Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 2602-2609
Received: 06-11-2020
Accepted: 04-12-2020

Ajender
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh, India

BS Thakur
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh, India

Corresponding Author:
Ajender
Department of Fruit Science, Dr. YS Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh, India

Effect of boron on growth, fruit quality and production of apple

Ajender and BS Thakur

Abstract
The experiment was laid out in the Telangi village of Kinnaur District. The experimental orchard lies under the high hills and cold desert area of Himachal Pradesh (India). There are situations where the absorbed nutrient may be poorly translocated within the plant under such situations addition of this nutrient to the soil will be inefficient and foliar feeding provides the best possibility to supplement the nutrient requirement. This may also be attributed to low boron, beside other micro nutrients. Good supply of Boron to the plant is beneficial for promoting calcium movement to the fruits. It is proposed to study the effect of Boron on growth, fruit quality and production of apple. The experiment on boron comprised of ten treatments of *viz.* recommended dose of boron 1% at pink bud stage and one month after pink bud stage, 100g, 200g and 300 g of boron through soil application fall stage (end of October), mid-February and tight cluster stage). The results revealed that fall application of boron @ 200g tree^{-1} was found to be the best treatment with respect to fruit set, fruit retention, yield and nutrient content of leaves which was at par with foliar application of boron @ 0.1% at pink bud stage.

Keywords: apple, boron, growth, production, quality

Introduction
The cultivated apple (*Malus* × *domestica* Borkh.) is a member of family Rosaceae sub family Pomoideae. In India, apple is mainly grown in the North Western Himalayan region comprising states of Jammu & Kashmir, Himachal Pradesh and Uttrakhand. Its cultivation has now been extended to north eastern states like, Arunachal Pradesh, Sikkim, Nagaland and Meghalaya. Apple cultivation in fact has revolutionized the socio-economic condition of the hill farmers where the land is considered less suitable for traditional agriculture due to its undulating topography and small holdings. It has grown to several hundred crore rupees industry sustaining the livelihood of about 1.50 lakh farmer families in the state beside other people engaged in its production as laborers, transporters, middleman etc. The area under apple in Himachal Pradesh increased from 3026 ha in 1960-61 to 314000 ha in 2018-19 with the corresponding increase in yield from 12000 tons in 1960-61 to 2503000 MT in 2018-2019. Apple alone accounts for more than 75 per cent of the horticultural income generated in the state (NHB 2016) [12].

There has been a steady increase in the area and production of apple up to mid eighties but the productivity has not kept pace with the increase in area due to various biotic and abiotic factors. Of the various factors responsible for low productivity, nutrition is of significance importance determining fruit quality. A comprehensive study of 42 apple orchards in Himachal Pradesh have revealed wide spread deficiencies of N, P, K, Ca, Mn and B (Chadha & Awasthi, 2005) [2]. The key nutrients invariably used by the farmers/orchardists are N, P and K. The other macro and micro nutrients are generally over looked. Availability of this nutrient in the soil may be limited because of soil related constraints like adverse soil pH, poor soil structure and due to its lesser mobility in soil etc. There are situations where the absorbed nutrient may be poorly translocated within the plant (B) under such situations addition of these nutrients to the soil will be inefficient and foliar feeding provides the best possibility to supplement the nutrient requirement.

Good supply of Boron to the plant is beneficial for promoting calcium movement to the fruit. deficiency of these elements has been reported to cause many physiological disorders like development of bitterpit, fruit russetting, besides many vegetative disorders. Such fruits generally have lower consumer preference in the market resulting in great economic loss to the fruit growers. This probably indicates the existence of some nutritional imbalance that may be due to climate/moisture stress. This may also be attributed to low calcium and boron, beside other micro nutrients. Keeping in view the above problems (physiological disorders); it is proposed to study the effect of Boron on growth, fruit quality and production of apple.

Material and Methods

The experiment was laid out at an elevation of 2169 m above mean sea level at 31° 33.483'N latitude and 78°16.512'E longitude in the Telangi Village of Kinnaur District. The experimental orchard lies under the high hills and cold desert area of Himachal Pradesh where, summer is moderately hot and dry during May-June while, winter is quite severe experiencing and heavy snowfall during winter (December-February). The experiment was carried out on 12 year old trees of apple cultivar Starking Delicious raised on seedlings rootstocks. The trees had been planted at a spacing of 7×7 meters and trained as modified leader system. For the present study, three trees per treatment were selected on the basis of uniform vigour and were maintained under uniform cultural practices during the entire course of investigation. The experiment was laid out in Randomized Block Design (RBD) with three replications. The details are given as under:

