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Effect of zinc and boron application on fruit set, quality and yield of apple (*Mallus* × *domestica* Borkh.) cv. *Red Delicious*

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ABSTRACT

An experiment was carried out during 2014 -2015 on twenty years old "Red Delicious" apple trees (Mallus × domestica Borkh.) at the experimental farm of UUHF Bharsar, Uttarakhand, to study the effect of zinc sulphate and boric acid on fruit set, quality and yield. Treatments including 20g of boric acid were applied per tree as a basal dose one month before the bud break stage, zinc sulphate (0.1%) and boric acid (0.2%) were applied as foliar spray at pink bud stage. The results revealed that the application of 20g boric acid (basal) in combination with zinc sulphate (0.1%) and boric acid (0.2%) as foliar spray significantly increased the fruit set (41.62%), fruit length (4.50 cm), fruit diameter (5.71 cm), fruit volume (20.88 cm^3), TSS (12.90 ^{o}Brix), Total sugar (7.76%), ascorbic acid (4.00 mg per 100g), pollen germination (69.08%), yield (72.89 Kg tree)$^{-1}$ and with minimum fruit drop (48.78%) and tritatable acidity (0.30 %) in comparison to other treatments. From current investigation, it is screened out that the application of zinc sulphate and boric acid as foliar spray in combination with basal dose of boric acid gave beneficial response as compared to single application under high hills of Uttarakhand.

Keywords: Apple, boric acid, quality, yield, zinc sulphate.

Apple (*Mallus* x *domestica* Borkh.) is one of the leading fruit crops grown in temperate region of the world. The area under apple cultivation in India is an account for 119,000 ha with total production of 2585, 000 MT. In Uttarakhand, it is grown under an area of 30,000 ha and has total production of 775,000 MT (Anon., 2014). Foliar fertilization with micronutrients is generally successful because deliverable amounts are enough to meet most tree requirements. At present, most growers apply foliar boron. Because transitory low boron status may limit fruit set, the goal of foliar boron programs is to increase boron in ûower buds. Boron sprays often are applied in early fall after harvest or during the pre pink blossom stage (Sánchez and Righetti, 2005).

Foliar application is method for reducing the use of chemical fertilizers (Malakouti and Tabatabaei, 1999). Among essential mineral nutrients, boron (B) and zinc (Zn) are important micronutrient involved in enzymatic systems essential for protein synthesis, pollen grain germination, pollen tube elongation, and consequently fruit set, seed development, and yield (Khan *et al*., 2015). The boron requirement is much higher for reproductive growth than for vegetative growth and increases flower production and retention, pollen tube elongation and germination, and seed and fruit (Sajid *et al*., 2010).

Zinc is essential element for crop production and optimal size of fruit, also it is required in carbonic enzyme which present in all photosynthetic tissues and required for chlorophyll biosynthesis. Zn have main role in synthesis of proteins, enzyme activating, metabolism of carbohydrates (Nevine *et al*., 2015).

Additionally, this type of fertilization largely contributes to environmental protection by reducing undesirable nutrient leaching from the soil, an accompanying manifestation of most other fertilization types (Dong *et al*., 2005; Totten *et al*., 2008). Foliar application of mineral nutrients is a method for quick supply of the elements for the higher plants. This technique allows the plants to consume nutrients much faster than their uptake from soil by their roots. Despite some shortcomings of nutrient foliar application, it is regarded as the best method under certain conditions (Marschner and Marschner, 2012). Keeping in view the above facts, the present investigation was carried out with an objective to evaluate the effect of boron and zinc application on fruit set, quality and yield of apple fruits.

The present study was conducted during 2014-2015 on 20 years old 'Red Delicious' apple trees (*Mallus* × *domestica* Borkh.). Trees were spaced at 6 x 6 meters apart grown in Research Farm of UUHF Bharsar, Uttarakhand. The experiment consisted of seven treatments viz., T_1- Control, T_2- 20 g boric acid per tree (basal), T_3- 0.2 % boric acid (foliar), T_4- 20 g per tree

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Short Communication

boric acid (basal) + 0.2 % boric acid (foliar), T_5-20 g tree^{-1} boric acid (basal) + 0.1 % zinc sulphate (foliar), T_6- 0.2 % boric acid (foliar) + 0.1 % zinc sulphate (foliar) and T_7- 20 g boric acid tree^{-1} (basal) + 0.2 % boric acid (foliar) + 0.1 % zinc sulphate (foliar) in 'Randomized Block Design' with three replication. All trees were healthy and similar in their vigour grown under accepted cultural operation during the course of investigation. Boric acid @ 20 gm tree^{-1} applied one month before bud break stage and foliar application of boric acid and zinc sulphate @ 0.2 and 0.1 per cent were applied at pink bud stage.

Prior to executing the experiment, the soil's physical and chemical properties of the experimental site were determined. The soil characteristics of apple orchard was loam clay in texture with moderately acidic pH (5.5), having low EC (0.36dSm^{-1}) indicates the soils of orchard were in normal condition. The available zinc (1.95 mg ha^{-1}) was estimated at high level and boron (0.38 mg ha^{-1}) was found low below the critical limit was determined by according to the method described by (Lindsay and Novell, 1978) and (Stinson ,1953).

