Original Research Article

Effect of zinc and boron on yield, quality and nutritional value of Broccoli head (*Brassica oleracea* var. *italica*) with different application methods in red and lateritic soils of Birbhum district.

ABSTRACT:

Aims: To improve yield, quality and nutritional value of broccoli head with different dose and application methods of zinc and boron and also decide the best possible treatment combination.

Study design: Factorial randomized block design consisting of 9 treatments of zinc and boron combination with different doses and application method replicated thrice.

Place and duration of study: This experiment was laid out in Palli sikhsha bhavana, agriculture farm, Visva Bharati (Sriniketan) during rabi seasons of 2018-19 and 2019-20 from October to January.

Methodology: Three treatments of Zinc viz. Z_0 (no zinc), Z_f (foliar application @0.5% $ZnSO_4$), Z_s (soil application @25kg/ha $ZnSO_4$) and three treatments of Boron viz. B_0 (no boron), B_f (foliar application @0.5% borax), B_s (soil application @2kg/ha borax) randomized among themselves The crop was planted (spacing of 50cm X 40cm), fertilized (N: P_2O_5: K_2O::150:100:100) and irrigated as per recommended practices. Five plants from each plot were randomly selected and tagged for data collection.

Result: The treatments had no effect on plant height but plant spread increased significantly with combined soil application of boron @2kg/ha and zinc @25kg/ha over the growth stages. Treatment (T8) combined application of boron soil @2kg/ha and zinc as foliar @0.5% was found superior for total yield (28.9 ton/ha) and head weight per plot (695.4gms). Head length, head width and stem girth were not significantly affected with applied treatments. Quality attributes like Vitamin C and total chlorophyll of broccoli head was significantly improved with combined application of zinc in soil @25kg/ha and boron as foliar @0.5% with highest value of 1117.5mg/g and 0.77mg/g respectively. Highest Total sugar and reducing content was recorded for combined application of boron in soil @2kg/ha as well as foliar @0.5% with value of 1.7 and 1.62. Crude protein content in broccoli head was significantly improved with zinc foliar application @0.5% with a value of 14.34%. Nutritional values viz. Zinc concentration and zinc uptake by broccoli head was significantly increased by zinc foliar application @0.5% recording highest value of 0.041% and 6.67kg/ha whereas boron concentration and uptake was improved by combined application of boron soil @2kg/ha and zinc as foliar @0.5% with a value of 0.0049% and 2.26kg/ha respectively.

Conclusion: The combined application of boron in soil @2kg/ha and zinc as foliar @0.5% would be the best treatment to impact on yield, quality and nutritional values of broccoli head in red and lateritic soils of Birbhum district.

Keywords: broccoli, zinc, boron, yield, quality, vitamin c, reducing sugar, total sugar, crude protein, plant spread area.

Introduction:

Red and lateritic soils cover almost 28% of geographical area of West Bengal (Anon, 1989) which are acidic in soil reaction, light textured, low organic matter and P and are often deficient in S and micronutrients like Zn, B, Mo (Panda *et al.* 1991, Sakal and Singh1997). Micronutrient has specific role to play in the plant and its presence in optimum concentration is a must for the plant to complete its life cycle which ends with maturity and harvesting of the economic produce. Zinc is an indispensable micronutrient for proper plant growth and development. It plays an important role in different plant metabolic processes such as enzyme activity, development of cell wall, respiration, photosynthesis, chlorophyll formation and other biochemical functions whereas Boron is required for the translocation of sugars, root extension and growth of meristematic tissues, the pyrimidine biosynthetic pathway and the ATPase, it is also involved in translocation of sugars, synthesis of amino acid, protein and carbohydrate metabolism. It plays a vital role in pollen enlargement, fertilization and flowering processes of plants. Broccoli is an important vegetable crop and has high nutritional and good commercial value (Yoldas *et al.*, 2008) native to Mediterranean region (Decoteau, 2000) which is high in vitamin C and good source of vitamin A, B_1, vitamin B_2 and calcium. Also, it has been appointed as an anti-cancer source by American Cancer Society (Yoldas *et al.*, 2008) because, it contains mostly sulforaphane (from the glucosinolates group) that checks the growth of tumors and reduces the risk of cancer. Zinc may represent a co-factor of the myrosinase in broccoli and favours the formation of sulforaphane at the initial reaction. (Liang *et al.* 2006).

Thus, the key role played by Zn and B nutrition in plant growth, the present study has been designed to find out the suitable dose and method of Zn and B application for broccoli production and to improve its quality and nutritional value.

Materials and method:

Present study was carried out in experimental site of Palli sikhsha bhavana farm, Visva Bharati (Sriniketan) in two rabi season of 2018-19 and 2019-20 which consisted of 9 treatments of zinc and boron combination with different doses and application method replicated thrice in factorial randomized block design. The treatments consisted of T1: only recommended dose of fertilizer (control); T2:RDF+ zinc foliar @0.5%; T3: RDF+ zinc soil application @ 25kg/ha; T4: RDF+ boron foliar application @ 0.5%; T5: RDF + combined application of boron foliar @0.5% and zinc foliar @0.5%; T6: RDF + combined application of boron foliar @0.5% and zinc soil @25kg/ha; T7: RDF + boron soil application @2kg/ha; T8: RDF + combined application boron soil application @2kg/ha and zinc foliar @0.5%; T9: RDF + combined application for boron soil @2kg/ha + zinc soil @25kg/ha.

The crop was planted (spacing of 50cm X 40cm), fertilized (N: P_2O_5: K_2O::150:100:100) and irrigated as per recommended practices. The fertilizer sources for nitrogen, phosphorous and potassium are urea, DAP and muriate of potash and sources for zinc and boron are zinc sulphate heptahydrate and borax. Before fertilizer application random soil samples were collected from experimental site for analysis which revealed the initial soil status of that site (table1).

