Effect of different macro and micronutrient uptake on soil and plant in cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Pusa Sharad

Abstract

A Field experiment was conducted to evaluate the effect of different macro and micronutrients on soil and plant in cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Pusa SharadatResearch cum Instructional farm of Horticulture, Department of Vegetable Science, IGKV, Raipur during two consecutive seasons *i.e.,Rabi* season 2017-18 and *Rabi* season 2018-19. The experiment was carried out under randomized block design consisting offifteen treatments in three replicates. The important parameters encompassed in the study wereavailable nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}), potassium (kg ha^{-1}), boron (ppm), molybdenum (ppm) andzinc (ppm) content in soil and nitrogen (%), phosphorous (%), potassium (%), boron (ppm), molybdenum (ppm) andzinc content (ppm) in plants. All the treatments had a remarkable effect on the growth and yield of cauliflower, of which T_5 (100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1})hadthe most significant influence on all parameters under the study as compared to T_1 (control). Micronutrient application can enhance the growth, curd maturity and curd yield of cauliflower.

Keywords: Micronutrient uptake,Cauliflower, available nitrogen, phosphorous, potassium.

Introduction

Cauliflower is one of the most popular cruciferous vegetables among cole crops and is widely grown across the globe. The 'cole group' is believed to be derived from the wild cabbage, "cole warts" (*Brassica oleracea* var. *sylvestris*), and eastern Mediterranean region is considered to be the centre of origin of cole group. Cauliflower (*Brassica oleracea* var. *botrytis* L.; 2n=18)) was introduced in India in 1822 (Swarup and Chatterjee, 1972) and is one of the most important cool season vegetable crops cultivated in India. It belongs to the family Brassicaceae and is well adapted to all soil types having good soil fertility (Islam, 2008). The economic part curd is pre-floral apical meristem, developed from center point that is short shoot system. It containshigh amount of minerals, protein and vitamins and is popular among the farmers due to its high yielding capacity. India is the second largest cauliflower producing country across the globe. In India, area under cauliflower production is 458.00 thousand hectares with a production of 8,668 thousand metric tons and productivity 19.30 tons/ha (National Horticulture Board, 2019-20). The main cauliflower cultivating states are West Bengal, Bihar, Maharashtra, Madhya PradeshOdisha, Gujarat and Chhattisgarh. The primary cauliflower growing districts in Chhattisgarh are Raipur, Durg, Bemetara, Kondagaon, Kanker and Korba.

The crop is known to be highly responsive and sensitive to the varying nutrient applications*viz*., nitrogen, phosphorus, potassium (major nutrients), boron, molybdenum and zinc (micronutrients), as these elements are essentialfor proper crop growth and development (Rahman *et al.*, 2007). Role of nitrogen in cauliflower is well known, as it is associated with vigorous vegetative growth as well as the development of large and compact curds. The proper use of nitrogen increases curd size, nutrient concentrations, and decreases the likelihood of buttoning in cauliflower (Markovic and Diurovaka, 1990). Phosphorus is a structural component of nucleic acids (DNA, RNA), co-enzymes, nucleotides, and phospholipids, and its optimal supply in the early stages of plant growth is critical for reproductive organ development (Ahmed, et al., 2003). Potassium is a key element for plants because it decreases water loss and maintains a balance among different metabolic responses during water scarcity conditions. It also boosts plant vigour and disease resistance (Das, 2012).

Apart from macronutrients, the role of micronutrients in plants is also well known. Though these are required in small amounts but they are equally indispensable for the normal growth of plant. These micronutrients increase seed germination, photosynthetic activity and metabolite content in leaves,decrease the incidence of diseases, pests and physiological disorders and improve the quality of crop produce. Among the micronutrients, boron, molybdenum and zinc are considered the most vital and significant for cauliflower production. In cauliflower, boron is correlated with improved curd production (Kumar *et al*., 2012; Kumar, 2010) and is also susceptible to boron deficiency (Alam and Raza, 2001). Molybdenum (Mo) is directly related to the metabolic function of nitrogen in the plants through nitrate reductase enzyme that reduces the nitrate to nitrite (Marschner, 1995; Bambara *et al*., 2010) and it is known to increase the cauliflower yield and ascorbic acid content (Joggi and Dixit, 1995; Hunashikatti, *et al*., 2000). In Chhattisgarh, Zinc deficiency is seen up to 55 to 60%in a variety of soil types and itplays an important role in internode elongation, pollen growth regulation, and auxin, protein, and carbohydrate metabolism (Marschner, 1995).

In agricultural production, the rate of fertilizer application has increased.However, micronutrient application has largely been neglected and thus, micronutrient insufficiency is more widespread in Indian soils. Another factor is plant over-mining of soil minerals, which causes most micronutrients to be in limited supply, resulting in crop diseases and low yields (Joshi, 1997). In India, particularly in Chhattisgarh, a declining trend in yield and deteriorating quality and curd production are widespread.As a result, boosting curd output per unit area in cauliflower would benefit from judicious and optimal application of micronutrients in combination with prescribed dose of fertilizers. Furthermore, most available studies are limited to either a single micronutrient or interaction of two elements, such as that of Lashkari et al., (2008) and Singh et al., (2017); and different micronutrients in relation to cauliflower development, yield and quality across multiple seasons are yet to be explored, particularly in the state of Chhattisgarh.Therefore, as per the above concerns, this study was taken to evaluate the effect of different macro and micronutrient uptake on soil and plant in cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. Pusa Sharad.

