International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(3): 214-217

Received: 02-03-2017
Accepted: 03-04-2017

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Effect of boron and Konkan Annapurna briquettes on yield, nitrogen use efficiency and Nutrient uptake by okra (*Abelmoschus esculentus* (L.)

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Abstract
The field study was carried out on a lateritic soils of Konkan for year (2015-2016) to study the effect of boron and Konkan Annapurna Briquettes on yield, nitrogen use efficiency and nutrient uptake by okra (*Abelmoschus esculentus* (L.)). It was observed that the split application of 75% RDN through tar coated Konkan Annapurna Briquettes (KAB) fortified with boron @ 4 kg ha^{-1} which was applied in two times i.e. 1/2 quantity of briquettes at 2-3 leaf emergence stage of okra plant and 1/2 quantity of briquettes at 30 DAS @ 2 briquettes per plant which found promising to enhance the okra green pod yield, nitrogen use efficiency, higher uptake in respect to N, P, K and B content found to be improved. The placement of boron fortified tar coated Konkan Annapurna Briquettes can reduce the recommended dose of fertilizer to the extent of 25% during *Kharif* season in Konkan region.

Keywords: Okra, boron, tar coated briquettes, yield, nitrogen use efficiency and uptake

1. Introduction
Application of fertilizer is one of the most important agronomical practices to boost the crop productivity. Okra is a vegetable crop that require medium supply of plant nutrients especially N, P, K fertilizers for ensuring good plant growth and giving higher yield. The increase in growth, yield and improvement in quality of any crop is linked with physiological activities of the plants for which the micronutrient are equally important. They are required in small quantity but are essential for higher crop yield and quality produce. Boron exhibits pronounced effect on yield and yield attributing character. Boron might have taken part in active photosynthesis and translocation of carbohydrates (Kumar and Sen, 2005) [9]. Boron influences greatly the flowering, fruit set, fruit development (Phookan *et al*, 1991) [12]. The quality parameters like protein, ascorbic acid and carbohydrate content were increased with increasing levels of B. Number of investigators has shown that there is a definite and nearly constant requirement of N, P, K for production of high yielding varieties crop. It is considered that coating fertilizer would retard its dissolution rate as well as reduce the surface area of contact with soil properties which may help the precipitation of nutrients and consequently increase the availability of nutrients (Subrahmanyam and Dixit, 1998) [18]. The low use efficiency of N and P is because of various reasons such as volatilization, denitrification, surface runoff, leaching losses and ammonia fixation in soil. More or less similar situation observed in case of phosphorus and potassium also. Therefore, it would be better if all the plant nutrients are used in the briquette form. The information regarding the effect of boron and Konkan Annapurna Briquettes on response to yield, quality parameter, nitrogen use efficiency and available nutrient status is not available. Keeping this points in view, a field experiment is decided to undertaken.

Material and Methods
A field experiment was conducted during *Kharif* season 2015 in factorial randomized block design comprising of fifteen treatment combinations with three replicate. The five levels of NPK application viz. F_1-100% RDF through straight fertilizers, F_2-75% RDN through KAB, F_3-75% RDN through tar coated KAB, F_4-50% RDN through KAB and F_5-50% RDN through tar coated KAB which was fortified with different boron levels i.e. B_0-no boron, B_1-2 kg B ha^{-1} and B_2- 4 kg B ha^{-1}. The recommended dose of fertilizer for okra crop is (100:50:25 kg N: P_2O_5: K_2O ha^{-1}).

In case of straight fertilizer, whole quantity of P and K applied at time of sowing and application of N in split doses i.e.50% N at sowing and 50% N at 30 DAS. The application of KAB and tar coated KAB (50% RDN) i.e. application of briquettes @ one briquettes per plant at 2-3 leaf emergence stage and (75% RDN) i.e @ 1/2 quantity of briquettes at 2-3 leaf emergence stage of okra plant and 1/2 quantity of briquettes at 30 days after sowing @ 2 briquettes per plant. The initial experimental soil was clay loam in texture, strongly acidic in reaction and showed low electrical conductivity. The soil found medium in organic carbon whereas, available N was low. The soil was medium in available P_2O_5 and high in available K_2O.