Table 1: Initial soil status of experimental site (0-15cm)

Particulars	Values obtained	Rating	Method
pH	6.1	Moderately acidic	Using glass electrode pH meter with 1:2.5 soil: water suspension (Jackson, 1973).
Electrical conductivity (dS/m) at 25°C	0.09	Normal	Conductivity meter(Jackson, 1973).
Organic carbon (%)	0.29	Low	Wet digestion method (Walkley and Black, 1934).
Available Nitrogen (kg/ha)	171.42	Low	Kjeldahl distillation process by using alkaline permanganate solution (Subbaiah and Asija, 1956).
Available Phosphorous (kg/ha)	16.4	Medium	Bray's No. 1 method (Bray and Kurtz, 1945).
Available Potassium(kg/ha)	183.31	Medium	Extraction with neutral normal Ammonium acetate (CH_3COONH_4), (Jackson, 1973)
Available Zn (mg/kg)	0.52	Low	Atomic absorption spectrophotometer using DTPA extractant(Lindsay and Norvell, 1978)
Available B (mg/kg)	0.09	Low	Hot water extractable method (Berger &Troug)

Different growth parameters that were observed are plant height and plant spread area and samples were collected at 30days interval till harvest. Data regarding yield and its attributes like head weight per plot, head length and width per plant, stem girth per plant were collected after harvesting. Quality parameters like vitamin C, reducing sugar, total sugar, crude protein and total chlorophyll were estimated from broccoli head as per standard procedure. Nutrient uptake was estimated from both broccoli plant and head for zinc and boron status after wet digestion in diacid mixture of nitric acid (HNO3) and perchloric acid at a ratio of 4:1 as per Jackson (1973) and dry ashing method respectively. Soil was again collected from each plot after harvesting of crops for analyzing available zinc and boron and were estimated in AAS and hot water extractable method respectively.

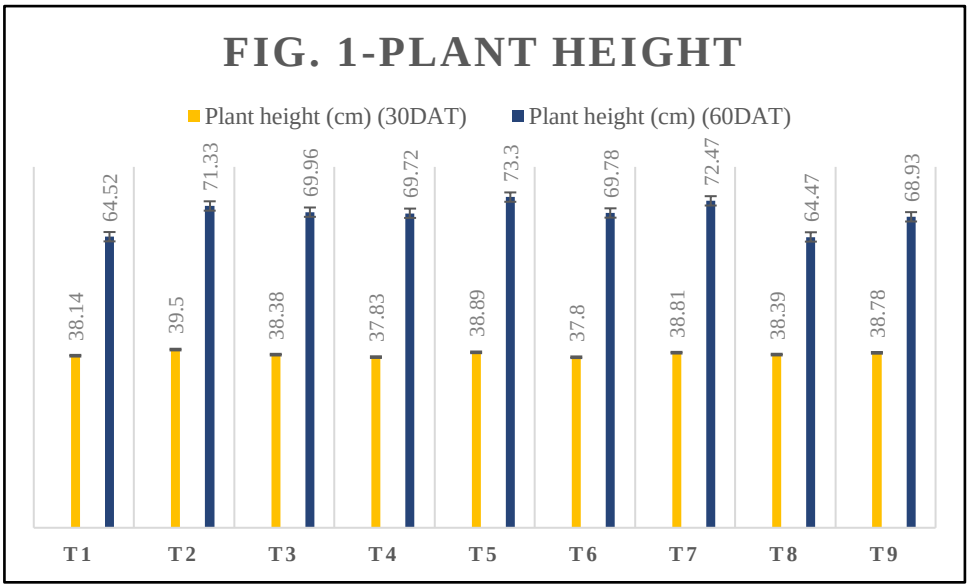
Statistical analyses were carried out following the method of analysis of variance (ANOVA). For comparisons between treatment means, standard error of the mean difference (Sd) and least significant difference (LSD) at $\alpha = 0.05$ level of significance were calculated (Gomez and Gomez, 1984) in Microsoft excel.

Result and discussion:

Growth parameters:

Data in table 2 indicate the values of both season and pooled analysis which reveals that the plant height was affected significantly by combined application of zinc and boron in both season at both growth stages. Highest value for plant height was recorded for treatment zinc foliar application @0.5% (T2) at 30 DAT and combined foliar application of zinc @0.5% and boron @0.5% at 60DAT and the lowest value was recorded by control plots. The

results were similar with **Prasad *et. al* (2020)** and **Parmar *et. al* (2023)** in their experiment on effect of micronutrient in broccoli where plant growth was influenced by combined application of zinc and boron. **Quratul *et al.* (2016)** found similar response in his experiment where 0.5% application of zinc sulphate and borax increased plant height. **Chowdhury *et al* (2017)** in his research of effect of boron, zinc and molybdenum on broccoli (cv-green magic) with sole doses of these three micronutrients found 0.5% application of zinc sulphate in promoting growth of broccoli plant. Plant spread area affected significantly with combined application of zinc and boron over control plots (T1) with no zinc and boron application. Highest value for spread area was recorded for combined soil application of zinc @25kg/ha and boron @2kg/ha (T9) at 30DAT which was at par with results of **Singh *et al.* (2017)** whereas for 60DAT highest value was recorded for combined foliar application of zinc @0.5% and boron @0.5% (T5). The results were similar with experiment conducted by **Kant *et al*. (2013)** where combined soil application of zinc and boron improved plant height and plant spread area.