Materials and methods

The whole experimental trial was designed and carried out for two consecutive *Rabi* seasons 2017-18 and 2018-19 at Horticultural Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The experimental site is characterized with sub-tropical conditions and located at 21°16´ N latitude and 81°36´ E longitude with an altitude of 298.56 meters above the mean sea level. The soil at experimental site was clay-loam in texture (*Vertisols*), having good drainage capacity and whole study was undertaken according to Randomized Block Design (RBD) with 15 treatments in three replicates. The seeds of variety ‘Pusa Sharad’ were sown in nursery bed under polyhouse conditions and transplanted in fields after five weeks. The recommended package of practices was followed to raise healthy seedlings in the nursery and need based plant protection measures were taken up as and when necessary. The treatment combinations were T_1 - Control (100 % RDF), T_2 -100 % RDF + Borax @ 20 kg ha^{-1}, T_3 - 100% RDF + Ammonium molybdate @ 2 kg ha^{-1}, T_4 - 100% RDF + $ZnSO_4$ @ 25 kg ha^{-1}, T_5 -100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}, T_6 -100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}, T_7 -100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg $ha^{-1,}$ T_8 -100% RDF + Borax 20 kg ha^{-1} + $ZnSO^4$ @ 25 kg ha^{-1}, T_9 -75% RDF + Borax @ 20 kg ha^{-1}, T_{10} - 75% RDF + Ammonium molybdate @ 2 kg ha^{-1}, T_{11} - 75% RDF + $ZnSO_4$ @ 25 kg ha^{-1}, T_{12} - 75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} +$ZnSO_4$ @ 25 kg ha^{-1}, T_{13} -75% RDF + Ammonium molybdate @ 2 kg ha^{-1}+ Borax @ 20 kg ha^{-1}, T_{14} -75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}, T_{15}- 75% RDF + Borax 20 kg ha^{-1} + $ZnSO^4$ @ 25 kg ha^{-1}.Available nitrogen (Subbiahand Asija, 1956), available phosphorus (Olsen, 1954), available potassium (kg ha^{-1}), available boron, DTPA-extractable molybdenum (Mo)and zinc (Zn) in soil and content of nitrogen (%), phosphorous (%), potassium (%), boron (ppm), molybdenum (ppm) and zinc content (Lindsayand Norvell, 1978)in plant were estimated.Nutrient uptake was recorded at the harvest stage from five tagged plants. The data collected was then subjected to analysis of variance technique (ANOVA) and the least significant difference test was applied to different treatment means (Panse and Sukhatme, 1967).

Results and Discussion

The effects of application of boron, molybdenum, and zinc on soil parameters such as available nitrogen, phosphorus, potassium, and micronutrients were evaluated under the cauliflower crop which isillustrated in Table 1 to 4 and Figure 1 to 4.

1. Soil Analysis

1.1 Available nitrogen (kg ha^{-1})

The available nitrogen (kg ha^{-1}) significantly ranged from 195.11 to 287.46 kg during first year, from 187.65 to 272.92 kg during second year and 191.38 to 280.19 kg when means were pooled (Table 1 and Fig.1). The highest available nitrogen *i.e.*, 287.46 kg, 272.92 kg and 280.19 kg ha^{-1} during first year, second year and pooled mean respectively, was observed under treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} *i.e.*, 268.01, 260.53 and 264.2719 kg $ha^{-1}$and treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} with 259.74 kg ha^{-1}, 255.08 kg ha^{-1} and 257.41 kg ha^{-1} during first year, second year and pooled mean, over control (195.11, 187.65 and 191.38 kg ha^{-1}, respectively).

The experimental results showed that different micronutrients applied in various combinations (treatments) resulted in higher nitrogen availability, along with combined application of RDF, withmicronutrientbeing the most effective treatments. The findings of Kachari (2007), Yadav et al. (2015), and Singh et al. (2018) corroborated with these findings.

1.2 Available phosphorus (kg ha^{-1})

The available phosphorus in soil was analyzed and recorded during both the years of experimentation and are presented in Table 1 and graphically depicted in Figure 1. The treatments varied significantly during both the years of experimentation.

The available phosphorus significantly varied from 12.41 to 24.25 kg ha^{-1} during first year, from 11.55 to 22.83 kg ha^{-1} during second year and from 11.98 to 23.54 kg ha^{-1} in pooled mean analysis. The maximum available phosphorus content *viz*., 24.25, 22.83 and 23.54 kg ha^{-1} during first year, second year and in pooled mean respectively, was recorded in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} with 22.64, 21.58, and 22.11 kg ha^{-1} and treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} with 22.19 kg ha^{-1}, 21.57 kg ha^{-1} and 21.88 kg ha^{-1} during year 2017-18, year 2018-19 and pooled mean respectively, over control (12.41, 11.55 and 11.98 kg ha^{-1}).

The application of micronutrients has a considerable impact on the available phosphorus content in soil, according to the experimental results based on average performance, which were similar with Singh et al. (2015). This could be attributed to a decrease in water soluble P fixation and an increase in mineralization, which resulted in greater phosphorus availability.

1.3 Available potassium (kg ha^{-1})

The mean data showed in Table 1 revealed that the application of different levels of micronutrients significantly influenced the potassium content in soil. The mean performance is depicted in Figure 1.The available potassium significantly ranged from 241.79 to 414.71 kg ha^{-1}, from 235.76 to 388.94 kg ha^{-1} and from 238.78 to 401.83 kg ha^{-1} during first year, second year and pooled mean analysis respectively. The maximum available potassium *i.e*., 414.71 kg ha^{-1} during first year, 388.94 kg ha^{-1} during second year and 401.83 kg ha^{-1} during pooled mean was observed with treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} followed by 396.81 kg ha^{-1} during first year, 387.85 kg ha^{-1} during second year, and 392.33 kg ha^{-1} during pooled mean with treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 378.99 kg ha^{-1}, 372.51 kg ha^{-1} and 375.75 kg ha^{-1} during first year, second year and pooled mean respectively, in treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}} when compared to control (241.79 kg ha^{-1} during first year, 235.76 kg ha^{-1} during second year and 238.78 kg ha^{-1} during pooled mean). Similar to the availability of N and P, the availability of K increased as a result of the administration of various nutrients, and these findings are consistent with those of Kachari, (2007) and Meena, (2017). The rise in K content was induced by the interaction of micronutrients with clay soil, which resulted in the reduction of fixed K and as a result, the release of K into the soils.

