

**FINAL REPORT OF THE
RESEARCH PROJECT
ON
EVALUATION OF SOLUBOR FOR THE MANAGEMENT OF BORON
DEFICIENCY IN COCONUT**

PROJECT TEAM

Dr. V. Krishnakumar, Head, ICAR CPCRI, Regional Station, Kayamkulam

Dr. Jeena Mathew, Scientist (Soil Science) ICAR CPCRI, Regional Station, Kayamkulam

Dr. C. G. Narayanan Namboothiri, Senior Technical Officer ICAR CPCRI, Regional Station, Kayamkulam



**ICAR-CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
REGIONAL STATION, KAYAMKULAM**

1. Introduction

Coconut is a perennial plantation crop which extensively removes major nutrients such as N (116.79 kg), P (14.02 kg), K (245.43 kg); secondary nutrients such as Ca (40.47 kg), Mg (33.66 kg), and micro nutrients such as Fe (1.14 kg), Mn (0.63 kg), Cu (0.13 kg), Zn (0.44 kg) and B (0.26 kg) per ha per year. Once the palms starts flowering, it continues to bear for another three to four decades. It is for this reason that scientific nutrient management based on the innate fertility of the soil is mandated for coconut productivity. In Kerala, coconut is cultivated in an area of 6.50 lakh ha, with a productivity of 7535 nuts per ha which implies an average of 44 nuts per palm per year, whereas, the average productivity in India is 60 nuts per palm per year (CDB Statistics, 2015).

Often the nutrient management strategies focus on major nutrients with little or less attention paid to the requirement of micronutrients. As per the report of the extensive survey conducted by the Kerala State Planning Board (2014), 90 per cent of the soil in Kerala is acidic in reaction with deficiency of Ca, Mg and B in a severe proportion. Having an annual removal of 0.26 kg boron per ha, coconut requires the application of boron when grown in a soil without sufficient levels to meet the crop requirement.

Among the seven micronutrients essential for crop growth and development, B plays a vital role in oilseed production. It is needed for carbohydrate transport as well as cellular differentiation and development. This element is directly involved in the process of fertilization contributing to pollen producing capacity of anther, viability of pollen tubes, pollen germination and pollen tube growth. It is also involved in stabilizing cell wall constituents and plasma membrane, enhancement of cell division and tissue differentiation, metabolism of nucleic acid,

carbohydrates, protein, auxin and phenols, fertilization and nitrogen metabolism. The translocation of carbohydrates from source to sink is associated with yield enhancement in oil seeds. Boron is also involved in oil synthesis and hence this element can be short listed as a vital element in the growth and productivity of oil seeds. Seed development is hindered by the short supply of B due to the phenol accumulation (Lee and Arnoff, 1967). At low B concentration, the growing points will become necrotic due to the accumulation of phenols and auxins in these regions (Krupnikova and Smrinov, 1981). Agarwala *et al.* (1981) established a close relationship between the boron supply and the pollen producing capacity of the anthers as well as viability of the pollen grains. The primary role of B is in cell wall biosynthesis, phenol metabolism and plasma membrane integrity (Marschner, 1995). According to Shelp *et al.* (1995), B is essential for the normal growth of monocots, dicots, conifers, ferns and several diatom species.

Low levels of boron found in tropical soils, according to Mattiello *et al.* (2009), is attributable to factors such as naturally occurring low fertility levels, removal of nutrients by several successive crops, and the increased use of fertilizers and acidity correctives, which contribute to decrease the solubility of several soil minerals (Keren and Bingham, 1985). Silva *et al.* (1995) and Communar and Keren (2006) also pointed out the importance of factors such as sandy soils, low in organic matter and exposed to heavy rains, which drain much of the boron to deeper layers.

Wide spread deficiency of boron is being reported in coconut. The major symptoms of boron deficiency in coconut are fasciation, inflorescence necrosis, button shedding, hen and chick symptom etc. Boron facilitates the division of meristematic tissues.

The role of boron in sustaining the productivity of coconut has been well documented in literature. It can be seen that boron is required for pollen germination, pollen tube growth and

fruit setting process. The viability of pollen is being facilitated by boron. Mild deficiency of boron is manifested as hooking of leaflets which are much rigid and cannot be straightened without tearing off the leaflets.

Santos *et al.* (2004), from an evaluation of the nutritional status of a coconut palm orchard, reported that boron was one of the most yield limiting factors. According to their findings, the most important elements for coconut production in the order of importance were $K > Ca > B$. Manciot *et al.* (1980) and Sobral (1998), Rognon (1984) observed the critical boron level in plant leaves to be 10 mg kg^{-1} .

In bearing coconut palms, it is recommended that the micronutrient should be applied directly into the soil - in a dosage of 2 kg ha^{-1} of B as borax (Sobral, 1998) when analysis indicates levels lower than 0.2 mg dm^{-3} (hot water) (Teixeira *et al.*, 2005). The application of boron directly into the soil is more efficient than foliar techniques due to the low mobility it shows in plant tissues. Boron applied to the soil has a more persistent effect than when it is deposited in leaf axillae (Pinho *et al.*, 2008b; Broschat, 2011).

