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Studies on the yield of broccoli (*Brassica oleracea* var. *italica*) as influenced by boron application in acid soil

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Abstract
A field experiment was conducted to assess the effect of boron on yield and yield attributes of Broccoli (*Brassica oleracea* var. *italica*) in acid soil during Rabi season of 2019-2020 and 2020-2021 at Research Farm of College of Agriculture, Central Agricultural University, Imphal, Manipur. The experiment was laid out following a factorial randomized block design with four replications. The treatment consist of three level of boron *viz*., 0, 1.0 kg B/ha and 1.5 kg B/ha. Economic analysis of treatments was also worked out to find out the profitable treatment. The result revealed that the effect of boron application on yield and yield attributes of broccoli was found positive and significant. Maximum curd diameter, curd weight, curd initiation, curd maturity, nutrient content and yield as well as highest net return and B:C ratio in both years were obtained from the application of 1.5 Kg/ha boron.

Keywords: Broccoli, boron, yield, nutrient content, net return, B:C

1. Introduction

Broccoli (*Brassica oleracea* var. *italica* L.), an important member of "Cole" crops, belongs to the family Brassicaceae. Broccoli being a cole crop is heavy feeder of plant nutrients. In India, it is commonly known as harigobhi and is well distributed to both tropical and sub-tropical region. Broccolis are rich source of glucosinolates, the precursor of the chemoprotective isothiocyanate (Sulphoraphane), a compound associated with reducing risk of cancer (Aires *et al*., 2006) [3]. It grows best when exposed to an average daily temperature between 18 - 23 °C. It is well known for its nutritional value, as it provides vitamins and fibre, preventing against some types of cancers, heart diseases and has already spread its popularity on global market (Baenas *et al.,* 2016) [4]. India rank second area and production in Broccoli. World area and production are 1.21 million hectare and 20.88 million tonne and Indian production and area are 6745 thousand tonnes and 369 thousand hectare (Anonymous, 2015) [1]. It is mostly cultivated in hilly areas of H.P., U.P., J &K, Nilgiri hills and Northern plains of India. It is sold in markets as fresh vegetable and used as curries, fried vegetables, soups and pickles. It is fairly high in protein (3.3%), vitamin 'A' (9000 IU) and ascorbic acid (137 mg/100g). It also contains appreciable quantities of carbohydrate (5.5%), calcium (1.29%), phosphorus (0.79%), sulphur (1.26%), thiamine, riboflavin, niacin and iron (Ramphal, 2000) [15].

Boron (B) is an essential micronutrient which is required for growth and development of the plant and is directly and indirectly involved in many plant metabolic functions. Essentiality of boron in plant was reported in 1923 by Warrington. It is a constituent of cell membrane and is essential for cell division. Boron promotes cell wall strength, flowering, pollination, IAA and carbohydrate metabolism seed set and translocation of sugar. In plants B is required in the structure of cell wall **(**O'Neil *et al*., 2004) [13]. However, B is neither an enzyme constituent nor does it directly affect enzyme activities (Prasad, 2007) [14]. Boron deficiency has been realized as the second most important micronutrient constraint in crops after that of zinc (Zn) on global scale (Ahmad *et al.*, 2012) [2]. It is well-researched that growth and quality of plants are greatly influenced by a wide range of nutrients. Hollow stem disorder is a major problems for broccoli production and is commonly associated with B deficiency (Shelp *et al.*, 1992) [16]. Application of boron significantly increases curd diameter, weight of curd, yield and quality of cauliflower (Kumar *et al.*, 2002). Mengal and Kirkby (1987) [10, 12] reported that boron requirement is high in cole crops like cauliflower and broccoli. Therefore, the present study was undertaken to work out the optimum dose of B for yield maximization of broccoli in acid soil of Manipur.

