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Impact of lime and micronutrients on nutrient uptake and post-harvest soil fertility status in broccoli (*Brassica oleracea* L. *italica*) var. "Palam Samridhi"

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Abstract
A field experiment was conducted at Department of Vegetable Science, College of Agriculture, OUAT, Bhubaneswar, during *rabi* season of 2017-18 to find out the optimum rate of B and Zn application for maximizing nutrient uptake and yield of broccoli (*Brassica oleracea* var. *italica*) in acidic soils of Odisha. The experiment was laid out in split plot design with lime (with or without) as main plot while 7 levels of micronutrients of both B and Zn (*viz;* soil application of B @1kg ha^{-1}, Zn@5kg ha^{-1} and their combinations as well as foliar spray of 0.2% borax, 0.5% $ZnSO_4$ and their combinations along with control) replicated thrice. The results revealed significant variations on yield and yield attributes with soil application of lime and micronutrient such as B and Zn when applied individually but their interactions were not significant. In this study it was found that application of lime and combined foliar spray of micronutrients (0.2% borax and 0.5% $ZnSO_4$) increased the soil pH, EC and OC, as well as uptake and availability of N,P,K,B and Zn in post-harvest soil as compared to control.

Keywords: Broccoli, lime, micronutrients, nutrient uptake, soil fertility

Introduction
Broccoli (*Brassica oleracea* L. *italica*) is one of the important export oriented vegetable crops of India. The popularity of broccoli is primarily due to its significant role towards nutritional security to combat various cancerous diseases. The principal compound having anti-cancer properties is due to sulphoraphane. Although broccoli is an export oriented vegetable but its productivity and quality is very poor under Indian condition contributed by several factors. Soil acidity is constantly limiting crop productivity; application of lime on acid soils is a common agricultural practice to ensure optimum crop production and a healthy soil (Kowalenko and Ihnat, 2009) [8]. Although lime can contribute calcium, another essential plant nutrient, it also influences the availability of many other nutrients and associated elements (Adams, 1984) [1]. The crop also required balanced amount of macro and micronutrient for higher yield with quality. Boron and zinc are most essential micronutrient for carbohydrate metabolism and water relation in plant growth (Brady, 1990) [4]. An abiotic disorder "hollow stem" is commonly associated with boron deficiency (Shelp *et al.*, 1992) [11]. Being an under exploited vegetable under Indian condition, not much information is available to increase the production, productivity and quality. Hence, there is need for standardization of micronutrient in acidic soil. Keeping this in view, a field experiment was conducted to study the impact of lime and micronutrients on nutrient uptake and soil fertility status for optimum production in broccoli var. "Palam Samridhi".

Materials and Method
The study was carried out at Department of vegetable science, College of Agriculture, OUAT, Bhubaneswar, Odisha, India during *rabi* season of 2017-18. The experiment was laid out in spilt-plot design with three replications. Main plot consisted of two lime treatments- without lime(L_O), with lime(L_1)and seven levels of micronutrients in subplots, *viz;*soil application of B @ 1kg ha^{-1} (M_1), foliar application of Borax @ 0.2% (M_2), soil application of Zn @ 5kg ha^{-1} (M_3), foliar application of $ZnSO_4$ @ 0.5% (M_4), combined soil application of B @ 1kg ha^{-1} + Zn @ 5kg ha^{-1} (M_5), combined foliar spry of Borax @ 0.2% + $ZnSO_4$ @ 0.5% (M_6), control (without B and Zn) (M_7). A uniform dose of FYM @ 25 tha^{-1} and 150:100:50 NPK kg ha^{-1} was applied. Borax and boric acid used as source of boron, while zinc sulphate was used as source of Zn. Three sprayings were done at 20, 35 and 50 days after transplanting according to the

treatment schedule. During the crop growth period regular and normal intercultural operations and insect pest and disease control measures were carried out as per requirement to maintain crop health. Initial soil status and post-harvest soil analysis was done by adopting different methods. The nutrient uptake through plant (leaf) was calculated after multiplying the nutrient concentration of individual nutrient with dry matter yield (root and leaf) of broccoli. Statistical analysis was done by adopting standard procedures.

Results and Discussion

Yield

The fresh head yield of broccoli due to application of B and Zn under limed and without lime treatment varied from 122.78- 136.80 q ha^{-1}. The maximum yield was recorded in M_6, followed by M_4, M_5, M_3, M_2, M_1 and M_7 in decreasing order presented in table no. 1. The mean head yield under limed condition was 134.73 q ha^{-1} and that of without lime was 124.06 qha^{-1}, which recorded 8.60% yield increases over without lime treatment.

