International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 581-587, 2022; Article no.IJPSS.95562
ISSN: 2320-7035

Incubation Studies to Find Out the Transformation of Different Fractions of Boron

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242676

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/95562

Original Research Article

Received: 25/10/2022
Accepted: 28/12/2022
Published: 29/12/2022

ABSTRACT

An incubation study was conducted in the laboratory of College of Agriculture, Central Agricultural University, Manipur, India, to know the transformation of applied Boron (B) in soils at field capacity. Soil samples was collected periodically at 0, 30, 60 and 90 days after incubation (DAI) and analyzed for different fractions of B. The experiment was carried out under completely randomized block design (CRD). Altogether there were 6 treatment replicated thrice namely, T_0= Control, T_1= 0.5 mg B kg^{-1} soil, T_2= 1 mg B kg^{-1} soil, T_3= 1.5 mg B kg^{-1} soil, T_4= 2 mg B kg^{-1} soil and T_5= 2.5 mg B kg^{-1} soil. From the incubation experiment, it was inferred that with applied B, the organically bound B fraction was higher next to residual form when compared to other forms of B. At 30 days of incubation, different fractions of B showed an increasing trend for added levels of B compared to control due to recently applied B into the soil solution. However, at 60 and 90 days different fractions of B in the soil started decreasing due the fact that boron entered into tightly bound state within the soil. In general, B fertilization increased the availability of B content in soil and hence increased its availability to the crop. The sequence of the content of different fractions of B in an acid soils of Imphal-West district was readily soluble-B>organically bound-B>oxide bound-B> specifically adsorbed-B> residual-B.

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Keywords: Boron; soil; fractions; incubation; transformation.

1. INTRODUCTION

Boron (B) is a chemical element which is represented by the symbol B and atomic number 5. B is among one of the essential plant nutrient and compounds of boron such as boric acid and borax are used in agriculture as fertilizers. Boron is required by the plants in petty quantities, with excess being toxic. Boron is non-metal micronutrients which is the only non-metal of the group 13 of the periodic table and has transitional properties between non-metals and metals. Boron constitutes about 0.001 percent by weight of Earth's crust. B in Indian agriculture has emerged as an important micronutrient and its deficiency was found next only to zinc [1]. About one third of the cultivated soils and on an average, 18.3% are deficient in Boron [2]. B deficiency are usually found in sandy soil prone to leaching, calcareous soils (>15% calcium carbonate), high pH soils (> 7) and soils which are recently limed [3,4].

Singh [5] reported that the contents of hot water soluble B in Indian soils ranged from 0.75 to 8.0 mg kg^{-1} and its availability to plants is often related to its total content as well as other properties such as pH, organic matter and $CaCO_3$ contents, interaction of nutrients, type of plant or variety and environmental factors, which strongly influence the emergence of its toxicity or deficiency in plants. Boron that are available to plant exists in soil mostly as a neutral boric acid molecule and decomposing organic matter serves as its main source. It is usually present as an un-dissociated boric acid in the soil solution which is taken up by the plants and its accessibility is highly influenced by the characteristics of soil such as pH, electrical conductivity, texture, cation exchange capacity, organic matter and calcium carbonate of soil.

Knowledge of different fractions of B is necessary to understand the chemistry of B in soils as it enables to know about plant availability, its binding forms, dynamics, and its possible impacts on environmental. The knowledge of the effect of different amendments and chemical fertilizers on native soil boron and the distribution of boron in different fractions are also essential for the proper management of soils. In soil, Boron is found in five different fractions *viz*. readily soluble, specifically adsorbed, oxide bound, organically bound, occluded or residual B. The relative concentration of these fractions in a soil at a given time depends on properties of soil like pH, amount and nature of clay, lime content, organic matter, soil moisture and plant factors. Only few forms of B are available to plants and their determination is important for evaluating its availability to plants. Padbhushan and Kumar [6] reported that residual B is the fraction present in soil solution which is absorbed by soil particles weakly, and for plant uptake, it is the most readily available form. It accounts for 1 to 2% of total B. The second most plant available form is specifically adsorbed boron which may be associated with organic matter (OM) or adsorbed onto clay surfaces or in soil. Distribution of these different forms of B in soil surface is always influenced by sub-surface soil and capability of these underlying B should also be taken into consideration while evaluating the reasons for variability of these forms. Considering these facts in mind, an experiment was conducted to find out the transformation of different fractions of Boron at different intervals.