Deficiency of boron is caused by insufficient B in the soil. Boron is readily leached through most soils, with a single heavy rain event temporarily leaching most available B out of the root zone. When this leaching stops, B released from decomposing organic matter will again provide adequate B for normal growth of palms wherever there is sufficient organic matter content in the soil. On the other hand, under bleached sandy soils where there is little organic matter, natural recovery of symptoms can seldom be expected. Under such conditions, it is imperative to explore external sources of boron to the soil. Solubor and borax are the two common sources of boron with contents 18 % and 11%, respectively.

The present recommendation for the management of boron deficiency in coconut is 120-180 g of borax in four split doses along with the application of farmyard manure or vermicompost.

2. Objective of the study

The present study was laid out to evaluate the effectiveness of solubor on the correction of boron deficiency symptoms of coconut in the sandy soil of Onattukara region.

3. Materials and Methods

The research programme was scheduled in the ICAR-CPCRI, Regional Station, Kayamkulam to evaluate the role of solubor on the remission of boron deficiency symptoms in coconut. The study was conducted during the period of 2012-2015. All the experimental palms were given fertilisers as per the package of practices recommendations ie., 500:300:1000 N, P₂O₅,K₂O g per palm per year.

3.1 Experimental site

3.1.1. Soil

The soil of the experimental site belongs to Oxyaquic Quartzi Psamment subgroup. Important physico-chemical properties of the soil estimated as per the standard procedures are given in Table 1.

3.1.2 Variety of coconut

West Coast Tall Variety of coconut palms having age 35 years were selected for the study.

3.1.3. Identification of palms

The objective of the study was to find out the effect of boron sources at different doses on the remission of symptoms of boron deficiency in coconut palms. Hence, palms were selected depending on the intensity of symptoms. The symptoms identified were fasciation, inflorescence necrosis, and button shedding. The symptoms were seen either alone or as a combination. For

each treatment, eight palms were selected for the study, thus, total of 24 palms were taken as experimental palms.

3.1.4. Design and layout of experiment

The layout plan of the experimental field is presented in Fig. 1

Design : Completely Randomised Design

No. of replications : 8

Spacing : 7.6 m X 7.6 m

Total number of palms : 24

No. of treatments : 3

T₁: RDF +60 g solubor in two split doses @ 25 and 35 g per palm

T₂: RDF + 250 g borax in two split doses

T₃: RDF alone

(RDF= Recommended dose of chemical fertilizers - 500:300:1000 g N:P₂O₅:K₂O per palm per year)

Borax (11% B) and solubor (18% B) were the sources of boron in the experiment.

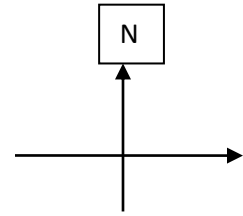
3.1.5. Treatment application

One-third of the recommended dose of chemical fertiliser was applied during May-June and the remaining 2/3rd of the fertiliser was given during in September- October. Along with the chemical fertilisers, the treatments were also applied as per the schedule. Fertilisers were supplied through urea, Mussoriephos and Muriate of Potash.

3.1.6. Observations recorded

3.1.6.1. Yield of nuts per palm

Coconut palms were harvested every 45 days. The number of nuts per palm were recorded during each harvest.



R1T1	R1T2	R4T1
R1T3	R6T1	R6T3
R2T2	R3T2	R3T3
R2T1	R5T3	R5T1
R5T2	R4T3	R7T2
R8T3	R4T2	R2T3
R7T1	R7T3	R3T1
R6T2	R8T1	R8T2

Fig.1. Layout plan of the experiment field, ICAR-CPCRI, Regional Station, Kayamkulam

3.1.6.2. Nut setting percentage

The youngest inflorescence in each palm was tagged and number of buttons in that bunch were counted and recorded as total number of female flowers. After six months, the number of buttons which were set into nuts was counted again from the tagged inflorescence along with tagging of the youngest inflorescence at that time. The total no. of female flowers from all bunches along with the number of fallen nuts were counted. The setting percentage was calculated as the percentage of buttons which have set into nuts upon the total number of female flowers in the tagged inflorescence.

3.1.7. Collection and analysis of soil samples

Soil samples were collected every year prior to the fertiliser application. Samples at two depths: 0-25 cm and 25-50cm were drawn at a distance of 1.5 m from the trunk of coconut palm. The samples were taken from diagonally opposite sides of the palm. They were mixed, dried in shade and packed in air tight containers. The samples were sieved through 2 mm sieve. The analysis of samples for organic carbon, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B, pH and EC were done using standard procedures as given in Table 1.