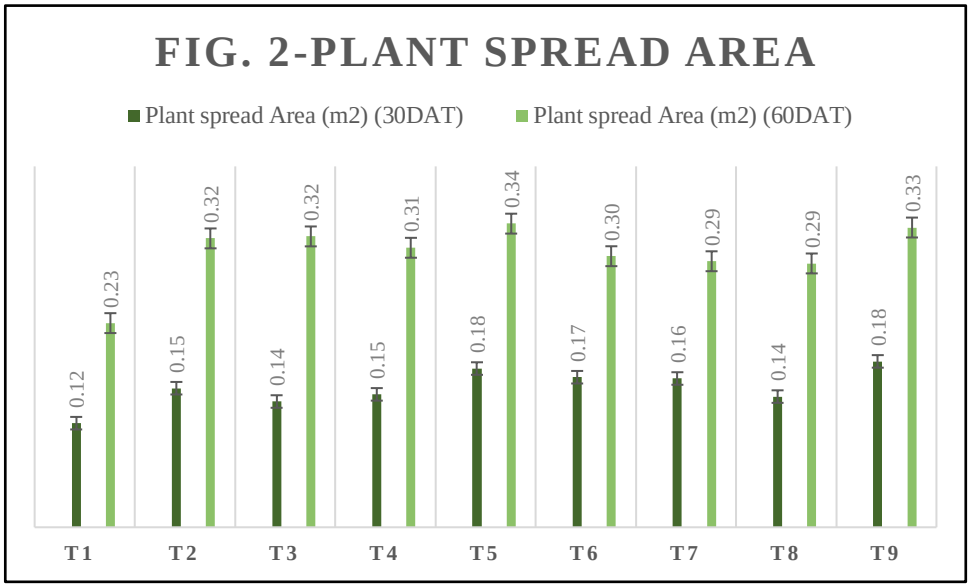


Fig. 1 & Fig. 2 illustrates different growth parameters as influenced by Zinc and Boron with different application methods (on the basis of pooled data)

Table 2: Growth parameters as influenced by Zinc and boron with different application methods at 30DAT and 60 DAT

Treatments		PLANT HEIGHT (cm)						PLANT SPERAD AREA (m2)					
		30 DAT			60 DAT			30 DAT			60 DAT		
		2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T1		37.34	38.94	38.14	60.07	68.97	64.52	0.12	0.11	0.12	0.23	0.23	0.23
T2		39.26	39.74	**39.5**	71.15	71.5	71.33	0.15	0.15	0.15	0.32	0.32	0.32
T3		38.46	38.29	38.38	69.85	70.06	69.96	0.14	0.14	0.14	0.32	0.32	0.32
T4		38.92	36.73	37.83	69.7	69.73	69.72	0.15	0.15	0.15	0.31	0.31	0.31
T5		38.67	39.11	38.89	73.43	73.16	**73.3**	0.17	0.18	0.18	0.34	0.34	0.34
T6		38.53	37.07	37.8	69.62	69.93	69.78	0.17	0.17	0.17	0.3	0.3	0.3
T7		38.77	38.85	38.81	72.36	72.58	72.47	0.16	0.17	0.16	0.29	0.3	0.29
T8		38.67	38.12	38.39	68.61	60.33	64.47	0.15	0.14	0.14	0.29	0.29	0.29
T9		38.71	38.85	38.78	68.81	69.06	68.93	0.18	0.18	**0.18**	0.33	0.33	**0.33**
Mean		38.59	38.41	38.5	69.29	69.48	69.38	0.15	0.15	0.15	0.3	0.3	0.3
SEM	B	0.842	0.604	0.622	1.179	1.064	0.928	0.007	0.01	0	0.01	0.01	0.01
	Zn	0.842	0.604	0.622	1.179	1.064	0.928	0.007	0.01	0	0.01	0.01	0.01
	B X Zn	1.458	1.047	1.077	2.042	1.843	1.607	0.012	0.01	0.01	0.017	0.02	0.02
CD (0.05)	B	*	*	*	*	*	*	*	0.02	0.01	*	0.04	0.03
	Zn	*	*	*	*	*	*	*	0.02	0.01	*	0.04	0.03
	B X Zn	*	*	*	*	5.52	4.82	*	0.04	0.02	*	0.07	0.05
CV (%)		6.54	4.72	4.84	5.1	4.59	4.01	13.94	13.45	6.25	9.76	13	9.03

Treatments: T1: only recommended dose of fertilizer (control); T2:RDF+ zinc foliar @0.5%; T3: RDF+ zinc soil application @ 25kg/ha; T4: RDF+ boron foliar application @ 0.5%; T5: RDF + combined application of boron foliar @0.5% and zinc foliar @0.5%; T6: RDF + combined application of boron foliar @0.5% and zinc soil @25kg/ha; T7: RDF + boron soil application @2kg/ha; T8: RDF + combined application boron soil application @2kg/ha and zinc foliar @0.5%; T9: RDF + combined application for boron soil @2kg/ha + zinc soil @25kg/ha.Recommended dose of fertilizer: N: P_2O_5: K_2O::150:100:100 (kg/ha) were applied through urea, DAP and muriate of potash.

Yield and its attributes:

Data regarding yield and its attributed has been depicted in table 3 (seasons 2018,2019 and pooled). The data shows combined application of zinc and boron had significant effect on broccoli yield and head weight per plot over control plots. Highest value was recorded for combined application of boron in soil @2kg/ha and zinc as foliar @0.5% (T8) for both seasons. **Singh *et al.* (2017)** in his experiment concluded application of boron @2kg/ha along with zinc as soil application promoted head weight, head diameter and plant weight. Although **Mahmoud *et. al* (2019)** concluded combined foliar application of zinc and boron recorded highest yield. The increase in yield maybe attributed due to combined effect of zinc and boron at the same time for particular treatments which boosted the plant metabolism. In addition, head length, width and stem girth were not significant with combined application of zinc and boron. Lowest value was recorded for control plots. **Sidhu *et. al* (2022)** in his experiment recorded highest head yield with combined application of boron @2kg/ha and zinc @2.5kg/ha.

