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Research Article

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Study on Supplying Boron to Coffee on Basaltic Soil in Central Highlands of Vietnam

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Abstract

Coffee trees have high nutrient requirements, including boron (B). A field experiment with 2 factors of applying methods (leaf and root) and doses (0, 1, 2 and 3 kgs B ha^{-1} yr^{-1}) was implemented on basaltic soil in Central Highlands of Vietnam during 2015-2016. The results showed that supplying B remained appropriate B content in leaves, reduced in curly leaves and dropped fruits and increased in coffee productivity by 2.3-10.2% in comparison with control. The treatments of supplying 3 kg ha^{-1} got highest productivity, 3.87 t ha^{-1}. In addition, the efficiency of B to coffee was quite clear, 76.7- 85.0 kg coffee kg B^{-1} in the cases of root applying and 95.0-123.3 kg in treatments of leaf spraying. Leaf spraying increased in yield of 0.11-0.23 t ha^{-1}, corresponding the profit of 94.5-247.3 USD ha^{-1} in comparison with root applying.

Keywords: Basaltic soil; Boron; Coffee; Fertilizer; Productivity

Introduction

Central Highlands are plateaus located at the middle of Vietnam where has humid tropical climate and large area of basaltic soil (volcanic soil), are suitable to coffee trees. It is the main coffee area, with 537,133.7 ha, occupies 83.7% total coffee area of the country. Coffee trees have high nutrient requirements, including macro, meso and micro elements [1-4]. Boron (B) is an important trace element for coffee [5]. Coffee is specie of crop which is sensitive to B [6]. B deficiency is widespread in Brazilian coffee plantations [7,8], results in a reduced root system, flower abortion, fruit malformation and consequently low yields. B fertilizer is recommended in Brazil when soil B content (hot water extraction) is below 0.06 mg dm^{-3} [9] or leaf B content below 60 mg kg^{-1} [8], but responses of coffee trees to B fertilizer have been erratic, depending on the time, way of applying and B source [10].

Previously because of low productivity, micro elements from soil or organic fertilizer are enough for coffee requirement. Currently, intensive farms have pushed yields to rise, creating pressure on supplying of nutrients from the soil, especially the trace elements. In many coffee farms there are deficiency symptoms of micro elements after few years of continuous high yield [11].

Today in Vietnam some kinds of organic or NPK fertilizer have been combined to micro elements, including B for the purpose of supplementing the essential micro nutrients for plants. However, the doses and methods of supplying B to crops in general and coffee in particular have not been clearly. Studies on using B for coffee in Vietnam has not yet completed. The paper aims to show role of boron and suitable measures of using this element for coffee on basaltic soil in Central Highlands of Vietnam.

Materials and Methods

Materials

Robusta coffee (10 years old) on basaltic soil (Rhodic Ferralsols); Urea: 46% N; Fused magnesium phosphate (FMP): 15% P_2O_5; KCl: 60% K_2O; H_3BO_3:17,1%B.

Methods

A field experiment of supplying method (root and leaf) and dose (0, 1, 2 and 3 kg B $ha^{-1}yr^{-1}$) was implemented, including 8 treatments as following.

A1B1: Root applying, 0 B; A1B2: Root applying, 1 kg B ha^{-1}; A1B3: Root applying, 2 kg B ha^{-1}; A1B4: Root applying, 3 kg B ha^{-1}

A2B1: Leaf spraying 0 B (1000-liter water ha^{-1}); A2B2: Leaf spraying 1 kg B ha-1 (1000 liter 0.1% B); A2B3: Leaf spraying 2 kg B ha^{-1} (1000 liter 0.2%B); A2B4: Root Leaf spraying 3 kg B ha^{-1} (1000 liter 0.3% B).

The treatments were arranged by split - plot - design with 3 replications on basaltic soil in Central Highlands of Vietnam during 2015-2016. Plot basic area is 90 m^2 (10 coffee trees). Following was the experimental diagram (Figure 1).

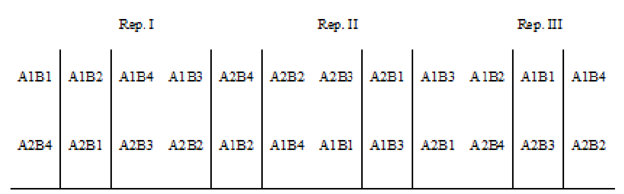

Figure 1: The experimental diagram.

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Experimental soil properties

The soil physical and chemical characteristics are presented in Tables 1 and 2. In generally, the soil is acid, quite rich in organic matter and nitrogen, very rich in potential phosphorus, poor in available phosphorus, potassium and very poor in calcium, magnesium, and boron. The texture is clay loam; bulk density is low; porosity is high.

