Influence ~~of micronutrients~~of micronutrients (Boron and Zinc) on uptake and availability of nutrients

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Abstract

An experiment was carried out SKUAST ~~-K in~~K intwo consecutive years (2016 and 2017) to study the effect of zinc and boron and their interaction on nutrient uptake in onion on nutrient uptake and soil properties of onion. In the experiment it was observed that sole zinc and boron levels, Z_3 (7.500 kg Zn ha^{-1}) and B_3 (1.500 kg B ha^{-1}) application proved superior in enhancing the uptake of all nutrients but exhibited lowest value in case of phosphorus uptake. It was further observed that interaction of zinc and boron proved superior to their sole applications in increasing uptake of nutrients. Treatment combination Z_3B_3 (7.500 kg Zn + 1.500 kg B ha^{-1}) recorded significantly maximum value for uptake of nitrogen (113.93 kg ha^{-1}), potassium (67.17 kg ha^{-1}), boron (125.58 g ha^{-1}) and zinc (184.01 g ha^{-1}) but exhibited lowest value in case of phosphorus uptake. Sole application of zinc and boron and their combination exhibited a non-significant influence on soil pH, electric conductivity, organic carbon (%) and organic matter (%).Application of zinc (7.500 kg ha^{-1}) and boron (1.500 kg ha^{-1}) improved the availability of all nutrients except of phosphorus availability. Interactions of zinc and boron, proved synergistic in augmenting available nutrients except for phosphorus availability.

Key words: Zinc, Boron, Nitrogen, availability and Uptake

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Introduction

Fertilization is an important practice required for cultivation of onion().Fertilizers offer the best means of increasing yield, quality and maintaining soil fertility. Results of various fertilizers have revealed that essential elements are important viz., nitrogen, phosphorus, potassium, sulphur, boron, zinc etc. Among them, nitrogen significantly contributes in vegetative and reproductive growth and thus helps for increasing yield. In most non-leguminous crop plants, leaves are the dominant organ in the amino acid synthesis and distribution (Noctor*et al.*, 2002). Phosphorus is one of 17 nutrients essential for plant growth including energy transfer, transfer of genetic characteristics from one generation to the next etc. Potassium is vital to many plant processes such as enzyme activation, photosynthesis and stomatal activity by maintaining turgor pressure etc. Sulphur plays an important role in sugar production, imparts deep rich green colour in leaves (Tarlok, 2005)~~. etc.~~

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In addition to nitrogen, phosphorus, potassium and sulphur, zinc as a micronutrient have great role in the fertilization program to achieve higher and sustainable bulb yields (Singh and Tiwari, 1996). Unfortunately zinc has received less attention in fertilizer management research, development and extension.Zinc is a micronutrient, which is required for plant growth and developmentrelatively in small amount. Zinc is involved in the formation of chlorophyll and carbohydrate and is involved in a diverse range of enzymesystem. The functional role of zinc includes auxin metabolism, influence onthe activities of dehydrogenase and carbonic anhydrase enzymes, synthesisof cytochrome and stabilization of ribosomal fractions (Tisdale *et al.*, 1984). Zinc also plays very important role for grain formation and nutrition. Zinc is taken up by plants as Zn^{+2}. The main source of zinc is minerals e.g.**,** sphalerite (ZnS), Smithsonite ($ZnCO_3$), Zinc sulphate ($ZnSo_4$) etc. Zinc deficient plants are stunted and have twisted, outward bending leaves. Older leaves take on an orange mottled appearance. Younger leaves have a faint chlorosis and yellow striping. Bulbing can be delayed and crops may not store well. Problems are more common on calcareous soils or during cold, wet weather (Diaz *et al.*, 2013)and nearly 50% of the soil which are used for ~~cultivation of~~cultivation ofcrops have low levels of bioavailable zinc (Cakmak, 2017). Zinc deficiency is prevalent worldwide in temperate and tropical climates (Fageria*et al.*, 2011). Zinc deficiency has been reported in soils of India and Kashmir (Mandal *et al.*, 2000 and Wani*et al.*, 2013). Soils are deficient of zinc in Kashmir and posses a range of 0.62±.09 ppm (Yatoo *et al.*, 2011). The critical level of zinc for soil is 0.64 ppm (Sanchez, 1996). A statistical analysis of zinc in the soil of Himalaya and a value with a mean of 0.29 mg of zinc kg^{-1} of soil was reported which is lower than the critical value (Rai *et al.*, 2005). The status of zinc in most parts of Pakistan occupied Kashmir soils were found 0.6 mg kg^{-1} which is lower than the normal range of 0.66-1.4 mg kg^{-1} of soil (Nazif*et al.*, 2006). Application of zinc significantly increased the yield and bulb quality of onion (Rafie*et al.*, 2016). Dry weight of onion bulbs also gets significantly enhanced by applying zinc (Gamelli*et al.*, 2000). Application of zinc increased the growth and yield of onion (Morteza and Ahmad, 2015). Zinc application influences the quality and yield of onion (Aske *et al.*, 2017).