Table.1 Analytical methods followed in soil analysis

Sl. No.	Parameter	Method	Reference
1	pH	Potentiometry	Jackson (1973)
2	Electrical Conductivity	Conductivity meter	Jackson (1973)
3	Organic carbon	Walkley and Black Chromic acid wet digestion method	Walkley and Black (1934)
4	Available P	Bray extraction and colorimetry	Jackson (1973)
5	Available K	Flame photometry	Pratt (1965)
6	Exchangeable Ca and Mg	Neutral ammonium normal acetate	

		extraction and determination in AAS	Hesse (1971)
7	Fe, Mn, Cu, Zn	Extraction using DTPA and read in Atomic Absorption Spectrophotometer	Lindsay and Norvell (1978)
8	B	Hot water extraction method	Berger and Truog (1939)

3.1.8. Collection and analysis of leaf samples

Leaf samples were collected from the youngest opened leaf and from the index leaf calculated based on the total number of leaves in the crown. If 'N' is the total number of leaves, then the index leaf is calculated as $N/2$, if N is an even number, whereas, if N is an odd number, it is calculated as $N+1/2$. The three leaflets from the middle of the leaves on either side were taken and after removing the midrib, washed in distilled water and dried in oven. Later, the analysis of nutrients in the leaf samples was carried out as per standard procedures (Table 2).

Table 2. Analytical methods followed in plant analysis

Sl. No.	Element	Method	Reference
1	N	Microkjeldhal digestion in sulphuric acid and distillation	Jackson (1973)
2	P	Nitric-perchloric acid digestion (9 : 3) and colorimetry making use of vanado molybdo phosphoric yellow colour method	Jackson (1973)
3	K	Nitric – perchloric acid (9 : 3) digestion and flame photometry	Jackson (1973)
4	Ca	Nitric – perchloric acid (9 :3)	Tandon (1993)

		digestion and determination using AAS	
5	Mg	Nitric – perchloric acid (9 : 3) digestion and determination in AAS	Tandon (1993)
6	Fe, Mn, Cu, Zn	Nitric – perchloric acid (9 : 3) digestion and Atomic Absorption spectrophotometry	Lindsay and Norvell (1978)
7	B	Azomethine –H colorimetric method	Bingham (1982)

3.1.9. Statistical analysis

The data pertaining to the observations as well as the leaf and soil analysis were statistically analysed ANOVA technique (Cochran and Cox,1969).

4. Results

Investigations were carried out in ICAR-CPCRI, Regional Station, Kayamkulam during 2012 to 2015 to study the effect of solubor on the performance of coconut. The results of the study are presented in the section.

4.1. Effect on coconut yield

The yield recorded as total number of nuts per palm per year was statistically analysed for three treatments as interaction with year as one factor and yield as another factor (Table 3). The interaction between these two factors was considered for the statistical analysis of yield data from the palms. It was observed that there was no significant difference between the treatments over the years, when their interaction was considered. But significant difference was observed between the treatments over the three years, when their individual effects were considered.

Palms selected for the experiment were over 35 years of age. Since it was imperative to carry out the trial in boron deficient palms, the palms were selected without considering their age. Hence, the productivity of the experiment palms was slightly low compared to the average productivity of the palms in the area.

During 2012, the average yield of palms under treatment with solubor @ 60 g per palm was 16 nuts per year. This showed an increase up to 17.5 nuts per year. Nine per cent increase in yield was observed for the experiment palms under treatment T₁. In the case of T₂, the increase in yield was observed to be 37 in 2015 from an initial yield of 35.4. This showed an increase of 4.71 per cent in yield.

In the control palms, where fertilisers alone was applied and no additional amendments have been done for combating boron deficiency, it was observed that there was a gradual

reduction in yield of palms which was 30.6 in 2012 which decreased to 26.8 in 2015. This showed a decrease of 14 per cent from the pre-treatment yield.

Application of either borax or solubor has definitely an impact on the improvement in yield of treated palms though there is no significant difference between them. This can be understood when analysing the yield of treated palms and comparing with that of the palms which received no application of boron.

Table 3. Yield of coconut (nuts/palm/year) as influenced by the application of treatments

	2012	2013	2014	2015	Mean
T ₁	16.25	14.88	16.50	17.50	16.21
T ₂	35.38	33.25	38.00	37.13	35.94
T ₃	30.63	29.00	25.50	26.75	27.97
Mean	27.41	25.71	26.50	26.79	
CD-A	NS				
CD-B	7.075				
CD-AXB	NS				

A-Year; B- Treatments

4.2. Effect on nut setting percentage (Table 4)

Observations on nut set were recorded from each palm twice in a year from May 2012 onwards. The youngest inflorescence in the crown was tagged and later the percentage setting was recorded. All bunches just below the tagged inflorescence were counted for the number of set female flowers (nuts). The setting percentage was worked out as total number of buttons which set into nuts, over the total female flowers in the tagged inflorescence.

Analysis of the data revealed that there was no significant difference between the two treatments T₁ and T₂ with regard to the nut setting percentage. Application of 60 g of solubor recorded 26.72 percentage, whereas, application of borax @ 250 g in two split doses recorded a setting percentage of 26.12. In the case of control palms which received neither borax nor solubor, the setting percentage was 21.69.

The percentage increase in nut set was computed by comparing the setting percentage recorded during 2012 and 2015. In 2012, the nut set percentage for T₁, T₂ and T₃ were 23.23, 20.46 and 25.80 respectively. The percentage change in nut set over that at 2015 is increase of 15.02 and 27.67 for T₁ and T₂ and decrease of 15.93 for the T₃ i.e. control plot.

