D-5949
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RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Residual Effect of Boron on Yield, Yield Parameters and Economics of Knol-Khol (*Brassica oleracea* var. gongylodes L.) in Coastal Regions of Odisha

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10.18805/ag.D-5949

ABSTRACT

Background: Rice-vegetable is one of the remunerative and profitable cropping systems in Odisha to be grown in *kharif and rabi* season, respectively. From GPS based soil survey and analysis by AICRP on Micronutrient, OUAT, Bhubaneswar, it was observed that boron deficiency is widespread in soils of Odisha (8-79%) and is a major constraint in light texture sandy loam soils under vegetable production. Growing of a shallow rooted crop like rice as direct crop followed by a deep-rooted vegetable crop can utilize leached boron efficiently from subsoil thereby benefitting both. farmers in coastal Odisha generally grow knol-khol after rice.

Methods: A field experiment was conducted at E-block of Central Research Station under AICRP on micronutrient, OUAT, Bhubaneswar to standardize the dose and frequency of boron application for rice-knolkhol cropping system, where boron is applied to first crop and knol-khol gets residual boron. In the present investigation, residual effect of different graded doses of boron and its frequency of application on growth, yield, quality, post-harvest shelf life and economics of knol-khol for the year 2018-19 was studied under factorial randomized block design with three replications and four doses of boron (0.5, 1.0 , 1.5 and 2.0 kg ha^{-1}) at three different frequencies (application of boron once, alternate year and every year).

Result: The maximum values of growth parameters, highest yield and yield attributing characters such as diameter of knob (8.70 cm), length of knob (6.53 cm) and total knob yield (224.72 q ha^{-1}), highest B: C (2.27) were recorded with residual effect of boron @ 1.5 kg ha^{-1} in every year application.

Key words: Economics, Growth, Residual boron, Yield.

INTRODUCTION

Rice-vegetable is one the important cropping systems of East and South east coastal plains of Odisha. Both the productivity of Rice and knol-khol in Odisha is below national average due to less use of balanced fertilization, less nutrient use efficiency, non-inclusion of micronutrients in the fertilization schedule *etc*. Knol-khol (*Brassica oleracea* var. *gongylodes* L.) is a cool season crop and is originated from the coastal areas of Mediterranean region. It is an herbaceous biennial, grown for its edible stem. The edible part is the tuber formed by the thickening of stem tissue above the cotyledons *i.e*. swollen stem called knob or tuber. Among cole crops, it is comparatively hardy and of short duration. The knob is generally used as cooked vegetable and also utilized for making salad and pickles. Micronutrients are very much essential for growth, development and yield of knol-khol (Warington, 1923; Mortvedt, 1999 and Mengel and Kirkby, 2001). On boron deficient soils, the production of food grain, vegetables and fruits is drastically low, as it is important in cell division and helps in germination and growth of pollen grains, sugar translocation and movement of growth regulators within the plant and lignin synthesis. It is seen that Zn and B leaves residual effect to the succeeding crops (Singh, 2004).

From GPS based soil survey and analysis by AICRP on micronutrient, OUAT, Bhubaneswar, it was observed that boron deficiency was widespread in different soils of Odisha (8-79%) and is a major constraint in vegetable production (Satisha and Ganeshamurthy, 2012). In general, vegetables of Brassicaceae families are more sensitive to

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How to cite this article: Panda, R.S., Sahoo, D., Jena, B., Tripathy, P., Das, I., Nayak, R.K. and Paramjita, D. (2024). Residual Effect of Boron on Yield, Yield Parameters and Economics of Knol-Khol (*Brassica oleracea* var. gongylodes L.) in Coastal Regions of Odisha. Agricultural Science Digest. doi: 10.18805/ag.D-5949.

Submitted: 22-01-2024 **Accepted:** 13-02-2024 **Online:** 27-02-2024

Boron deficiency than other crops and respond to added Boron (Gupta, 1983). Information on Boron requirement in knol-khol has been summarized by Singh *et al*. (2015) and Mishra *et al*. (2014, 2015).