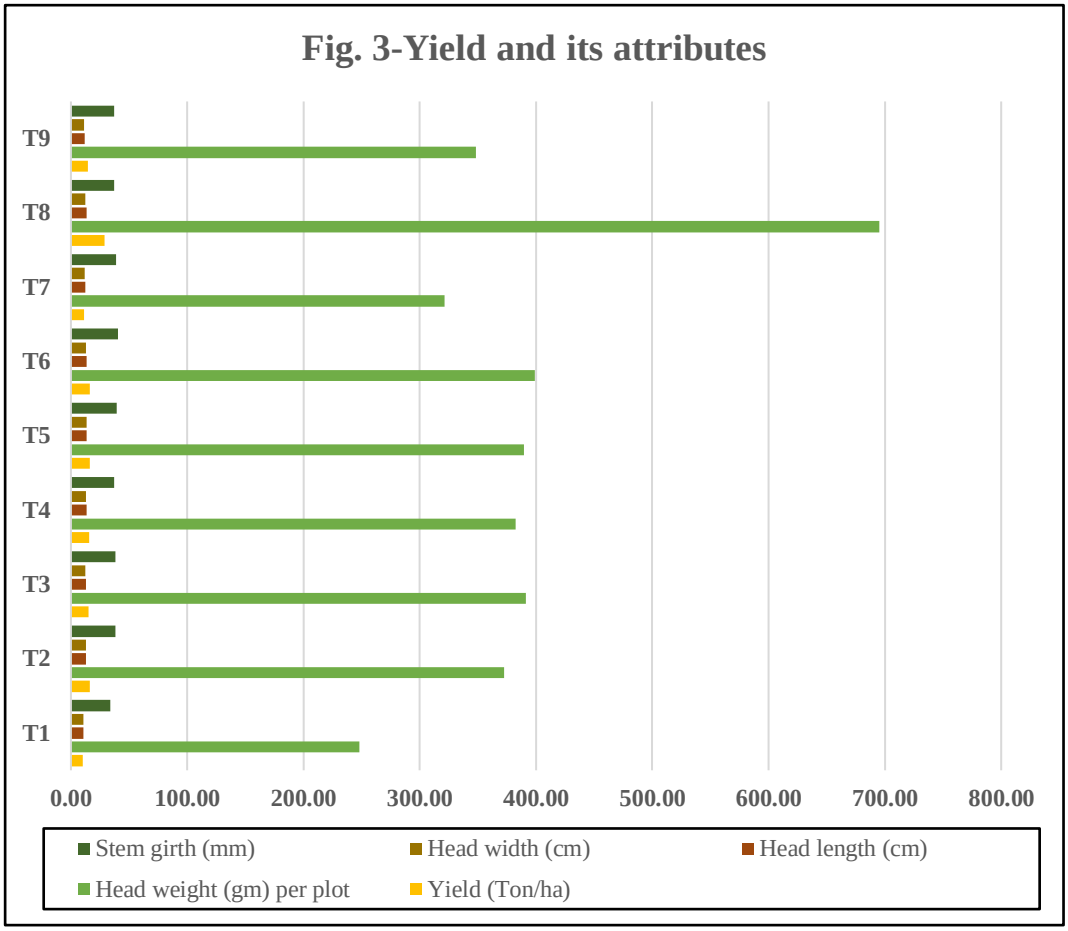


Fig. 3 illustrates Yield and its attributes as influenced by Zinc and Boron with different application methods (on the basis of pooled data)

Table 3: Yield and its attributes as influenced by Zinc and boron with different application methods

Treatments		Yield (ton/ha)			Head weight (gm) per plot			Head length (cm) per plant			Head width (cm) per plant			Stem girth (mm) per plant		
		2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T1		14.41	5.93	10.17	364.61	131.96	248.28	14.19	7.82	11	12.89	8.04	10.46	38.85	28.38	33.61
T2		21.03	11.56	16.3	484.6	260.2	372.4	14.99	11.17	13.08	13.69	11.65	12.67	40.27	36.39	38.33
T3		19.51	11.12	15.32	495.94	286.18	391.06	14.76	11.37	13.06	12.59	12.17	12.38	38.73	38.01	38.37
T4		19.36	12.4	15.88	470.97	293.7	382.33	14.87	12.6	**13.74**	13.45	12.66	13.05	38.54	35.81	37.17
T5		18.37	14.34	16.36	440.04	339.61	389.83	14.33	12.29	13.31	13.73	13.17	**13.45**	41.89	37.3	39.59
T6		19.01	13.42	16.21	462.83	335.55	399.19	15.27	11.57	13.42	13.05	12.75	12.9	40.3	41.04	**40.67**
T7		15.95	6.37	11.16	467	175.22	321.11	15.08	9.75	12.42	13.18	10.11	11.64	39.42	37.83	38.62
T8		16.22	41.58	**28.9**	381.13	1009.61	**695.37**	15.68	10.94	13.31	13.12	11.5	12.31	38.18	36.48	37.33
T9		17.39	11.75	14.57	382.59	314.52	348.55	14.21	9.12	11.66	13.35	9.26	11.31	38.95	35.65	37.3
Mean		17.92	14.28	16.1	438.86	349.61	394.24	14.82	10.74	12.78	13.23	11.25	12.24	39.46	36.32	37.89
SEM	**B**	0.674	1.001	0.7	18.462	3.293	10.2	0.369	0.311	0.22	0.319	0.222	0.21	0.619	1.13	0.72
	Zn	0.674	1.001	0.7	18.462	3.293	10.2	0.369	0.311	0.22	0.319	0.222	0.21	0.619	1.13	0.72
	B X Zn	1.167	1.734	1.21	31.978	5.704	17.66	0.638	0.538	0.37	0.552	0.384	0.36	1.073	1.956	1.25
CD (0.05)	**B**	*	3.001	2.09	*	9.872	30.56	*	*	0.65	*	*	0.62	*	*	*
	Zn	*	3.001	2.09	*	9.872	30.56	*	*	0.65	*	*	0.62	*	*	*
	B X Zn	*	5.197	3.63	*	17.098	52.94	*	*	1.12	*	*	1.07	*	*	*
CV (%)		11.28	21.03	13.02	12.62	2.83	7.76	7.46	8.69	5.06	7.23	5.91	5.03	4.71	9.33	5.71