This shows that application of boron either as borax or as solubor can favour the setting of nuts in the palms through the prevention of button shedding. This data on improvement in the setting percentage can be validated with that of the improvement in yield of the palms.

Analysis of yield data revealed that T₂ recorded significantly higher yield than T₁. But the percentage increase over the pre treatment yield was higher with the application of boron as solubor compared to the application as borax. This implies that the entire nuts which have set might not have become fully developed nuts which may be due to pest and disease attack, for which there will be no uniformity at the field level. Hence, it can be inferred that the yield level of nuts on the basis of setting percentage was on par for both the treatments T₁ and T₂.

4.3. Recovery of boron deficiency symptoms

The experimental palms were selected based on the exhibition of symptoms such as fasciation, inflorescence necrosis and button shedding. It was observed that 62.5% of the palms with solubor treatment recovered from fasciation, inflorescence necrosis and button shedding during the last observation taken during mid June 2015 (Table 4).

In the case of T₂, 75 per cent of the palms recovered from fasciation, inflorescence necrosis and button shedding. In the treatment T₃ which received no boron sources, very severe fasciation and inflorescence necrosis prevailed in all the observation palms.

This shows the effectiveness of boron sources such as borax and solubor on the alleviation of deficiency symptoms. The efficiency of these sources in sandy soil could have

been improved if there was the addition of organic manure and also the correction of soil pH was also taken care of.

Table 4. Recovery of symptoms and nut set as influenced by the treatments

Treatments	No. of palms with fasciation		No. of palms with inflorescence necrosis		No. of palms with button shedding		Total recovery (%)	Setting (%)
	Pre treatment	Post treatment	Pre treatment	Post treatment	Pre treatment	Post treatment		
T ₁	5	1	1	1	2	1	62.5	26.79
T ₂	5	1	1	1	2	0	75	26.12
T ₃	5	5	0	0	3	3	0	21.69

4.4. Nutrient content in leaf tissues

The leaf samples from the experiment palms were collected periodically during May 2012, 2014 and 2015. After estimating the total number of leaves, the first leaf and the index leaf were collected for the estimation of boron; other macro, secondary and micronutrients, respectively (Table 5).

4.4.1 Major nutrients

There was no significant difference between the treatments with regard to the concentration of leaf phosphorus between the years 2012 and 2014. The highest value of 0.172% was recorded by T₂ and for T₁ it was 0.148%.

In the case of the potassium concentration in the leaf, there was significant difference between the two treatments over the years. It can be seen that there was an increase in the leaf concentration for all the three treatments, but this increase cannot be attributed to the application of boron, as the highest percentage increase (13.84) was observed for the control treatment which received neither borax nor solubor. It was 12.3 per cent for the treatment which received 250 g of borax in two split doses. For T₁, the percentage increase in leaf concentration was 13.57.

4.4.2. Secondary Nutrients

In the case of leaf calcium concentration, though there was no significant difference between the treatments over the two years, a general decrease in the concentration was observed. In 2014, the calcium concentration was 0.317% for T₁, followed by T₂ with a concentration of 0.299%. In the case of control palms, the concentration was 0.256%.

With regard to the concentration of magnesium in the leaf tissues, there was significant difference between the treatments. Concentration of magnesium showed a decreasing trend with regard to the application of boron compounds as indicated by the lower values for the treatments receiving boron as borax or solubor. In the case of T₁, the value was 0.206 per cent in 2014, which was 0.273 in 2012, showing a decrease of 24.5 per cent. In the case of T₂, the content was 0.21% in 2014 and showed a decrease of 63.4 per cent over the pre treatment concentration.

Boron and magnesium has been reported to have antagonistic effects in the plant tissues. This is evident in the results as the percentage decrease was 18.36 over the pre treatment for the control palms.

4.4.3. Leaf Boron

Boron concentration in the leaf was significantly different for the two years and there was significant difference between the treatments. The concentration was 14.16 mg per kg for T₁ and was 17.74 mg per kg for T₂. In the case of control palms, the concentration was 12.48 mg per kg.

The average concentration of boron in the leaf is critical for the alleviation of boron deficiency symptoms in the palm. Considering the increase in leaf concentration, borax was contributing significantly higher leaf concentration compared to the solubor @ 60 g per palm.