Table 1: Effect of different micronutrients on available nitrogen, phosphorus and potassium in soil after the harvest of cauliflower

Treatment	After harvest (kg ha^{-1})								
	Available nitrogen			Available phosphorus			Available Potassium		
	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1: Control (100 % RDF)	195.11	187.65	191.38	12.41	11.55	11.98	241.79	235.76	238.78
T_2: 100 % RDF + Borax @ 20 kg ha^{-1}	223.76	219.25	221.50	17.14	16.63	16.89	321.42	295.79	308.61
T_3: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1}	227.50	224.44	225.97	18.04	17.22	17.63	343.71	332.30	338.01
T_4: 100% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	221.88	217.83	219.85	16.75	15.85	16.30	331.06	325.81	328.44
T_5: 100% RDF +Borax @ 20kg ha^{-1} +Ammonium molybdate @ 2kg ha^{-1} + $ZnSO_4$ @ 25kg ha^{-1}	287.46	272.92	280.19	24.25	22.83	23.54	414.71	388.94	401.83
T_6: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	255.46	242.95	249.20	21.14	20.62	20.88	378.99	372.51	375.75
T_7: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + ZnSO4 @ 25 kg ha^{-1}	259.74	255.08	257.41	22.19	21.57	21.88	357.04	355.04	356.04
T_8: 100% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	248.21	240.82	244.51	20.76	19.81	20.29	377.54	367.81	372.68
T_9: 75% RDF + Borax @ 20 kg ha^{-1}	211.27	202.74	207.00	14.95	14.22	14.59	261.95	255.81	258.88
T_{10}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1}	217.83	214.33	216.08	15.97	15.62	15.80	285.02	271.82	278.42
T_{11}: 75% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	204.74	198.35	201.54	14.07	12.36	13.22	252.66	241.47	247.07
T_{12}: 75% RDF +Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2kg ha^{-1}+ $ZnSO_4$ @ 25kg ha^{-1}	268.01	260.53	264.27	22.64	21.58	22.11	396.81	387.85	392.33
T_{13}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	241.16	234.62	237.89	20.06	19.67	19.87	354.91	350.45	352.68
T_{14}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	237.37	230.37	233.87	18.64	17.96	18.30	345.62	336.56	341.09
T_{15}: 75% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	230.22	227.81	229.01	19.03	18.53	18.78	351.55	343.39	347.47
Mean	**235.31**	**228.65**	**231.98**	**17.73**	**17.73**	**18.14**	**334.32**	**324.09**	**329.21**
SEm±	**8.62**	**9.33**	**10.92**	**0.59**	**0.62**	**0.48**	**12.92**	**13.54**	**13.15**
CD (P=0.05)	**24.98**	**27.01**	**31.65**	**1.71**	**1.79**	**1.38**	**37.42**	**39.24**	**38.08**
CV (%)	**6.35**	**7.06**	**8.16**	**5.75**	**6.05**	**4.56**	**6.69**	**7.24**	**6.92**

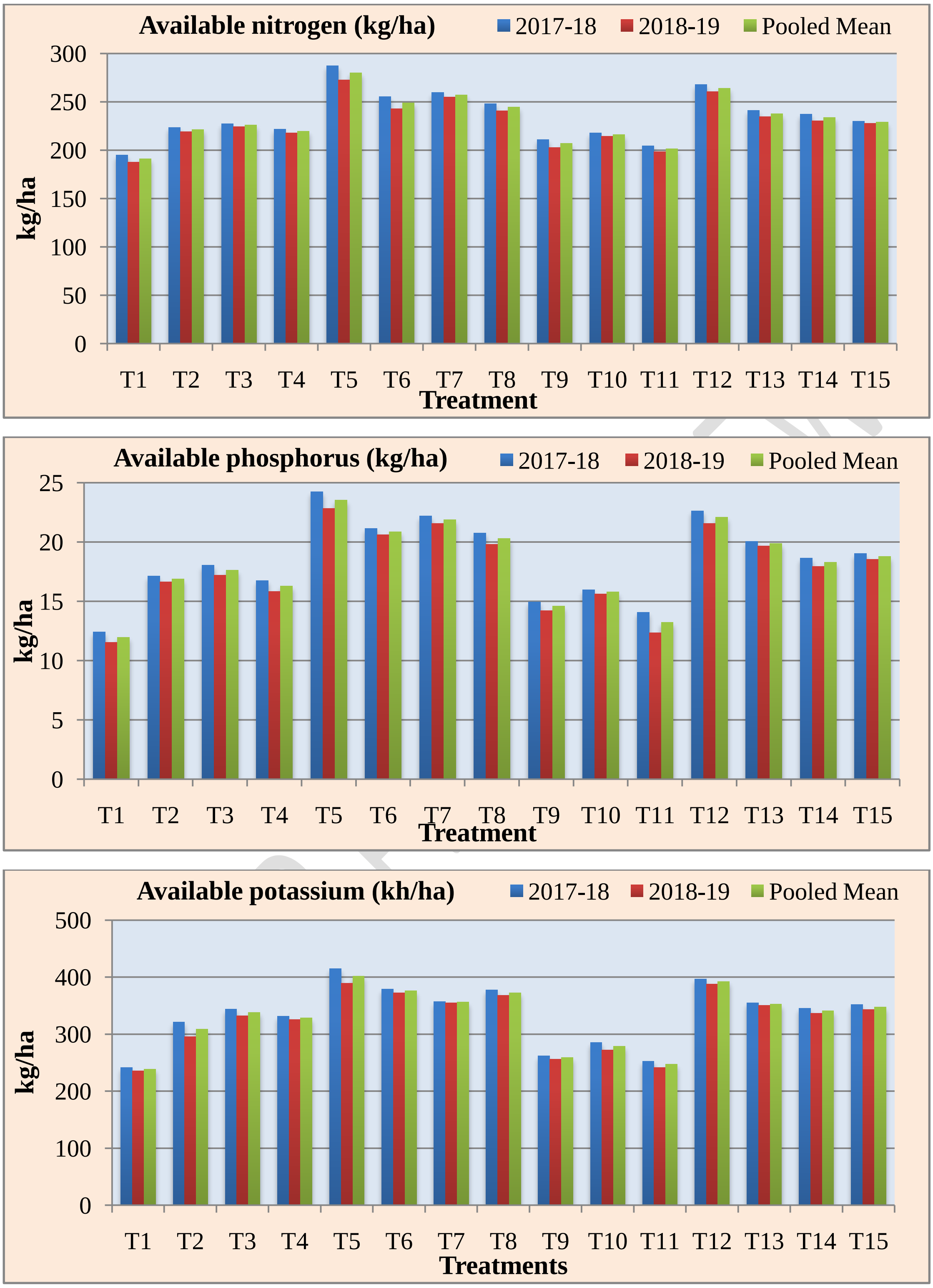

Figure 1. Effect of different micronutrients on available nitrogen,phosphorus and potassium in soil after the harvest of cauliflower

1.4 Available boron (ppm)

The mean data pertaining to available boron in soil after the harvest of cauliflower during both the years and pooled analysis have been presented in Table 2 and graphically depicted in figure 2. The analysis of variance revealed that significant differences were observed due to the application of varied boron levels.The available boron significantly varied from 0.38 to 0.97 ppm, from 0.37 to 0.95 ppmand from 0.38 to 0.96 ppm during year 2017-18, year 2018-19 and pooled mean analysis respectively. The highestavailable boron in soil *i.e.*, 0.97, 0.95 and 0.96 ppm during year 2017-18, year 2018-19 and pooled mean analysis respectively, was noticed in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 0.95, 0.94, and 0.95 ppm during year 2017-18, year 2018-19 and pooled mean analysis respectively, in treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 0.92, 0.91 and 0.92 ppm during first year, second year and pooled mean respectively, in treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} when compared to control *viz.*, 0.38, 0.37 and 0.38 ppm during year 2017-18, year 2018-19 and pooled mean analysis respectively.The experimental findings suggested that the application of micronutrients in different treatments significantly improved the available B status of soil during both the years and similar results have been also reported by Renukadevi (2000), Janaki (2001) and Sakal *et al.* (2002).