2. Materials and Methods

The experiment was conducted at the research farm at College of Agriculture, Central Agricultural University, Iroisemba, Imphal, Manipur during the Rabi season of 2019-2020 and 2020-2021.The climatic condition of Imphal is sub-tropical with an average annual rainfall ranges from 1250 mm to 2700 mm. The treatments included three levels of Boron *viz*., B_1(0), B_2(1 kg/ha) and B_3(1.5 kg/ha).The trial was made in factorial randomized block design with four replications. The size of each plot was 8.4 m^2. The variety of Green magic was used as test crop. The recommended doses of nitrogen, phosphorous, potash were applied during final land preparation. Nitrogen, phosphorus and potash were applied basally through urea, DAP and MOP. Boron was also applied as per the treatment. Borax was used as sources of boron. Twenty five days old, uniform and healthy seedlings were selected and transplanted in the experimental plots. Seedlings were transplanted at a distance of 60 cm x 45 cm. Five plants were selected from each plots and observation were made on curd diameter(cm), curd weight (g/plant) and curd yield(t/ha) at the time of harvest. The days taken in curd initiation was worked out by counting the days taken from transplanting to the initiation of curd. Curd maturity was also worked out by counting the days from curd initiation to curd maturity stage.

Surface soils (0-15cm) were collected and air-dried, thoroughly mixed and ground to pass through a 2-mm sieve for determination of physico-chemical properties of the soil. Soil pH and EC were determined following the method of Jackson (1973) [9] while cation exchange capacity (CEC) was extracted with neutral normal ammonium acetate extract (Jackson 1973) [9]. Available nitrogen, phosphorus and potassium were done as described by Subbiah and Asija (1956), Bray's and Kurtz (1945) [7] and Jackson (1973) [9] respectively. Available boron was extracted by the hot water method (Berger and Truog, 1940) [5]. The data obtained from the experiment were subjected to analysis of variance by F-test. For computing economics, the average treatment yield along with prevailing market rates of the produce and cost of inputs were used. B: C ratio was work out by dividing gross returns with cost of cultivation for each treatment.

3. Result and discussion

3.1 Physico-chemical characteristics of the experimental soil

The result of physico-chemical characteristics of soil sample and its evaluation for fertility status is shown in Table.1.The soil of the experimental site was slightly acidic and clayey with high organic matter. It was also revealed that the available nitrogen was 313.21Kg/ha, available phosphorous was 26.12 kg/ha, available potassium was 236.52.

Table 1: Physico-chemical parameters of soil before treatment of the experimental site

Parameters	Value	Status
A. Physical properties		
1.Soil texture		
i) Sand (%)	17.5	Clay
ii) Silt (%)	31.8	
iii) Clay (%)	50.7	
Chemical properties		
1. pH	5.6	Acidic
2. CEC [cmol (p +)/Kg]	11.12	Medium
3. EC (dSm^{-1})	0.23	Low
4. Organic carbon (%)	1.89	High
5. Available Nitrogen(Kg/ha)	313.21	Medium
6. Available phosphorous (Kg/ha)	26.12	Low
7. Available potassium (Kg/ha)	236.52	Medium
8. Available boron (mg/kg)	0.23	Low

3.2 Yield and yield parameter

3.2.1 Curd diameter

Main curd diameter was significantly influenced by the application of boron. Maximum curd diameter 17.05 cm in 1st year and 16.29 cm in 2nd year was recorded from the 1.5kg B/ha which was statistically at par with 1 kg B/ha. Minimum curd diameter was found in control. These observations corroborate the finding of Farooq *et al*. (2018) [8]. The result are exhibited in Table.2 and graphically present in Fig.1.

3.2.2 Curd weight (g/plant)

Maximum curd weight 433.53g in 1st year and 411.43g in 2nd year were observed in the treatment 1.5kg B/ha which was statistically at par with 1 kg B/ha while the minimum curd diameter was found in control. It might be due to the role of boron in cell differentiation and development, translocation of photosynthates and growth regulators from source to sink. Similar result is obtained by Farooq *et al*. (2018) [8]. The results are presented in Table 3 and Fig. 2.