Fruit set was estimated from the four uniform limb units per tree evenly spaced around the tree. Affected and shaded limbs should be avoided. The fruit set was obtained by counting the number of fruits of each tagged limb and calculated by using formula suggested by Westwood (1993) and expressed as:

$$\text{Per cent fruit set} = \frac{\text{No. of fruits at pea stage x100}}{\text{No. of flowers}}$$

Per cent fruit drop

$$= \frac{\text{No.of fruits at pea stage - No. of fruits at harvest x100}}{\text{No. of fruits at pea stage}}$$

Ten fruits were picked randomly from the tagged plants. Length and diameter was measured with the help of vernier callipers. For determining the fruit volume formula as suggested by (Westwood, 1993) was used 4.186 ab2 where, a is 1/2 of major axis (long axis) and b is 1/2 0f minor axis (shorter axis) and expressed in cubic centimeter. Fruit yield tree^{-1} was calculated when entire fruit which reached to its maturity was harvested by hand picking from each tree, weighed by an ordinary balance and yield was recorded in kilograms (Kg tree^{-1}).

The total soluble solids were observed directly on "Zeise" Hand Refrectrometer in ^{o}Brix. Ascorbic acid was estimated by visual titration method (Ranganna, 1986). 10ml of the sample was made up to 100 ml with 3 per cent metaphosphoric acid and filtered. 10ml of the filtrate was taken and added with 1ml of 40 per cent formaldehyde and 0.1 ml of HCl and kept for 10 minutes. The sample was titrated with the standard 2.6-dichlorophenol-indophenol dye to a pink end-point that should persist for at least 15seconds. Total sugar and titratable acidity was calculated as per method of (AOAC, 1980).

The Pollen of each treatment was collected during flowering. The flowers with dehiscent anthers were brought into the laboratory and pollen shed over the next 2 hours were collected. Pollen were germinated on a medium containing 20 per cent (w/v) sucrose, l.0 mol·m$^{"3}$ calcium chloride, 100 g m$^{"3}$ boric acid, and 0.65 per cent (w/v) agar (Luza and Polito, 1991)

The maximum fruit set (41.62%) was recorded in T_7 was given in table 1. which was statistically *at par* with T_6 (39.79%). The plants under T_1 (control), showed considerably lowest fruit set percentage (36.87%). Analogous findings were recorded by (Balesini *et al*., 2013) while working on apple. Shukla (2011) recorded a significant increase in fruit set by foliar application of calcium carbonate and borax in Indian gooseberry. Shahin *et al.* (2010) also reported that ' Anna' apple sprayed with Fertifol Mist (N, P, K, Mg, Zn, Fe, Mn, Cu, Mo and B) plus GA_3 resulted in an increased fruit set as against control trees.

The data derived from the fruit set and fruit retention were subjected to statistical analysis. It is obvious from the application of zinc sulphate and boric acid proved significantly affective in reducing fruit drop percentage. The minimum fruit drop (48.78 %) was recorded in T_7. The maximum fruit drop (62.20 %) was recorded under T_1 (control) was given in table 1. Gurjar *et al.* (2015) also observed that the foliar application of zinc and boron on kinnow mandarin. Reduction in fruit drop in apple trees with spray of boric acid and zinc sulphate can be due to the indirect action of boron in auxin synthesis that delayed the formation of abscission layer during early stages of fruit development (Guardiola and Garcia, 2000).

The highest fruit yield in this study was obtained in response to application of boric acid and zinc sulphate @ 0.2% and 0.1% with basal application of boric acid 20g tree^{-1} (T_7). It was statistically *at par* with T_6, T_5 and $T_{3,}$ but it was significantly higher in T_4 and T_1. The enhanced yield (Kg tree^{-1}) in present study is consequences of enhancement in fruit set, which ascertains the yield. The results in this document are in conformity with the findings of (Wojcik and Wojcik, 2003; Perveen and Rehman, 2000). The beneficial effect of boron may be due to physiological role in plants where, boron facilitates transport of carbohydrates through cell membrane *i.e.* starch and sugar.

Table 1:Effect of zinc and boron application on physico-chemical characteristics of apple cv. Red Delicious.