1.5 Available molybdenum (ppm)

The mean data pertaining to the available molybdenum in soil after harvest during 2017-18, 2018-19 and pooled mean analysis as significantly influenced by various levels of micronutrients have been presented in Table 2 and illustrated graphically in figure 2.The available molybdenum in soil varied significantly from 0.12 to 0.27 ppm, from 0.11 to 0.26 ppm and from 0.12 to 0.27 ppm during first year, second year and pooled mean analysis respectively. The highest available molybdenum in soil *i.e.*, 0.27, 0.26 and 0.27 ppm during first year, second year and pooled mean analysis respectively, was observed under the treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 0.26, 0.25, and 0.26 ppm during first year, second year and pooled mean analysis respectively,in treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 0.24, 0.23 and 0.24 ppm during first year, second year and pooled mean respectively, in treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, over control *viz*., 0.12, 0.11 and 0.12 ppm during first year, second year and pooled mean analysis respectively.The results revealed that the Mo content in soil was significantly affectedby the application of different micronutrients in different combinations with macronutrient and our results were in close conformity with the findings of Lakshmana Rao *et al.* (1990), Sharma and Minhas (1992) and Kotur (1990, 1994 and 1995), who also reported increased molybdenum content in soil.

1.6. Available zinc (ppm)

The available zinc in soil was analyzed and recorded during both the years and on pooled mean basis of experimentation and presented in Table 2 and graphically depicted in figure 2.The treatments had significant differences during both the years.The available zinc ranged from 0.58 to 1.48 ppm during year 2017-18, from 0.57 to 1.45 ppm during year 2018-19 and from 0.58 to 1.47 ppm during pooled mean analysis. The highest zinc content in soil *viz.*, 1.48, 1.45 and 1.47 ppm during first year, second year and pooled mean analysis respectively, was observed in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 1.45, 1.44 and 1.45 ppm during first year, second year and pooled mean analysis respectively, with T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 1.41, 1.40 and 1.41 ppm during first year, second year and pooled mean respectively, in treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, when compared to control *viz.,* 0.58, 0.57 and 0.58 ppm during first year, second year and pooled mean analysis respectively.The results indicated that the application of micronutrients along with RDF in different combinations significantly enhanced the zinc content in soil and our results were in close conformity with the findings of Moklikar*et al*. (2015) and Singh and Singh (2017) who also reported an increased available Zn in soil.

Table 2: Effect of different micronutrients on available boron, molybdenum and zinc in soil after harvest of the cauliflower

Treatment	After harvest(ppm)								
	Available boron			Available molybdenum			Available zinc		
	2017 -18	2018 -19	Pooled Mean	2017-18	2018-19	Pooled Mean	2017 -18	2018-19	Pooled Mean
T_1:Control (100 % RDF)	0.38	0.37	0.38	0.12	0.11	0.12	0.58	0.57	0.58
T_2: 100 % RDF + Borax @ 20 kg ha^{-1}	0.64	0.61	0.63	0.15	0.15	0.15	0.90	0.88	0.89
T_3: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1}	0.67	0.66	0.67	0.16	0.15	0.16	0.98	0.97	0.98
T_4: 100% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	0.58	0.58	0.58	0.15	0.14	0.15	0.87	0.87	0.87
T_5: 100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	0.97	0.95	0.96	0.27	0.26	0.27	1.48	1.45	1.47
T_6: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	0.88	0.87	0.88	0.22	0.21	0.22	1.35	1.32	1.34
T_7: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	0.92	0.91	0.92	0.24	0.23	0.24	1.41	1.400	1.41
T_8: 100% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	0.86	0.84	0.85	0.21	0.20	0.21	1.30	1.28	1.29
T_9: 75% RDF + Borax @ 20 kg ha^{-1}	0.45	0.43	0.44	0.13	0.13	0.13	0.76	0.75	0.76
T_{10}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1}	0.52	0.51	0.52	0.14	0.13	0.14	0.84	0.84	0.84
T_{11}: 75% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	0.42	0.39	0.41	0.12	0.12	0.12	0.67	0.65	0.66
T_{12}: 75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	0.95	0.94	0.95	0.26	0.25	0.26	1.45	1.44	1.45
T_{13}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	0.82	0.81	0.82	0.20	0.19	0.20	1.22	1.21	1.22
T_{14}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	0.73	0.73	0.73	0.19	0.18	0.19	1.09	1.05	1.07
T_{15}: 75% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	0.79	0.78	0.79	0.17	0.16	0.17	1.16	1.15	1.16
Mean	**0.71**	**0.69**	**0.70**	**0.18**	**0.17**	**0.18**	**1.07**	**1.06**	**1.06**
SEm±	**0.02**	**0.02**	**0.02**	**0.006**	**0.006**	**0.005**	**0.03**	**0.03**	**0.03**
CD (P=0.05)	**0.06**	**0.06**	**0.05**	**0.018**	**0.016**	**0.014**	**0.09**	**0.09**	**0.10**
CV (%)	**5.39**	**4.95**	**4.12**	**5.76**	**5.50**	**4.66**	**5.16**	**4.95**	**5.35**