3.1.3 Days to Curd initiation

The effect of boron application on days taken to curd initiation was found to be significant. The result are presented in Table 4 and Fig. 3. The number of days required to first curd initiation varied from 43.51 to 46.24 days in 1st year and 44.43 to 47.30 in 2nd year. The lowest number of days 43.51 in 1st year and 44.43 in 2nd year to curd initiation was recorded with the application of 1.5 kg B/ha. This might be due to high doses of nutrients which resulted in hastening of different reproductive growth phases whereas the onset of different reproductive phases were drastically delayed in case of plants receiving low rate of nutrients or no nutrients. The results were in conformity with that of Islam *et al*. (2015).

3.1.4 Days to Curd harvest

The response of days taken to curd harvest to boron application was found to be significant. It is presented in Table 4 and fig.4. It was varied from 59.65 to 62.04 days and 58.65 to 61.57 days in 1st and 2nd years respectively. The highest number of days to curd maturity was recorded with the application of 1.5kg/ha having 62.04 days and 61.57 days in both years. The lowest number of days was recorded from control. This is due to more uptakes of nutrients which in turn enhanced the vegetative growth leading to more days of maturity. Similar result was obtained by Islam *et al*. (2015).

3.1.5 Curd yield (t/ha)
A significantly higher yield 8.87 t and 8.75 t in 1st and 2nd years respectively were obtained from the treatment 1.5 Kg B/ha while minimum curd yield was found in control. The results were presented in Table 5 and Fig.5. The above results are in close conformity with the reports of Farooq *et al.* (2018) [8]. This might be due to the application of boron which helps in sugar translocation across the cell membrane, carbohydrates metabolism, tissue development, cell differentiation and development. This in turn, helps in increasing the yield of the crop.

3.2. Nutrient content
Application of boron significantly influenced on nutrient content of broccoli. Maximum nutrient content (N, P, K, B and S) was achieved from 1.5 Kg B/ha. There was no significant difference between 1 and 1.5 kg B/ha, but differed significantly from control. Maximum concentration of N (3.41% in 1st year and 3.34% in 2nd year), P (0.356% in 1st year and 0.342% in 2nd year), K (2.64% in 1st year and 2.59% and 2nd year) was obtained with the application of 1.5 Kg B/ha. Lowest N, P and K content was recorded from control. Application of boron might have resulted in increased availability of boron which in turn has influenced DNA and protein synthesis leading to increased nitrogen content and uptake. The increase in the phosphorus content with the increase in boron application could be due to favourable influence of boron on various metabolic processes like photosynthesis, respiration, enzyme activity. This result was corroborates with the findings of Islam *et al.* (2015). Maximum boron (40.98 mg/kg in 1st year and 40.17 mg/kg in 2nd year) and sulphur content (1.25% in 1st year and 1.23% in 2nd year) was obtained with the application of 1.5 Kg B/ha. The increase in the content of nutrient by boron fertilization could be attributed to better growth of crop resulting in greater absorption of nutrients from soil leading to its higher content. The content of any nutrient in the plant is directly related to its availability in the feeding zone and the growth of the plant. Similar results were also obtained by Kumar *et al.* (2012) [11]

3.3. Economic analysis
The economics of broccoli data is presented in table 4. The result revealed that the application of 1.5 Kg B/ha fetched maximum net return of Rs. 2, 33,100/- ha^{-1} and B: C ratio of 2.95 followed by 1 kg B/ha (net return of 2, 24,955/- ha^{-1} and B: C ratio of 2.92). The minimum net return and B: C ratio was found from control.