Table 5. Effect of treatments on the foliar nutrient levels during 2012 and 2014

Parameters	Year	T ₁	T ₂	T ₃	Mean	CD
P(%)	2012	0.148	0.172	0.159	0.160	A-NS
	2014	0.155	0.165	0.163	0.161	B-NS
	Mean	0.152	0.168	0.161		AXB-NS
K(%)	2012	1.407	1.349	1.35	1.37	CD(A):0.13
	2014	1.59	1.515	1.54	1.55	CD(B):NS
	Mean	1.50	1.432	1.45		CD(AXB):NS
Ca(%)	2012	0.352	0.306	0.300	0.319	CD(A):0.028
	2014	0.317	0.299	0.256	0.291	CD(B):0.024
	Mean	0.335	0.303	0.278		CD (AXB):NS
Mg(%)	2012	0.273	0.273	0.294	0.280	CD(A):0.028
	2014	0.206	0.210	0.240	0.219	CD(B):NS
	Mean	0.239	0.242	0.267		CD(AXB):NS
Fe(mg/kg)	2012	63.68	64.08	64.48	64.08	CD:A-NS
	2014	62.49	59.44	71.63	64.52	CD:B-NS
	Mean	63.08	61.76	68.06		CD:AXB-NS
Mn(mg/kg)	2012	114.19	113.32	93.06	106.85	CD(A)-NS
	2014	105.89	107.25	93.06	102.07	CD(B)-NS
	Mean	110.03	110.28	93.06		CD(AXB)-NS
Cu(mg/kg)	2012	8.963	8.60	9.17	8.91	CD(A):0.831
	2014	6.86	7.26	5.07	6.40	
	Mean	7.91	7.93	7.12		CD(AXB):1.44
Zn(mg/kg)	2012	20.04	13.51	19.20	17.58	CD(A):NS
	2014	22.54	14.76	17.95	18.41	CD(B):4.52
	Mean	21.29	14.13	18.58		CD(AXB)-NS
B(mg/kg)	2012	10.49	10.88	10.7	10.69	CD(A):1.77
	2014	14.16	17.74	10.47	14.12	CD(B):2.17
	Mean	13.70	15.99	10.59		CD(AXB)-NS

A- Year; B- Treatments

Table 6. Effect of treatments on the foliar nutrient levels during 2012 and 2015

Parameters	Year	T ₁	T ₂	T ₃	Mean	CD
P(%)	2012	0.148	0.172	0.159	0.160	CD(A): 0.016
	2015	0.125	0.132	0.137	0.131	CD(B):NS
	Mean	0.137	0.152	0.148		CD(AXB): NS
K(%)	2012	1.41	1.349	1.351	1.37	CD (A):0.122
	2015	1.77	1.87	1.599	1.75	CD(B):NS
	Mean	1.59	1.61	1.475		CD:AXB-NS
Ca(%)	2012	0.352	0.306	0.300	0.319	CD(A):0.028
	2015	0.180	0.173	0.134	0.162	CD(B):0.035
	Mean	0.266	0.240	0.217		CD:AXB-NS
Mg(%)	2012	0.273	0.273	0.294	0.280	CD(A):0.027
	2015	0.130	0.150	0.163	0.148	CD(B):NS
	Mean	0.202	0.211	0.229		CD(AXB):NS
Fe(mg/kg)	2012	63.68	64.08	64.48	64.08	CD(A):11.79
	2015	134.60	142.20	146.35	141.05	CD(B):NS
	Mean	99.14	103.14	105.42		CD(AXB):NS
Mn(mg/kg)	2012	114.19	113.32	93.07	106.86	CD(A):12.74
	2015	74.60	74.68	69.86	73.05	CD(B):NS
	Mean	94.4	93.99	81.47		CD(AXB):NS
Cu(mg/kg)	2012	8.96	8.60	9.18	8.91	CD(A):15.04
	2015	7.40	7.55	7.29	7.41	CD(B):NS
	Mean	8.18	8.08	8.23		CD(AXB):NS
Zn(mg/kg)	2012	20.04	13.51	19.21	17.58	CD(A):2.61
	2015	12.05	11.62	16.12	13.26	CD(B):3.19
	Mean	16.05	12.57	17.66		CD(AXB):NS
B(mg/kg)	2012	10.49	10.88	10.7	10.69	CD(A):1.65
	2015	19.15	19.03	10.39	16.19	CD(B):2.03
	Mean	16.19	16.64	10.86		CD(AXB):2.87

A-Year; B- Treatments

4.4.4. Major nutrients

There was a decrease in the content of phosphorus over the years for all the treatments, but the highest content was recorded by T₂ (0.172%) in 2012 as well as in 2014 (0.132%). But the difference was not significant. Though leaf potassium was also significantly not influenced by the application of treatments, the highest value of 1.41% was recorded by T₁ followed by T₂

with 1.35% in 2012. In the second year, the content increased for all the treatments, but the percentage increase was higher with T₂ compared to T₁.

4.4.5. Secondary nutrients

Leaf calcium concentration was significantly influenced by the treatments over the years. There was a decrease in the content of calcium over the years possibly due to crop removal and uptake. The decrease was gradual from 2012 to 2014 and to 2015 as evidenced by the data presented in the Table 6.

During 2012, the concentration was 0.352% for T₁ which decreased to 0.180 %. In the case of T₂, the initial concentration was 0.306% which decreased to 0.173% in 2015. On comparing the means, T₁ was significantly superior to all other treatments which imply the significance of solubor treatments in palms.

The critical nutrient for coconut production in Onattukara sandy soil is magnesium. Though no significant difference between the treatments over the years was noticed in the case of magnesium, there was a gradual decrease in the content of Mg over the years and the decrease was more for T₁ (51%) compared to T₂ (44%). The negative or antagonistic relationship between the leaf Mg and B status was reported in several crops.