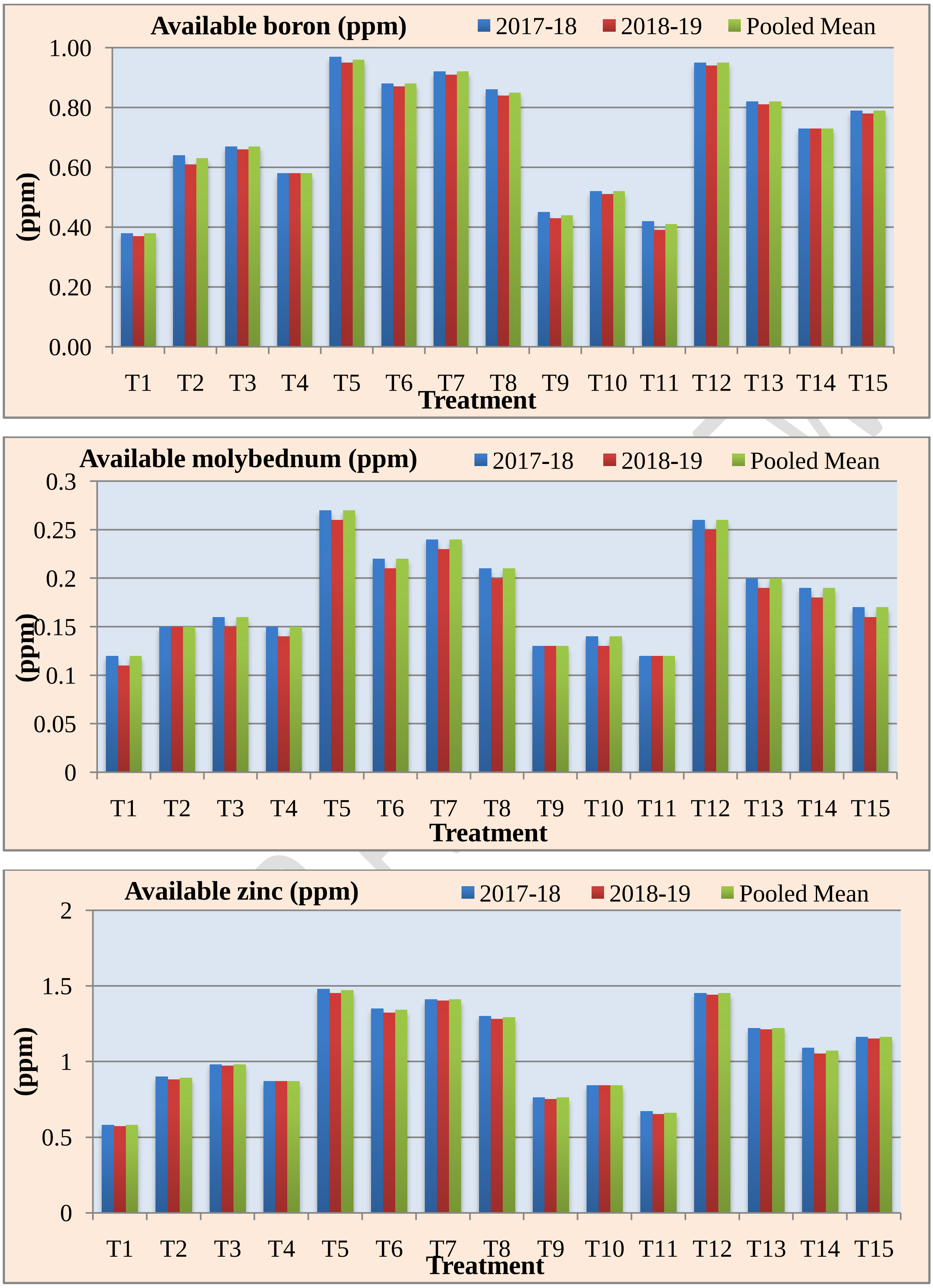

Figure 2: Effect of different micronutrients on available boron,molybdenum and zinc in soil after the harvest of cauliflower.

2. Plant Analysis

2.1. Nitrogen content (%)

The *per se* performance pertaining to nitrogen content in curd during year 2017-18, 2018-19 and pooled mean analysis as significantly influenced by various levels of micronutrients have been presented in Table 3 and illustrated graphically in figure 3.The nitrogen content in curd varied significantly from 1.92to 3.15% (year 2017-18), 1.84to 3.06% (year 2018-19) and 1.88to 3.10% (Pooled mean) respectively. The significantly maximum nitrogen content *i.e*., 3.15, 3.06 and 3.10% during year 2017-18, 2018-19 and pooled mean respectively, was noted with treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 2.97%, 2.91%, and 2.94% during year 2017-18, 2018-19 and pooled mean respectively, with treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 2.83%, 2.76% and 2.80% during year 2017-18, 2018-19 and pooled mean respectively, with treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} compared to control (1.92%, 1.84% and 1.88% during year 2017-18, 2018-19 and pooled mean, respectively). The results indicated that the supply of varied micronutrients and RDF improved the N content in curd and the higher N content in curd was recorded when nutrients were applied in combination. The increased N content in curd is due theto fact that application of optimal amount of nutrients in balanced manner enhances the uptake of NPK as well as other micronutrients. Further our results were found in well accordance with the reports ofBalyan *et al.* (2004) in cauliflower and Choudhary *et al*. (2012) in sprouting broccoli.

2.2. Phosphorous Content (%)

The phosphorus content in curd was significantly affected by the application of different micronutrients along with RDF. The *per se* performances are presented in Table 3 and illustrated graphically in figure 3.The phosphorous content in curd varied from 0.08to 0.29 % (year 2017-18), 0.07to 0.27 % (year 2018-19) and 0.08 to 0.28% (pooled mean). The significantly highest phosphorous content *i.e*., 0.29% during year 2017-18, 0.27% during year 2018-19 and 0.28% during pooled mean analysis was recorded from treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 0.27% during year 2017-18, 0.26% during year 2018-19 and 0.27% in pooled mean analysis from treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 0.26% during year 2017-18, 0.24% during year 2018-19 and 0.25% during pooled mean data from treatment T_8 {100% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} when compared to control (0.08% during year 2017-18, 0.07% during year 2018-19 and 0.08% in pooled mean analysis).Similar to N content, phosphorus content was also found to increase, which might be due to the combined application of micronutrients along with RDF and the results were well supported by the observation of Robertson and Loughman (1974). Loughman (1977) found that the application of micronutrients helps in phosphate transport across cell membranes. Furthermore, the report of Malewar and Indulkar (1993) revealed that the micronutrients significantly increased the phosphorus uptake.