Table 2: Effect of Boron on curd diameter (cm)

	Curd diameter(cm)		
Boron Doses	**2019-2020**	**2020-2021**	**Pooled**
0 Kg/ha	14.49	14.30	14.47
1 kg/ha	16.39	15.61	16.03
1.5 Kg/ha	17.05	16.29	16.77
S.Ed (±)	0.35	0.29	0.24
CD (0.05)	0.71	0.58	0.49

Table 3: Effect of Boron on weight (g/plant)

	Curd weight(g/plant)		
Boron level (Kg/ha)	**2019-2020**	**2020-2021**	**Pooled**
0 Kg/ha	312.91	299.83	306.37
1 kg/ha	422.88	403.32	413.10
1.5 Kg/ha	433.53	411.43	422.48
S.Ed (±)	9.47	9.47	7.01
CD (0.05)	19.27	19.27	14.27

Table 4: Effect of boron on days taken for curd initiation and curd maturity

	Curd initiation			**Curd maturity**		
Boron level (Kg/ha)	**2019-2020**	**2020-2021**	**Pooled**	**2019-2020**	**2020-2021**	**Pooled**
0 Kg/ha	46.24	47.30	46.77	59.67	58.65	59.16
1 kg/ha	43.82	44.58	44.20	61.83	61.15	61.49
1.5 Kg/ha	43.51	44.43	43.97	62.04	61.57	61.80
S.Ed (±)	0.16	0.15	0.12	0.25	0.29	0.19
CD (0.05)	0.33	0.30	0.25	0.51	0.59	0.38

Table 5: Effect of Boron on yield

	Curd yield (t/ha)		
Boron level(Kg/ha)	**2019-2020**	**2020-2021**	**Pooled**
0 Kg/ha	6.42	6.28	6.35
1 kg/ha	8.62	8.47	8.55
1.5 Kg/ha	8.87	8.75	8.81
S.Ed (±)	0.16	0.18	0.14
CD (0.05)	0.32	0.36	0.28

Table 6: Effect of Boron on Nitrogen content

	Nitrogen content (%)		
Boron level(Kg/ha)	2019-2020	2020-2021	Pooled
0 Kg/ha	3.05	2.85	2.98
1 kg/ha	3.36	3.31	3.36
1.5 Kg/ha	3.41	3.34	3.40
S.Ed (±)	0.03	0.05	0.03
CD (0.05)	0.07	0.11	0.07

Table 7: Effect of Boron on phosphorous content

	Phosphorous content (%)		
Boron level(Kg/ha)	2019-2020	2020-2021	Pooled
0 Kg/ha	0.290	0.273	0.281
1 kg/ha	0.346	0.334	0.340
1.5 Kg/ha	0.356	0.342	0.349
S.Ed (±)	0.006	0.006	0.005
CD (0.05)	0.013	0.013	0.011

Table 8: Effect of boron on Potassium content

	Potassium content (%)		
Boron level(Kg/ha)	2019-2020	2020-2021	Pooled
0 Kg/ha	2.40	2.32	2.39
1 kg/ha	2.62	2.56	2.59
1.5 Kg/ha	2.64	2.59	2.62
S.Ed (±)	0.024	0.023	0.02
CD (0.05)	0.048	0.046	0.041

Table 9: Effect of boron on boron content

	Boron content (%)		
Boron level(Kg/ha)	2019-2020	2020-2021	Pooled
0 Kg/ha	33.00	32.32	32.64
1 kg/ha	39.70	39.25	39.47
1.5 Kg/ha	40.98	40.17	40.58
S.Ed (±)	0.89	0.80	0.81
CD(0.05)	1.83	1.64	1.67

Table 10: Effect of boron on sulphur content o

	Boron content (%)		
Boron level(Kg/ha)	2019-2020	2020-2021	Pooled
0 Kg/ha	1.16	1.12	1.14
1 kg/ha	1.24	1.22	1.23
1.5 Kg/ha	1.25	1.23	1.24
S.Ed (±)	0.01	0.01	0.01
CD(0.05)	0.03	0.03	0.02

Table 11: Effect of boron on broccoli production (pooled data)

Boron (Kg ha^{-1})	Yield (t ha^{-1})	Cost of production including cost of borax (Rs.ha^{-1})	Gross return (Rs.ha^{-1})	Net Return (Rs.ha^{-1})	B:C ratio
0 Kg/ha	6.35	112500	254000	141500	2.26
1 kg/ha	8.55	117045	342000	224955	2.92
1.5 Kg/ha	8.81	119300	352400	233100	2.95