In the present study, residual effect of boron was also studied since its leaching is a common process in light texture sandy loam soil during *kharif.* Thus, growing of a shallow rooted crop like rice as direct crop followed by a deep-rooted crop can utilize leached B efficiently from subsoil. Farmers in coastal Odisha generally grow knol-khol after rice and apply B frequently to both. Limited information exists on the residual effect of boron fertilization on knol-khol growth and yield in a rice-knolkhol cropping system. No standardized method or dose of boron for a long-term rice-based vegetable cropping system is available. Therefore, an experiment was designed under AICRP on Micronutrient, OUAT, Bhubaneswar, involving different graded doses of boron applied at different frequencies to the rice-knolkhol cropping system. The study aims to assess the residual effects on knol-khol on growth, yield and yield attributing characteristics, as well as the economic implications.

MATERIALS AND METHODS

An experiment was conducted during *kharif* and *rabi* season of the year 2018-19 at E block of Central Research Station, OUAT, Bhubaneswar, which is situated at 20°15″N latitude and 85°52″E longitude with elevation of 25.9 m above Mean Sea level. The experimental site comes under the Agro-Climatic Zone East and South Eastern Coastal plain of Odisha and East Coastal Plains and Hills zone of the humid tropics of India. The study year (2018-2019) was a part of a long-term field experiment conducted at AICRP on micronutrient, OUAT, Bhubaneswar. In this experiment, Boron was applied once in four different doses (T_1: 0.5, T_2: 1.0, T_3: 1.5 and T_4: 2.0 kg ha^{-1}) to the *kharif* rice. In another set of treatments, same doses of boron were applied to the *kharif* rice in alternate years (T_5: 0.5, T_6: 1.0, T_7: 1.5 and T_8: 2.0 kg ha^{-1} and every year (T_9: 0.5, T_{10}: 1.0, T_{11}: 1.5 and T_{12}: 2.0 kg ha^{-1}) and Control (T_{13} with no B application).

Three weeks old seedlings of knol-khol were transplanted, when average height of seedlings were about 10-12 cm.The distance between row to row and plant to plant were kept at 40 cm × 30 cm. 100% recommended dose was common to all treatments of knol-khol and boron was applied as per treatment. The recommended dose of fertilizer for knol-khol was 100:75:75 kg ha^{-1} N, P and K that were applied from Urea, Diammonium phosphate and Muriate of potash, respectively. Full dose of diammonium phosphate, muriate of potash and half dose of urea were applied as the basal. Remaining half dose of urea was given as top dressing in two split doses at 30 and 45 days after transplanting. Boron was applied as per treatment combination through Agriculture Grade elemental borax containing 10.5% boron, that was broadcasted before transplanting and incorporated in the soil. The soil in the study area belongs to a textural class of sandy loam and low in nitrogen, phosphorus, potassium and boron content with a pH of 5.40, which is slightly acidic. The experiment was laid out in Factorial Randomized Block Design with three replications and thirteen treatments. Observations were recorded manually on growth parameters, yield and yield attributing characters and economics of its cultivation. The data so generated was statistically analyzed and ANOVA (analysis of variance) technique was used to test the overall significance of the data. Mean comparison to calculate significant difference between treatments was performed using CD at 0.05 level of probability.

RESULTS AND DISCUSSION

Growth

The results of the present studies revealed (Table 1) that the growth parameters of knol-khol like plant height and leaf area index were significantly influenced by graded doses and frequency of boron application. The maximum plant height (31.87 cm) and leaf area index (0.314) were noticed by D_3F_3 (residual application of 1.5 kg ha^{-1} boron every year), which was significantly superior than all other treatments and at par with D_4F_2 (residual application of 2 kg ha^{-1} boron in alternate year). All these parameters were found minimum in the control plots, where no boron was applied which was in accordance with the results of Ningawale *et al*. (2016). Application of 1.5 kg ha^{-1} boron every year significantly increased the plant height and leaf area index over control in knol-khol but application of 2 kg ha^{-1} boron (residual) every year significantly decreased the values of plant height and leaf area index (Table 1). This might be due to toxic effects of excessive application of boron. Under boron toxicity, photosynthetic rate is reduced due to reduction in the level of photosynthetic pigments as reported by Abhisree *et al*. (2022). These findings were also in close conformity with findings of Nieuwhoff (1969) in cole crops, Randhwa and Bhail (1976) in cauliflower and Hussain *et al*. (2012) in broccoli.