Treatments: T1: only recommended dose of fertilizer (control); T2:RDF+ zinc foliar @0.5%; T3: RDF+ zinc soil application @ 25kg/ha; T4: RDF+ boron foliar application @ 0.5%; T5: RDF + combined application of boron foliar @0.5% and zinc foliar @0.5%; T6: RDF + combined application of boron foliar @0.5% and zinc soil @25kg/ha; T7: RDF + boron soil application @2kg/ha; T8: RDF + combined application boron soil application @2kg/ha and zinc foliar @0.5%; T9: RDF + combined application for boron soil @2kg/ha + zinc soil @25kg/ha.Recommended dose of fertilizer: N: P_2O_5: K_2O::150:100:100 (kg/ha) were applied through urea, DAP and muriate of potash.

Quality aspects and nutritional value:

Data in table 4 indicates the various quality parameters which includes vitamin C, reducing sugar, total sugar, crude protein and total chlorophyll content in broccoli head of both seasons and pooled analysis. It reveals Vitamin C and total chlorophyll content was found highest in combined application of zinc soil application @25kg/ha and boron foliar application @0.5% (T6). The result is at par with findings of **Singh *et al.* (2017) and Al-Zubaidi *et al.* (2022)**. This may be due to zinc which plays vital role in enzymatic activity and has direct role in chlorophyll content. Even **Puspanjali *et al.* (2018)** recorded similar results where maximum vitamin C was in combined soil application of boron and zinc over the control plots (no micronutrients). Highest reducing sugar and total sugar content in broccoli head was found in boron soil application @2kg/ha and boron foliar application @0.5%. This can be explained with the fact that boron influences the availability and uptake of other plant nutrients from the soil. An apparent increase in the uptake and translocation of P, N, K, Zn, Fe, and Cu in leaves, buds, and seeds (**Shireen *et. al*, 2018**). Again, highest crude protein content was seen in Zinc foliar application @0.5% since Zinc is required as structural and catalytic components of protein and enzymes for normal growth and development (**Broadley *et al.*, 2007**). Highest crude protein was recorded for solo application of zinc foliar @0.5% (T2). Similar findings were noticed by **Chowdhury *et. al* (2017)** where sole application of zinc sulphate @0.5% have improved quality aspects of broccoli (cv 'Green magic'). Although, **Al-Zubaidi *et al.* (2022)** have reported combined application of boron and zinc can improve quality aspects of broccoli. Since, zinc involves in translocation of sugar and protein. Sole application of zinc can also be suggested. All the parameters responded significantly to treatments over control plots which recorded least value.

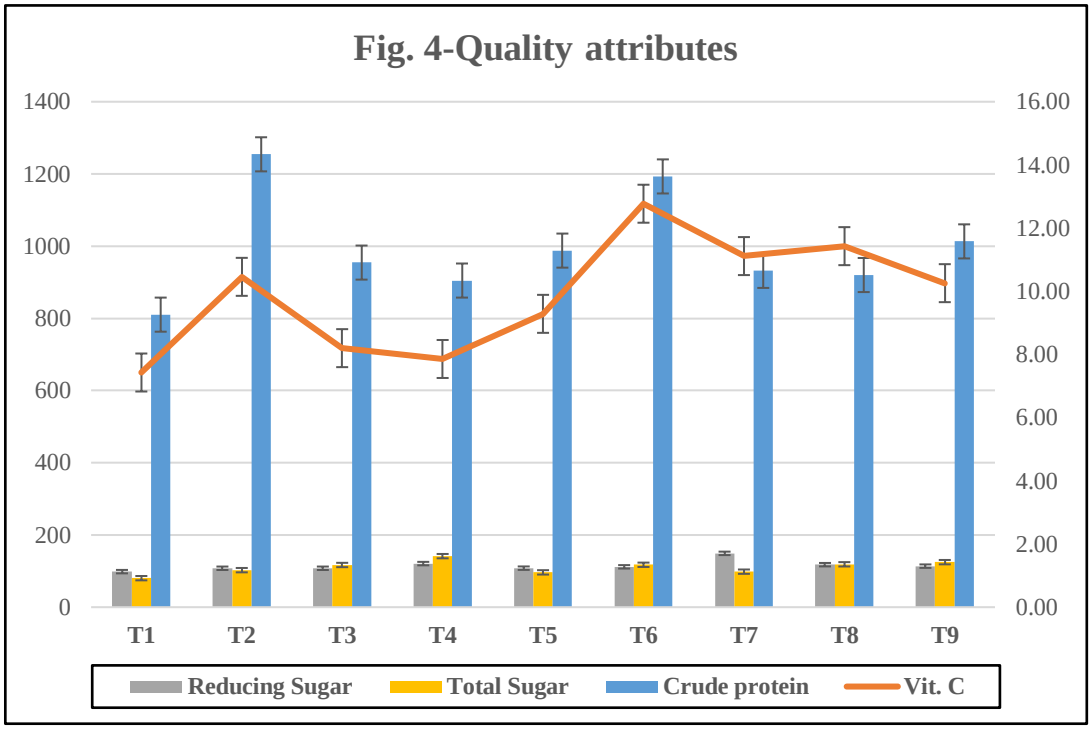


Fig. 4 illustrates different quality parameters as influenced by Zinc and Boron with different application methods (on the basis of pooled data)