Boron is essential for normal growth and production of sound and healthy vegetables. Boron has been linked with initiation and development of growing points, movement of sugars and starches to developing parts, movement of nutrient elements within the plant, formation of plant hormones affecting growth, root growth and health of fleshy roots, flower and fruit set and quality and flavour of vegetables (Vitosh*et al.*, 2001). Boron is one of the important micronutrients for onion production and is essential for cell division, nitrogen and carbohydrate metabolism, protein formation and water relation in plant growth (Brady, 2010). It is essential for cell wall formation. It also maintains balance between sugars and starch in plant body. It increases the growth of primary and lateral roots. Although it is quickly taken up from the soil, it is relatively immobile in the plant. Young leaves develop yellow and green mottling. Older leaves become yellow and undergo dieback. Light yellow lines appear and develop into ladder-like transverse cracks on the upper surfaces of older leaves. They become brittle and deep green in colour. Plants can be stunted or distorted. Soils with higher clay and organic matter content adsorb higher contents of boron than medium textured soils containing low organic matter. Most of the soils (fine as well as coarse textured) are considered to be low in available boron as it has been reported that <0.50 mg kg^{-1} boron is not sufficient for optimum plant growth (Reisenauer*et al.*, 2008). Boron deficiency has been observed in soils with low organic matter contents (Valk and Bruin2009). Soils of Jammu and Kashmir are mostly dominated by Lithic or TypicUdorthents (Sidhu *et al.*, 1999). These soils have already been reported to be deficient in boron (Mondal, 2002).The soils of Himalayas were found very low in boron (Khatri and Ghimire, 1992).Application of boron thus increases bulb size, bulb weight and yield of onion (Manna *et al.*, 2014).

Boron and zinc are vey essential micronutrients for onion growth, plant height and fresh weight of leaves. Combined application of zinc and boron exhibited significant influence on the vegetative growth of onion (Shajalal, 2011). In addition to above, combination of zinc and boron have been found to enhance the fresh weight of onion bulbs significantly (Manna *et al.*, 2014). Conjugation of zinc and boron is good for the cultivation of onion as these micronutrients increases growth and yield (Aske *et al.*, 2017). The limited availability of zinc and boron in our soils calls urgent need for the standardization of an optimum dose of these micronutrients for harnessing higher yield and quality production of onion.

In view of above facts and ~~as~~has since no research work on the use of different levels of boron and zinc other than nitrogen, phosphorus, potassium and sulphur fertilizers in onion have been carried out in Kashmir, therefore, the present study was undertaken to investigate the **"Interaction effect of zinc and boron on nutrient uptake and soil nutrients of onion".**

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Materials and methods~~:~~

The present investigation ~~entitled **"Interaction effect of zinc and boron on nutrient uptake and soil nutrients of onion"**~~ in Kashmir valley was carried out during Rabi2016-17 and 2017-18 at Vegetable Experiment Farm, Division of Vegetable Science, SKUAST-K, Shalimar. The details of the materials used, and the techniques adopted during the course of experimentation are described below:

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Experimental location and Experimental materials

The vegetable experimental farm of the Division of Vegetable Science, SKUAST-Kashmir, Shalimar is 15 km away from Srinagar city on the foot hills of Mahadev. An onion variety namely Yellow Globe was grown at Vegetable Experimental Farm of Division of Vegetable Science, SKUAST-Kashmir. Two types of fertilizers (zinc sulphate and Solubor) with and without recommended dose of fertilizers were used as nutrient sources. Beckman's Glass Electrode pH Meter, Solubridge conductivity meter, Solubridge conductivity meter, Kjeldahl', Vanadomolybdate phosphoric acid, Flame photometer, spectrophotometer, Azomethine –H, sulphuric acid, alkaline $KMnO_4$ etc., were used as instruments and chemical to carry out analysis of soil and plant samples.