Plant and fruit samples were analyse for total N, P, K and B. The treatment wise plant and fruit samples were collected. The samples were first washed with tap water and with deionized water and then were air dried and preserved in the brown paper bags labeled with permanent marker. These representative samples were adequately dried in oven at a temperature of 60 ± 5°C and ground in Willey type grinding machine and stored in polythene bags for analysis. The samples were then analyzed to know the content and the uptake of nutrients was worked out using yield data. The nutrient content in plant and fruit sample was determined by following the standard procedure. The plant and fruit samples were digested with conc. H_2SO_4 + H_2O_2 (30%) and the total nitrogen content was determined, For determination of P and K, B 1.0 fruit and plant sample was digested with nitric and perchloric acid, the final volume was made to 100 ml with distilled water and P and K, B in extract was determined (Singh *et al*., 1999) [16]. The total N (Tandon, 1993) [19], P (Chopra and Kanwar., 1978) [5], K (Piper, 1966) [13] and B (Tandon, 1993) [19]. Data were subjected to statistical analysis following Panse and Sukhatme (1967) [11].

Nitrogen use efficiency was estimated by using the following formulae:

$$\text{NUE (\%)} = \frac{\text{N uptake by fertilized plot (kg ha}^{-1}) - \text{N uptake by in control plot (kg ha}^{-1})}{\text{Quantity of fertilizer applied (kg ha}^{-1})} \times 100$$

Results and Discussion

Effect of boron and Konkan Annapurna Briquettes on fruit and stover yield of okra

The data pertaining to the green coloured, fresh okra fruit yield was also influenced significantly due to both factors applied and their combination also given in Table 1

Table 1: Effect of Boron and Konkan Annapurna Briquettes on fruit and Stover yield of okra plant

Treatments	Fruit yield (q ha^{-1})						Stover yield (q ha^{-1})					
	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean
B_0	114.61	127.18	150.32	125.71	133.85	130.33	35.03	50.78	66.22	47.23	60.00	51.85
B_1	116.46	128.48	144.62	128.28	142.85	132.14	42.28	53.23	70.27	51.90	65.22	56.58
B_2	121.67	140.07	171.44	153.22	160.51	149.38	43.66	56.87	76.45	54.66	67.01	59.73
Mean	117.58	131.91	155.46	135.73	145.74		40.33	53.63	70.98	51.26	64.08	
	F		B		F x B		F		B		F x B	
S.E. ±	2.84		2.20		4.92		2.29		1.77		3.96	
C.D(P=0.05)	8.22		6.37		14.24		6.63		5.14		11.48	

From the data, with respect to the application of different levels of NPK, it was observed that the maximum yield of okra fruit (155.46 q ha^{-1}) and stover yield (70.98 q ha^{-1}) was recorded in the treatment F_3 in which the 75 % RDN through tar coated KAB was applied which found significantly superior over rest of all the treatments. Regarding the application of different levels boron, it was observed that the B_2 treatment in which boron @ 4 kg ha^{-1} was applied which recorded maximum okra yield (149.38q ha^{-1}) and stover yield (59.73q ha^{-1}) which was also found significantly superior over rest of all of all the treatments. It was observed that the interaction effect showed significant results. The F_3B_2 treatment combination i.e.75 % RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} was applied recorded significantly highest yield of okra (171.44 q ha^{-1}) and stover yield (76.45q ha^{-1}) which was found at par with F_5B_2 treatment combination in which 50% RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} was applied.

It might be due to the slow release of nutrients through tar coated KAB for longer time which helped to release nutrients whenever required by the plants. This war reflected in terms of yield. Similarly boron influences greatly the flowering, fruit set, fruit development and seed development (Phookan *et al*, 1991) [12] hence resulted in to the increase in okra yield in combination with tar coated KAB which supplies nutrient for longer period. (Torane, 2014) [20] and also the briquette form of fertilizer recorded maximum yield of tomato than non-briquette form, reported by Kadam *et al.* (2005) [8].