Treatments	Fruit set (%)	Fruit drop (%)	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cm^3)	Yield (Kg $tree^{-1}$)	TSS (^{0}Brix)	Titratable acidity (%)	Ascorbic acid (mg $100g^{-1}$)	Total sugar (%)	Pollen germination (%)
T_1 (Control)	36.87	62.20	3.23	4.90	53.66	67.34	10.76	0.45	3.10	6.20	58.00 ($49.59^{\#}$)
T_2	38.81	57.78	3.55	5.23	68.86	68.35	11.83	0.39	3.23	6.36	63.00 (52.69)
T_3	38.21	55.05	3.60	5.26	71.37	70.69	11.70	0.33	3.33	6.33	64.00 (53.15)
T_4	38.83	53.55	3.81	5.30	80.89	68.67	12.16	0.36	3.53	6.50	66.33 (54.53)
T_5	39.05	53.25	3.86	5.30	82.90	72.89	12.53	0.31	3.51	6.53	65.00 (53.72)
T_6	39.79	51.76	4.13	5.20	93.25	70.80	12.80	0.31	3.84	7.60	76.00 (61.28)
T_7	41.62	48.78	4.50	5.71	120.88	72.89	12.90	0.30	4.00	7.76	87.00 (69.08)
SE(d)	**1.12**	**1.80**	**0.14**	**0.11**	**6.105**	**1.05**	**0.21**	**0.02**	**0.19**	**0.49**	**6.80 (4.45)**
LSD(0.05)	**2.48**	**3.98**	**0.30**	**0.26**	**13.44**	**2.31**	**0.47**	**0.06**	**0.43**	**1.09**	**14.99 (9.81)**

 # Figures in parentheses are transformed value

Data in table 1 showed the effect of boric acid and zinc sulphate on fruit length, diameter and volume of Red delicious apple trees. In this study the maximum fruit length (4.50 cm) was obtained in T_7, it was statistically *at par* as in T_6 (4.13 cm). Moreover, fruit diameter and fruit volume was significantly higher than in other treatments, while minimum fruit length, diameter and volume were found in T_1 (control). The increase in fruit length, diameter and volume might be due to increased rate of cell division and cell enlargement leading to more accumulation of metabolites in the fruit (Gurjar *et al*., 2015; Dutta and Banik, 2007).

From the results, it's clear that using foliar zinc sulphate and boric acid @ 0.1 and 0.2 per cent with basal application of boric acid @ 20g tree^{-1} improved significantly TSS synthesis. Total soluble solids (TSS) was found maximum (12.90 ^{o}Brix) in T_7, it is statistically *at par* with T_6 (12.80 ^{o}Brix) and T_5 (12.53 ^{o}Brix). The minimum TSS (10.76 ^{o}Brix) was found in T_1 (Control). The results are similar to the findings of (Trivedi *et al.*, 2012; Anees *et al*., 2011). The higher total soluble solids might be due to the efficient translocation of photosynthates to the fruit by regulation of boron.

It is evident from table 1 that significantly lower acidity (0.30%) was recorded in treatment T_7 (boric acid and zinc sulphate @ 0.2 and 0.1 per cent with basal application of boric acid 20g tree^{-1}), it is statistically *at par* with T_6, T_5 and T_4. Whereas, the highest value of fruit acidity was determined in control (0.45%). Similar findings were reported by (Nikkhah *et al.,* 2013; Sarrwy *et al.,* 2012). The decrease in acidity of fruits might have been attributed to their conversion in sugars and their derivatives by the reactions involving reversal of glycolytic pathway and also might be used in respiration.

The significant effect of foliar application of zinc sulphate and boric acid @ 0.1 and 0.2 per cent in combination with basal application of boric acid 20g tree^{-1} on ascorbic acid showed in table 1. The highest values of ascorbic acid was obtained in T_7 (4.00 mg 100g^{-1}), it is statistically *at par* T_6 (3.38 mg100g^{-1}), while lowest value was recorded in T_1 (3.10 mg 100g^{-1}). The results are in conformity with the findings of (Anees *et al.,* 2011) in mango, (Khan *et al.,* 2012) in citrus. It may be due to the possible influence of these micro nutrients on biosynthesis of ascorbic acid from sugars or inhibition of oxidative enzymes or both. Combined application of 6000 ppm $ZnSO_4$ +5000 ppm H_3BO_3 increased the ascorbic acid of guava fruit may be due to higher synthesis of nucleic acid as a consequence of maximum availability of plant metabolism (Trivedi *et al*., 2012).

Data recorded on fruit sugar content of apple cv. Red Delicious showed in table 1. Herein, the highest value of total sugar content T_7 (7.76%), was obtained when trees were applied with foliar zinc sulphate and boric acid @ 0.1 and 0.2 per cent in combination with basal application of 20g boric acid tree^{-1} which was closely followed by T_6 (7.60%). However, minimum total sugar content (6.20%) was observed in control. These results are in conformity with the findings of (Trivedi *et al*., 2012). The higher total sugar might be due to the efficient translocation of photosynthesis to the fruits by the formation of ionizable complex between boron and sugar. Boron plays a key role in higher plants by facilitating the short and long distance transport of sugars via the formation of borate – sugar complexes and formation of cis-dol borate complexes and boron may facilitate sugar uptake by leaves.

The highest pollen germination was obtained in T_7 (87.00 %), it is statistically *at par* with T_6 (76.00 %), while the minimum pollen germination (58.00 %) was found in T_1 (Control). The beneficial effect of foliar application of B and Zn on pollen germination in apple trees was observed during present study. The results are in general concurrence with those of (Lee *et al.,* 2009) in pear and (Nymora *et al.,* 1997) in almond. Boron plays an important role in pollen germination and pollen tube growth (Storey, 2007).

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