The details are given as under

T_1:	Foliar application of B (Borax) @ 0.1% at pink bud stage & one month after pink bud stage (Control)
T_2:	Soil application of B (Borax) @ 100g tree-1 in mid February
T_3:	Soil application of B (Borax) @ 100g tree-1 at tight cluster stage
T_4:	Soil application of B (Borax) @ 200g tree-1 in mid February
T_5:	Soil application of B (Borax) @ 200g tree-1 at tight cluster stage
T_6:	Soil application of B (Borax) @ 300g tree-1 in mid February
T_7:	Soil application of B (Borax) @ 300g tree-1 at tight cluster stage
T_8:	Soil application of B (Borax) @ 100g tree-1 at fall application (End of October)
T_9:	Soil application of B (Borax) @ 200g tree-1 at fall application (End of October)
T_{10}:	Soil application of B (Borax) @ 300g tree-1 at fall application (End of October)

Measurements

The data on tree growth, fruit set and crop yield to study the effect of different treatments were recorded. Observations regarding growth parameters, *viz*. annual shoot growth and leaf area were recorded as per standard procedures during the course of study. For taking fruit yield the crop load removed from the trees at the time of harvest season was recorded as kg $tree^{-1}$. The fruits were harvested carefully at full maturity and brought to the laboratory for analysis. After harvest fruit yield, fruit size, weight, fruit volume and fruit firmness were recorded with the standard procedure (A.O.A.C., 1980) [1] to determine physical properties of fruits. The fruit firmness was determined by a pressure tester which recorded the pressure necessary for the plunger to penetrate the flesh of apple fruits. The firmness was expressed in kg cm^2. Fruit set was determined as per the procedure suggested by Westwood (1978) [16].

For estimation of macro and micronutrient status of foliage, forty-five fully mature and expanded current seasons leaves located at the 8th position from the apex were collected all round the periphery of the plant. The collected leaf samples were washed first under tap water followed by 0.1 M HC1, distilled water and finally with double distilled water. The drying, grinding and storing of samples were carried out in accordance with the procedure described by Kenworthy (1964). Leaf nutrient estimation was estimated by one gram well dried and grinded leaf samples were used for estimation of leaf nitrogen. The samples were digested on automatic digestion system using one gram of digestion mixture and 20 ml of concentrated sulphuric acid. The digestion mixture was prepared by mixing 400 parts potassium sulphate, 20 part copper sulphate. The boiling of samples was continued till the appearance of light blue color. The samples were cooled and diluted to 100 ml with distilled water. The samples were fed to Auto analyzer Kjeltec FOSS Tecator Model 2300 for auto distillation and titration of the samples. The end point was the appearance of slight red colour. For the estimation of other nutrients, one gram of dried and grinded sample was transferred into 250 ml conical flasks. 20 ml of diacid mixture (comprising of 4 parts of nitric acid and 1 part of perchloric acid) was added to these flasks. The samples were digested on electric hot plate. The digestion continued till 2-3 ml of clear digested material was left in the conical flasks. After complete digestion the samples were diluted to 100 ml with the help of distilled water. Total phosphorous was estimated by vanado-molybdo phosphoric acid method (Jackson, 1973) [8]. Five ml of extract (digested sample) was taken in 25 ml of volumetric flask. To this flask 20 ml of working solution was added and final volume was made to 25 ml with distilled water. The contents were mixed and used for estimation of phosphorous on Spectronic-20 D at 470 nm wavelength using red filter. The colour intensity (yellow) was recorded and the phosphorous content was depicted with the help of standard curve. The potassium in plant tissue was estimated on flame photometer (Jackson, 1973) [8]. The digested samples were diluted to 100 ml with distilled water 5 ml of this prepared sample was diluted to 50 ml with distilled water. The samples vis-a-vis to standards were fed one by one to the instrument and readings were recorded in per cent. Same procedure was followed for the estimation of calcium. The determination of Mg was carried out on Atomic Absorption Spectrophotometer Model 4141 by using 10 ml of 100 ml prepared sample, which was further diluted to 5 ml with distilled water. The macro and micronutrients of leaves were computed on dry weight basis and expressed as per cent and ppm, respectively.

Statistical analysis

The data generated from these investigations were appropriately computed, tabulated and analyzed by applying Randomized Block Design (RBD) Gomez and Gomez, 1984 [7]. The level of significance was tested for different variables at 5 per cent level of significance using the statistical analysis program (SPSS).

Result and Discussion

Annual shoot growth

The data presented in Table 1 revealed that boron had a significant effect on annual shoot growth during both the years of study. During the year 2015, highest shoot growth was recorded in T_1 (41.25 cm) followed by T_9 (40.90 cm), T_4 (39.18 cm) and T_5 (38.98 cm). The lowest was recorded in T_3 (33.85 cm). During the year 2016, the maximum shoot growth was recorded in T_1 (43.65 cm) which was statistically at par with T_9 (43.17 cm), T_4 (42.67 cm) and T_5 (42.33 cm) treatments. Minimum shoot growth was recorded in treatments T_3 (35.90 cm).