Climate~~:~~

The climate is temperate with June and July being hottest months and December, January and February the coldest months.

Soil characteristics of the experimental site

The of soil analysis before laying out the experiment Ph (7.51), EC(0.144 ds m^{-1}), organic carbon (0.51 %), available N (288.83 kg ha^{-1}), available P (15.71 kg ha^{-1}), available K (155.97 kg ha^{-1}), available S (26.23 kg ha^{-1}), available Zn (0.58 mg kg^{-1}) and available B (0.41 mg kg^{-1}) and methods employed for estimation of Ph (1:2.5 soil water suspension with Beckman's Glass Electrode pH Meter, Jackson, 1967), EC(Solubridge conductivity meter- Jackson, 1973), organic carbon (Walkley and Blacks Method, 1934), available N (Alkaline potassium permanganate method given by Subbiah and Asija in 1956), available P (Olsens Method, 1954), available K (Extraction with Neutral Normal Ammonium Acetate, Jackson, 1967), available S (Extraction by Williamns and Steinberg, 1959 method and determination by turbidimetric, Chesnin and Yien, 1951), available Zn (Atomic absorption spectrophoto-meter) and available B (Azomethine –H method, John *et al.* 1975).

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Experimental details

The present investigation ~~entitled~~ ~~**"Interaction effect of zinc and boron on nutrient uptake and soil nutrients of onion"**~~was carried out during Rabi 2016-17 and Rabi 2017-18 at vegetable experiment farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar. The experimental was laid in RCBD with 16 treatment combinations in 3 replications. Detail of treatment combinations are described below.

Chart ~~1 :~~1:Treatment combinations and their detail

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Treatment	**Treatment combinations**	**Structure of the treatment Combination (kg ha^{-1})**
T_1	Z_0 B_0 (control)	No Zinc + No Boron
T_2	Z_0 B_1	No Zinc + 0.500 Boron
T_3	Z_0 B_2	No Zinc + 1.000 Boron
T_4	Z_0 B_3	No Zinc + 1.500 Boron
T_5	Z_1B_0	2.500 Zinc + No Boron
T_6	Z_1 B_1	2.500 Zinc + 0.500 Boron
T_7	Z_1 B_2	2.500 Zinc + 1.000 Boron
T_8	Z_1 B_3	2.500 Zinc + 1.500 Boron
T_9	Z_2 B_0	5.000 Zinc + No Boron
T_{10}	Z_2 B_1	5.000 Zinc + 0.500 Boron
T_{11}	Z_2B_2	5.000 Zinc + 1.000 Boron
T_{12}	Z_2 B_3	5.000 Zinc + 1.500 Boron
T_{13}	Z_3 B_0	7.500 Zinc + No Boron
T_{14}	Z_3 B_1	7.500 Zinc + 0.500 Boron
T_{15}	Z_3 B_2	7.500 Zinc + 1.000 Boron
T_{16}	Z_3 B_3	7.500 Zinc + 1.500 Boron

FYM, Nitrogen (N), Phosphorus (P_2O_5), Potassium (K_2O) and Sulphur was applied as per recommended package for the region i.e., 25 t ha^{-1}, 100 kg ha^{-1}, 80 kg ha^{-1}, 60 kg ha^{-1} and 45 kg ha^{-1} respectively.

Observations recorded

Plant analysis

Based on the nutrient concentration in plants the uptake of nitrogen, phosphorus, potassium, sulphur, zinc and boron was worked out by multiplying dry matter content (kg ha^{-1}) with respective nutrient concentration (%) in plant samples. The methods employed for estimation of these nutrients include Micro Kjeldahl'smehod for uptake of nitrogen (Tandon, 1993), Vanadomolybdate phosphoric acid yellow colour method using spectrophotometer for uptake of phosphorus (Jackson, 1973), flame photometer method for uptake of potassium, Turbidimetric method using spectrophotometer for uptake of sulphur (Chesinin and Yein, 1951), Azomethine –H method for uptake of boron and Atomic absorption spectrophotometer for uptake of zinc (Piper, 1966)

Soil nutrient analysis

Representative soil samples of the experimental site before the start of experiment as well as after the harvest of each crop from each treatment were taken from a depth of 0-15 cm and analyzed for pH, E.C, organic carbon, organic matter, available nitrogen, phosphorus, potassium, sulphur, boron and zinc using standard procedure.

pH and Electrical conductivity (ds m^{-1}): The pH of the soil sample was determined by digital pH meter in 1:2.5 ratio of soil water suspension (Jackson 1973) and Electrical conductivity was estimated by solubridge conductivity meter- Jackson (1973).

