Sulphur Nutrition of Coconut

● K.S. Shanmugam

Former Chief Agronomist, The Fertilisers And Chemicals Travancore Ltd, Udyogamandal, Kochi – 683501. Kerala.

ABSTRACT

Sulphur deficiency in coconut is not reported in India even though it is increasingly reported in many other crops in India. There is every possibility of the incidence of sulphur deficiency in coconut since all the causes for the occurrence of sulphur deficiency in other crops are equally applicable to coconut also. It can be presumed that coconut palms in India suffer from sulphur deficiency and it may have been overlooked because of absence of visual symptoms.

Available information on Sulphur Nutrition of Coconut are gleaned from various literature and are compiled in this Review Article. Sulphur deficiency symptoms in coconut are illustrated guidelines for sulphur management for coconut are formulated.

The coconut palm (Cocos nucifera L) is one of the important plantation crops of India. India produces 21665 million coconuts annually from an area of 2.14 million hectares with a productivity of 10122 nuts per hectare. (2013-14). Coconut crop contributes Rs. 10,000 crores to the GDP of the country and earns Rs. 2700 crores (US $ 420 million) of valuable foreign exchange. Coconut crop provides food and livelihood security to 12 million people in India.

Since the scope for area expansion is limited, productivity improvement is the only option. There is good scope for productivity improvement in coconut. While the yield of best managed coconut gardens is 27300 nuts per hectare, the national average is 10122 nuts per hectare. The yield gap is whopping 60%. This yield gap can be bridged by improving coconut productivity, which can be accomplished by adopting best cultivation practices in general and balanced application of plant nutrients in particular.

Coconut is an exhaustive crop and it requires considerable quantity of plant nutrients for its sustainable performance.

Nutrient uptake by Coconut palm (kg)

	Particulars	Nutrients					
		N	P	K	S	Ca	Mg
		(Nutrients are in elemental form)					
1.	Nutrient uptake (kg) by 150 palms, yielding 100 nuts per palm i.e. 15000 nuts per hectare.	49	7	96	4	5	8
2.	Nutrient uptake (kg) by palms producing 6.7 tons copra:						
	A) By Whole palms	174	20	250	30	70	39
	B) By Nuts only	108	15	193	9	9	15
3.	Nutrient uptake (kg) per ton of copra.	16.1	2.2	28.8	1.3	1.3	2.2

Source : IFA World Fertiliser use Manual. 1992.

Coconut farmers apply Nitrogen (N), Phosphorus (P) and Potassium (K) only. Other nutrients are taken up by the palms from the soil thereby depleting their soil reserves and causing deficiencies in soils. Such a phenomenon is now occurring with respect to sulphur, causing sulphur deficiency in soils and palms in coconut gardens.

Sulphur in plants

German Botanist Julius von Sachs had in 1860 that sulphur is an essential for the growth and development of plants. As an essential plant nutrient, sulphur has certain specific functions to perform in plants.

Some key functions of sulphur in plants

1. Protein production: Sulphur is a vital constituent of three amino acids viz cystine (27%S), cysteine (26%S) and methionine (21%S), which are the building blocks of protein.

2. Chlorophyll formation: Although not a constituent, sulphur is required for the formation of chlorophyll, the green substance in leaves and stems, which carries out photosynthesis, the primary function of green plants.

3. Biosynthesis of oils: Sulphur is known as the master nutrient for oil production in plants. Sulphur is crucial for oil yielding crops like coconut, oil palm etc.

4. Sulphur is required for biosynthesis of vital biocompounds such as vitamins (Biotin and Thiamin), glutathione, coenzyme A, sulfolipids and ferredoxin.

Sulphur is absorbed by plant roots in sulphate form (SO4). Plants generally contain 0.2-0.4% sulphur. Sulphur is relatively immobile within the plants but it is mobile in soils. Sulphur use efficiency is found to be 10%.