Leaf area

From the perusal of data presented in Table 1, it was revealed that there were significant differences among boron treatments with respect to the leaf area. During the year 2015, the maximum leaf area was recorded in T_1 (35.86 cm^2), which was statistically at par with T_9 (35.23 cm^2) and T_4 (35.00 cm^2) treatments. The minimum leaf area was recorded in treatment T_2 (33.36 cm^2). A similar trend was followed during the year 2016, with maximum leaf area recorded in T_1 (36.39 cm^2) and the minimum in T_2 (32.35 cm^2). Rest of the treatments were intermediate.

Table 1: Effect of soil and foliar application of boron on shoot extension growth and leaf area of apple

Parameters / Treatments	Annual extension shoot growth (cm)		Leaf area (cm^2)	
	2015	2016	2015	2016
T_1-Foliar application B @ 0.1% at pink bud stage & one month after pink bud stage	41.25	43.65	35.86	36.39
T_2–Soil application B (Borax) @100g tree^{-1} in mid February	35.03	36.52	33.36	32.35
T_3- Soil application B (Borax) @ 100g tree^{-1} at tight cluster stage	33.85	35.90	33.88	33.28
T_4- Soil application B (Borax) @200g tree^{-1} in mid February	39.18	42.67	35.00	35.12
T_5- Soil application B (Borax) @ 200g tree^{-1} at tight cluster stage	38.98	42.33	34.26	34.78
T_6- Soil application B (Borax) @ 300g tree^{-1} in mid February	37.33	38.92	34.33	33.80
T_7- Soil application B (Borax) @ 300g tree^{-1} at tight cluster stage	38.22	37.47	33.91	34.47
T_8- Soil application B (Borax) @ 100g tree^{-1} at fall application (End of October)	37.43	38.43	34.13	33.55
T_9 - Soil application B (Borax) @ 200g tree^{-1} at fall application (End of October)	40.90	43.17	35.23	36.27
T_{10} - Soil application B (Borax) @ 300g tree^{-1} at fall application (End of October)	35.35	36.58	34.30	33.76
$CD_{(0.05)}$	1.78	2.14	0.99	1.56

Fruit set

The perusal of data presented in Table 2 revealed that boron had significant effect on fruit set during both the years of study. During the year 2015, the highest fruit set was recorded in treatment T_9 (80.19%) followed by T_1 (79.21%), T_5 (78.22%), T_4 (77.91%) and T_6 (75.36%). The lowest fruit set was recorded in T_7 (69.87%).

A similar trend was followed during the year 2016, highest fruit set was again recorded in T_9 (76.97%) followed by T_1 (75.96%), T_5 (74.56%), T_3 (73.94%) and T_6 (73.32%) and lowest set was recorded in T_{10} (63.57%).

Fruit retention

The data presented in Table 2 revealed that effect of different concentration of boron as soil and foliar application on fruit retention was significant during both the years of study. During the year 2015, the highest fruit retention was recorded in treatment T_9 (51.76%) at par with treatment T_1 (50.88%), T_5 (50.17%) and T_4 (49.73%). The lowest fruit retention was recorded in T_6 (42.31%). During the year 2016, the highest fruit retention was recorded in T_9 (48.91%) followed by T_1 (47.64%), T_4 (46.86%) and T_5 (45.74%) and the lowest was recorded in T_6 (38.51%).

Fruit yield

It is evident from the data presented in Table 2 that yield per tree was significantly affected by different concentration of boron during both the year under study. During the year 2015, the highest fruit yield was recorded in T_9 (76.58 Kg/tree) followed by T_1 (74.07 Kg/tree), T_5 (71.00Kg/tree) and T_4 (69.25 Kg/tree). The lowest fruit yield of 62.20 Kg/tree was recorded in treatment (T_2). During in the year 2016, the highest fruit yield was recorded in T_9 (71.67 Kg/tree) which was statistically at par with T_1 (69.08 Kg/tree), T_8 (65.37 Kg/tree) and T_5 (64.85 kg/tree). The lowest was recorded in T_2 (57.92 Kg/tree).

Table 2: Effect of soil and foliar application of boron on fruit set, fruit retention and yield of apple