Organic carbon (%) and Organic matter (%): The organic carbon content was estimated by Walkley and Black (1934) oxidation method where organic matter in finely ground soil was oxidised by chromic acid by making use of heat of dilution of sulphuric acid for reaction (Jackson, 1967). Organic carbon content of soils was expressed in percent and for estimation of organic matter per cent, organic carbon per cent was multiplied by Benlemns factor (1.72) (Walkley and Black, 1934).

Available nitrogen (kg ha^{-1}): Available nitrogen was estimated by alkaline $KMnO_4$ method where the organic matter in soil was oxidised with hot alkaline $KMnO_4$ solution. The ammonia (NH_3) evolved during oxidation was distilled and trapped in boric acid mixed indicator solution. The amount of NH_3 trapped was estimated by titrating with standard acid (Subbiah and Asija, 1956).

Available phosphorus (kg ha^{-1}): Available phosphorus was extracted with sodium bicarbonate (0.5 M) at pH 8.5 (Olsen's reagent) and the amount of phosphorus in the extract was estimated by chloro-stannous reduced phosphorus molybdate blue colour method using spectrophotometer at wave length of 660 mm (Jackson, 1973).

Available potassium (kg ha^{-1}): Available potassium was extracted with neutral normal ammonium acetate and determined by flame photometer (Jackson, 1967).

Available sulphur (kg ha^{-1}): Available sulphur was estimated by turbidmetric method (Chesnin and Yien, 1951) where $CaCl_2$ (0.15%) extract was reacted with barium chloride crystals and the intensity of turbidity formed was measured using spectrophotometer at a wave length of 420 nm (Jackson, 1973).

Available Boron (ppm): Available boron was estimated by azomethine-H method John *et al.* (1975)

Available zinc (ppm): Available zinc was estimated by DTPA extraction method (Lindsay and Norwell, 1978).

Statistical analysis: In order to test the significance of results, the experimental data was subjected to statistical analysis as per the standard statistical procedure given by Gomez and Gomez (1984). Levels of significance used for 'F' and 'T' tests were p= 0.05 as given by Fisher (1970).Statistical test was done by OP software.

Results and Discussion:

Effect of Zinc on nutrient uptake

Table 1 showed that increasing level of zinc from Z_{0-} Z_3 registered an increase in nitrogen uptake of onion. Maximum uptake of 107.92 kg N ha^{-1} was recorded with treatment Z_3 (7.500 kg Zn ha^{-1}) in polled analysis which was significantly superior to the values recorded with other levels including control, which recorded an uptake of 89.51 kg N ha^{-1}in pooled data while pooled analysis of data revealed significant variation for phosphorus uptake due to zinc application. Increasing levels of zinc registered a decline in phosphorus uptake.Control registered maximum uptake of 13.60 kg P ha^{-1}, which was significantly superior to the values recorded with other levels, but was found statistically at par with Z_1 (5.000 kg Zn ha^{-1}) recording an uptake of 13.47 kg P ha^{-1}.In case of potassium uptake and sulphur uptake, Z_3 recorded significantly maximum values of 62.17 kg K ha^{-1} and (22.48 kg ha^{-1}) respectively. Increasing level of zinc registered an increase in boron and zinc uptake and highest uptake of 114.48 g B ha^{-1} and (22.48 kg ha^{-1}) was recorded with Z_3 (7.500 kg Zn ha^{-1}) which were significantly superior as compared to other levels including control which recorded an uptake of 91.47 g B ha^{-1} in both years. The possible reasons for enhanced uptake might be increased crop growth and yield due to enhanced nutrient utilization and translocation into the plant parts resulting in higher uptake of nutrients with higher rates of zinc applications as reported by Meena and Singh (1999) and Gugala*et al.*, (2011) in onion; Das *et al.*(2005) and Banerjee *et al.*,(2016) in potato and Kavvadias (2013) in spinach. Phosphorus uptake (12.59 kg ha^{-1}) was found lowest at highest rate of zinc application, which might be due to antagonistic effect between zinc and phosphorus as reported by Amin *et al.* (2014) in sweet coron. Similar findings were found in onion by Hasani*et al.* (2012) and Keram*et al.* (2013).Adequate boron nutrition improves root uptake of potassium by maintaining proper function (through ATPase activity) and structure of root cell membranes. The higher uptake of nutrients with addition of boron might be attributed to increased vigour of crop growth with enhanced nutrient utilization and translocation into different plant parts as reported by Shamsuddoha*et al.*, (2011) in mungbean. The results are in agreement with findings of Francois (1991) and Ali and Ceyhan (2001) in onion; Davis *et al.*, (2003) in tomato; Patel and Golakiya (1986) in groundnut; Rajaie*et al.*, (2009) in lemon and Ali *et al.*, (2015) in tobacco.