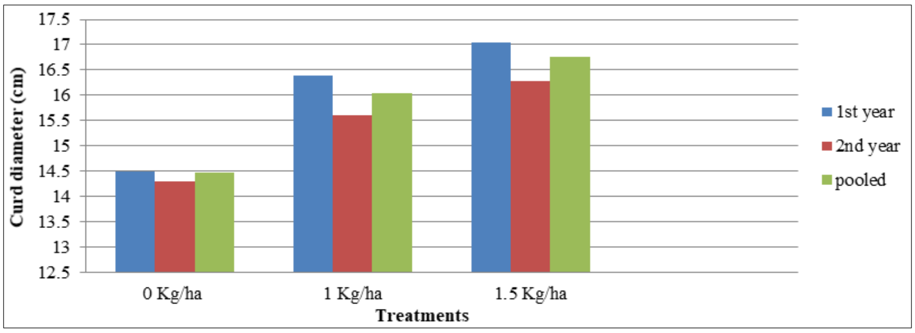

Fig 1: Graphical representation on effect of B on curd diameter (cm)

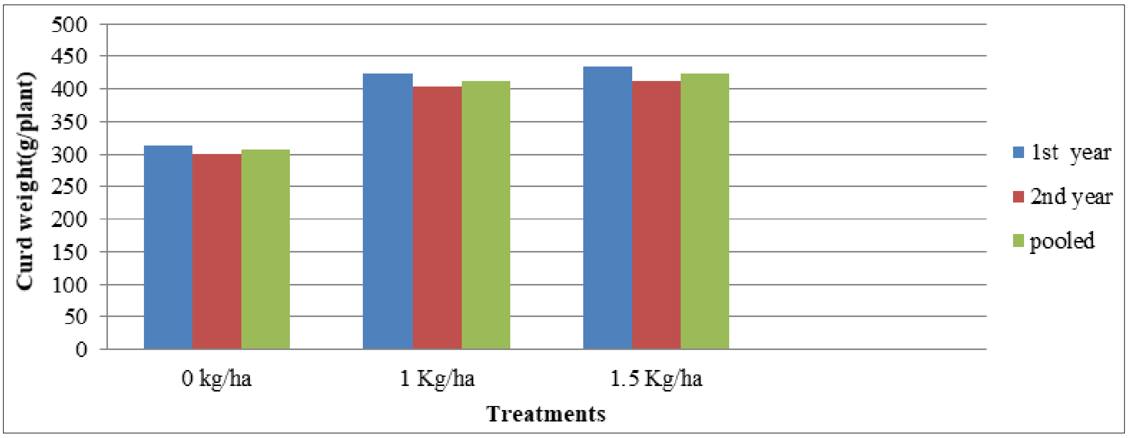

Fig 2: Graphical representation on effect of B on curd weight (g/plant)