2.3. Potassium content (%)

The potassium content in curd varied significantly due to the application of different micronutrients and data regarding mean performance of both the years andpooled meansare explicated in Table 3 and figure 3.The potassium content in curd varied from 0.98to 1.92% (year 2017-18), 0.94to 1.85 % (year 2018-19) and 0.96to 1.89% (pooled mean), respectively. The maximum potassium content *i.e.*, 1.92%, 1.85% and 1.89% during year 2017-18, year 2018-19 and pooled mean analysis,respectively was observed in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 1.86%, 1.82% and 1.84% during year 2017-18, year 2018-19 and pooled mean analysis, respectively in treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 1.81%, 1.76% and 1.79% during year 2017-18, year 2018-19 and pooled mean analysis, respectively in treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, when compared to control (0.98%, 0.94% and 0.96% during year 2017-18, year 2018-19 and pooled mean analysis, respectively.Increase in the uptake of nitrogen, phosphorus and potassium might be due to the fact that boron helps in absorption and translocation of nitrogen, phosphorus and potassium in curd. Higher boron uptake at higher borax level was due to increased availability of boron in soil with higher rate of application. These results corroborated with the earlier findings of Singh *et al.* (1994) and Gupta *et al.* (2002).

2.4.Boron content (ppm)

The data regarding boron concentration in curd was recorded during year 2017-18, 2018-19 and have been presented in Table 4and illustrated in figure 4. The analysis of variance indicated significant differences among the treatments.The boron content (ppm)ranged significantly from 21.94to 39.67 ppm (year 2017-18), 20.43 to 37.98 ppm (year 2018-19) and 21.19 to 38.83 ppm (pooled mean), respectively. The significantly maximum boron content in curd *viz.,* (39.67, 37.98 and 38.83 ppm during year 2017-18, year 2018-19 and pooled mean analysis,respectively) was noticed in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 37.51, 36.71, and 37.11 ppm during year 2017-18, year 2018-19 and pooled mean analysis, respectively with treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 36.55, 35.92 and 36.24 ppm during year 2017-18, year 2018-19 and pooled mean analysis, respectively with treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, as compared to control (21.94, 20.43 and 21.19 ppm during year 2017-18, year 2018-19 and pooled mean analysis).The results obtained from our experiment confirmed that the uptake of B was enhanced by the combined application of micronutrient, which was well supported by the earlier works of Stoyanov (1971); Kotur and Kumar (1989) and Gupta (1993) who also reported similar trends of increased B content in curd. Along with that, the higher boron uptake was also recorded when borax was applied in higher concentrations, which corroborated with the findings of Singh and Dixit 1994; and Gupta *et al.* 2002. Our results also indicated that there was a steady increase in B uptake with the stage of the crop and the highest uptake was recorded at the harvest stage.

2.5.Molybdenum content (ppm)

The mean observation was recorded for Mo content in curd during the year 2017-18, 2018-19 and pooled mean. The mean data for molybdenum concentration in curd on dry weight basis have been presented in Table 4 and graphically shown in figure 4. During both the years and pooled mean analysis, significant differences among the treatments was observed.The molybdenum content in curd varied from 0.38 to 0.98 ppm, from 0.34to 0.95 ppm and from 0.36 to 0.97 ppm during first year 2017-18, 2018-19 and pooled mean analysis, respectively. The maximum molybdenum content *i.e.*, 0.98, 0.95 and 0.97 ppm during year 2017-18, year 2018-19 and pooled mean analysis,respectively was observed in treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 0.95, 0.94, and 0.95 ppm during year 2017-18, year 2018-19 and pooled mean analysis, respectively in treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 0.91, 0.89 and 0.90 ppm during year 2017-18, year 2018-19 and pooled mean analysis, respectively in treatment T_6 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}}, when compared to control (100% RDF) *viz.*, 0.38 (year 2017-18), 0.34 (year 2018-19) and 0.36 ppm (pooled mean).These results clearly indicated an increase in Mo content due to the application of various micronutrients and the results were found in well accordance with the findings of Gupta (1990) and Saha *et al.* (2010) who reported molybdenum in leaf tissues increased as the level of molybdenum increased in soil.

2.6.Zinc content (ppm)

The zinc concentration in curd was analyzed and recorded during both the years of experimentation. The significant differences were observed during both the years among different treatments. The mean performance data are presented in Table 4and graphically depicted in figure 4. The zinc content in curd varied significantlyfrom 38.55 to 49.67 ppm, from 38.12 to 48.56 ppm and from 38.34 to 49.12 ppm during year 2017-18, 2018-19 and pooled mean analysis, respectively. The highest zinc content *i.e.*, 49.67, 48.56 and 49.12 ppm during year 2017-18, 2018-19 and pooled mean analysis, respectively was observed with treatment T_5 {100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, followed by 48.92, 48.27 and 48.60 ppm during year 2017-18, 2018-19 and pooled mean analysis, respectively with treatment T_{12} {75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}} and 48.05, 47.69, and 47.87 ppm during year 2017-18, 2018 -19 and pooled mean analysis, respectively with treatment T_7 {100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}}, when compared to control (100% RDF) *viz*., 38.55 (year 2017-18), 38.12 (year 2018-19) and 38.34 ppm (pooled mean analysis), respectively.The results indicated an obvious increase in Zn uptake by the crop as a result of various treatment application and the Zn content in curd was reported highest when micronutrients were applied in combination. The reports on increased Zn uptake in curd due to application of different micronutrients are sparse though, an increased Zn uptake through B fertilization in oilseeds crop was earlier reported by Balyan and Singh (1994) in cauliflower; Varghese *et al*. (2005) and Jat and Mehra (2007).