2. MATERIALS AND METHODS

An incubation study was conducted in the laboratory to know the transformation of applied Boron in soils at field capacity. Forty gram of air dried soil was taken in each of a series of 100mL beakers. Boron treatments were added in the form of solution ($Na_2B_40_710H_2O$) and mixed uniformly with 40g of soil. The samples were incubated in the laboratory at room temperature for a period of 90 days. Soils of each treatment were maintained at the respective water holding capacity of the soil. Any loss of water through evaporation was compensated by periodic addition of double distilled water. Soil samples was collected periodically at 0, 30, 60 and 90 days after incubation (DAI) and analyzed for different fractions of B viz. readily soluble B, specifically adsorbed B, oxide bound B, organically bound B and residual B. The experiment was carried out under completely randomized block design (CRD). Altogether there were 6 treatment replicated thrice. Treatments included in the incubation studies were: T_0= Control, T_1= 0.5 mg B kg^{-1} soil, T_2= 1 mg B kg^{-1} soil, T_3= 1.5 mg B kg^{-1} soil, T_4= 2 mg B kg^{-1} soil and T_5= 2.5 mg B kg^{-1} soil. The fractions of boron were estimated by using different extractants as explained by Datta et al. [7]. The Readily soluble

B was extracted by 0.01M $CaCl_2$ solution (soil:extractant ratio of 1:2) and shaked for 16 hrs. Specifically adsorbed B is extracted with 0.05M KH_2PO_4 (1:2) and shaked for 1 hr. Oxide bound B was extracted by 0.175M NH_4-oxalate (1:4) and shaked for 4 hrs. Organically bound B was extracted by 0.5M NaOH (1:4) and heating at 85^0C. Residual B can be extracted with 1:5:5 ratios of HF, H2SO4, HClO4 and heating at 135^0C. The different fractions of B from the above extract were determined by following Azomethine-H method [8]. Statistical Analysis was done by the help of an online statistical software-OPSTAT.

3. RESULTS AND DISCUSSION

3.1 Readily Soluble B

Among the different fractions, readily soluble B fraction exhibit an increasing trend for elevated levels of B compared to control (Table 1 and Fig. 1). At 30 days of incubation, the readily soluble B in soils reached a maximum content (0.64 kg ha^{-1}) at B level of 2.5 kg ha^{-1}. At 60 and 90 days after incubation, the release pattern of this fraction with the application of B fertilizer at the rate of 2.5 kg ha^{-1} exhibited a decreasing course with figures of 0.57 and 0.47 kg ha^{-1} respectively. During the incubation period, the readily soluble B in soils ranged from 0.05 to 0.64 kg ha^{-1} and reached the maximum at B level of 2.5 kg ha^{-1} after 30 days of incubation. This paltry contribution in soil under this study might be due to its low availability. Similar discoveries also described by Karthikeyan and Shukla, [9].

3.2 Specifically Adsorbed Boron

The specifically adsorbed boron fraction in soils increased with elevated levels of boron application and reached a peak on 30^{th} day of incubation. The boron level of 2.5kg ha^{-1} had increased the specifically adsorbed boron content at 0 and 30 days after incubation (0.66 and 0.69 kg ha^{-1} respectively). Altogether from the inception to end of the incubation period, soils noted the highest specifically adsorbed boron content with 0.69 kg ha^{-1} at 30 days due to administration of B fertilizer at the rate of 2.5 kg ha^{-1}. At 60 and 90 days after incubation, the release pattern of this fraction with the application of B at the rate of 2.5 kg ha^{-1} exhibited a decreasing course with figures of 0.62 and 0.52 kg ha^{-1} (Table 1 and Fig. 2), respectively. In terms of their contribution to total boron in soil, the released fraction was found to be lowest which differ from 0.11 to 0.69 kg ha^{-1}. This might be probably due to the derivation of specifically adsorbed boron from weak binding sites of either the organic and inorganic constituents, as established with the findings of Hou et al. [10].