Sulphur as a plant nutrient is becoming increasingly important in Indian agriculture because of the increasing incidences of sulphur deficiency and crop responses to sulphur application are being reported from various parts of the country. (Shanmugam.K.S. 1995). Sulphur is now recognized as the Fourth Major Plant Nutrient along with Nitrogen (N), Phosphorus (P) and Potassium (K).

Sulphur deficiency in Coconut

Sulphur deficiency in coconut was first reported in 1959 by S.C. Baseden in Papua New Guinea. In 1960, Velasco et al described sulphur deficiency symptoms exhibited by young coconut palms, grown in sand culture by omitting sulphur. P.J. Southern investigated sulphur deficiency in coconut by conducting field experiments in Papua New Guinea. He illustrated the field symptoms of sulphur deficiency in coconut. He recommended 2 pounds (900 grams) sulphur per palm to ameliorate sulphur deficiency in coconut. (Southern P.J. 1969). Sulphur deficiency in coconut has been reported in several countries such as Pacific Islands, Comoro Islands, Mozambique, the Philippines, Indonesia and Sri Lanka.

It is a paradox that sulphur deficiency in coconut has not been reported in India where all causes of sulphur deficiency are existent and where many other crops respond to sulphur application, which confirm the prevalence of suboptimal level of available sulphur in soils. Systematic research on 'Sulphur nutrition of coconut' has not been attempted in India. Database on

sulphur nutrition of coconut is almost nil. Even sulphur uptake and removal data are not available for coconut in India.

A survey of coconut growing tracts in Kerala, conducted in 1975, indicated that sulphur content of 14th leaf of the palm ranged from 0.10 to 0.16 percent, which were below the optimum level of 0.19 percent sulphur. (Cecil, SR and Khan, HH. 1993). That survey presumably suggested the possibility of incidence of sulphur deficiency in coconut palms in Kerala, most probably the hidden hung sulphur deficiency without the visual symptoms.

Sulphur deficiency symptoms in coconut palms

Crop plants, including coconut, suffering from sulphur deficiency exhibit characteristic symptoms which are visible to naked eye. Sulphur deficiency symptoms in coconut palms are described as follows:

Coconut seedlings:

In sulphur deficient coconut seedlings, youngest leaves are worst affected. The colour of leaves varies from pale green through yellow to yellowish orange. Leaves become necrotic in severely affected seedlings and many seedlings die.

Young Coconut palms:

In sulphur deficient young palms, length of leaves which emerge after field planting is much shorter than normal, with abnormally early splitting of leaflets. Colour of leaves ranges from yellow to orange. Tips of leaflets become grey, necrosed and curled. Necrosis spreads rapidly all over the leaf, which dries out completely. Growth in young palms stops and the palms remain stunted. (Southern .P.J. 1967; Ollagnier .M and Ochs .R 1972).

Adult Coconut palms:

In sulphur deficient adult palms, chlorosis and yellowing of leaves appear first in the oldest leaves and gradually spread to other leaves in the crown. Colour of the leaves ranges from bright yellow to vivid orange. In individual leaflets, chlorosis starts from the tips, rapidly extends until whole leaflet including midrib becomes chlorotic. Leaf size is very much reduced. Abnormal arching of leaves appears prematurely as the midrib becomes weak and pliant. There is a marked tendency of sulphur deficient palms to retain their dead leaves for more than an year. Such dead leave hang around the stem like an apron. Number of leaves in the crown is lesser than normal. Such live leaves are shorter in length and they stand in upright position. Constriction is seen in the stem diameter. Nuts are few and small in size. Nuts, particularly of button size nuts, fall prematurely. (Ohler. J.G. 1999; Southern .P.J. 1960)

Matured nuts have normal kernel thickness but on drying the kernel collapses into thin, soft, flexible and leathery copra, often brown in colour, which is usually referred to as rubbery copra, possessing poor physical and chemical qualities, particularly with a very low oil content (38% oil). This rubbery copra readily absorbs more moisture than the normal copra, leading to rapid deterioration. (Southern .P.J. 1967)

Hidden hunger of Sulphur deficiency

Hidden hunger in plants is a nutrient deficient condition, which depresses plant yield without showing visual symptoms. (Wahid .P.A. 1984). In coconut palms, Sulphur deficiency without visual symptoms occurs when the sulphur content in the 14th leaf of the palm is less than the optimum level of 0.19 percent, whereas visual symptoms of sulphur deficiency appear on the palm when the leaf sulphur content is less than the critical level of 0.13 percent. It can be presumed that coconut palms in India suffer from sulphur deficiency and it may have been overlooked because of the absence of visual symptoms.