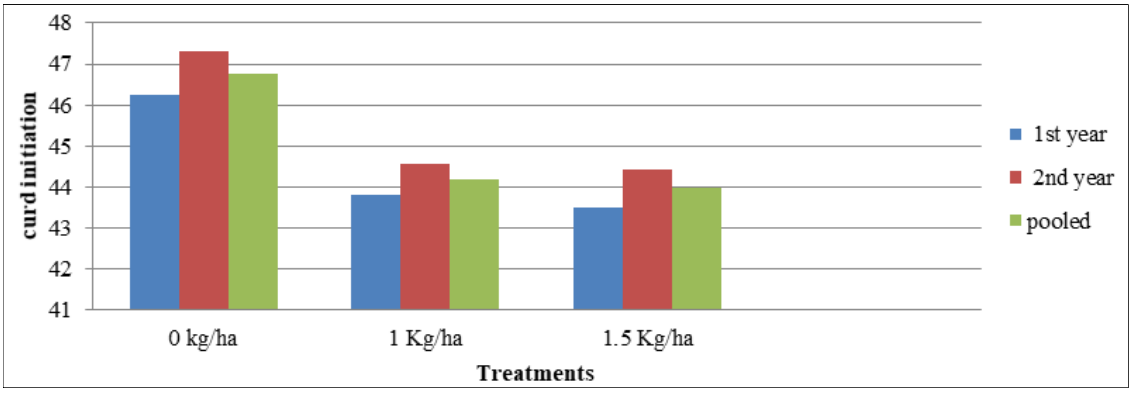

Fig 3: Graphical representation on effect of B on curd initiation

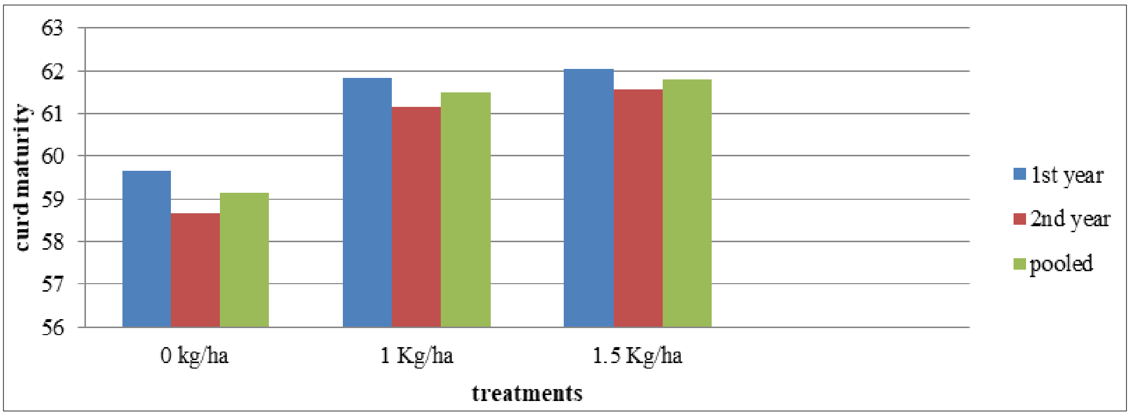

Fig 4: Graphical representation on effect of B on curd maturity

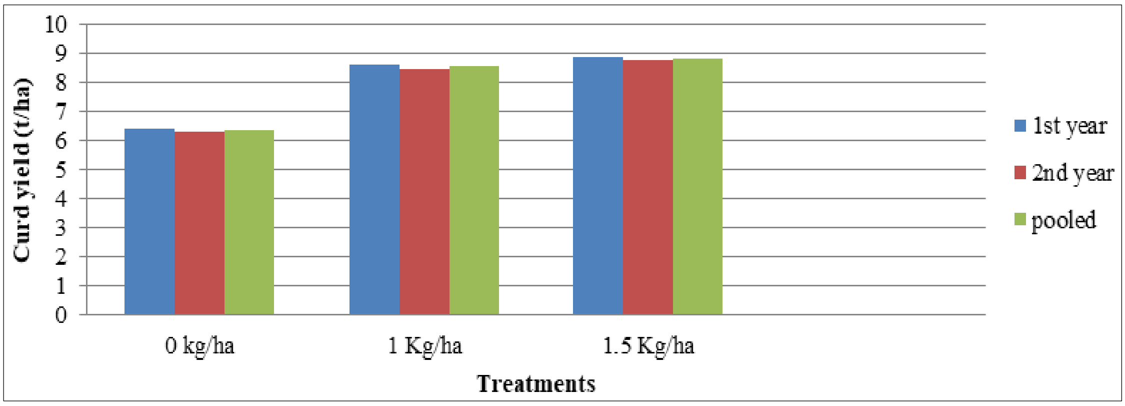

Fig 5: Graphical representation on effect of B on curd yield (t/ha)