Table 4: Quality attributes as influenced by Zinc and boron with different application methods

Treatments		Vitamin C (mg/g)			Reducing sugar			Total sugar			Crude protein (%)			Tot Chl in head (mg/g)		
		2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T1		510	790	650	1.26	0.99	1.13	0.75	1.09	0.92	9.25	9.28	9.26	0.37	0.36	0.36
T2		730	1100	915	1.37	1.09	1.23	1.14	1.21	1.17	14.44	14.23	**14.34**	0.4	0.4	0.4
T3		520	915	717.5	1.39	1.07	1.23	1.32	1.35	1.34	10.85	10.97	10.91	0.48	0.58	0.53
T4		550	825	687.5	1.51	1.25	1.38	1.93	1.31	**1.62**	10.3	10.38	10.34	0.55	0.54	0.55
T5		650	975	812.5	1.4	1.07	1.24	1.1	1.11	1.1	11.2	11.38	11.29	0.63	0.62	0.62
T6		1020	1215	**1117.5**	1.43	1.13	1.28	1.37	1.31	1.34	13.68	13.59	13.64	0.79	0.76	**0.77**
T7		810	1135	972.5	1.92	1.49	**1.7**	1.1	1.15	1.12	10.79	10.5	10.65	0.57	0.56	0.57
T8		890	1110	1000	1.53	1.16	1.35	1.3	1.42	1.36	10.41	10.62	10.51	0.44	0.48	0.46
T9		600	1195	897.5	1.42	1.18	1.3	1.21	1.64	1.43	11.49	11.67	11.58	0.53	0.54	0.53
Mean		697.78	1028.89	863.33	1.47	1.16	1.31	1.24	1.29	1.27	11.38	11.4	11.39	0.53	0.54	0.53
SEM	**B**	33.64	26.83	13.55	0.07	0.05	0.04	0.08	0.07	0.05	0.08	0.11	0.08	0.02	0.01	0.01
	Zn	33.64	26.83	13.55	0.07	0.05	0.04	0.08	0.07	0.05	0.08	0.11	0.08	0.02	0.01	0.01
	B X Zn	58.27	46.48	23.46	0.13	0.09	0.06	0.14	0.12	0.08	0.14	0.19	0.14	0.04	0.02	0.02
CD (0.05)	**B**	100.85	80.44	40.61	0.22	0.16	0.11	0.25	*	0.14	0.24	0.33	0.24	0.07	0.03	0.04
	Zn	100.85	80.44	40.61	*	*	0.11	*	0.2	0.14	0.24	0.33	0.24	*	0.03	0.04
	B X Zn	174.67	139.32	70.34	*	*	0.19	0.43	*	0.25	0.42	0.57	0.42	0.12	0.05	0.06
CV (%)		14.46	7.82	4.71	15.19	13.72	8.23	19.96	15.87	11.44	2.13	2.91	2.11	13.4	5.54	6.78

Treatments: T1: only recommended dose of fertilizer (control); T2:RDF+ zinc foliar @0.5%; T3: RDF+ zinc soil application @ 25kg/ha; T4: RDF+ boron foliar application @ 0.5%; T5: RDF + combined application of boron foliar @0.5% and zinc foliar @0.5%; T6: RDF + combined application of boron foliar @0.5% and zinc soil @25kg/ha; T7: RDF + boron soil application @2kg/ha; T8: RDF + combined application boron soil application @2kg/ha and zinc foliar @0.5%; T9: RDF + combined application for boron soil @2kg/ha + zinc soil @25kg/ha.Recommended dose of fertilizer: N: P_2O_5: K_2O::150:100:100 (kg/ha) were applied through urea, DAP and muriate of potash.

Table5 reveals the nutritional value of zinc and boron in broccoli head and plant of 2018-19,2019-20 and pooled analysis. Data indicates highest zinc concentration and zinc uptake by plant was in combined application of boron soil application @2kg/ha and zinc foliar @0.5% (T8). Zinc boosts plant metabolism when directly applied through leaves. In case of broccoli head, highest zinc concentration and uptake was found in zinc foliar application @0.5% (T2). Boron concentration and uptake by plant was found highest in combined application of boron soil 2kg/ha and zinc foliar 0.5% (T8). Boron is mobile in plants through xylem tissue directly to vegetative parts. Again, in case of broccoli head, highest boron concentration and uptake by broccoli head was found in combined application of boron soil @2kg/ha and zinc foliar application @0.5% (T8). Boron being in xylem tissue, adsorbed from soil as neutral molecules and accumulates in broccoli head. Combined application of boron and zinc resulted in enhanced vegetative growth, improved physical quality, and increased nutritional value of the broccoli heads **(Mahmoud *et. al*, 2019)**. All the values were found significant over control plots.