Table 3: Effect of different micronutrients on nitrogen, phosphorus and potassium content in curd after the harvest of cauliflower

Treatment	After harvest (%)								
	Nitrogen content			Phosphorus content			Potassium content		
	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1: Control (100 % RDF)	1.92	1.84	1.88	0.08	0.07	0.08	0.98	0.94	0.96
T_2: 100 % RDF + Borax @ 20 kg ha^{-1}	2.52	2.43	2.47	0.15	0.14	0.15	1.56	1.48	1.52
T_3: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1}	2.57	2.49	2.53	0.14	0.13	0.13	1.67	1.55	1.61
T_4: 100% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	2.37	2.37	2.37	0.16	0.16	0.16	1.49	1.46	1.48
T_5: 100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	3.15	3.06	3.10	0.29	0.27	0.28	1.92	1.85	1.89
T_6: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	2.81	2.73	2.77	0.23	0.22	0.23	1.78	1.74	1.76
T_7: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	2.83	2.76	2.80	0.22	0.21	0.22	1.81	1.76	1.79
T_8: 100% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	2.80	2.69	2.74	0.26	0.24	0.25	1.77	1.68	1.73
T_9: 75% RDF + Borax @ 20 kg ha^{-1}	2.23	2.2	2.21	0.10	0.10	0.10	1.22	1.18	1.20
T_{10}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1}	2.36	2.33	2.35	0.12	0.11	0.12	1.42	1.33	1.38
T_{11}: 75% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	2.17	2.06	2.12	0.09	0.08	0.09	1.34	1.26	1.30
T_{12}: 75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	2.97	2.91	2.94	0.27	0.26	0.27	1.86	1.82	1.84
T_{13}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	2.74	2.65	2.70	0.18	0.18	0.18	1.69	1.57	1.63
T_{14}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	2.71	2.63	2.67	0.17	0.15	0.16	1.73	1.62	1.68
T_{15}: 75% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	2.60	2.52	2.56	0.18	0.17	0.18	1.74	1.66	1.70
Mean	**2.58**	**2.51**	**2.55**	**0.18**	**0.17**	**0.17**	**1.60**	**1.53**	**1.56**
SEm±	**0.13**	**0.12**	**0.12**	**0.01**	**0.01**	**0.01**	**0.06**	**0.05**	**0.05**
CD (P=0.05)	**0.38**	**0.35**	**0.35**	**0.02**	**0.02**	**0.02**	**0.16**	**0.14**	**0.14**
CV (%)	**8.81**	**8.25**	**8.23**	**5.30**	**6.12**	**5.61**	**6.16**	**5.64**	**5.48**

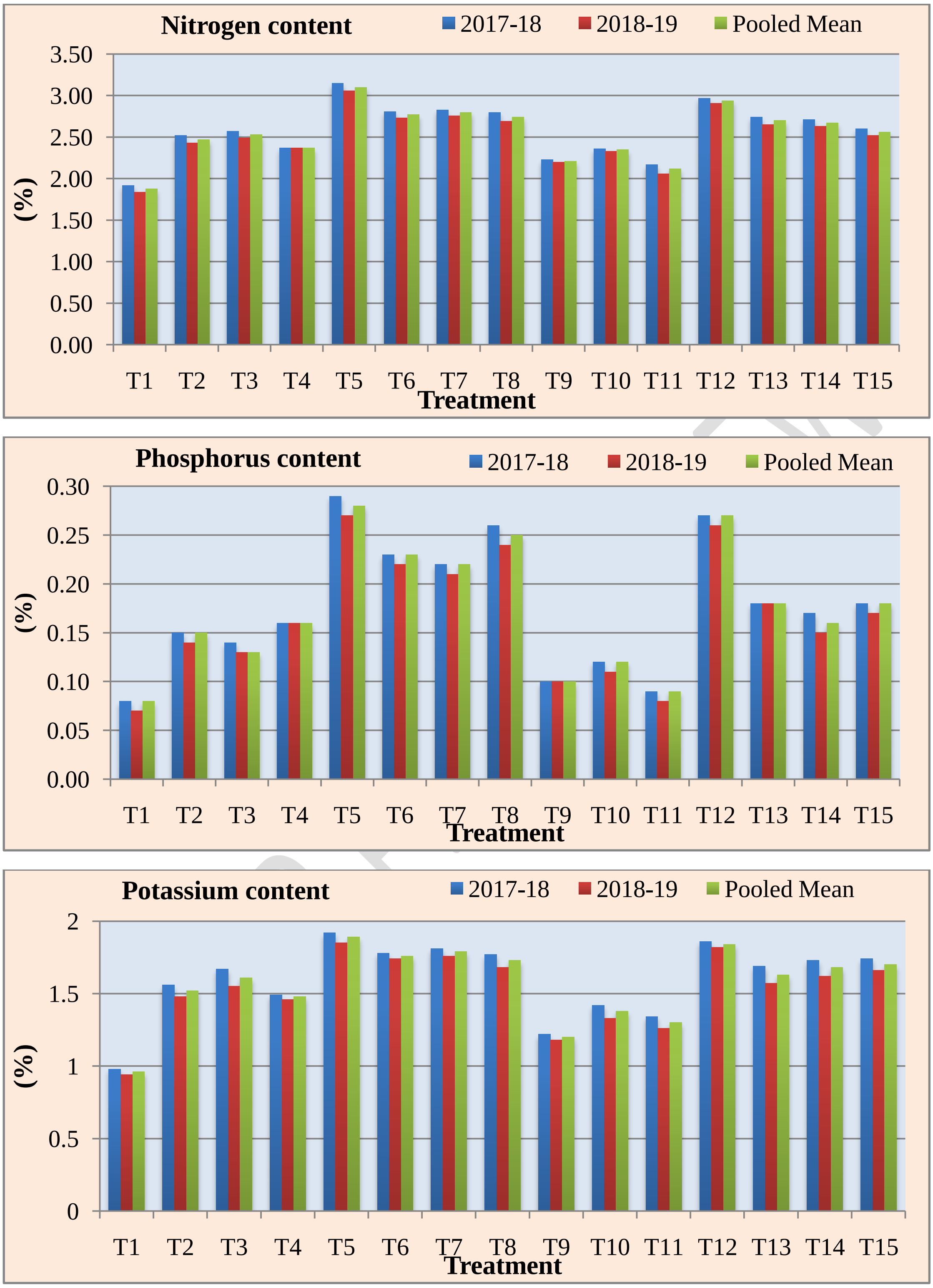

Figure 3.Effect of different micronutrients on nitrogen, phosphorus and potassium content in curd after the harvest of cauliflower

Table 4: Effect of different micronutrients on boron (B), molybdenum (Mo) and zinc (Zn) content in curd after the harvest of cauliflower.