3.3 Oxide Bound Boron

The oxide bound boron fraction in soils increased with elevated levels of boron application and highest release was found on 30^{th} day of incubation. The effect of different boron levels at the rate of 2.5 kg ha^{-1} had increased the content at 0 and 30 days after incubation (1.13 and 1.16 kg ha^{-1} respectively). Altogether from the inception to end of the incubation period, soils noted the highest oxide bound boron content with 1.16 kg ha^{-1} at 30 days due to administration of B fertilizer at the rate of 2.5 kg ha^{-1}. Throughout the period of this incubation experiment, the oxide bound form of boron differs from 0.68 to 1.16 kg ha^{-1} (Table 1 and Fig. 3). At 60^{th} and 90^{th} day of incubation, this form exhibit a reduced trend which might be due the reason that oxide bound boron fraction entered into tightly bound boron at surfaces of mineral as well as Al or Fe that has been replaced isomorphously by B within the octahedral sheet of the minerals. The outcome also validated with prior discovery of Hou et al., [10].

3.4 Organically Bound Boron

The boron level of 2.5 kg ha^{-1} had boosted the organically bound boron content at 0 and 30 days after incubation (1.63 and 1.65 kg ha^{-1} respectively). The organically bound boron fraction in soils increased with elevated levels of boron application. Altogether from the inception to end of the incubation period, soils noted the highest organically bound boron content with 1.65 kg ha^{-1} at 30 days due to administration of B fertilizer at the rate of 2.5 kg ha^{-1}. The level of boron at the rate of 2.5 kg ha^{-1} rose the organically boron which differ from 1.16 to 1.65 kg ha^{-1}. At 60 and 90 days after incubation, the release pattern of this fraction with the application of B at the rate of 2.5 kg ha^{-1} exhibited a reduced trend with figures of 1.58 and 1.48 kg ha^{-1} (Table 1 and Fig. 4), respectively. This form of boron increased with increasing levels of boron which solely depend on the organic carbon content of the soil [9].

3.5 Residual Boron

It was observed that the residual boron fraction in soils increased with elevated levels of boron application. Boron level of 2.5 kg ha^{-1} had increased the content of residual boron at 0 and 30 days after incubation (38.31 and 38.34 kg ha^{-1}, respectively). Altogether from the inception to end of the incubation period, soils noted the highest residual boron content with 38.34 kg ha^{-1} at 30 days due to administration of B fertilizer at the rate of 2.5 kg ha^{-1} which was the maximum among all the fractions of boron. The residual boron fractions predominated in the soil and stretched from 31.65 to 38.34 kg ha^{-1} which contributed to 92.22 percent to total boron due to administration of B fertilizer at the rate of 2.5 kg ha^{-1} (Table 1 and Fig. 5). The residual form of boron was found to be the highest amounts that contributed to soil boron which generally differ from 70 to 99% of total soil boron [11]. This fraction of boron was considered to be the major contribution to total boron among all other fractions of boron [9].