Parameters / Treatments	Fruit set (%)		Fruit Retention (%)		Yield (Kg/tree)	
	2015	2016	2015	2016	2015	2016
T_1- Foliar application B @ 0.1% at pink bud stage & one month after pink bud stage	79.21 (8.95)	75.96 (8.77)	50.88 (7.20)	47.64 (6.97)	74.07	69.08
T_2-Soil application B (Borax) @100g tree^{-1} in mid February	73.62 (8.64)	71.71 (8.53)	46.66 (6.90)	41.72 (6.54)	62.20	57.92
T_3- Soil application B (Borax)@ 100g tree^{-1} at tight cluster stage	74.17 (8.67)	73.94 (8.66)	47.97 (7.00)	40.83 (6.47)	65.00	59.50
T_4- Soil application B (Borax) @200g tree^{-1} in mid February	77.91 (8.88)	67.55 (8.28)	49.73 (7.12)	46.86 (6.92)	69.25	62.58
T_5- Soil application B (Borax)@ 200g tree^{-1} at tight cluster stage	78.22 (8.90)	74.56 (8.69)	50.17 (7.14)	45.74 (6.84)	71.00	64.85
T_6- Soil application B (Borax)@ 300g tree^{-1} in mid February	75.36 (8.74)	73.32 (8.62)	42.31 (6.58)	38.51 (6.29)	67.50	61.80
T_7-Soil application B (Borax)@ 300g tree^{-1} at tight cluster stage	69.87 (8.42)	66.98 (8.24)	43.13 (6.64)	41.12 (6.49)	68.70	60.03
T_8-Soil application B (Borax)@ 100g tree^{-1} at fall application (End of October)	75.06 (8.72)	68.27 (8.32)	44.94 (6.78)	42.77 (6.62)	66.92	65.37
T_9 -Soil application B (Borax)@ 200g tree^{-1} at fall application (End of October)	80.19 (9.01)	76.97 (8.83)	51.76 (7.26)	48.91 (7.06)	76.58	71.67
T_{10} -Soil application B (Borax)@ 300g tree^{-1} at fall application (End of October)	74.96 (8.72)	63.57 (8.04)	44.41 (6.74)	41.57 (6.53)	65.67	63.37
$CD_{(0.05)}$	5.24 (0.30)	3.77 (0.23)	5.38 (0.38)	1.24 (0.10)	2.61	1.83

*The figures in parentheses are square root transformed values

Fruit size

The data pertaining to the effect of Boron on fruit size is presented in Table 3.

Fruit length

The data presented in Table 3 indicated that the soil and foliar application of boron at different concentration exerted a significant effect on fruit length. During the year 2015, the maximum fruit length was recorded in T_5 (68.88 mm) which was at par with T_4 (68.81 mm), T_9 (68.55 mm) and T_6 (67.92 mm). The minimum fruit length was recorded in T_7 (62.45 mm). During the year 2016, maximum fruit length was recorded in T_4 (78.45 mm) and the minimum was recorded in T_{10} (70.54 mm).

Fruit breadth

The data presented in Table 3 revealed that boron had a significant effect on fruit breadth during the years. During the year 2015, the maximum fruit breadth was recorded in T_9 (73.61 mm), which was at par with treatment T_4 (72.22 mm),

T_8 (70.52 mm) and T_6 (70.36 mm). The minimum was recorded in T_2 (65.99 mm). During the year 2016, the maximum fruit breadth was recorded in T_9 (80.77 mm) followed by T_4 (79.16 mm) and T_6 (77.46 mm) and the minimum was recorded in T_2 (72.58 mm).

Fruit weight

It is evident from the data presented in Table 3 that fruit weight was significantly affected by different concentration of boron. During the year 2015, the highest fruit weight was recorded in T_9 (173.77 g) followed by T_4 (163.50 g) and T_5 (162.27 g).

The lowest was recorded in treatment T_2 (131.67 g). During the year 2016, highest fruit weight was recorded in T_9 (219.43 g) which was at par with T_9 (213.96 g) and lowest was recorded in T_2 (172.17 g).

Fruit volume

The data on fruit volume is presented in Table 3. During the year 2015, the maximum fruit volume was recorded in T_9 (184.05 cc) followed by treatment T_4 (174.07 cc), T_5 (173.07 cc) and T_6 (162.12 cc). The minimum was recorded in T_2 (142.07 cc). During the year 2016, maximum fruit volume was recorded in T_9 (229.05 cc) followed by T_4 (223.73 cc) and T_5 (207.02 cc). The minimum was recorded in T_2 (182.05 cc).

Fruit firmness

Soil and foliar application of boron at different concentration exhibited significant effect on fruit firmness as shown in Table 3. During the year 2015, the highest fruit firmness was recorded in treatment T_9 (8.19 Kg/cm^2) at par with T_4, T_5 and T_8 (8.17, 8.14 and 8.09 Kg/cm^2) respectively. The lowest was recorded in treatment T_2 (7.65 Kg/cm^2). During the year 2016, maximum fruit firmness was recorded in treatment T_9 (8.20 Kg/cm^2) followed by T_5 (8.10 Kg/cm^2), T_4 (8.03 Kg/cm^2), T_7 (7.99 Kg/cm^2), T_8 (7.98 Kg/cm^2) and T_{10} (7.97 Kg/cm^2). The minimum was recorded in treatment T_2 (7.77 Kg/cm^2).