4.4.6. Micronutrients

Nutrients such as iron, manganese, copper, zinc and boron were estimated from the corresponding index leaf tissues. It was observed that there was no significant difference between the treatments with regard to Fe, Mn and Cu, but the treatments effects were significant with regard to zinc and boron.

There was significant difference between the treatments over the years with respect to the content of Zn in the leaf. But the content showed a decreasing trend over the years.

For the two treatments which received boron either as solubor or as borax, there was a reduced content compared to that of the T₃. This implies the negative effect of boron on zinc concentration of leaf. The finding owes its significance in zinc deficient soils, where supplementation of zinc containing sources is necessary along with the application of boron carriers.

Statistical analysis revealed that there was significant difference between the treatments over the years with respect to the content of boron in the leaf. During 2012, before the application of boron sources, all the palms had a lower content of leaf boron in them. Later during 2015, application of treatments recorded significant improvement in the content of boron where T₁ and T₂ are on par and are significantly superior to T₃. The content of boron in solubor and borax is sufficient to increase the content in leaf tissues. It can be observed that the initial boron content in the leaf issues were 10.49 mg/kg, 10.88 mg/kg and 10.7 mg/kg for the treatments T₁, T₂ and T₃, respectively. As scheduled in the experiment, borax and solubor were applied to the experiment palms in two split doses. In 2015, the content in the leaf increased to 19.15 mg/kg, for T₁ and T₂ 19.03 mg/kg respectively. The percentage increase in boron content in the leaf tissues was 82.56 for T₁ followed by 74.91 in T₂. Better nutrient partitioning in the leaf tissue was observed for T₁ as compared to T₂ which may be due to the higher boron content in solubor compared to borax. The increased boron concentration in the leaf tissues might have facilitated the recovery of deficiency symptoms with the application of split doses of borax and solubor.

4.5. Effect of treatments on the soil nutrient status

Parameters such as soil pH, electrical conductivity, organic carbon, available phosphorus, potassium, calcium, magnesium, boron, zinc and copper in soil were estimated

before the application of treatments in 2012 as well as at the final stage of the experiment in 2015. Data presented in Table 7 compares the effect of treatments on soil parameters during 2012 and 2015.

4.4.1. Soil pH

Soil pH values in general showed an increasing trend irrespective of treatments during the period from 2012 to 2015. But the treatment effects were not significant over the years. The highest percentage increase in pH (7.49) over the pre treatment was recorded by T₁ followed by T₂. The increase in pH might be due to the soil management practices along with the application of treatments.

4.4.2. Available phosphorus

Influence of treatments over the years was not significant with regard to the content of available phosphorus in soil. Available P showed a general decrease over the years. Considering the pre treatments soil test phosphorus values which were on the higher side (> 20 ppm), phosphorus fertilisers were not applied to the soil along with the other treatments which may be reason for the general decrease in available P status of the soil.

4.4.3. Available potassium

Though the treatment effects were non-significant, increase in available potassium status was observed for the application of both solubor as well as borax. This may be due to the availability as influenced by the regular application of recommended dose of fertilisers, rather than the influence of borax or solubor in soil.

4.4.4. Micronutrients

Availability of boron and copper were significantly influenced by the treatments, as indicated by the data presented in Table 7. There was an increase in the content of zinc and

copper over the years for all the treatments. Better soil reaction facilitated by the regular application of fertilisers and treatments might have favoured the availability of zinc and copper in soil. But both zinc and copper are below the general critical level to be maintained in the soil. However adoption of measures to increase the nutrient use efficiency of boron in sandy soil may enhance the availability of zinc and copper in soils.

Even though boron sources are applied to soil, significant difference between the treatments was not observed over the years. But for both the treatments with borax and solubor, a general increase over that of the pre treatment values was noticed. In the case of treatment with solubor the, percentage increase was 43.15, whereas, in the case of treatment with borax, the percentage increase was 69.77. In the case of T₃, where no boron application was done, the percentage decrease was 12.38.

Table.7. Available nutrients as influenced by the application of treatments

	Year	T ₁	T ₂	T ₃	Mean	CD
pH (0-25 cm)	2012	4.54	4.70	4.64	4.63	CD (A):0.22
	2015	4.88	4.86	4.98	4.91	CD(B):NS
	mean	4.71	4.78	4.81		CD(AXB):NS
(25-50 cm)	2012	4.34	4.52	4.41	4.425	CD (A):0.202
	2015	4.93	4.990	4.55	4.823	CD(B):NS
	mean	4.64	4.76	4.48		CD(AXB):NS
OC (0-25 cm) (%)	2012	0.418	0.391	0.384	0.398	CD (A):0.004
	2015	0.307	0.329	0.259	0.298	CD(B):0.004
	mean	0.363	0.360	0.321		CD(AXB):0.006
OC (25-50 cm)	2012	0.206	0.290	0.290	0.262	CD (A):0.064
	2015	0.203	0.229	0.283	0.238	CD(B):NS
	mean	0.204	0.259	0.280		CD(AXB):NS
Avail.P (ppm) 0-25	2012	46.09	54.53	42.66	47.76	CD (A):5.56
	2015	39.69	31.88	30.18	33.92	CD(B):NS
	mean	42.89	43.20	36.42		CD(AXB):NS
Avail.P(ppm) (25-50 cm)	2012	25.99	42.66	23.53	30.73	CD (A):
	2015	11.77	16.16	15.63	14.52	CD(B):
	mean	18.88	29.41	19.58		CD(AXB):