Depth (cm)	pHKCl	Total (%)				Available (ppm)			Exchangeable (meq/100 g)	
		OM	N	P_2O_5	K_2O	P_2O_5	K_2O	B	Ca	Mg
0 - 30	4.49	4.72	0.185	0.18	0.07	74	145	3.1	1.5	1.3
30 - 80	4.56	1.68	0.076	0.12	0.05	33	83	2.8	1.3	1.1
0 - 120	4.73	0.43	0.045	0.10	0.04	17	54	2.5	0.8	0.6

Table 1: Chemical characteristics of basaltic soil.

Depth (cm)	Texture (%)		
	Clay	Loam	Sand
0 - 30	26.7	49.0	24.3
30 – 80	35.2	48.0	16.8
80 - 120	30.3	40.6	29.0

Table 2: Physical characteristics of basaltic soil.

The B content in coffee leaves

The analyzing results showed that before trial (May, 2014) B content in coffee leaves arranged from 24.1 to 26.8 ppm. That was necessary time to supply B for the crop. After root applying or leaf spraying, B content in coffee leaves increased. The more B supplied, the longer appropriate B content remained. The effectiveness of 2 kg B ha^{-1} were 40 days and 3 kg B ha^{-1} were 50 days. B content in coffee leaves got a peak after 10 days of leaf spraying and 20-30 days of root applying. However, influenced period of root applying and leaf spraying was similar (Figure 2).

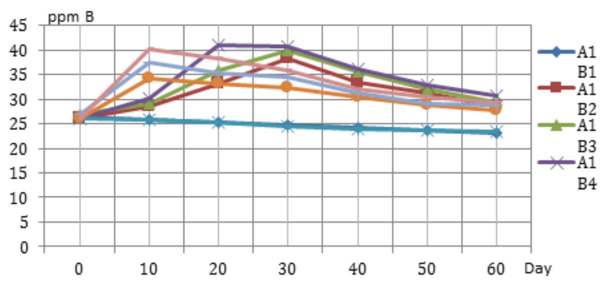

Figure 2: Changing B content in coffee leaves.

The effect of B on leaf curly disease of coffee

Before implementing trial, curly coffee leaves appeared over the farm. After providing B leaf curl tended to decrease. The rate of leaf curl increased in the treatments without B (Table 3).

Method (A)	Dose (B)	Before applying		Before harvesting		Changing (%)
		Rate	%	Rate	%	
A1	B1	3/30	10.0	4/30	13.3	+3.3
	B2	2/30	6.6	2/30	6.6	0.0
	B3	3/30	10.0	2/30	6.6	-3.4
	B4	4/30	13.3	3/30	10.0	-3.3
A2	B1	2/30	6.6	3/30	10.0	+3.4
	B2	3/30	10.0	3/30	10.0	0.0
	B3	4/30	13.3	3/30	10.0	-3.3
	B4	4/30	13.3	2/30	6.6	-6.7

Table 3: The rate of leaf curl increased in the treatments without B. Notes: Numerator: number of diseased trees; Denominator: number of observed trees.

The effect of B on dropping coffee fruits

The rate of dropped fruits arranged in 24.5- 31.1%. In that, the treatments without B had highest rate of dropped fruits, 30.5%. The treatments of supplying 3 kg B ha^{-1} (A2B4, A1B4) got lowest rate of dropped fruits, 24.5-26.4%, corresponding 4,4-6,0% lower than the treatments without B. The dropped rate in leaf spraying B was 2.1% lower than in root applying (Table 4).

Method (A)	Dose (B)				Average of A
	B1	B2	B3	B4	
A1	31.1	29.1	29.4	26.4	29.0
A2	29.8	27.9	25.2	24.5	26.9
Average of B	30.5	28.5	27.3	25.5	

Table 4: The effect of B on rate of dropped coffee fruits (%). $LSD_{0.05}$ A=1.75; B=0.81; A^*B=0.98.

The effect of B on fruit weight and size

The influence of B on the weight and volume of fruits is presented in Tables 5 and 6. The weight of 100 fruits arranged in 96.9-99.7 g and the volume was 99.8-105.8 cm^3. The treatments of supplying 3 kg B ha^{-1} (leaf spraying or root applying) gave highest weight and volume of 100 fruits, 99.6 g and 105.7 cm^3. They were 2.8% in weight and 6.0% in volume higher than without B.

Method (A)	Dose (B)				Average of A	%
	B1	B2	B3	B4		

A1	96.9	97.3	98.5	99.4	98.0	100.0
A2	96.8	97.5	98.8	99.7	98.2	100.2
Average of B	96.9	97.4	98.7	99.6		
%	100.0	100.5	101.9	102.8		

Table 5: The effect of B on fruit weight (g/100 fruits). $LSD_{0.05}$ A = 0.93; B = 0.88; A^*B = 1.25

Method (A)	Dose (B)				Average of A	%
	B1	B2	B3	B4		
A1	99.8	102.1	104.4	105.6	103.0	100.0
A2	99.6	102.8	104.7	105.8	103.2	100.2
Average of B	99.7	102.5	104.6	105.7		
%	100.0	102.8	104.9	106.0		

Table 6: The effect of B on fruit volume (cm^3/100 fruits). $LSD_{0.05}$ A=1.37; B=2.26; A^*B=3.2.