Table 3: Effect of soil and foliar application of boron on fruit physical characters and firmness of apple

Parameters / Treatments	Fruit Length (mm)		Fruit Breadth (mm)		Fruit Weight (g)		Fruit Volume (cc)		Fruit Firmness (Kg/cm^2)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1-Foliar application B @ 0.1% at pink bud stage & one month after pink bud stage	67.64	73.99	69.84	75.37	145.03	194.02	156.05	203.97	7.98	7.90
T_2–Soil application B (Borax) @100g tree^{-1} in mid February	63.85	71.17	65.99	72.58	131.67	172.17	142.07	182.05	7.65	7.77
T_3- Soil application B (Borax)@ 100g tree^{-1} at tight cluster stage	64.75	72.91	67.36	73.91	136.83	182.92	147.38	192.82	7.74	7.84
T_4- Soil applicationB (Borax) @200g tree^{-1} in mid February	68.81	78.45	72.22	79.16	163.50	213.96	174.07	223.73	8.17	8.03
T_5- Soil application B (Borax)@ 200g tree^{-1} at tight cluster stage	68.88	74.38	69.81	76.99	162.27	197.39	173.07	207.02	8.14	8.10
T_6- Soil application B (Borax)@ 300g tree^{-1} in mid February	67.92	73.35	70.36	77.46	151.17	195.94	162.12	205.83	7.88	7.95
T_7- Soil application B (Borax)@ 300g tree^{-1} at tight cluster stage	62.45	73.86	66.80	75.79	138.70	183.94	149.05	193.92	7.90	7.99
T_8- Soil applicationB (Borax)@ 100g tree^{-1} at fall application (End of October)	66.91	72.45	70.52	75.61	149.67	186.99	160.50	196.78	8.09	7.98
T_9 - Soil applicationB (Borax)@ 200g tree^{-1} at fall application (End of October)	68.55	77.74	73.61	80.77	173.77	219.43	184.05	229.05	8.19	8.20
T_{10} - Soil application B (Borax)@ 300g tree^{-1} at fall application (End of October)	65.68	70.54	69.49	74.68	144.10	183.88	155.55	193.77	7.94	7.97
$CD_{(0.05)}$	2.77	3.14	2.27	3.01	10.24	18.61	10.48	18.51	0.21	0.10

Macro nutrients

The data pertaining to the effect of soil and foliar application of boron on the macro nutrients (N, P, K, Ca and Mg) content of leaves during the year 2015 and 2016 are enumerated in Table 4.

Nitrogen (N)

It is evident from the data presented in table 4 that leaf nitrogen content was significantly affected by different concentration of boron during both the years of study. During the year 2015, highest leaf nitrogen content was recorded in T_4 (2.11%) which was at par with treatment T_9 (2.09%), T_5 (2.06%) and T_1 (2.05%) and the lowest was recorded in treatment T_3 (1.81%). During the year 2016, highest leaf nitrogen was recorded in treatment T_4 (2.09%) followed by T_9 (2.07%), T_5 (2.04%) and the lowest was recorded in treatment T_3 (1.81%)

Phosphorus (P)

The perusal of data presented in Table 4 revealed that boron had significant effect on leaf phosphorus. During the year 2015, maximum leaf phosphorus content was recorded in treatment T_9 (0.30%) followed by T_4 (0.29%), and the minimum was recorded in treatment T_2 (0.21%).

A similar trend was followed during the year 2016, being maximum in treatment T_9 (0.31%) followed by T_4 (0.30%), and the lowest phosphorus content was recorded in T_2 (0.22%).

Potassium (K)

The data pertaining to the effects of different concentration of boron treatments on the leaf potassium content are presented in Table 4. It is evident from the data that leaf potassium was found non-significant during both the years of study. During the year 2015, highest leaf potassium was recorded in treatment T_4 (2.68%) followed by T_9 (2.57%), T_1 (2.56%) and the lowest was recorded in treatment T_3 (2.41%). A similar trend was followed during the year 2016, with maximum leaf potassium in treatment T_4 (2.92%) followed by T_9 (2.75%) and the minimum was recorded in treatment T_3 (2.45%).

Calcium (Ca)

The data on leaf calcium content is presented in table 4. It is evident from the data that boron treatments exerted a significant effect on calcium content of leaves during both the years of study. During the year 2015, maximum leaf calcium was recorded in T_9 (1.95%) which was statistically at par with treatment T_4 (1.81%), T_5 (1.79%), T_1 (1.70%) and T_6 (1.65%) and minimum was recorded in treatment T_2 (1.39%). Similarly during the year 2016, maximum leaf calcium content was recorded in T_9 (1.90%) which was at par with treatment T_4 (1.85%), T_5 (1.82%), T_1 (1.78%) and T_{10} (1.77%) and the minimum was recorded in treatment T_2 (1.58%).

Magnesium (Mg)

It is evident from data presented in Table 4 that leaf magnesium was significantly affected by different concentration of boron. During the year 2015, highest leaf magnesium content was recorded in T_4 (0.54%) followed by T_9 (0.53%) and the lowest was recorded in treatment T_2 (0.42%). A similar trend was followed during the year 2016, was highest leaf magnesium in treatment T_4 (0.60%) and the lowest in treatment T_2 (0.45%).