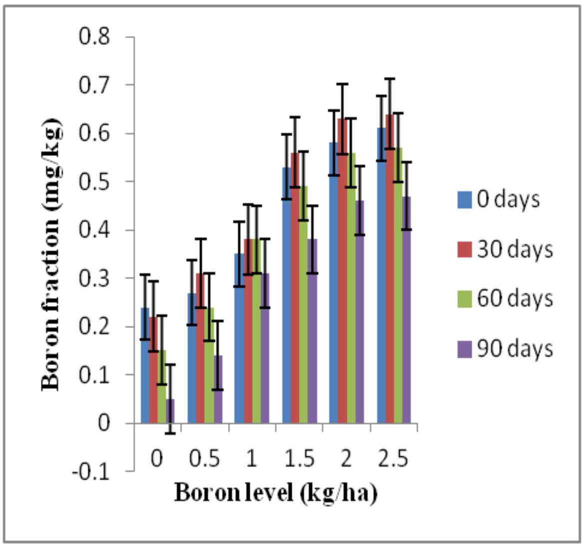

Fig. 1. Transformation of readily soluble B

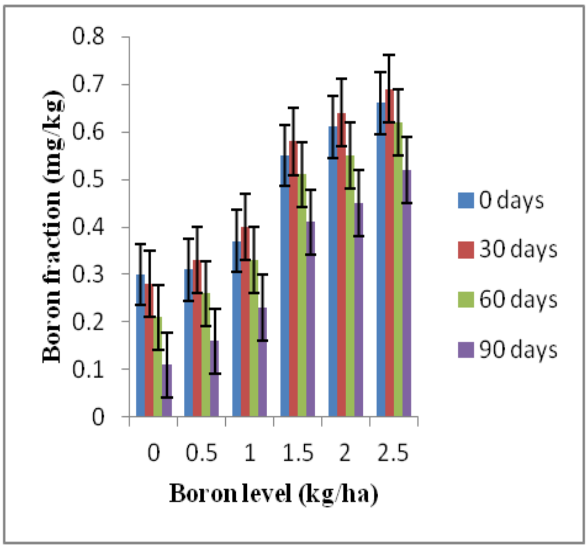

Fig. 2. Transformation of specifically adsorbed B

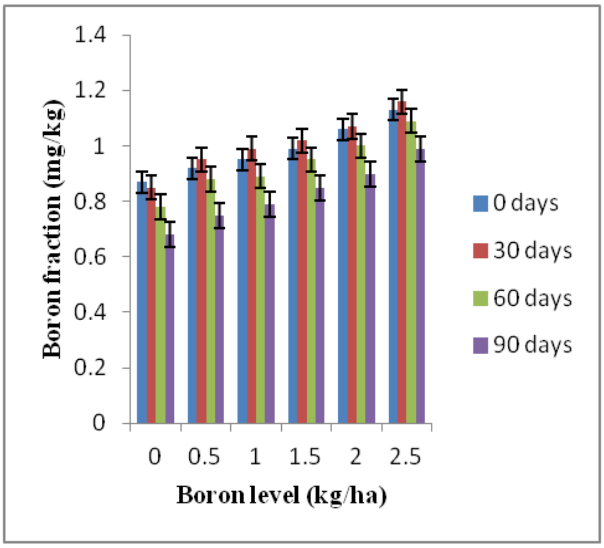

Fig. 3. Transformation of oxide bound B

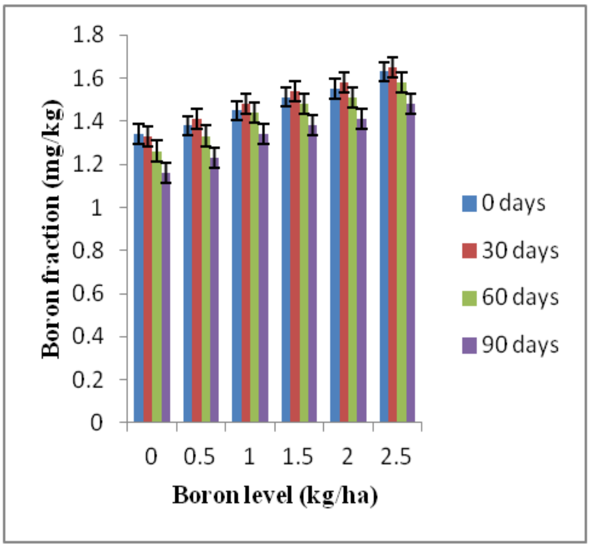

Fig. 4. Transformation of organically bound B

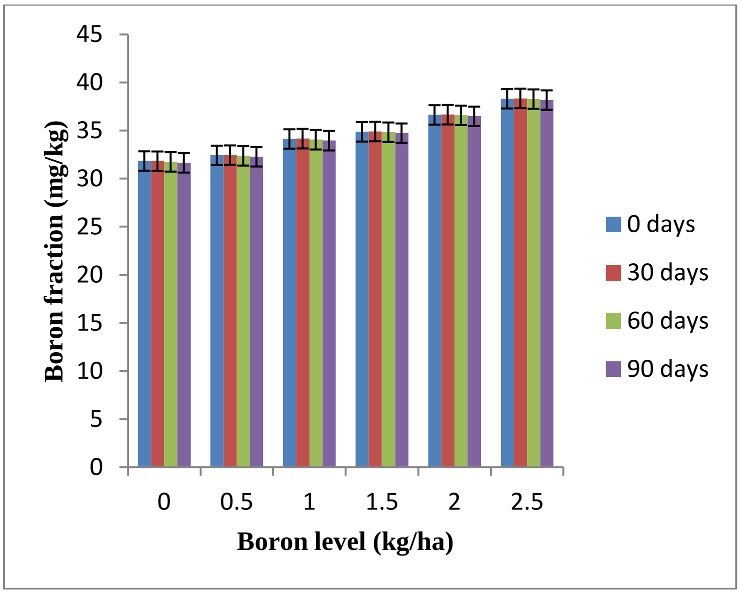

Fig. 5. Transformation of residual B

Table 1. Transformation of boron in soil at different intervals

Days after incubation	B levels (kg ha^{-1})	Boron fractions (mg kg^{-1})					
		Rea. S	Spe. ad	Ox. bound	Og. bound	Residual	Mean
0	0.0	0.24	0.30	0.87	1.34	31.84	6.92
	0.5	0.27	0.31	0.92	1.38	32.42	7.06
	1.0	0.35	0.37	0.95	1.45	34.13	7.45
	1.5	0.53	0.55	0.99	1.51	34.87	7.69
	2.0	0.58	0.61	1.06	1.55	36.63	8.09
	2.5	0.61	0.66	1.13	1.63	38.31	8.47
	Mean	**0.43**	**0.47**	**0.99**	**1.48**	**34.70**	
		T	F	T*F			
	S.Ed	0.013	0.011	0.028			
	C.D$_{0.05}$	0.025	0.022	0.055			
30	0.0	0.22	0.28	0.85	1.33	31.82	6.90
	0.5	0.31	0.33	0.95	1.41	32.45	7.09
	1.0	0.38	0.40	0.99	1.48	34.16	7.48
	1.5	0.56	0.58	1.02	1.54	34.9	7.72
	2.0	0.63	0.64	1.07	1.58	36.65	8.11
	2.5	0.64	0.69	1.16	1.65	38.34	8.50
	Mean	**0.46**	**0.49**	**1.01**	**1.50**	**34.72**	
		T	F	T*F			
	S.Ed	0.012	0.011	0.028			
	C.D$_{0.05}$	0.024	0.022	0.054			
60	0.0	0.15	0.21	0.78	1.26	31.75	6.83
	0.5	0.24	0.26	0.88	1.33	32.38	7.02
	1.0	0.38	0.33	0.89	1.44	34.05	7.42
	1.5	0.49	0.51	0.95	1.48	34.83	7.65
	2.0	0.56	0.55	1.00	1.51	36.58	8.04
	2.5	0.57	0.62	1.09	1.58	38.27	8.43
	Mean	**0.40**	**0.41**	**0.93**	**1.43**	**34.64**	

Days after incubation	B levels (kg ha^{-1})	Boron fractions (mg kg^{-1})					
		Rea. S	**Spe. ad**	**Ox. bound**	**Og. bound**	**Residual**	**Mean**