Avail.K(ppm)	2012	118.63	150.81	171.56	147.0	CD (A):
	2015	188.19	176.13	127.44	163.92	CD(B):
	mean	153.41	163.47	149.50		CD(AXB):
Avail.K(ppm) (25-50 cm)	2012	56.63	65.56	101.75	74.65	CD (A):
	2015	159.44	126.44	76.19	20.69	CD(B):
	mean	108.03	96.00	88.97		CD(AXB):
Ca(ppm) 25-50	2012	128.41	111.28	79.72	106.47	CD (A):
	2015	140.72	124.18	110.10	125.00	CD(B):
	mean	134.5	117.73	94.91		CD(AXB):
Ca(ppm) 0-25	2012	102.0	99.06	103.41	101.49	CD (A):86.18
	2015	153.28	136.467	138.00	142.58	CD(B):NS
	mean	127.64	117.77	120.70		CD(AXB):NS
Mg(ppm) 0-25	2012	14.40	19.78	11.99	15.39	CD (A):
	2015	18.61	15.91	16.69	15.55	CD(B):
	mean	14.98	19.19	13.95		CD(AXB):
Mg(ppm) 25-50	2012	22.38	6.13	8.91	12.47	CD (A):
	2015	7.73	8.49	11.82	9.35	CD(B):
	mean	15.06	7.31	10.36		CD(AXB):
Cu(ppm)	2012	0.381	0.434	0.509	0.441	CD (A):0.17
	2015	0.515	1.27	0.886	0.889	CD(B):NS
	mean	0.448	0.850	0.698		CD(AXB):NS
Cu(ppm) (25-50 cm)	2012	0.430	0.365	0.344	0.380	CD (A):NS
	2015	0.274	0.655	0.621	0.517	CD(B):NS
	mean	0.352	0.510	0.483		CD(AXB):NS
Zn(ppm)	2012	0.290	0.356	0.446	0.364	CD (A):0.095
	2015	0.490	0.912	0.674	0.692	CD(B):NS
	mean	0.390	0.634	0.560		CD(AXB):NS
Zn(ppm) (25-50 cm)	2012	0.222	0.350	0.411	0.328	CD (A):NS
	2015	0.333	0.737	0.799	0.623	CD(B):NS
	mean	0.277	0.544	0.605		CD(AXB):0.18
Avail.B(ppm) 0-25	2012	0.248	0.268	0.130	0.215	CD (A):NS
	2015	0.355	0.455	0.116	0.309	CD(B):0.162
	mean	0.301	0.361	0.123		CD(AXB):NS
Avail.B(ppm) 25-50	2012	0.185	0.370	0.047	0.201	CD (A):NS
	2015	0.386	0.108	0.086	0.193	CD(B):0.149
	mean	0.286	0.239	0.067		CD(AXB):NS

A-Year; B- Treatments

Conclusion

Boron is an inevitable micronutrient in coconut production system. Owing to the deficient levels of boron in soil, and also to the occurrence of deficiency symptoms in the coconut palms, it is imperative to apply boron containing sources such as solubor and borax. The present study has revealed that application of solubor @ 60 g per palm in two split doses is as effective as the application of borax @ 250 gram per palm in two split doses, with regard to the alleviation of deficiency symptoms as well as to the enhancement of yield and yield attributes of coconut.

Acknowledgement

The project was taken up as a contract research project. The project team acknowledges the timely financial support rendered by M/S Rallis India Limited, Bangalore for carrying out the research work.

5. Executive summary

An investigation was carried out in ICAR-Central Plantation Crops Research Institute, Regional Station, Kayamkulam during 2012-2015 to evaluate the efficiency of solubor on the amelioration of boron deficiency symptoms of coconut palms in Onattukara sandy soil. The treatments were application of solubor @ 60 g per palm in two split doses i.e., 25 g and 35 g during May-June and in September-October along with recommended dose of fertilisers (T₁), 250 g of borax in two split doses along with recommended dose of fertilisers (T₂) and recommended dose of fertiliser alone (T₃). Twenty four palms exhibiting boron deficiency symptoms such as fasciation, inflorescence necrosis, and button shedding were selected in Block V of the Regional Station and the experiment was laid out with Completely Randomised Design. The salient results of the study are summarised below:

- Nine per cent increase in nut yield per palm was observed for the treatment with application of solubor @ 60 g per palm, whereas, 4.7 per cent increase was noticed for treatment with 250 g of borax per palm. When left untreated, the boron deficient palms showed a decrease of 14 per cent over the pre treatment yield.
- Percentage increase in nut setting was the highest for treatment with borax @ 250 g per palm. However, the treatment effects were non- significant between treatment with application of solubor @ 60 g per palm and treatment with 250 g of borax per palm for the nut setting percentage as well as nut yield per palm.
- Seventy five per cent recovery of boron deficiency symptoms were observed for the treatments with borax and solubor.