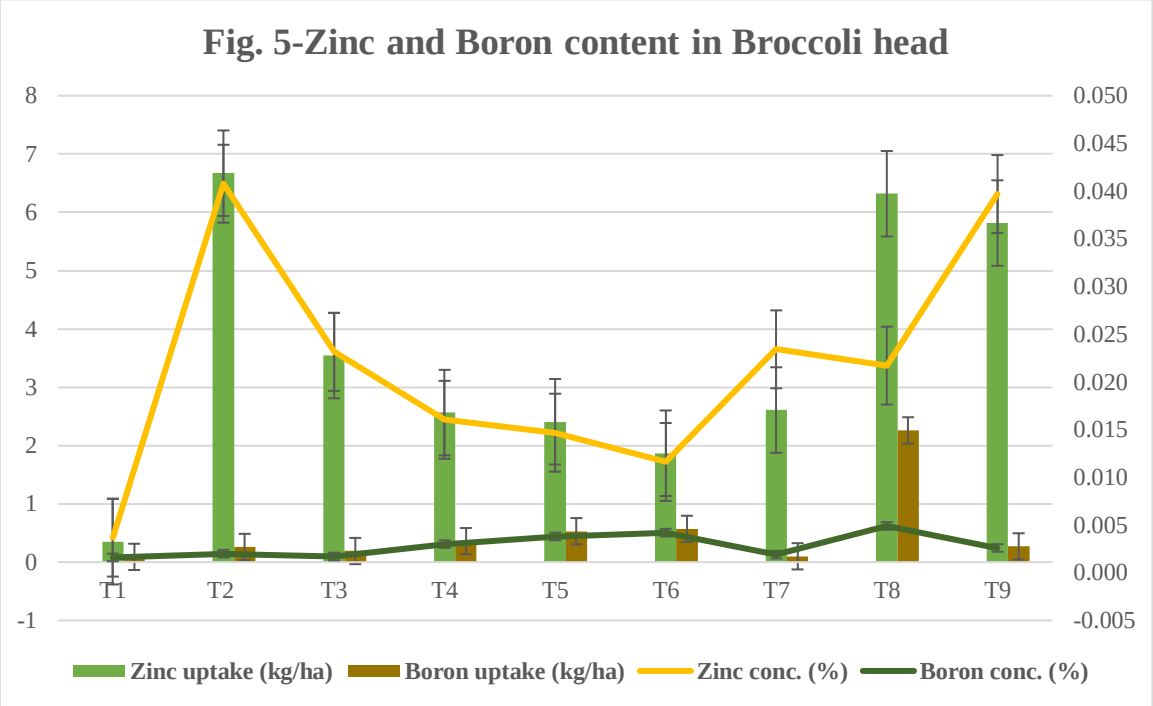


Fig. 5 illustrates nutritional value (zinc and boron content) of broccoli head as influenced by Zinc and Boron with different application methods (on the basis of pooled data)

Table 5: Nutritional value (Zn and B content) of broccoli head as influenced by Zinc and boron with different application methods

Treatments		Zn conc. (%)			Zn uptake (kg/ha)			B conc. (%)			B uptake (kg/ha)		
		2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T1		0.004	0.004	0.004	0.48	0.22	0.35	0.0014	0.0017	0.0016	0.09	0.1	0.09
T2		0.041	0.040	**0.041**	8.67	4.67	**6.67**	0.0019	0.0021	0.0011	0.24	0.29	0.26
T3		0.023	0.023	0.023	4.49	2.60	3.54	0.0016	0.0019	0.0017	0.16	0.23	0.19
T4		0.016	0.016	0.016	3.08	2.05	2.56	0.0032	0.0029	0.003	0.31	0.4	0.36
T5		0.015	0.015	0.015	2.73	2.09	2.41	0.0036	0.0039	0.0038	0.51	0.55	0.53
T6		0.011	0.012	0.012	2.15	1.59	1.87	0.004	0.0045	0.0042	0.53	0.6	0.57
T7		0.023	0.024	0.023	3.72	1.50	2.61	0.0018	0.0019	0.0019	0.1	0.1	0.1
T8		0.022	0.022	0.022	3.52	9.12	6.32	0.0047	0.0052	**0.0049**	2.2	2.32	**2.26**
T9		0.040	0.039	0.040	6.99	4.65	5.82	0.0023	0.0028	0.0026	0.3	0.25	0.27
Mean		0.02	0.022	0.022	3.98	3.17	3.57	0.0027	0.0051	0.0039	0.49	0.54	0.52
SEM	**B**	0.000	0.001	0.000	0.257	0.30	0.26	0.001	0.001	0.001	0.008	0.008	0.008
	Zn	0.000	0.001	0.000	0.257	0.30	0.26	0.002	0.001	0.001	0.008	0.007	0.008
	B X Zn	0.001	0.001	0.001	0.445	0.53	0.46	0.002	0.001	0.002	0.010	0.008	0.014
CD (0.05)	**B**	0.001	0.002	0.001	0.770	0.91	0.79	0.003	0.002	*	0.025	0.032	0.027
	Zn	0.001	0.002	0.001	0.770	0.91	0.79	*	*	*	*	*	*
	B X Zn	0.002	0.003	0.002	1.334	1.58	1.37	*	0.005	0.005	*	0.04	0.044
CV (%)		4.51	7.762	5.640	19.37	28.87	22.10	9.80	8.89	11.02	6.47	8.45	4.87

Treatments: T1: only recommended dose of fertilizer (control); T2:RDF+ zinc foliar @0.5%; T3: RDF+ zinc soil application @ 25kg/ha; T4: RDF+ boron foliar application @ 0.5%; T5: RDF + combined application of boron foliar @0.5% and zinc foliar @0.5%; T6: RDF + combined application of boron foliar @0.5% and zinc soil @25kg/ha; T7: RDF + boron soil application @2kg/ha; T8: RDF + combined application boron soil application @2kg/ha and zinc foliar @0.5%; T9: RDF + combined application for boron soil @2kg/ha + zinc soil @25kg/ha.Recommended dose of fertilizer: N: P_2O_5: K_2O::150:100:100 (kg/ha) were applied through urea, DAP and muriate of potash.