Nutrient uptake

The results data presented in table no. 2 and 3 revealed that application of lime significantly increased the uptake (kg ha^{-1}) of nutrients in terms of nitrogen (90.73), phosphorus (63.61), potassium (52.55), boron (0.21) and zinc (1.43) than corresponding control without lime (82.25, 56.49, 48.32, 0.184 and 1.36, respectively), irrespective of micronutrients application. Significant increase in uptake of both macro and micronutrients observed in the present study might be due to the enhanced pH 5.54 to 5.60 (table no.4), there by induced the release of nutrients from the soil and available to the plant. Similar report of increased uptake of nutrients due to lime along with RDF and FYM application has been reported by Otieno *et al.*(2018) [8]. Increased uptake of nutrients by broccoli might be due to the ameliorated soil pH in and around the root rhizosphere that encouraged healthy root development with improved uptake of nutrients (Cifu *et al.*, 2004) [5]. Similar findings of increasing uptake of NPK due to liming have been reported by Dixit *et al.* (1995) [6] and Setthy *et al.* (2003) [12].

Sole application of B and Zn through soil resulted uptake ($kgha^{-1}$) of nitrogen (99.32), phosphorus (72.67), potassium (57.10), boron (0.232) and zinc (1.64). Micronutrients in general, might not reached the plant from soil through roots due to soil acidity and other probable factors. In the present study, foliar application of micronutrients showed significantly better vegetative yield attributing parameters and yield as well as higher uptake ($kgha^{-1}$) of nutrients such as nitrogen (79.47, 94.75 and 99.32), phosphorus (56.70,70.14 and 72.67), potassium (47.23, 55.32 and 57.10), boron (0.225, 0.223 and 0.232) and zinc (1.42, 1.58 and 1.64). This might be due to quick and easy absorption of micronutrients directly by leaves in broccoli as foliar spray than that of soil application, combination of boron and zinc created a congenial environment for better growth and development of broccoli plants, there by increased uptake of nutrients. Boron helps in nitrogen metabolism (Saha *et al.*, 2010) [9]. Similar report of significantly increased boron content in cauliflower with combined application of lime, FYM and boron was reported by Sen *et al.* (2017) [10] in cauliflower.

Post- harvest soil properties

The effect of lime, boron and zinc application on some basic properties of soil (like pH, EC and OC) and available N P and K were studied in broccoli crop and presented in table no. 4, 5 and 6.

The post-harvest soil pH variation due to micronutrient application ranged between 5.35 - 5.78. The post-harvest soil pH were increased in M_3, M_4 and M_6 treatments and decreased in other treatments over initial soil pH (5.54). The mean post-harvest soil pH in limed plots was 5.60 and 5.45 was found in unlimed plots. There was an increase of 0.06 unit of pH in limed treatments whereas there was a decrease of 0.09 units under unlimed condition. Liming helped in increasing the post-harvest soil pH. Liming has wide ranging effects on the soil and applications are usually made to improve soil quality and nutrient availability (Sen *et al.*, 2017) [10]. Application of Zn alone or in combination with B increase post-harvest soil pH. The EC of post-harvest soil was reduced compared to initial value (0.20 dsm^{-1}). The organic carbon content of post-harvest soil was increased with micronutrient application. The available N and P of post-harvest soil was decreased in all treatments compared to initial 255.5 kg ha^{-1}. It was due to uptake of N and P by broccoli crop from the above soil pool. The available K content in post-harvest soil was increased in all treatments except M_2 and M_7 compared to initial value due to less yield. Available B and Zn content in post-harvest soil increased in all treatments due to application od B and Zn. Application of lime helped in increasing the availability of micronutrients (B and Zn) in soil. The increasing availability of NPK due to liming may be the favourable effect on soil pH (Dixit *et al.*, 1995; Setthy *et al.*, 2003) [6, 12].

Table 1: Response of lime, boron and zinc on head yield (kg $plot^{-1}$) in Broccoli var. Palam Samridhi

	Total yield (q ha^{-1})		
Treatment	**Lime**		**Lime**
	L_0	**L_1**	**Mean**
M1	119.57	126.00	122.78
M2	120.76	135.51	128.13
M3	123.73	140.10	131.92
M4	137.43	133.25	135.34
M5	119.07	140.49	129.78
M6	130.53	143.07	136.80
M7	117.33	124.71	121.02
Mean	124.06	134.73	129.40
	SE(m)±	CD(5%)	CV(%)
Lime	1.03	6.29	3.66
Micronutrients	2.31	6.74	4.37
Interaction	3.27	9.70	

- L_o: Without lime; L_1: With lime
- M_1: Soil application of boron@1kg ha^{-1} ; M_2: Foliar spray of borax @ 0.2%
- M_3: Soil application of zinc @5kg ha^{-1}; M_4: Foliar spray of $ZnSO_4$ @ 0.5%
- M_5: Combined soil application of @1kg ha^{-1} + zinc @5kg ha^{-1}; M_6: Combined foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5%
- M_7: Control (Without lime, boron and zinc)