Effect of boron and Konkan Annapurna Briquettes on total nutrient uptake by okra plant

Effect on total nitrogen uptake by okra

The total uptake of nitrogen in okra plant varied from 21.44 to 65.15 kg ha^{-1} in all treatment combinations. The maximum total uptake of nitrogen by okra plant (59.32 kg ha^{-1}) was recorded in the treatment F_3 in which 75% RDN through tar coated KAB was applied which was found significantly superior over all the treatments. Similarly, it was observed that the significantly maximum total uptake of nitrogen by okra plant (47.57 kg ha^{-1}) was recorded in the treatment B_2 i.e. 4 kg B ha^{-1}. It was found that the F_3B_2 treatment combination in which 75 % RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} recorded maximum total uptake of nitrogen by plant (65.15 kg ha^{-1}) which was found at par with the tar coated KAB treatment combinations. In general, it was found that the tar coated KAB was applied with increasing levels of boron which recorded maximum uptake of nitrogen in okra plant. Shinde (2011) [14] reported that there was significant increase in nitrogen uptake by groundnut in the treatment receiving fertilizer in the form of briquettes.

Effect on total phosphorus uptake by okra plant

The total uptake of phosphorus in okra plant varied from 12.17 to 38.37 kg ha^{-1}. The application of 75% RDN through tar coated KAB recorded maximum total uptake of phosphorus by okra plant (33.85 kg ha^{-1}) which found significantly superior over rest of all the treatments. Similarly, The treatment B_2 i.e. 4 kg B ha^{-1} recorded maximum total

uptake of phosphorus by okra plant (28.03kg ha^{-1}) which also found significantly superior. Similarly, the interaction effect showed significant results and the highest total uptake of phosphorus by okra plant (38.37 kg ha^{-1}) was recorded in the treatment combination F_3B_2 in which 75% RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} which was found at par with the F_5B_2 treatment combination. Bagal (2009) [1] and Bulbule *et al.* (2008) [3] a showed increase in P uptake due to the deep placement of briquettes containing NPK in different levels.

Effect on total potassium uptake by okra plant

The total uptake of potassium by okra plant varied from 84.43 to 301.27 kg ha^{-1} in all the treatment combinations. It was observed that the treatment F_3 i.e. 75% RDN through tar coated KAB recorded maximum total uptake of potassium by okra plant (254.65 kg ha^{-1}) which was found at par with the F_5 treatments. Similarly, in respect to different levels of boron, it was found that the significantly highest total uptake of potassium by okra plant (224.92 kg ha^{-1}) was recorded in the treatment B_2 i.e. 4 kg B ha^{-1}. The F_3B_2 treatment combination i.e. 75 % RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} was applied and recorded the maximum total uptake of potassium by okra plant (301.27 kg ha^{-1}) was found to be at par with the coated as well as non-coated KAB treatment combinations. The briquette form of fertilizer recorded highest potassium uptake by tomato plant than non-briquette form which was opined by Kadam and Sahane (2002) [7].

Effect on total boron uptake by okra plant

The total uptake of boron by okra plant ranged from 294.89 to 626.91 g ha^{-1} in all the treatment combinations. Both the factors showed individually significant results and recorded maximum uptake of boron by okra plant. The maximum uptake of total boron (554.58 g ha^{-1}) was recorded in the F_3 treatment i.e.75 % RDN through tar coated KAB was applied which found at par with the F_5 treatment. Similarly, the B_2 treatment i.e.4 kg B kg ha^{-1} recorded maximum uptake of total boron (484.69 g ha^{-1}) of okra plant. The maximum uptake of boron in okra plant (626.91 g ha^{-1}) was recorded in the treatment combination F_3B_2 in which 75 % RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} which was found at par with the F_3B_1 and F_5B_2treatment combinations. Similar results were found by Shorrocks, 1997 [15]; Chiu and Chang, 1985 [4]; Woodruff *et al.* 1987 [21], Singh *et al.* (2009) [17] in okra crop and Nawaz *et al.* (2014) in peanut crop.

