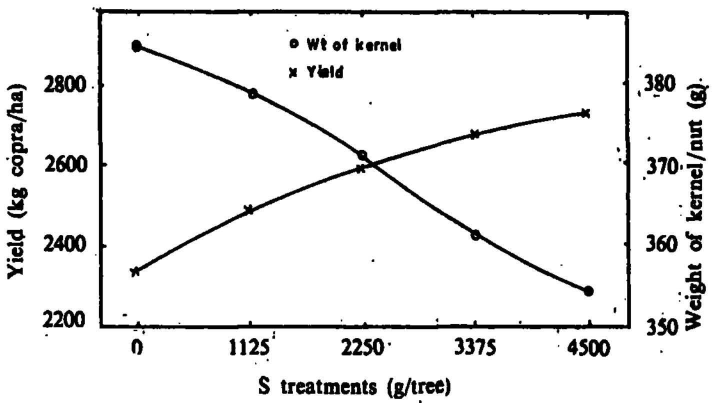

Fig. 3. Relations between yield of copra and weight of kernel per nut, in relation to applied levels of S.

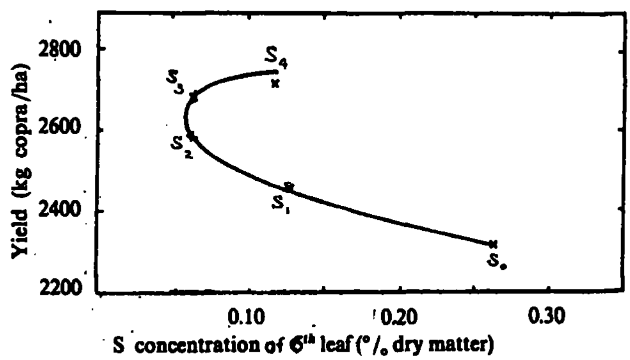

Fig. 4. Relations between yield and S concentration of sixth leaf (S applied/tree/annum; S_0 = nil, $S_1 \doteq 1125$ g, $S_2 = 2250$ g, $S_3 = 3375$ g and $S_4 = 4500$ g).

If it is considered that this trend is inevitable, but could be explained in terms of quotients of utilization, then (as suggested by Steenbjerg and Jakobsen for a nutrient in minimum) these quotients may reflect a measure of the 'metabolic situation' in the plant. A situation has been established in which high utilization quotients occur with enhanced growth and production. In simple terms, this should mean that if production is limited due to a nutrient being present at deficient levels, restoration of its supply causes growth dilution to take place as a result of a rapid initial increase in growth. The resulting intial drop in the tissue concentration of S is thus considered to be a manifestation of this phenomenon. Subsequently, when growth is normalized to the extent that tissue nutrient levels respond positively to treatments, the characteristic sigmoid form of curve is manifest.

ACKNOWLEDGEMENT

The work was financed by the Coconut Research Board of Sri Lanka. The authors wish to express their gratitude to the Director, Coconut Research Institute of Sri Lanka for providing facilities, to Mr. V. Abeywardena for statistical advice, and to the Staff of the Soil Chemistry Division of the Coconut Research Institute for technical assistance.

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