		T	F	T*F			
	S.Ed	0.011	0.010	0.024			
	$C.D_{0.05}$	0.021	0.01	0.047			
90	0.0	0.05	0.11	0.68	1.16	31.65	6.73
	0.5	0.14	0.16	0.75	1.23	32.28	6.91
	1.0	0.31	0.23	0.79	1.34	33.95	7.32
	1.5	0.38	0.41	0.85	1.38	34.73	7.55
	2.0	0.46	0.45	0.90	1.41	36.48	7.94
	2.5	0.47	0.52	0.99	1.48	38.17	8.33
	Mean	**0.30**	**0.31**	**0.83**	**1.33**	**34.54**	
		T	F	T*F			
	S.Ed	0.016	0.014	0.035			
	$C.D_{0.05}$	0.031	0.028	0.069			
		Rea. S	Spe. ad	Ox. bound	Og. bound	Residual	
Range		**0.05-0.64**	**0.11-0.69**	**0.68-1.16**	**1.16-1.65**	**31.65-38.34**	
Mean		**0.40**	**0.42**	**0.94**	**1.44**	**34.65**	

$C.D_{0.05}$ = significant at 5% level, T= Treatments, F= Fractions

4. CONCLUSION

From the incubation experiment, it was inferred that with applied boron, the organically bound B fraction was higher next to residual form when compared to other forms of boron. At 30 days of incubation, different fractions of boron showed an increasing trend for added levels of boron compared to control due to recently applied boron into the soil solution. However, at 60 and 90 days different fractions of boron in the soil started decreasing due the fact that boron entered into tightly bound state within the soil. In general, Boron fertilization increased the availability of boron content in soil and hence increased its availability to the crop. The sequence of the content of different fractions of boron in an acid soils of Imphal West District was Readily soluble-B>Organically bound-B>Oxide bound-B> Specifically adsorbed-B> Residual-B.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.4141/S01-027

Peer-review history:
The peer review history for this paper can be accessed here:
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