Conclusion:

The present study was conducted to investigate the different application methods (viz. soil and foliar) of zinc and boron on broccoli with special emphasis on yield, quality and nutritional value. Combined application of borax in soil @2kg/ha and zinc sulphate as foliar @0.5% responded significantly and influenced yield (ton/ha) and head yield per plot whereas borax as foliar application influenced head length and head width. Quality parameters like Ascorbic acid content (Vitamin C), Total Sugar, Reducing Sugar and chlorophyll content in broccoli head responded positively to combined application of borax as foliar @0.5% and zinc sulphate as soil application @25kg/ha except for crude protein content in broccoli which was influenced by zinc sulphate as foliar application @0.5%. Nutrient concentration and uptake by broccoli head were mostly influenced by zinc sulphate as foliar application @0.5% but in certain cases it responded positively in combination with borax in soil @2kg/ha. Thus, it can be concluded that combined application of boron in soil @2kg/ha and zinc as foliar @0.5% would enhance bioavailability of zinc and boron in broccoli head which is evident from growth parameters. Moreover, combined application of boron in soil and zinc as foliar would improve quality attributes in broccoli head. This would be an effective practice to increase nutrient concentration in broccoli head and consumption of broccoli would mitigate chances of cancer in human because of zinc.

Reference:

Al-Zubaidi, N. W. Q., & Al-Bayati, H. J. M. (2022). Effect of foliar application with zinc and boron sulfate on the quality of two broccoli hybrids. *Euphrates Journal of Agriculture Science*, 14(2), 153-163.

Choudhury, R., Sarangthem, I., Singh, A. H., Devi, K. N., & Singh, N. O. (2022). Studies on the yield of broccoli (*Brassica oleracea* var. italica) as influenced by boron application in acid soil. *The Pharma Innovation Journal*, 11(4), 595-601.

Chowdhury, R. S., Kumari, M., Jana, J. C., Basfore, S., & Sikder, S. (2019). Effect of lime and boron on growth and yield of sprouting broccoli under Sub-Himalayan foothills of West Bengal, India. *International Journal of Current Microbiology and Applied Sciences*, 8(01), 2319-7706

Kant, Kamal, Singh, K.P., Singh, V.K. and Ranjan, Ashish (2013). Effect of boron, zinc and their combinations on the yield of cauliflower (Brassica oleracea var. Botrytis Linn.) hybrid cultivar – Himani, Asian J. Hort., 8(1) : 238-240.

Mahmoud, S. H., Abd-Alrahman, H. A., Marzouk, N. M., & EL-Tanahy, A. M. M. (2019). Effect of zinc and boron foliar spray on growth, yield, quality, and nutritional value of broccoli heads. *Plant Archives*, 19(2), 2138-2142. ISSN: 0972-5210 (print), e-ISSN: 2581-6063

Moniruzzaman, M., Rahman, S. M. L., Kibria, M. G., Rahman, M. A. and Hossain, M. M. (2007). Effect of Boron and Nitrogen on Yield and Hollowstem of Broccoli. J .Soil .Nature .1(3): 24-29.

Parmar Vijaykumar, K., Piyush, V., & Mori, C. V. (2023). Effect of different micronutrients and their methods of application on growth, yield, and quality of broccoli (Brassica oleracea var. italica) cv. Palam Samridhi. *The Pharma Innovation Journal*; 12(2): 2421-2429

Prasad, M. B. N. V. and Singh, D. P. (1988). Varietal seeing in cauliflower against boron difficiency in Chotanagpur region. Indian Journal of Horticulture.45 (3- 4) : 307-311.

Prasad, P. N. S., Subbarayappa, C. T., Sathish, A., & Ramamurthy, V. (2021). Impact of Zinc Fertilization on Tomato (Solanum lycopersicum L.) Yield, Zinc use Efficiency, Growth and Quality Parameters in Eastern Dry Zone (EDZ) Soils of Karnataka, India. *International Journal of Plant & Soil Science*, 33(7), 20-38. Article no. IJPSS.67161. ISSN: 2320-7035.

Pushpanjali Pankaj, Pradeep Kumar Kujur and S Saravanan (2018). Effect of different micronutrient on plant quality of broccoli (*Brassica oleracea* var. *italica*) CV green magic. *Journal of Pharmacognosy and Phytochemistry,* SP1: 2825-2828

QuratulAin, Gohar Ayub, Mohammad Ilyas, Manzoor Ahmad, Farzana Begum, Luqman, Ammara Saeed, Mohammad Imtiaz Khan and Kamran Shah. Response of broccoli to foliar application of zinc and boron concentrations. Pure and Applied Biology. Vol. 5, Issue 4, pp841-846

Sidhu, G. S., & Kaur, H. (2022). Growth and yield of broccoli (Brassica oleracea L. var. italica) as influenced by different micronutrients under open field conditions. *The Pharma Innovation Journal*, 11(11), 1547-1549.

Singh G, S.Sarvanan, Rajawat K S, Rathore J S and Gurvinder Singh (2017) Effect of Different Micronutrients on PlantGrowth, Yield and Flower Bud Quality of Broccoli (Brassica Oleracea Var. Italica), Current Agriculture Research Journal, Vol. 5(1), 108-115

Singh, A. K. and Jhekr O. P. (1991). Effect of B &Mo in curd yield of Cauliflower. Himachal journal of Agriculture research.17 (1-2) : 137-142.

Singh, D. N. (2003). Effect of boron on growth and yield of cauliflower in lateritic soil of western Orissa. Indian Journal of Horticulture, 60 (3) : 283-286.