Treatment	After harvest (ppm)								
	B content (%)			Mo content (%)			Zn content (%)		
	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean	2017-18	2018-19	Pooled Mean
T_1: Control (100 % RDF)	21.94	20.43	21.19	0.38	0.34	0.36	38.55	38.12	38.34
T_2: 100 % RDF + Borax @ 20 kg ha^{-1}	28.37	26.54	27.46	0.58	0.57	0.58	42.77	42.13	42.45
T_3: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1}	30.16	29.05	29.61	0.61	0.61	0.61	44.92	43.68	44.30
T_4: 100% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	27.85	26.13	26.99	0.51	0.48	0.50	43.15	42.75	42.95
T_5: 100% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	39.67	37.98	38.83	0.98	0.95	0.97	49.67	48.56	49.12
T_6: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	36.22	35.48	35.85	0.91	0.89	0.90	47.78	46.87	47.33
T_7: 100% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	36.55	35.92	36.24	0.84	0.83	0.84	48.05	47.69	47.87
T_8: 100% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	35.18	35.04	35.11	0.81	0.76	0.79	47.22	46.18	46.70
T_9: 75% RDF + Borax @ 20 kg ha^{-1}	24.17	23.72	23.95	0.47	0.45	0.46	40.84	39.16	40.00
T_{10}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1}	25.44	24.81	25.13	0.50	0.48	0.49	41.37	40.77	41.07
T_{11}: 75% RDF + $ZnSO_4$ @ 25 kg ha^{-1}	22.67	22.37	22.52	0.44	0.41	0.43	39.15	39.02	39.09
T_{12}: 75% RDF + Borax @ 20 kg ha^{-1} + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	37.51	36.71	37.11	0.95	0.94	0.95	48.92	48.27	48.60
T_{13}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + Borax @ 20 kg ha^{-1}	33.87	32.76	33.32	0.77	0.75	0.76	45.73	44.56	45.15
T_{14}: 75% RDF + Ammonium molybdate @ 2 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	34.95	33.98	34.47	0.76	0.72	0.74	46.08	45.72	45.90
T_{15}: 75% RDF + Borax 20 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}	31.68	31.44	31.56	0.65	0.62	0.64	46.73	46.33	46.53
Mean	**31.08**	**30.16**	**30.62**	**0.68**	**0.65**	**0.67**	**44.73**	**43.99**	**44.36**
SEm±	**1.08**	**1.25**	**1.14**	**0.02**	**0.02**	**0.02**	**2.06**	**2.18**	**2.19**
CD (P=0.05)	**3.13**	**3.62**	**3.29**	**0.05**	**0.05**	**0.06**	**5.97**	**6.32**	**6.34**
CV (%)	**6.02**	**7.17**	**6.43**	**4.41**	**4.83**	**5.05**	**7.98**	**8.59**	**8.55**

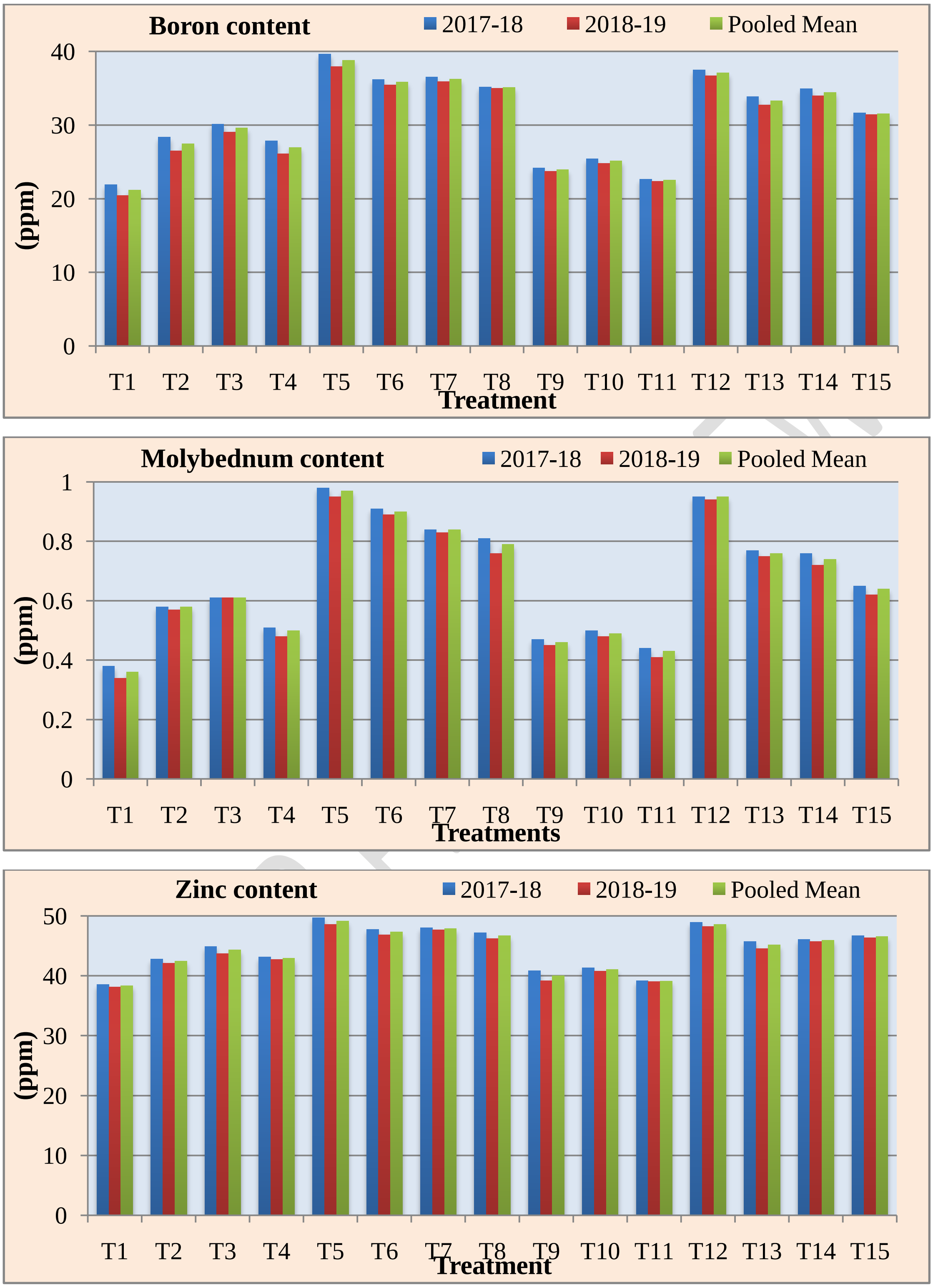

Figure 4.Effect of different micronutrients on boron, molybdenum and zinc content in curd after the harvest of cauliflower.

Conclusion

The present study can be concluded as the balanced application of essential plant nutrient including the micro-nutrients not only help in maintaining the soil fertility but also improve the yield and quality of the curd in cauliflower.

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