Table 4: Effect of soil and foliar application of boron on macronutrient contents of leaves

Parameters / Treatments	Leaf macronutrients status (%)									
	Nitrogen		Phosphorus		Potassium		Calcium		Magnesium	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
T_1-Foliar application B @ 0.1% at pink bud stage & one month after pink bud stage	2.05	2.00	0.27	0.28	2.56	2.72	1.70	1.78	0.51	0.52
T_2–Soil application B (Borax) @100g tree^{-1} in mid February	1.83	1.85	0.21	0.22	2.42	2.46	1.39	1.58	0.42	0.45
T_3- Soil application B (Borax)@ 100g tree^{-1} at tight cluster stage	1.81	1.81	0.22	0.23	2.41	2.45	1.50	1.65	0.43	0.47
T_4- Soil applicationB (Borax) @200g tree^{-1} in mid February	2.11	2.09	0.29	0.30	2.68	2.92	1.81	1.85	0.54	0.60
T_5- Soil application B (Borax)@ 200g tree^{-1} at tight cluster stage	2.06	2.04	0.28	0.29	2.56	2.74	1.79	1.82	0.52	0.53
T_6- Soil application B (Borax)@ 300g tree^{-1} in mid February	1.92	1.92	0.24	0.25	2.49	2.51	1.65	1.72	0.46	0.51
T_7- Soil application B (Borax)@ 300g tree^{-1} at tight cluster stage	1.87	1.89	0.23	0.24	2.48	2.53	1.63	1.74	0.48	0.49
T_8- Soil applicationB (Borax)@ 100g tree^{-1} at fall application (End of October)	1.90	1.87	0.26	0.27	2.44	2.47	1.54	1.73	0.47	0.48
T_9 - Soil applicationB (Borax)@ 200g tree^{-1} at fall application (End of October)	2.09	2.07	0.30	0.31	2.57	2.75	1.95	1.90	0.53	0.56
T_{10} - Soil application B (Borax)@ 300g tree^{-1} at fall application (End of October)	1.89	1.94	0.25	0.26	2.43	2.56	1.62	1.77	0.49	0.50
$CD_{(0.05)}$	0.10	0.09	0.01	0.01	NS	NS	0.20	0.14	0.03	0.04

Micro nutrients

The data on the effect of different concentration of boron treatments on micro nutrients (Zn, Fe, Mn, and Cu) content of leaves are enumerated in Table 5. Zinc (Zn)

The perusal of data presented in Table 5 revealed that the boron had a non-significant effect on leaf zinc content during the course of study. During the year 2015, highest leaf zinc content was recorded in treatment T_9 (44.00 ppm) followed by T_4 (43.00 ppm), T_6 (42.00 ppm) and the lowest was recorded in treatment T_2 (35.33 ppm). During the year 2016, highest leaf zinc content was recorded in T_9 (44.68 ppm) followed by T_4 (44.67 ppm), T_5 (43.33 ppm) and T_6 (42.33 ppm). The lowest was recorded in treatment T_2 (36.67 ppm).

Iron (Fe)

It is evident from the data presented in Table 5 that iron content of leaves was found to be non-significant during both the years of study. In 2015, maximum leaf iron was observed in treatment T_5 (271.67 ppm) followed by T_9 (269.67 ppm), T_4 (268.00 ppm) and minimum was recorded in treatment T_2 (245.00 ppm). A similar trend was followed during the year 2016, being highest in treatment T_5 (276.00 ppm) and lowest was recorded in treatment T_3 (249.67 ppm).

Manganese (Mn)

The data enumerated in Table 5 that different concentration of boron had a non-significant effect on manganese content of leaves during both the years. However, during the year 2015, maximum leaf manganese content was recorded in treatment T_5 (77.53 ppm) followed by T_4 (76.07 ppm) and the lowest was recorded in treatment T_3 (71.87 ppm). A similar trend was followed during the year 2016, wherein, highest leaf manganese was recorded in treatment T_5 (77.63 ppm) which was at par with T_4 (76.40 ppm), T_6 (75.50 ppm) and T_9 (75.33 ppm) and the lowest was recorded in treatment T_3 (72.00 ppm).

Copper (Cu)

It is evident from the data presented in Table 5 that copper content of leaves had a significant effect during both the years of study. During the year 2015, highest copper content of leaf was recorded in T_9 (7.70 ppm) followed by T_4 (7.64 ppm) and the lowest was recorded in treatment T_2 (7.14 ppm). Similarly, in 2016, highest leaf copper was recorded in treatment T_9 (8.15 ppm) followed by T_4 (7.84 ppm), T_5 (7.81 ppm) and the lowest was recorded in T_2 (7.23 ppm).