Causes of Sulphur deficiency in India

It is now well established that sulphur deficiency is wide spread in Indian soils and crops. The following causes are attributed to sulphur deficiency in India.

Increased uptake of sulphur by crops

Uptake of all plant nutrients including sulphur by a crop is a function of its growth and yield. (Shanmugam .K.S. 1995). Average yield of coconut in India has increased from 5238 nuts per hectare in 1950-51 to 10122 nuts pet hectare in 2013-14. Increased yields of coconuts have invariably increased the uptake of sulphur from soils and depleted soil sulphur reserves considerably over the years and consequently caused sulphur deficiency in soils and palms in coconut gardens. With an area of 2.14 million hectares in India coconut crop removes annually about 8560 tonnes of sulphur from soil.

2.Use of Sulphur free fertilisers

In the early years, when Ammonium sulphate and Superphosphate were the major source of fertilisers, sulphur deficiency had not occurred in our crops as these fertilisers supplied 24% and 12% sulphur respectively as incidental nutrient to crops. With the large scale use of sulphur free fertilisers like Urea and Diammonium phosphate (DAP) incidental supply of sulphur to crops is reduced drastically thereby causing sulphur deficiency in our crops (Shanmugam.K.S. 1995)

Research conducted by S.K. Das and N.P. Datta has shown that with the continuous use of sulphur free fertilisers, the reserve sulphur status in the soil goes down and after the harvest of 6th crop, the soil reached a deficient level of available sulphur and the 7th crop started responding to sulphur application. (Das .S.K and Datta. N.P. 1973). This finding is indeed an eye opener of the imminent danger of continuous use of sulphur free fertilisers like Urea and Diammonium phosphate (DAP)

Mozambique lesson

Because of change in the fertiliser policy, coconut planters in Mozambique switched over to Urea from Ammonium sulphate. As long as planters used Ammonium sulphate (24% S) no symptom of sulphur deficiency appeared in their coconut palms. But when urea was used, leaf colour turned yellow and orange with numerous fungal lesions. (Ohler .J.G. 1999). Such a situation prevails now in India also. Because of change in our fertiliser subsidy policy, consumptions of Urea and Diammoium phosphate (DAP) have increased dramatically at the cost of Ammonium sulphate and Superphosphate thereby causing widespread sulphur deficiency in Indian soils and crops.

3. Low organic matter content of Indian soils

Soil organic matter acts as a store house of soil sulphur and about 50-90 percent of soil sulphur is found in soil organic matter. Indian soils are invariably poor in organic matter because hot tropical climate of India is not conducive for higher accumulation of organic matter in soils. Moreover continuous cultivation of crops with repeated tillage readily destroys soil organic matter by increased mineralization. Paucity of organic matter in Indian soils makes them poor in sulphur also. This is further aggravated by lack of addition of organic manures by Indian farmers. In early 1970's, 70 percent of cattle dung in India was used for manuring but it is reduced to 30% in the recent years.

4. Leaching and Erosion losses of sulphur

Because of anionic nature and high solubility, leaching losses of sulphate sulphur (SO4) are generally large, especially in coarse textured soils (Eg. Coastal soils on which coconut is predominantly grown) and in high rainfall areas (Eg. Kerala where large area is under coconut).Sulphur losses through erosion in India can be estimated at 1,30,000 tonnes annually (Tandon. HLS. 2011). Sulphur losses through leaching and erosion are some of the important causes for growing incidence of sulphur deficiency in India.