The increase in plant height and leaf area index could be attributed due to inter nodal elongation by cell division and synthesis of higher photosynthates due to application of recommended doses of N, P, K and boron, which was involved in enzyme system as cofactors and helped in acting as an electron carrier in the enzyme systems that are responsible for the oxidation and reduction in plant.

Residual application of boron significantly increases the growth attributing characters in knolkhol. This might be due to the auxin metabolism and increased photosynthesis rate by interaction of residual amount of boron with applied RDF. This was further supported by Rao and Vidyasagar (1981). Boron is also concerned with the precipitation of excess cations, buffer action and maintenance of conduction tissue that helps in absorption of nitrogen, which resulted in increased growth of knolkhol (Singh, 1991). Boron concentrations greatly improved plant height in broccoli (Nadian *et al*., 2010).

Yield and yield attributing characters

The results of the present studies (Table 2, Fig 1) revealed that the maximum diameter of knob (8.70 cm), length of knob (6.53 cm), volume of knob (230 cc), weight of knob (324.55 g), root length (28.07 cm), total knob yield (224.48 q ha^{-1}) and minimum days taken for harvestable maturity of knob (54.27 days), percentage of knob cracking (0%) were noticed by D_3F_3 (residual application of 1.5 kg ha^{-1} boron every year), which was significantly superior than all other treatments and at par with D_4F_2 (residual application of 2 kg ha^{-1} boron in alternate year) in characters diameter of knob (8.30 cm), root length (25.93 cm) and knob cracking (0%).

Table 1: Residual effect of graded doses and frequency of boron application on different parameters of knolkhol.

Treatment	Plant height (cm)	LAI	Diameter of knob (cm)	Length of knob (cm)	Volume of knob (cm)	Days for harvestable maturity of knob (days)	Weight of knob (g)	Root length (cm)	Knob cracking (%)	Total knob yield (q ha^{-1})
D_1 (0.5 kg)	18.14	0.089	6.38	4.63	105.44	71.17	209.09	17.88	3.29	145.52
D_2 (1.0 kg)	20.14	0.121	6.62	4.99	117.00	67.24	226.95	19.53	2.10	156.21
D_3 (1.5kg)	23.60	0.185	7.33	5.43	155.78	62.73	250.14	23.14	1.12	172.49
D_4 (2 kg)	21.70	0.140	6.99	5.23	129.56	66.02	238.95	21.83	1.31	166.90
SE (m) ±	0.19	0.004	0.08	0.06	2.93	0.45	2.23	0.47	0.09	1.57
CD (P=0.05)	0.56	0.013	0.23	0.19	8.56	1.30	6.50	1.36	0.26	4.58
F_1	16.05	0.068	5.82	4.37	95.83	74.74	180.11	16.08	3.10	124.75
F_2	22.21	0.153	7.18	5.23	131.33	64.16	249.01	22.32	1.43	172.21
F_3	24.43	0.181	7.48	5.56	153.67	61.48	263.98	23.39	1.33	183.90
SE (m) ±	0.22	0.005	0.09	0.07	3.39	0.51	2.57	0.54	0.10	1.81
CD (P=0.05)	0.64	0.015	0.27	0.22	9.88	1.50	7.50	1.57	0.31	5.29
Mean	20.90	0.134	6.83	5.07	126.95	66.79	231.28	20.60	1.96	160.28
Control	11.43	0.046	5.18	3.64	69.97	85.37	163.97	8.27	10.27	118.35
C versus RSE (d) ±	0.40	0.009	0.16	0.13	6.11	0.93	4.63	0.97	0.19	3.27
C versus RCD (P=0.05)	0.82	0.019	0.34	0.28	12.60	1.91	9.56	2.00	0.39	6.74

D: Graded doses of boron F: Frequency of B application.
D_1: Mean of B applied @ 0.5 kg ha^{-1} once, alternate year and every year.
D_2: Mean of B applied @ 1.0 kg ha^{-1} once, alternate year and every year.
D_3: Mean of B applied @ 1.5 kg ha^{-1} once, alternate year and every year.
D_4: Mean of B applied @ 2.0 kg ha^{-1} once, alternate year and every year.
F_1: Mean of frequency of B applied once.
F_2: Mean of frequency of B applied alternate year.
F_3: Mean of frequency of B applied every year.