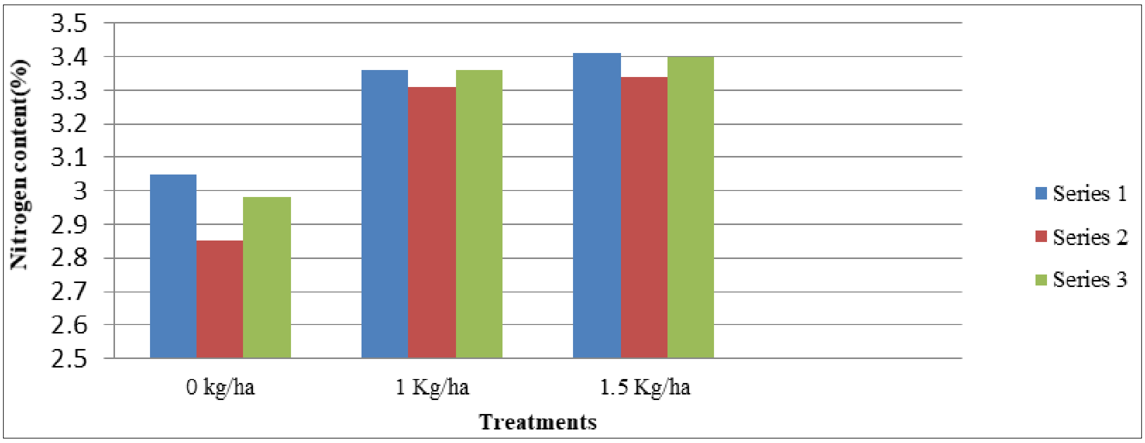

Fig 6: Graphical representation on effect of B on nitrogen content in plants

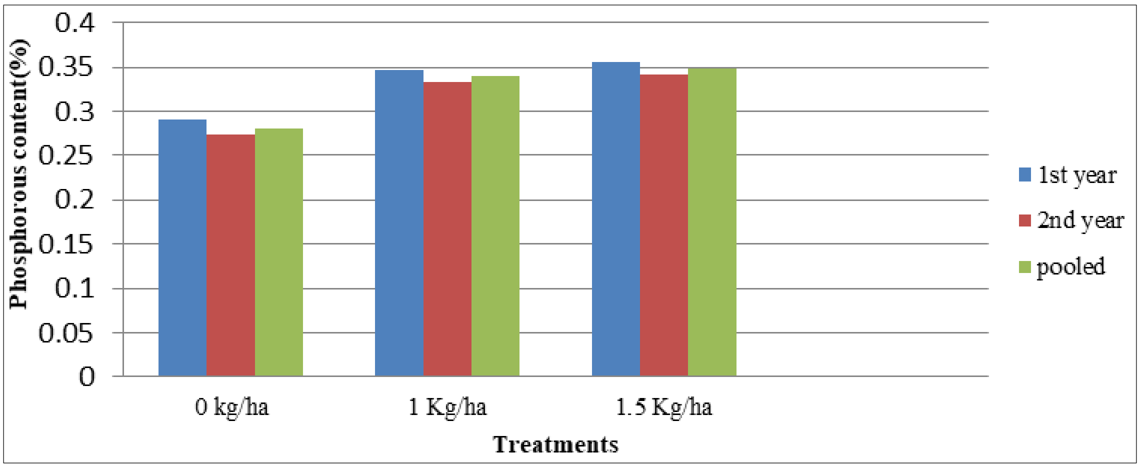

Fig 7: Graphical representation on effect of B on phosphorous content in plants

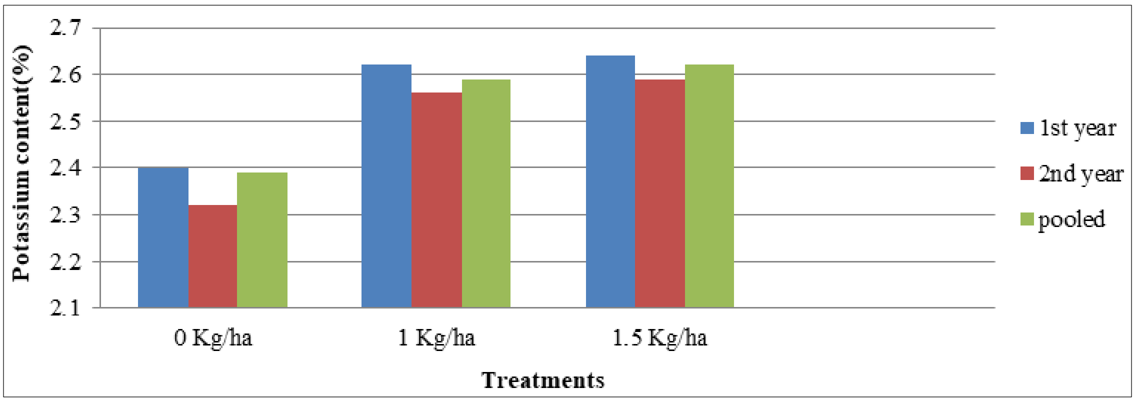

Fig 8: Graphical representation on effect of B on potassium content in plants

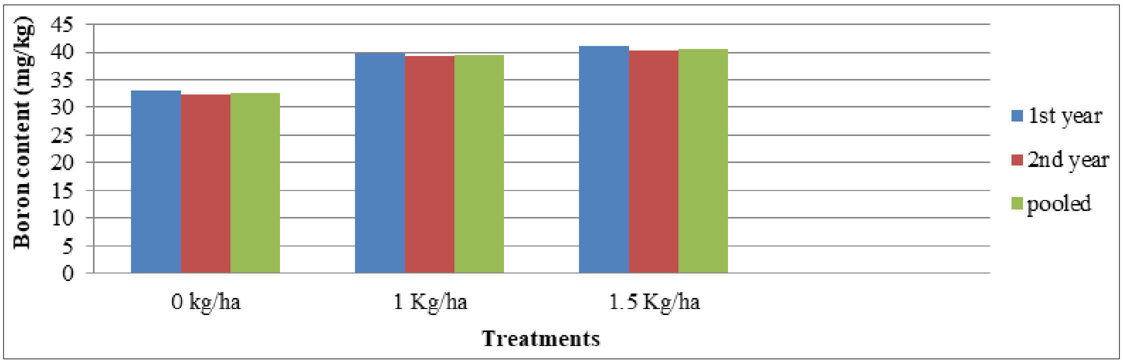

Fig 9: Graphical representation on effect of B on boron content in plants

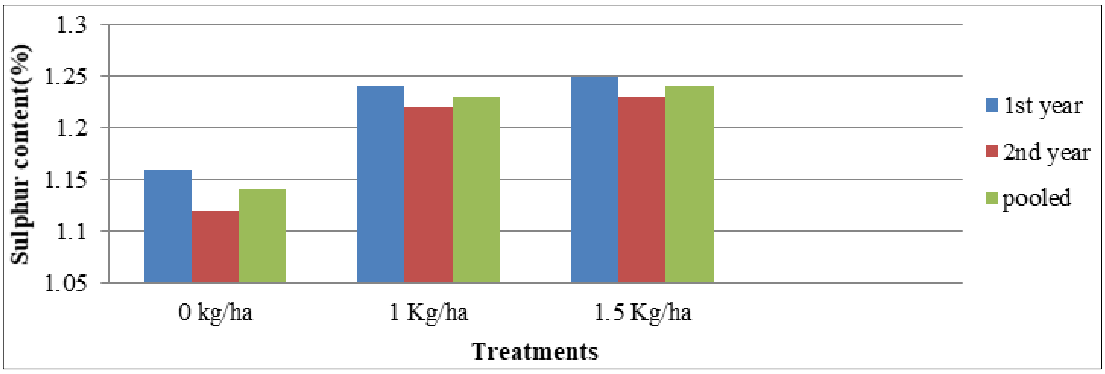

Fig 10: Graphical representation on effect of B on sulphur content in plants

4. Conclusion

From the above studies, it can be concluded that the boron application improves the yield, yield parameters of broccoli. Optimum yield, nutrient content in plants as well as net return and B: C ratio was obtained when boron was applied at the rate of 1.5 kg/ha. Thus, it is advisable to farming community that 1.5 kg B/ha was economically profitable for obtaining higher productivity of broccoli.

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