5.Multistoied mixed cropping in coconut gardens

Wide plant spacing of 7.5m x 7.5m and conducive canopy and root architecture of coconut palms permit multistoried, mixed cropping in coconut gardens. Mixed crops like banana, pineapple, cocao and pepper remove good quantity of sulphur from soil thereby aggravating sulphur deficiency in coconut gardens.

6.Higher Sulphur deficiency in Southern States

Extent of sulphur deficiency is found to be higher in the four southern states, which account for 90% of coconut area and 93% of coconut production of the country. Such a higher sulphur deficiency in the southern states can be detrimental to the coconut production of the country.

Extent of Sulphur deficiency in Southern States			
State	Percentage of soil samples in the category of		
	Low	Medium	High
Kerala	81	18	1
Tamilnadu	26	41	33
Karnataka	43	32	25
Andhra Pradesh	56	34	10
Source : Fertiliser Statistics of FAI, New Delhi 2013-14			

Soils of 'Low' and 'Medium' categories respond well to sulphur application

Diagnostic Tests for Sulphur Deficiency:

1.Soil test for Sulphur deficiency.

Soil sulphur extracted by means 0.15% CaCl2 extractant gives good correlation with sulphur uptake by plants and dry matter yield of plants. Hence this method is commonly used for estimating plant available sulphur in soils. The sulphur status of soils are categorized as follows:

Soil sulphur category	Sulphur content
Low	Less than 7.5 mg S per kg soil
Medium	7.5 – 15.0 mg S per kg soil
High	More than 15 mg S per kg soil

Soils of 'Low' and 'Medium' sulphur category respond well to sulphur application. 10-13 mg sulphur per kg soil is found to be critical for optimum plant growth.

2. Plant test for Sulphur deficiency.

Plant test (Leaf analysis) is accepted as the most reliable method of detecting nutrient deficiencies in a perennial crop like coconut. Magat et al, who studied sulphur deficiency in coconut in the Philippines, found out by means of leaf analysis that the critical level and optimum level of sulphur content of the 14th leaf of coconut palms are 13% S and 19% S respectively.

(Ohler. J.G. 1999). Sulphur deficiency occurs in coconut palms when the leaf sulphur content is below the optimum level. Optimum level of sulphur depends upon nitrogen nutrition of the palms since these two nutrients are intimately linked and are often found to be co-limiting. Nitrogen: Sulphur (N:S) ratio in coconut should be between 10:1 and 13:1. (Ohler.J.G. 1999).

3. Nut water test for sulphur deficiency.

P.J. Southern found out by his research that sulphate content of nut water was an excellent indicator of sulphur deficiency in coconut. He reported that sulphur deficiency symptoms appeared in coconut palms when the sulphate content of nut water was less than 10 ppmS. No symptom of sulphur deficiency appeared when the sulphate content was above 20 ppmS. (Southern. P.J. 1969)

Guidelines for Sulphur management for coconut.

1. Sustainable management of sulphur nutrition of coconut involves judicious blend of organic manures and mineral fertilisers. Despite low efficiency of organic manures, their inclusion in sustainable sulphur management is recommended. Results of Long Term Fertiliser Experiments (LTFE) revealed that regular, annual application of Farmyard manure (FYM) is able to maintain sulphur status in soils to guard against sulphur deficiency.

Sulphur content of some organic manures					
	Nutrient content (%)				
	Organic manure	Sulphur	N	P_2O_5	K_2O
1.	Farmyard manure	0.13	0.50	0.30	0.50
2.	Neem cake*	1.40	5.20	1.00	1.40
3.	Mustard cake	0.68	4.50	1.80	1.40
4.	Cowpea Green manure	0.37	0.71	0.15	0.58
*Among the oil cakes, Neem cake has the highest content of 1.40 percent sulphur.					

Any one of the sulphur containing fertilisers, listed below, should be included in the fertiliser schedule for coconut. This is the most reliable and assured way of sulphur management for coconut crop.