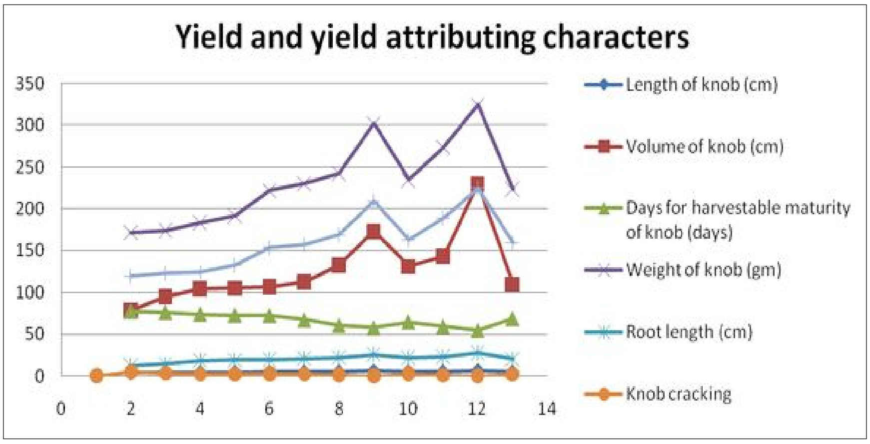

Fig 1: Residual effect of graded doses and frequency of boron application on yield and yield attributing characters.

Days taken to harvestable maturity of knob (85.37 days) and knob cracking (10.27 %) was found maximum in the control plots where no boron was applied.

The increase in yield (Singh, 2004) and yield attributing characters is due to increased starch, soluble protein, specific activity of carbonic anhydrase, specific activity of acid phosphatase and ribonuclease in leaves and pods by interaction of residual amount of boron with applied recommended dose. This was also similar with the results of Naik *et al.* (2023), who reported that soil application with Borax at various levels significantly influenced growth attributes, yield and economics of oats seed production. Hamsa *et al.* (2012) recorded that higher amount of pods $plant^{-1}$ (25.66), highest pod length (12.8 cm) and higher pod yield (9871.55 kg ha^{-1}) in French bean due to residual boron application in a French bean-rice cropping system. The results of the investigation under study were in conformity with Jena *et al.* (2009) in cabbage-okra cropping system, Ganeshmurthy *et al.* (2014) in French bean-cabbage cropping system and Jena *et al.* (2017) in rice-vegetable cropping system grown in inceptisols of Odisha.

Knob diameter, length of knob, volume of knob, weight of knob and total knob yield were significantly influenced by graded doses and frequency of boron application. It might be due to proper utilization of carbohydrates, proteins and accumulation of photosynthates and many functions like carbohydrate metabolism and enzyme activation etc. by the supply of optimum level of boron. These findings are also confirmed with the earlier workers like Pizetta *et al.* (2005) in cauliflower, Supe and Marbhal (2008) in cabbage and Shah *et al.* (2010) in knol-khol.

Increase in net weight of knob and knob yield due to boron application might be due to increase in gross weight of plant, knob diameter, knob length, knob volume and weight of knob as observed by Shah *et al.* (2010) in knol-khol and also due to better availability of soil nutrients that produced healthy plant with large vegetative growth, which reflected in yield and yield attributing parameters and improvement of soil chemical and physical properties by using boron. These findings are also confirmed with Singh *et al.* (2017) in broccoli.

Boron significantly improves the yield and yield attributing parameters of cole crops (Singh, 2003). In Cole crops like knol-khol, cauliflower and broccoli, boron requirement is high so increased availability of boron has positive influence on knob yield. These results are in conformity with investigations of Talukder *et al.* (2000) and Noor *et al.* (2000) in cauliflower and Ain *et al.* (2016) in broccoli. Therefore, it is very much essential to optimize the dose of boron for successful cultivation of cole crops.

Root length increases significantly by application of boron as it involves in indoleacetic acid oxidase activity, auxin

Table 2: Interaction residual effect of graded doses and frequency of boron application on different parameters of knolkhol.