- Increase in the content of leaf potassium was observed for the treatments with borax and solubor.
- Decrease in the content of leaf magnesium was observed for treatment with application of solubor @ 60 g per palm and treatment with 250 g of borax per palm emphasising the antagonistic relationship between magnesium and boron in the plant system. Supplementation of magnesium sources should be done along with the application of boron sources, for the correction of boron deficiency symptoms in coconut.
- Both borax and solubor are effective in increasing the boron content of the youngest leaf to the critical concentration level.

Abstract

A field experiment to evaluate the efficiency solubor on the alleviation of boron deficiency symptoms in coconut was designed and laid out in ICAR-CPCRI, Regional Station, Kayamkulam during 2012-2015. Twenty four West Coast Tall palms of 35 years of age were selected for the study. The palms exhibited typical boron deficiency symptoms such as fasciation, inflorescence necrosis, and button shedding of varying intensity. There were three treatments comprising solubor@ 60 g per palm in two split doses (T₁), borax@ 250 g in two split doses (T₂) and control with no application of any boron source (T₃). All the treatments were applied along with regular recommended dose of fertilisers.

Observations were recorded each year on the remission/recovery of symptoms. Application of either borax or solubor has definitely an impact on the improvement in yield of treated palms though there is no significant difference between them. This can be understood when analysing the yield of treated palms and comparing with that of the palms which received no treatments.

Both borax and solubor were equally effective on the enhancement of yield of coconut palms as indicated by the data. However, there was no significant difference between the treatments when applied in the Onattukara sandy soil with soil treatment as the mode of application. Observations on improvement in nut setting percentage also recorded the same trend where both borax and solubor were efficient in improvement of the setting percentage in coconut. On the basis of recovery of boron deficiency symptoms, it could be seen that 62.5% of the palms with solubor treatment recovered from fasciation, inflorescence necrosis and button shedding three years after the application of solubor. As for the treatment with the application of borax, it could be seen that 75 % of palms recovered from fasciation, inflorescence necrosis and

button shedding. In the treatment T₃ which received no boron sources, very severe fasciation and inflorescence necrosis persisted in all the observational palms.

There was a decrease in the content of phosphorus over the years for all the treatments, but the highest content was recorded by T₂ (0.172%) in 2012 as well as in 2015 (0.132%). Leaf potassium was also significantly not influenced by the application of treatments. In the second year, the content increased for all the treatments, but the percentage increase was higher with T₂ compared to T₁. Leaf calcium concentration was significantly influenced by the treatments over the years. There was a decrease in the content of Ca over the years possibly due to crop removal and uptake. The decrease was gradual from 2012 to 2014 and to 2015. There was no significant difference between the treatments on the content of leaf magnesium over the years. But there was a gradual decrease in the content of Mg over the years emphasising the negative or antagonistic relationship between the leaf Mg and B status. There was significant difference between the treatments over the years with respect to the content of Zn in the leaf. But the content showed a decreasing trend over the years. For the two treatments which received boron either as solubor or as borax, there was a reduced content compared to that of the one which received neither of these. Foliar concentration of zinc and boron may be having an antagonistic relationship and under conditions of deficiency zinc carriers may be supplied along with boron sources in zinc deficit soils. During 2012, before the application of boron sources, all the treatments have a lower content of leaf boron in them. Later during 2015, it was revealed that application of treatments there was significant improvement in the content of boron where T₁ and T₂ are on par and are significantly superior to T₃. The content of boron in solubor and borax is sufficient to increase the content in leaf tissues. It can be observed that the initial boron content in the leaf issues were 10.49 mg/kg, 10.88 mg/kg and 10.7 mg/kg for the treatments T₁, T₂ and T₃

respectively. As scheduled in the experiment, borax and solubor were applied to the experiment palms in two split doses. In 2015, the content in the leaf increased to 19.15 mg/kg, for T₁ and T₂ 19.03 mg/kg respectively. The percentage increase in boron content in the leaf tissues was 82.56 for T₁ followed by 74.91 in T₂. Better nutrient partitioning in the leaf tissue was observed for T₁ as compared to T₂ which may be due to the higher boron content in solubor compared to borax. The increased boron concentration in the leaf tissues might have facilitated the recovery of deficiency symptoms with the application of split doses of borax and solubor.

From the results of the study it can be inferred that solubor and borax are effective on the remission of boron deficiency symptoms in coconut. Management strategies such as addition of organic manure along with the amendments, inclusion of dolomite for the correction of soil pH as well as for the supplementation of magnesium have to be adopted for increasing the nutrient use efficiency of boron supplied either through borax or through solubor. Moreover, more split application of the sources at quarterly intervals can ensure the better use efficiency of boron in sandy soil of Onattukara region.