Table 5: Effect of soil and foliar application of boron on micronutrient content of leaves

Parameters / Treatments	Leaf micronutrients status (ppm)							
	Zinc		Iron		Manganese		Copper	
	2015	2016	2015	2016	2015	2016	2015	2016
T_1-Foliar application B @ 0.1% at pink bud stage & one month after pink bud stage	39.33	42.00	264.67	270.67	74.70	75.17	7.57	7.71
T_2–Soil application B (Borax) @100g tree^{-1} in mid February	35.33	36.67	245.00	250.00	72.23	72.73	7.14	7.23
T_3- Soil application B (Borax)@ 100g tree^{-1} at tight cluster stage	36.67	38.50	246.67	249.67	71.87	72.00	7.26	7.25
T_4- Soil applicationB (Borax) @200g tree^{-1} in mid February	43.00	44.67	268.00	269.33	76.07	76.40	7.64	7.84
T_5- Soil application B (Borax)@ 200g tree^{-1} at tight cluster stage	41.33	43.33	271.67	276.00	77.53	77.63	7.58	7.81
T_6- Soil application B (Borax)@ 300g tree^{-1} in mid February	42.00	42.33	251.33	258.00	73.50	75.50	7.39	7.56
T_7- Soil application B (Borax)@ 300g tree^{-1} at tight cluster stage	35.67	39.67	257.67	256.67	73.37	73.00	7.36	7.43
T_8- Soil applicationB (Borax)@ 100g tree^{-1} at fall application (End of October)	36.67	41.00	259.67	253.33	72.57	72.67	7.29	7.47
T_9 - Soil applicationB (Borax)@ 200g tree^{-1} at fall application (End of October)	44.00	44.68	269.67	272.33	75.20	75.33	7.70	8.15
T_{10} - Soil application B (Borax)@ 300g tree^{-1} at fall application (End of October)	36.00	40.00	258.67	251.33	73.00	72.87	7.27	7.39
$CD_{(0.05)}$	NS	NS	NS	NS	NS	NS	0.31	0.50

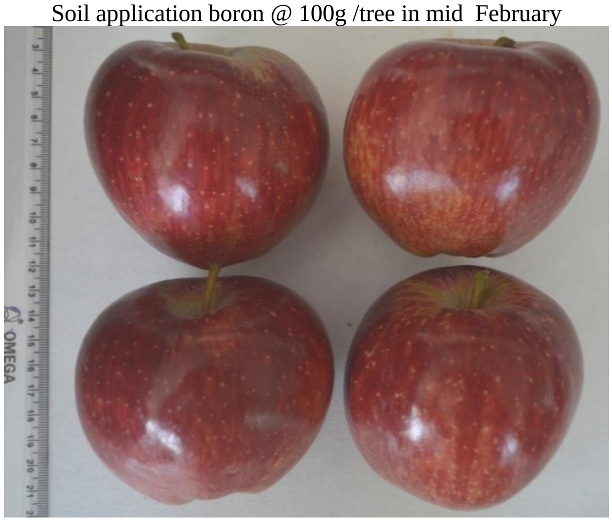
Plate 1: Effect of boron on fruit set

Plate 2: Deficiency symptoms of boron on apple

Soil application of boron @ 200g /tree at fall application (End of October)

Soil application boron @ 100g /tree in mid February

Foliar spray of boron @ 0.1% at pink bud stage one month after pink bud stage



Soil application of boron @ 200g /tree in mid February

Soil application of boron @ 200g /tree at tight

Soil application of boron @ 300g /tree in mid February

Plate 3: Effect of boron on fruit quality of apple

Discussion

A significant effect was observed on annual shoot growth and leaf area when boron was applied through soil and foliar application. Similar results have been reported by Wojcik, (2002) [17] who also reported to have non- significant effects on the plant vigour of conference pear following soil and foliar fertilization of boron. Wojcik, 2007 [18] further reported that the boron fertilization had no effect on vigour of sweet cherry trees despite increased concentration of boron in flower and leaf tissues. Kassem *et al.*, (2016) [9, 10] reported that foliar spray of boron increased shoot length and leaf area compared with the control trees. Paparnakis, (2013) resulted that addition of boron increased the total shoot length as compared to the control. The increase in leaf area by boron foliar application might be due to its prime role in cell elongation rather than cell division (Birnabaum *et al.*, 1974 and Lovatt *et al.*, 1981).

In the present studysoil and foliar application of boron at different concentration showed significant influence on fruit set, fruit retention and yield of fruits.The results revealed that foliar applications of boron at pink bud stage and a month before pink bud increased fruit set, retention and yield. These results are supported by the finding of Visser, (1955) who reported that a continuous and ample supply of boron was required for pollen tube growth, and subsequent fruit set. Heinickee, (1942) also reported that boron is known to be associated positively with the early stages of development, resulting in increased fruit retention. Wojcik *et al.*, (2008) observed that pre bloom foliar application of boron to apple trees increases fruit set as well as yield. Peryea *et al.*, (2003) [14] also found that foliar applications of boron before full bloom or after harvest increased fruit set and fruit yield of apple trees. Dar, (2017) who reported that the boron during flowering increased the growth of the pollen tube and in the development of the flowering and fruiting stages. Boron foliar sprays to boron deficient fruit trees under dry conditions delay bloom and increase fruit set and final fruit number per tree. Also, these sprays result in improved yields, mainly when both fall and spring boron foliar sprays are applied. Soil and foliar application of Boron increased yield, however boron sprays were more efficient than soil fertilization.