Table 1: Effect of different levels of zinc on nutrient uptake in onion

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Zinc	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})	Sulphur uptake (kg ha^{-1})	Boron uptake (g ha^{-1})	Zinc uptake (g ha^{-1})
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Z_0	89.51	15.71	44.67	13.68	91.47	134.88
Z_1	95.99	15.56	51.67	16.43	98.05	144.08
Z_2	103.39	14.58	58.89	21.33	108.92	156.83
Z_3	107.98	14.29	62.17	22.48	114.48	162.53
C.D ($p \leq 0.05$)	0.65	0.25	0.65	0.41	1.25	1.76
S.E (m)	0.22	0.07	0.23	0.14	0.43	0.61

Pooled data over years revealed a significant increase in nitrogen uptake with increasing level of boron. Highest uptake ~~of 103.96~~of 103.96 kg N ha^{-1} was recorded with B_3 which were significantly superior to the uptake recorded with other levels including control, which recorded a nitrogen uptake of 92.69 kg ha^{-1}. Pooled analysis of data revealed, increase in boron levels resulted decrease in the phosphorus uptake. Highest uptake of phosphorus (13.48 kg ha^{-1}) was recorded with B_0 and was significantly superior to other treatments except B_1 where it exhibited statistically at par results (13.29 kg P ha^{-1}). B_3 recorded significantly lowest value of 12.91 kg ha^{-1} for uptake of phosphorus.Perusal of pooled data reflected that uptake of potassium were enhanced significantly with increase in levels of boron. Maximum uptake of potassium (59.19 kg ha^{-1}) was observed with B_3 (1.500 kg ha^{-1}) which was significantly superior to the values recorded with other levels. Control (B_0) recorded significantly minimum uptake of 48.46 kg K ha^{-1}. Perusal of the pooled data (Table- 2) depicted that increasing level of boron registered an increase in boron uptake and significantly maximum uptake of 113.48 g B ha^{-1} was recorded with B_3 (1.500 kg B ha^{-1}) while lowest value of 91.46 g B ha^{-1} was recorded with control. Pooled data regarding zinc uptake revealed that increasing levels of boron registered an increase in zinc uptake. Highest uptake 167.97 g ha^{-1} was recorded when boron was applied at the rate of 1.500 kg B ha^{-1} (B_3) which was significantly superior to the uptake recorded with other levels including control, which recorded an uptake 129.11 g Zn ha^{-1}. Increase in the uptake of nitrogen might be due to increase in the activity of N-Rase enzyme which in turn increased the translocation of nitrogen. Adequate boron nutrition improves root uptake of potassium by maintaining proper function (through ATPase activity) and structure of root cell membranes. The higher uptake of nutrients with addition of boron might be attributed to increased vigour of crop growth with enhanced nutrient utilization and translocation into different plant parts as reported by Shamsuddoha*et al.*, (2011) in mungbean. The results are in agreement with findings of Francois (1991) and Ali and Ceyhan (2001) in onion; Davis *et al.*, (2003) in tomato; Patel and Golakiya (1986) in groundnut; Rajaie*et al.*, (2009) in lemon and Ali *et al.*, (2015) in tobacco.