Effect of Boron and Konkan Annapurna Briquettes nitrogen use efficiency in okra plant

The data regarding the application of different levels of NPK and boron on nitrogen use efficiency in okra plant was found significant and the data presented in Table 2

Table 2: Effect of Boron and Konkan Annapurna Briquettes on total uptake of nutrient and nitrogen use efficiency in okra plant

Treatments	Total uptake of N (kg ha^{-1})						Nitrogen use efficiency (%)					
	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean
B_0	21.44	30.94	54.26	33.16	43.38	36.64	11.39	27.86	58.95	46.23	66.67	42.22
B_1	25.13	40.60	58.56	38.98	48.20	42.29	15.08	40.73	64.68	57.85	76.30	50.93
B_2	27.52	48.23	65.15	42.87	54.04	47.57	17.47	50.91	73.47	65.65	87.98	59.10
Mean	24.70	39.93	59.32	38.34	48.54		14.65	39.83	65.70	56.58	76.99	

	F	B	F x B	F	B	F x B	F	B	F x B
S.E. ±	2.21	1.71	3.83	3.73	2.89	6.45	3.73	2.89	6.45
C.D (P=0.05)	6.40	4.96	11.08	10.79	8.36	18.69	10.79	8.36	18.69

N uptake in control (10.05 kg ha^{-1})

Treatments	Total uptake of P (kg ha^{-1})						Total uptake of K (kg ha^{-1})					
	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean
B_0	12.17	21.91	29.32	20.22	27.97	22.32	84.43	160.05	222.05	141.85	187.14	159.10
B_1	14.43	23.31	33.85	22.71	31.08	25.08	110.17	201.75	240.62	186.72	197.54	187.36
B_2	16.28	26.17	38.37	25.20	34.12	28.03	146.88	206.20	301.27	224.84	245.40	224.92
Mean	14.29	23.80	33.85	22.71	31.06		113.83	189.33	254.65	184.47	210.03	

	F	B	F x B	F	B	F x B	F	B	F x B
S.E. ±	0.88	0.68	1.53	20.62	15.98	35.72	35.72		35.72
C.D (P=0.05)	2.56	1.98	4.43	59.75	46.28	103.48	103.48		103.48

Treatments	Total uptake of P (kg ha^{-1})						Total uptake of K (kg ha^{-1})					
	F_1	F_2	F_3	F_4	F_5	Mean	F_1	F_2	F_3	F_4	F_5	Mean
B_0	12.17	21.91	29.32	20.22	27.97	22.32	84.43	160.05	222.05	141.85	187.14	159.10
B_1	14.43	23.31	33.85	22.71	31.08	25.08	110.17	201.75	240.62	186.72	197.54	187.36
B_2	16.28	26.17	38.37	25.20	34.12	28.03	146.88	206.20	301.27	224.84	245.40	224.92
Mean	14.29	23.80	33.85	22.71	31.06		113.83	189.33	254.65	184.47	210.03	

	F	B	F x B	F	B	F x B	F	B	F x B
S.E. ±	0.88	0.68	1.53	20.62	15.98	35.72		35.72	35.72
C.D (P=0.05)	2.56	1.98	4.43	59.75	46.28	103.48		103.48	103.48

Treatments	Total uptake of B (g ha^{-1})					
	F_1	F_2	F_3	F_4	F_5	Mean
B_0	294.89	327.70	469.52	326.39	423.17	368.33
B_1	298.87	421.60	567.29	360.79	489.51	427.61
B_2	353.39	477.57	626.91	401.06	564.52	484.69
Mean	315.72	408.96	554.58	362.74	492.40	

	F	B	F×B
S.E. ±	22.45	17.39	38.88
C.D (P=0.05)	65.03	50.37	112.64

It was revealed that the different levels of NPK application showed significant results with respect to a nitrogen use efficiency in okra plant. The maximum nitrogen use efficiency (76.99%) in okra plant was recorded in the treatment F_5 in which 50 % RDN through tar coated KAB which was found significantly superior over rest of all the treatments. Similarly, the application of different levels of boron showed significant results. The maximum nitrogen use efficiency (59.10%) in okra plant was recorded by the B_2 treatment in which 4 kg B ha^{-1} was applied which found at par with the B_1 treatment. The interaction effect of both the factors recorded significant results. The maximum nitrogen use efficiency (87.98 %) in okra plant was recorded in F_5B_2 treatment combination in which 50 % RDN through tar coated KAB fortified with boron @ 4 kg ha^{-1} was applied which found at par with the F_5B_1 and F_3B_2 treatment combinations. The similar findings were obtained by Havlin *et al*. (2005) [6] and Blaylock *et al*., (2005) [2]

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