Table 2: Response of Broccoli var. Palam Samridhi to boron, zinc and lime application on uptake of NPK (kg ha^{-1})

	N-uptake (kgha^{-1})			P-uptake (kgha^{-1})			K-uptake (kgha^{-1})		
Treatment	**Lime**			**Lime**			**Lime**		
	L_0	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**
M1	70.34	77.83	74.09	52.95	55.13	54.04	42.73	48.83	45.78
M2	72.83	86.10	79.47	47.69	65.70	56.70	43.53	50.93	47.23
M3	86.93	96.03	91.48	52.94	54.96	53.95	49.37	52.77	51.07
M4	89.73	99.77	94.75	69.45	70.83	70.14	53.37	57.27	55.32
M5	91.80	99.53	95.67	58.84	69.27	64.05	52.70	55.73	54.22
M6	94.47	104.17	99.32	69.73	75.60	72.67	56.03	58.17	57.10
M7	69.63	71.70	70.66	43.80	53.78	48.79	40.50	44.13	42.32
Mean	82.25	90.73	86.49	56.49	63.61	60.05	48.32	52.55	50.43
	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)
Lime	0.91	5.55	4.84	0.60	3.66	4.59	0.19	1.15	1.72
Micronutrients	1.73	5.05	4.90	1.27	3.71	5.19	0.73	2.14	3.56
Interaction	2.45	NS		1.80	5.34		1.04	NS	

- L_o: Without lime; L_1: With lime
- M_1: Soil application of boron@1kg ha^{-1} ; M_2: Foliar spray of borax @ 0.2%
- M_3: Soil application of zinc @5kg ha^{-1}; M_4: Foliar spray of $ZnSO_4$ @ 0.5%
- M_5: Combined soil application of @1kg ha^{-1} + zinc @5kg ha^{-1}; M_6: Combined foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5%
- M_7: Control (Without lime, boron and zinc)

Table 3: Response of Broccoli var. Palam Samridhi to boron, zinc and lime application on uptake of boron and zinc (kg ha^{-1})

	B uptake (kgha^{-1})			Zn uptake (kgha^{-1})		
Treatment	**Lime**			**Lime**		
	L_0	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**
M1	0.171	0.207	0.189	1.28	1.37	1.32
M2	0.207	0.243	0.225	1.40	1.44	1.42
M3	0.179	0.213	0.196	1.43	1.49	1.46
M4	0.199	0.247	0.223	1.56	1.61	1.58
M5	0.207	0.230	0.218	1.53	1.59	1.56
M6	0.217	0.247	0.232	1.60	1.67	1.64
M7	0.110	0.130	0.120	0.70	0.81	0.75
Mean	0.184	0.217	0.200	1.36	1.43	1.39
	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)
Lime	0.002	0.015	5.53	0.01	0.06	3.39
Micronutrients	0.004	0.011	4.70	0.02	0.07	3.98
Interaction	0.005	NS		0.03	NS	

- L_o: Without lime; L_1: With lime
- M_1: Soil application of boron@1kg ha^{-1} ; M_2: Foliar spray of borax @ 0.2%
- M_3: Soil application of zinc @5kg ha^{-1}; M_4: Foliar spray of $ZnSO_4$ @ 0.5%
- M_5: Combined soil application of @1kg ha^{-1} + zinc @5kg ha^{-1}; M_6: Combined foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5%
- M_7: Control (Without lime, boron and zinc)

Table 4: Response of lime, boron and zinc on soil properties in Broccoli var. Palam Samridhi

	Soil pH (1:2.5)			EC(dSm^{-1})			OC (%)		
Initial soil status	**5.54**			**0.20**			**0.45**		
Treatment	**Lime**			**Lime**			**Lime**		
	L_0	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**
M1	5.34	5.45	5.39	0.167	0.170	0.168	0.46	0.51	0.49
M2	5.31	5.39	5.35	0.168	0.170	0.169	0.49	0.53	0.51
M3	5.71	5.72	5.71	0.170	0.170	0.170	0.51	0.57	0.54
M4	5.41	5.72	5.57	0.173	0.173	0.173	0.52	0.59	0.56
M5	5.35	5.69	5.52	0.169	0.170	0.170	0.56	0.58	0.57
M6	5.76	5.80	5.78	0.170	0.173	0.172	0.49	0.66	0.58
M7	5.30	5.44	5.37	0.138	0.157	0.148	0.39	0.41	0.40
Mean	5.45	5.60	5.53	0.165	0.169	0.167	0.49	0.55	0.52
	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)
Lime	0.014	0.09	1.19	0.002	NS	5.45	0.01	0.06	8.03
Micronutrients	0.092	0.27	4.09	0.003	0.009	4.54	0.03	0.08	13.10
Interaction	0.130	NS		0.004	NS		0.04	NS	