Sulphur content of some of the fertilisers

	Name of the fertiliser	Nutrient content (%)			
		Sulphur	N	P_2O_5	K_2O
1.	Ammonium sulphate	24	20.6	0.0	0.0
2.	Superphosphate	12	0.0	16.0	0.0
3.	Ammonium phosphate sulphate	13-15	20.0	20.0	0.0
4.	Potassium sulphate	18	0.0	0.0	50.0
5.	Magnesium sulphate	12	0.0	0.0	0.0
6.	Agrl. grade mined Gypsum	13-15	0.0	0.0	0.0
7.	Phosphogypsum*	18-20	0.0	0.5 – 1.2	0.0

* Phosphogypsum is a by product from phosphate fertiliser factories. It is a high grade gypsum and is better than agricultural grade mined gypsum because of its higher purity of 90-95%, finer particle size of 100 mesh and higher sulphur content of 18-20%. Agricultural grade mined gypsum has a purity of 60-70%, particle size of 30 mesh and sulphur content of 13-15%. Phosphogypsum is preferable for sulphur nutrition of crops.

Improvement of leaf sulphur content and maintenance of leaf sulphur level at 0.20 to 0.23% in the 14th leaf of coconut palm due to regular application of sulphur containing fertilisers are observed (Cecil.S.R. and Khan.H.H. 1993).

Due to synergistic interaction between sulphur and nitrogen, combined application of sulphur and nitrogen increases the uptake and concentration of each other in coconut palm. Hence fertilisers like Ammonium sulphate and Ammonium phosphate sulphate which can supply both sulphur and nitrogen simultaneously are preferable. They also help to maintain optimum Nitrogen:Sulphur (N:S) ratio between 10:1 and 13:1 in coconut palms.

Continuous application of sulphur free fertilisers like Urea and Diammmonium phosphate (DAP) should be avoided. In the absence of application of sulphur containing fertiliser, application of phosphogypsum at the rate of 2 kg per palm per year can be done. Root feeding of 0.2% phosphogypsum (2 grams phosphogypsum per litre of water) is recommended. Application of Neem cake at the rate of 3-5 kg per palm per year and application of farmyard manure (FYM) at the rate of 30-50 kg per palm per year is recommended. Sulphur availability is reduced in poorly drained soils. Hence drainage facilities in coconut gardens should be improved. Improved drainage would improve sulphur availability in soils.

Present fertiliser recommendation for coconut crop is confined to Nitrogen (N), Phosphorus (P) and Potassium (K) only. Application of NPK only depletes sulphur reserves in soils and causes sulphur deficiency.

Declining use of sulphur containing fertilisers; increasing use of sulphur free fertilisers; increasing uptake of sulphur by crops due to increased yields; lower sulphur content of Indian soils due to their lower organic matter content and larger losses of soil sulphur through leaching and erosion are some of the important causes for sulphur deficiency in Indian soils and crops. All these causes of sulphur deficiency are equally applicable to coconut crop also. Hence there is every possibility of incidence of sulphur deficiency in coconut palms in India, most probably hidden hunger of sulphur deficiency without visual symptoms. It is high time to consider inclusion of sulphur at the rate of 300 grams per palm per year in the State level General NPK Fertiliser recommendation for coconut so as to guard against sulphur deficiency and to prevent yield decline in coconut.

Although the database on sulphur deficiency in coconut crop may be meager, the ominous signs are that sulphur deficiency is a creeping sickness of coconut crop in India. Unless appropriate action is taken, not only could sulphur deficiency become a major yield limiting factor with consequent yield decline in coconut but the efficiency of other applied major nutrients and the economics of their use will be seriously affected, apart from considerable loss of coconut production, which India cannot afford.

Present Address, G3, Deva Shree Flats, 5. VGP Avenue, Seethapathy Nagar, Velachery, Chennai – 600 042. Phone : 044 – 2243 5139, Mobile : 09962980412 ■

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