The effect of B on coffee productivity

Results from the experiment showed that there was significant difference of coffee productivity among the experimental treatments, arranged in 3.52-3.98 t ha^{-1}. The treatments without B (A1B1, A2B1) had lowest coffee yield, 3.52-3.61 t ha^{-1}, average of 3.57 t ha^{-1}. The treatments which got highest yield were A1B4, A2B4 (3 kg ha^{-1}), arranged in 3.75-3.89 t ha^{-1}, average of 3.87 t ha^{-1}. Treatments of leaf spraying increased in yield by 0.11-0.23 t ha^{-1}, average of 0.12 t ha^{-1} in comparison with root applying (Table 7).

Method (A)	Dose (B)				Average of A	%
	B1	B2	B3	B4		
A1	3.52	3.60	3.69	3.75	3.64	100.0
A2	3.61	3.71	3.80	3.98	3.78	103.7
Average of B	3.57	3.66	3.75	3.87		
%	100.0	102.4	104.9	108.3		

Table 7: The effect of B on coffee productivity (t ha^{-1}). $LSD_{0.05}$ A = 0.20; B = 0.72; A^*B = 0.11.

The effectiveness of B on coffee

The calculated results showed that the efficiency of 1 kg B was 76.7-85.0 kg coffee in the cases of root applying and 95.0-123.3 kg coffee in the treatments of leaf spraying (Table 8). Applying B added cost of 26.8-158.6 USD ha^{-1}, but income increased by 121.8-563.5 USD ha^{-1}, so profit was improved (Table 9).

Treatment	Dose (kg B /ha^{-1})	Productivity (kg coffee ha^{-1})	Increasing (kg coffee ha^{-1})	Efficiency (kg coffee kg B^{-1})
A1B1	0	3,520	-	-
A1B2	1	3,600	80	80.0
A1B3	2	3,690	170	85.0
A1B4	3	3,750	230	76.7
A2B1	0	3,610	-	-
A2B2	1	3,710	100	100.0
A2B3	2	3,800	190	95.0
A2B4	3	3,980	370	123.3

Table 8: The effectiveness of B on coffee.

Treatment	Cost	Income	Profit
A1B1	3,202.0	5,360.0	2,158.0
A1B2	3,228.8	5,481.8	2,253.0
A1B3	3,258.0	5,618.9	2,360.8
A1B4	3,280.1	5,710.2	2,430.1
A2B1	3,224.5	5,497.0	2,272.6
A2B2	3,301.8	5,649.3	2,347.5
A2B3	3,331.0	5,786.4	2,455.4
A2B4	3,383.1	6,060.5	2,677.4

Table 9: The economic efficiency of B on coffee (USD ha^{-1}).

Discussion

The appropriate B content in coffee leaves arranged from 35 to 90 ppm [12]. The B content of coffee leaves in Vietnam was 30-50 ppm [2]. The B content in coffee leaves before experiment were below demand of coffee tree. Applying B increased in B content of coffee leaves. In generally, influence of leaf spraying was faster than root applying.

Leaf curly disease usually appears on coffee plantations in Vietnam. It is caused by the incompliance or imbalance of nutrients and called physiological disease. The disease reduces in photosynthesis, growth, and productivity of coffee trees [2]. Using B reduced in rate of leaf curly evidently [11].

In Central Highlands of Vietnam climate and soil condition, dropping fruits usually occurs for coffee trees. It is due to physiological processes of plants or storms or lack of water and nutrient. Leaf spraying or roots applying B reduced in rate of dropped fruits by 5.8% [2].

In Vietnam weight and size of coffee fruit increase quickly and get a maximum in July. Dry matter accumulation reaches a peak also in July. During the period, deficient and imbalanced providing B results in small and light fruits [2]. There was significant difference of fruit weight and volume among treatments of leaf spraying and root applying [2].

On basaltic soil the B requirement of coffee was quite high. The efficiency of B to coffee on basaltic soil was quite clear. Spraying B increased coffee productivity by 3.3% in comparison with root applying [13,14].

Conclusions

Supplying B to coffee on basaltic soil in Central Highlands of Vietnam remained appropriate B content in leaves, reduced in curly leaves and dropped fruits and increased in coffee productivity by 2.3-10.2% in comparison with control. The dose of 3 kg B ha^{-1} (17.5 kg H_3BO_3 ha^{-1}) got highest yield, average of 3.87 t ha^{-1}. Treatments of leaf spraying increased in yield by 0.11-0.23 t ha^{-1}, corresponding the profit of 94.5-247.3 USD ha^{-1} in comparison with root applying.

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