Treatment	Plant height (cm)	LAI	Diameter of knob (cm)	Length of knob (cm)	Volume of knob (cm)	Days for harvestable maturity of knob (days)	Weight of knob (g)	Root length (cm)	Knob cracking (%)	Total knob yield (q ha^{-1})
D_1F_1	15.37	0.054	5.53	4.07	78.33	77.07	171.25	12.17	5.18	119.61
D_2F_1	15.83	0.064	5.62	4.27	95.00	75.90	173.88	14.10	3.23	122.82
D_3F_1	16.13	0.080	5.93	4.47	104.67	73.63	183.59	18.83	2.20	124.04
D_4F_1	16.90	0.073	6.20	4.67	105.33	72.37	191.73	19.20	1.80	132.51
D_1F_2	17.60	0.083	6.33	4.70	106.67	72.03	221.65	19.53	2.43	154.14
D_2F_2	20.13	0.112	6.73	5.13	112.67	66.90	230.32	21.30	2.13	156.79
D_3F_2	22.80	0.163	7.37	5.30	132.67	60.30	242.29	22.51	1.17	168.97
D_4F_2	28.30	0.254	8.30	6.03	173.33	57.40	301.87	25.93	0	208.92
D_1F_3	21.47	0.130	7.27	5.13	131.33	64.40	234.38	21.93	2.27	162.80
D_2F_3	24.47	0.188	7.50	5.57	143.33	58.93	273.74	23.20	0.93	189.02
D_3F_3	31.87	0.314	8.70	6.53	230.00	54.27	324.35	28.07	0	224.48
D_4F_3	19.90	0.095	6.47	5.00	110.00	68.27	223.26	20.37	2.13	159.28
SE (m) ±	0.38	0.009	0.16	0.13	5.87	0.89	4.45	0.93	0.18	3.14
CD (P=0.05)	1.11	0.026	0.46	0.37	17.12	2.60	12.99	2.72	0.53	9.16

D: Graded doses of boron F: Frequency of B application.

D_1: Mean of B applied @ 0.5 kg ha^{-1} once, alternate year and every year.

D_2: Mean of B applied @ 1.0 kg ha^{-1} once, alternate year and every year.

D_3: Mean of B applied @ 1.5 kg ha^{-1} once, alternate year and every year.

D_4: Mean of B applied @ 2.0 kg ha^{-1} once, alternate year and every year.

F_1: Mean of frequency of B applied once.

F_2: Mean of frequency of B applied alternate year.

F_3: Mean of frequency of B applied every year.

Table 3: Cost of cultivation per ha of knol-khol under rice-vegetable cropping system with residual boron (2018-19).

Treatment	Fruit yield (q ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C
T_1 : Boron @ 0.5 kg ha^{-1} once	119.41	77216	95528	18312	1.24
T_2 : Boron @ 1 kg ha^{-1} once	123.14	77216	98512	21296	1.28
T_3 : Boron @ 1.5 kg ha^{-1} once	126.90	77216	101520	24304	1.31
T_4 : Boron @ 2 kg ha^{-1} once	132.93	77216	106344	29128	1.38
T_5 : Boron @ 0.5 kg ha^{-1} in alternate year	154.32	77216	123456	46240	1.60
T_6 : Boron @ 1 kg ha^{-1} in alternate year	159.64	77216	127712	50496	1.65
T_7 : Boron @ 1.5 kg ha^{-1} in alternate year	168.60	77216	134880	57664	1.75
T_8: Boron @ 2 kg ha^{-1} in alternate year	208.73	77216	166984	89768	2.16
T_9: Boron @ 0.5 kg ha^{-1} every year	162.03	77877.5	129624	51746	1.66
T_{10}: Boron @ 1 kg ha^{-1} every year	189.73	78539	151784	73245	1.93
T_{11}: Boron @ 1.5 kg ha^{-1} every year	224.72	79200.9	179776	100575.5	2.27
T_{12}: Boron @ 1.5 kg ha^{-1} every year	157.77	79862	126216	46354	1.58
T_{13}: Control (No boron application)	118.20	77216	94560	17344	1.22

synthesis, nucleic acid synthesis, nitrogen-based synthesis or utilization and involved in RNA metabolism. These findings are confirmation with the reports of Abd El-All (2014) and Ain *et al.* (2016) in broccoli.