Table 2: Effect of different levels of boron on nutrient uptake in onion

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Boron	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})	Sulphur uptake (kg ha^{-1})	Boron uptake (g ha^{-1})	Zinc uptake (g ha^{-1})
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
B_0	92.69	13.48	48.46	15.29	91.46	129.11
B_1	98.02	13.29	53.29	17.25	101.05	143.88
B_2	102.21	13.12	56.45	19.63	107.92	160.88
B_3	103.96	12.91	59.19	21.35	113.48	167.97
C.D ($p \leq 0.05$)	0.65	0.25	0.65	0.41	1.25	1.76
S.E (m)	0.22	0.07	0.23	0.14	0.43	0.61

Interaction effect of different levels of zinc and boron on nutrient uptake in onion

Pooled analysis over years reveal that interaction between different levels of zinc and boron exhibited a significant influence on ~~uptake of~~uptake ofnitrogen and other nutrients. Analysis revealed that maximum uptake of 113.93 kg N ha^{-1}, 67.17 kg K ha^{-1}, 25.96 kg S ha^{-1}, 125.58 g B ha^{-1}~~and 184.01~~and 184.01 g Zn ha^{-1}with Z_3B_3 and found significantly superior to the uptake recorded with other treatment combinations including Z_0B_0. Pooled analysis revealed that conjugation of zinc and boron did not cause any significant variation in the phosphorus uptake. The extent of increase in uptake of nitrogen, potassium boron and zinc due to Z_3B_3 was 34.71, 63.75, 52.88 and 55.26 percents, respectively over control. This might be possible due to synergistic effect of zinc and boron in augmenting uptake of all these nutrients. The increase in uptake may be attributed to more favourable conditions either through an increase in solubility in soil solution or by possible stimulation of root absorption. The better crop vigour and growth due to enhanced nutrient utilization and translocation of photosynthates from source to sink augmenting bulb yield of onion might be possible reason for increased uptake of nutrients as reported by Thiyageshwari and Ramanathan (2001) in soyabean, Farshid(2011) in corn and Singh *et al.* (2014) in pea.

Table 3: Interaction effect of different levels of zinc and boron on nutrient uptake in onion

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Zn × B	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})	Sulphur uptake (kg ha^{-1})	Boron uptake (g ha^{-1})	Zinc uptake (g ha^{-1})
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Z_0B_0	84.58	13.96	41.02	11.87	82.14	118.52
Z_0B_1	87.81	13.71	43.09	13.13	86.81	125.62

Z_0B_2	92.51	13.53	46.24	14.54	95.28	134.47
Z_0B_3	93.42	13.21	48.28	15.17	101.64	137.82
Z_1B_0	89.65	13.71	45.91	13.99	88.33	129.79
Z_1B_1	96.27	13.56	51.91	16.12	99.02	144.02
Z_1B_2	97.63	13.42	53.29	17.03	100.48	147.51
Z_1B_3	100.45	13.22	55.56	18.61	104.37	152.16
Z_2B_0	96.16	13.60	52.35	16.68	95.94	142.89
Z_2B_1	102.23	13.22	57.44	20.38	106.01	156.61
Z_2B_2	107.14	13.07	60.07	22.32	112.47	167.88
Z_2B_3	108.05	12.91	65.71	25.96	121.28	176.17
Z_3B_0	100.39	12.88	54.57	18.61	99.32	148.32
Z_3B_1	105.78	12.69	60.71	20.96	112.30	162.07
Z_3B_2	111.84	12.46	60.21	24.64	120.71	178.32
Z_3B_3	113.93	12.31	67.17	25.67	125.58	184.01
C.D ($p \leq 0.05$)	1.31	N.S	1.31	0.82	2.51	3.51
S.E (m)	0.45	0.11	0.46	0.28	0.86	1.22