- L_o: Without lime; L_1: With lime
- M_1: Soil application of boron@1kg ha^{-1} ; M_2: Foliar spray of borax @ 0.2%
- M_3: Soil application of zinc @5kg ha^{-1}; M_4: Foliar spray of $ZnSO_4$ @ 0.5%
- M_5: Combined soil application of @1kg ha^{-1} + zinc @5kg ha^{-1}; M_6: Combined foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5%
- M_7: Control (Without lime, boron and zinc)

Table 5: Effect of boron, zinc and lime application in Broccoli var. Palam Samridhi on available NPK (kg ha^{-1}) of post-harvest soil

	Available N (kgha^{-1})			Available P (kgha^{-1})			Available K (kgha^{-1})		
Initial soil	**255.5**			**82.6**			**198.3**		
Treatment	**Lime**			**Lime**			**Lime**		
	L_0	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**
M1	152.00	153.33	152.67	73.83	76.27	75.05	223.33	230.80	227.07
M2	139.50	140.73	140.12	70.33	72.67	71.50	183.67	185.60	184.63
M3	140.00	159.33	149.67	73.60	83.37	78.48	248.90	250.73	249.82
M4	139.17	153.67	146.42	70.87	79.27	75.07	233.67	240.37	237.02
M5	149.40	153.40	151.40	78.80	84.30	81.55	251.37	255.70	253.54
M6	146.30	151.70	149.00	70.57	78.07	74.32	191.80	223.23	207.52
M7	120.50	125.00	122.75	61.90	74.27	68.08	165.33	179.27	172.30
Mean	140.98	148.17	144.57	71.41	78.31	74.86	214.01	223.67	218.84
	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)
Lime	0.68	4.12	2.15	0.83	5.04	5.07	1.23	7.46	2.57
Micronutrients	1.59	4.65	2.70	2.55	7.44	8.34	6.84	19.98	7.66
Interaction	2.25	6.69		3.60	NS		9.68	NS	

- L_o: Without lime; L_1: With lime
- M_1: Soil application of boron@1kg ha^{-1} ; M_2: Foliar spray of borax @ 0.2%
- M_3: Soil application of zinc @5kg ha^{-1}; M_4: Foliar spray of $ZnSO_4$ @ 0.5%
- M_5: Combined soil application of @1kg ha^{-1} + zinc @5kg ha^{-1}; M_6: Combined foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5%
- M_7: Control (Without lime, boron and zinc)

Table 6: Effect of boron, zinc and lime application in Broccoli var. Palam Samridhi on available boron and zinc (kg ha^{-1}) post-harvest soil

	Available Boron (kgha^{-1})			Available Zinc (kgha^{-1})		
Initial soil	**0.85**			**1.02**		
Treatment	**Lime**			**Lime**		
	L_0	**L_1**	**Mean**	**L_0**	**L_1**	**Mean**
M1	1.18	1.27	1.23	1.56	1.65	1.61
M2	0.89	1.12	1.01	1.30	1.35	1.33
M3	1.11	1.25	1.18	1.70	1.74	1.72
M4	0.95	1.05	1.00	1.17	1.19	1.18
M5	1.22	1.26	1.24	1.45	1.57	1.51
M6	1.13	1.19	1.16	1.42	1.47	1.45
M7	0.52	0.80	0.66	1.02	1.23	1.12
Mean	1.00	1.13	1.07	1.38	1.46	1.42
	SE(m)±	CD(5%)	CV(%)	SE(m)±	CD(5%)	CV(%)
Lime	0.01	0.06	4.32	0.01	0.06	3.16
Micronutrients	0.03	0.07	5.82	0.11	0.31	18.18
Interaction	0.04	0.11		0.15	NS	

- L_o: Without lime; L_1: With lime
- M_1: Soil application of boron@1kg ha^{-1} ; M_2: Foliar spray of borax @ 0.2%
- M_3: Soil application of zinc @5kg ha^{-1}; M_4: Foliar spray of $ZnSO_4$ @ 0.5%
- M_5: Combined soil application of @1kg ha^{-1} + zinc @5kg ha^{-1}; M_6: Combined foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5%
- M_7: Control (Without lime, boron and zinc)

Conclusion

It is evident from the study that, foliar application of micronutrient performed better as compared to their corresponding soil application. Similarly, lime application is essential in acidic soil as it increases post-harvest soil pH. Combine foliar spray of borax @ 0.2% + $ZnSO_4$ @ 0.5% along with lime increases N,P,K, B and Zn content in broccoli plant. Hence, application of lime and micronutrient (B and Zn) not only increases vegetative growth, head yield, head quality attributes in broccoli but also increase the nutrient uptake with maintenance of the post-harvest soil fertility status.

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