Days taken for harvestable maturity of knob was significantly influenced by graded doses and frequency of boron application. It might be due to availability of boron that mainly ascribed to the process of plant growth regulations which has an influence on less days taken for harvestable maturity of knob. These findings are in confirmation with the reports of Shah *et al.* (2010) in knolkhol, Singh *et al.* (2015) and Islam *et al.* (2015) in broccoli.

Knob cracking (%) was significantly influenced by insufficient supply of boron since boron is a constituent of cell membrane that is essential for cell division. In case of boron deficiency cell division ceases at the growing point leading to disorder like knob cracking in knol khol (Shah *et al.,* 2010).

Application of 1.5 kg ha^{-1} boron every year significantly increase the values of diameter of knob, length of knob, volume of knob, weight of knob, root length, total knob yield and decrease the values of days taken for harvestable maturity of knob and knob cracking (%) over control in knolkhol (Table 1, Fig 1). These findings are in close conformity with earlier findings of Hussain *et al.* (2012) and Ain *et al.* (2016) in broccoli, Kumar *et al.* (2012) in cauliflower but application of 2 kg ha^{-1} boron every year significantly decreased the values of all yield attributing parameters except the values of days taken for harvestable maturity of knob and knob cracking (%), this might be due to toxic effects of excessive application of boron.

Economics

Residual application of graded doses and frequency of boron application exhibited noticeable influence in the economics of knol-khol cultivation comprising cost of cultivation, gross return, net return and B:C during the investigation (Table 3). Maximum involvement of cost was marked when 2 kg boron was applied under residual condition per ha every year (₹ 79862). The lowest cost of cultivation was incurred in rest treatments where boron was not applied in the period of investigation. Boron was not applied in 2017-18 in the treatments (T_1, T_2, T_3 and T_4) where boron was applied once in 2012-13 and also in treatments (T_5, T_6, T_7 and T_8) where, boron was applied in 2016-17 *i.e.* alternate year.

Application of boron @ 1.5 kg ha^{-1} every year under residual condition recorded the highest gross return of (₹ 179776/-) whereas, the lowest gross return (₹ 94560/-) was obtained in control where no boron was applied. The highest net return of (₹ 100575/-) was also observed in the treatment where 1.5 kg boron (residual) was applied as compared to other treatments tried in the experiments. The highest gross return and net return was mainly due to higher total knob yield However the lowest net return was calculated to be (₹ 17344/-).

Highest B:C of 2.27 was observed in treatment where 1.5 kg boron (residual) was applied per ha every year where as the lowest B:C of 1.22 was observed in case of control where no boron was applied. Mathew *et al.* (2024) reported that application of B @ 2.5 kg ha^{-1} along with the recommended dose of N, P and K resulted in the highest net returns estimated in terms of B:C. Kumar *et al.* (2012) observed that highest B:C (2.70) was obtained when boron was applied 1.5 kg ha^{-1} along with 20 t ha^{-1} FYM in cauliflower. Similar findings were also reported by Shah *et al.* (2010) in knolkhol, Naryanemma *et al.* (2009), Patil *et al.* (2013) in bitter gourd and Kumar *et al.* (2010) in cauliflower.

CONCLUSION

It can be summed up that residual effect of boron @ 1.5 kg ha^{-1} in every year (D_3F_3) showed significant result with respect to growth, yield and yield attributing characteristics of knol-khol in a light textured sandy loam soil under rice-vegetable cropping system of Odisha.

As regards to the net return maximum return of ₹ 100575/- per ha was obtained when the crop was applied with 1.5 kg boron per ha every year (D_3F_3). Maximum B:C (2.27) was also noticed in boron application @ 1.5 kg per ha every year (D_3F_3) as compared to other treatment. The B:C further indicated that the treatment 1.5 kg boron applied per ha every year (D_3F_3) is the best nutrient management practice where the farmer can earn ₹ 2.27 per ₹ 1 of investment. Thus, investigations carried out on the studies on residual effects of graded doses and frequency of boron application on Knol-Khol revealed that the vegetable crop knol-khol could be profitably grown under residual condition of a rice-vegetable cropping system receiving 1.5 kg B every year to the rice crop which will be suitable for most of the rice-vegetable cropping system followed in Odisha.

Conflict of interest

All authors declared that there is no conflict of interest.

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