Effect of different levels of zinc on soil properties

Pooled data in Table 4reflected that, lower value of 6.71 for soil pH while highest values for EC (0.154 d Sm^{-1}), organic carbon (0.61%) and organic matter (1.04%) were recorded with zinc application at the rate of 7.500 kg ha^{-1}. However, the effects were found nonsignificant. The reduction in pH might have been possible due to neutralization of bases with application of zinc in the form of zinc sulphate. This might be due to the sulphate ions present in zinc sulphate. The increase in EC might be possible due to contribution of more ions as compared to lower levels while slight increase in organic carbon and organic matter might be due to acceleration of decomposition of FYM and other organic residues. The results are in conformity as reported by Meena*et al.*(2006), Keram*et al.* (2012) and Dogra *et al.* (2016).Application of zinc at the rate of 7.500 kg ha^{-1} (Z_3) recorded significantly higher value for available nitrogen (294.72 kg ha^{-1}), potassium (165.31 kg ha^{-1}), sulphur (29.29 kg ha^{-1}), boron (0.65 mg kg^{-1}) and zinc (1.01 mg kg^{-1}) as compared to rest of the levels but exhibited lower available phosphorus content of 14.29 kg ha^{-1}. Highest available phosphorus 15.71 kg ha^{-1} was found when no zinc was applied to the soil. The increase in availability of nitrogen can be attributed to increase in population of soil microbes as zinc activates enzymatic activities of soil microflora. Therefore, these microbes bring decomposition of organic matter which increases availability of nitrogen. Increase in organic matter addition prevents fixation of K^+ by interacting with clay content of soil which might be the reason for increased availability of K^+. Availability of sulphur increased with application of zinc as zinc sulphate. It might be due to presence of sulphate ions as sulphate is one of the constituents of zinc sulphate. Availability of zinc increased with increased application of zinc. This could be possible due to increase in unused pool of nutrients in soil with application of zinc. Availability of boron increased at highest level of zinc. This may possible due to decrease in pH resulting in better boron availability. Increasing level of zinc decreased availability of phosphorus which might be due to antagonistic effect between zinc and phosphorus. Our results are in line with those of Netrapal (2011), Kavvadias *et al.* (2013) and Keram*et al.* (2013).

Table 4: Effect of different levels of zinc on soil properties

Zinc	pH	E.C (dSm^{-1})	O.C	O.M	Available Nitrogen	Available phosphorus	Available potassium	Available sulphur	Available zinc	Available Boron

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	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Z_0	7.43	0.147	0.52	0.94	289.85	15.71	158.17	26.61	0.64	0.53
Z_1	7.29	0.150	0.56	0.97	291.44	15.56	162.18	27.45	0.76	0.56
Z_2	7.22	0.151	0.58	0.99	293.58	14.58	162.63	28.18	0.88	0.61
Z_3	6.71	0.154	0.61	1.04	294.72	14.29	165.31	29.29	1.01	0.65
C.D ($p \leq 0.05$)	N..S	N.S	N.S	N.S	1.01	0.25	0.58	0.23	0.011	0.011
S.E (m)	0.0092	0.0023	0.027	0.036	0.35	0.08	0.20	0.08	0.004	0.04

Effect of different levels of boron on soil properties

Application of boron at the rate of 1.500 kg ha^{-1} (B_3) recorded high values for soil pH (7.46), EC (0.157 d Sm^{-1}), organic carbon (0.61%) and organic matter (1.05%) but the effects were found non-significant (Table 5). Increase in pH might be due to formation of NaOH in soil with application of boron in the form of solubour as sodium is one of the constituent of solubor while increase in EC might be due to increase in ions. Further increase in organic carbon and organic matter might be due to either residual effect or to increase in decomposition. The results are in agreement with the findings of Barman *et al.* (2011), Hemantha*et al.* (2014) and Naveen*et al.* (2015). Boron application at the rate of 1.500 kg ha^{-1} recorded significantly maximum values for available nitrogen (293.96 kg ha^{-1}), potassium (164.35 kg ha^{-1}), sulphur (28.61 kg ha^{-1}), boron (0.71 mg kg^{-1}) and zinc (0.90 mg kg^{-1}).The synergistic effect of boron with the major nutrient content of soil might have resulted in enhanced availability of plant nutrients. Boron availability increased with application of boron. This could be possible due to increase in unused pool of nutrients in soil with application of boron as reported by Lawandek (2011) in onion. Reduction of boron adsorbing free sesquioxides under boron application could be another reason for increased boron availability. Also zinc availability increased as synergetic reaction between zinc and boron. Boron at the highest rate registered low available phosphorus (14.82 kg ha^{-1}) which might be due to antagonistic reaction between phosphorus and boron. These findings are in confirmation with Chander*et al.*, (2010), Parray*et al.*, (2011) and Haribhushan *et al.*, (2015).

Table 5: Effect of different levels of boron on soil properties

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Boron	pH	E.C (dSm^{-1})	O.C	O.M	Available Nitrogen	Available phosphorus	Available potassium	Available sulphur	Available zinc	Available Boron
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
B_0	7.14	0.147	0.54	0.92	290.79	15.39	160.37	27.28	0.75	0.46
B_1	7.17	0.149	0.56	0.96	291.90	15.12	161.52	27.61	0.80	0.55
B_2	7.22	0.151	0.59	1.01	292.94	14.89	162.45	28.05	0.85	0.61
B_3	7.46	0.157	0.61	1.05	293.96	14.82	164.35	28.61	0.90	0.71
C.D ($p \leq 0.05$)	N..S	N.S	N.S	N.S	1.01	0.25	0.58	0.23	0.011	0.011
S.E (m)	0.0092	0.0023	0.027	0.036	0.35	0.08	0.20	0.08	0.004	0.04

Interaction effect of different levels of zinc and boron on soil properties

Combined application of zinc and boron exhibited a non-significant effect on pH, EC, organic carbon and organic matter of soil (Table 6). Similar results were also obtained byHallur*et al.* (2013), Singh *et al.* (2014) and Sharma *et al.* (2016). Pooled analysis reflected maximum values for available nitrogen (296.54 kg ha^{-1}), potassium (168.77 kg ha^{-1}), sulphur (30.47 kg ha^{-1}), boron (0.83 mg kg^{-1}) and zinc (1.09 mg kg^{-1}) when zinc and boron were applied in conjugation Z_3B_3 (7.500 kg Zn + 1.500 kg B ha^{-1}).Maximum availability of nutrients might be due synergetic effects except in available phosphorus whose interaction effects were found non-significant, whereas increase in availability of boron and zinc might be due to increase in unused pool of nutrients in soil as reported by Hageman (2007) in brinjal. Present results are in line with those of Hemantha*et al.*, (2014), Abd EL-Kader (2013) and Kumbhar*et al.*,(2017).

Table 6: Interaction effect of different levels of zinc and boron on soil properties

Zn × B	pH	E.C (dSm^{-1})	O.C	O.M	Available Nitrogen	Available phosphorus	Available potassium	Available sulphur	Available zinc	Available Boron
	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
Z_0B_0	7.33	0.144	0.51	0.88	288.55	16.11	156.50	26.06	0.55	0.40
Z_0B_1	7.34	0.146	0.54	0.92	289.17	15.74	157.41	26.36	0.66	0.50
Z_0B_2	7.39	0.147	0.56	0.97	290.45	15.56	159.01	26.82	0.65	0.57
Z_0B_3	7.88	0.151	0.58	1.00	291.24	15.44	161.38	27.18	0.83	0.64
Z_1B_0	7.26	0.146	0.52	0.90	290.48	15.74	161.23	26.88	0.65	0.44
Z_1B_1	7.28	0.148	0.56	0.95	290.84	15.70	161.86	27.15	0.75	0.53
Z_1B_2	7.29	0.149	0.57	0.98	291.41	15.46	162.22	27.79	0.89	0.60
Z_1B_3	7.59	0.151	0.60	1.04	293.01	15.34	163.41	28.12	1.00	0.66
Z_2B_0	7.17	0.147	0.55	0.94	291.86	15.74	161.41	27.69	0.70	0.48
Z_2B_1	7.21	0.151	0.57	0.97	293.07	15.70	162.40	28.06	0.81	0.58
Z_2B_2	7.24	0.152	0.59	1.01	294.33	15.46	162.86	28.31	0.89	0.63
Z_2B_3	7.35	0.155	0.60	1.04	295.05	15.34	163.83	28.67	0.95	0.73
Z_3B_0	6.43	0.151	0.57	0.97	292.24	14.58	162.31	28.48	0.80	0.52
Z_3B_1	6.66	0.154	0.58	1.00	294.54	14.38	164.39	28.85	0.92	0.59
Z_3B_2	6.84	0.157	0.63	1.09	295.56	14.13	165.73	29.39	1.00	0.65
Z_3B_3	7.00	0.158	0.65	1.11	296.54	14.03	168.77	30.47	1.09	0.83
C.D ($p \leq 0.05$)	N.S	N.S	N.S	N.S	N.S	N.S	1.16	0.45	0.022	0.022
S.E (m)	0.018	0.0046	0.054	0.071	0.69	0.52	0.41	0.16	0.008	0.08

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