Further, the results indicate that both soil and foliar application of boron at different concentration had significant affect on the fruit size, weight and volume. Soil application of boron was found better results than the foliar application of boron in terms of fruit size, weight, fruit volume and fruit firmness. These results are in line with the findings of Wojcik *et al.*, (2008) who reported that soil application of boron improved yield but the efficiency of foliar boron spray was higher than soil boron fertilization. Similarly Kumar *et al.*, (2003) reported that pre harvest spray of boric acid at 0.2 per cent significantly increased fruit size in apple as compared to untreated fruits. Wojcik *et al.*, (2008) also observed that soil boron application increased apple calcium concentration and also increased fruit firmness. Kassem *et al.*, (2016) [9, 10] reported that foliar spray of boron increased fruit firmness compared with the control fruits.

In the present study different concentration of boron significantly increased the nitrogen (N), phosphorus (P), calcium (Ca) and magnesium (Mg) content of apple leaves. Trees sprayed with different concentration of boron had a non-significant effect on the potassium (K) content of leaves. While, micro nutrients namely copper (Cu) content of leaves was significantly affected by boron. However, iron (Fe), manganese (Mn) and zinc (Zn) content of leaves were not affected by boron application. The results of present study are in accordance with the findings of Mouhtaridou *et al.*, (2004) [11] who reported that by increasing boron concentration in the *in vitro* cultures of apple rootstock (MM 106) significantly improved the contents of B, P, Ca, and Mg in explants, whereas K, Fe, Mn, and Zn contents decreased. Dhar (1987) [5] also reported that application of boric acid significantly increased the phosphorus and calcium content of leaves. On the other hand Ganai, (2006) [6] reported that there was a decrease in K content of leaves as well as fruits with the application of boron treatments. Fruit K content were found with untreated control.

Conclusion

From the present study it can be inferred that soil application of boron @ 200g tree^{-1} at fall application (End of October) was observed to be most effective in terms of fruit set and other quality parameters. However, foliar application of boron @ 0.1% at pink bud stage & one month after pink bud stage was observed to be at par with the above treatment for the said traits.

References

1. AOAC. Official methods of analysis of association of analytical chemists, 13 th ed. (ed. W. Horowitz).

Benjamin Franklin Station. Washington, D.C 1980, 1018p.
2. Chadha KL, Awasthi RP. The Apple: Improvement, Production and Post-Harvest management. Malhotra Publishing House. New Delhi 2005, 238-239
3. Dart J. Zinc deficiency in apple. Prime fact 396 New South Wales 2007, 1-2
4. Dev G, Kapoor ML. Note on zinc content in apple leaves and soils in relation to deficiency symptoms in Kullu Valley of Himachal Pradesh. Journal of Agriculture Science 1973;43:212-213
5. Dhar RP. Cold storage behaviour of Starking Delicious apple in relation to pre and post harvest treatments. Ph.D. Thesis Dr. Y. S. Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh 1987.
6. Ganai NAS, Banday FA. Effect of pre-harvest calcium and boron application on the quality and yield of apple (*Malus x domestica borkh*). cv Red Delicious under temperate conditions of Kashmir Ph.D. Thesis Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir 2006.
7. Gomez KA, Gomez AA. Statistical procedure for agricultural research. IInd ed. John Wiley and Sons, New York 1984, pp. 357-427 .
8. Jackson ML. Soil Chemical Analysis. Prentice hall, New Delhi 1973, 120p.
9. Kassem HA, Marzouk HA, Al-Kobbia AM. Response of Anna apples yield, quality and storage potential to boron and zinc foliar sprays. Journal of Scientific and Engineering Research 2016;3(5):144-152.
10. Kassem HA, Marzouk HA, Al-Kobbia AM. Response of Anna apples yield, quality and storage potential to boron and zinc foliar sprays. Journal of Scientific and Engineering Research 2016;3(5):144-152.
11. Mouhtaridou GN, Sotiropoulos TE, Dimassi KN, Therios IN. Effects of boron on growth, and chlorophyll and mineral contents of shoots of the apple rootstock MM 106 cultured *in vitro.* Biologia Plantarum 2004;48(4):617-619.
12. NHB. National Horticulture Board Statistical Database. New Delhi 2016.
13. NHB. National Horticulture Board Statistical Database. New Delhi 2019.
14. Peryea FJ. Comparison of commercial boron spray products applied at the pink flowering stage on ‘Fuji’ apple. Hort Science 2005;40(5):1487-1492.
15. Sharma U, Bhandari AR. Survey of the nutrient status of apple orchards in Himachal Pradesh. Indian Journal of Horticulture 1992;49:234-241.
16. Westwood MN. Plant efficiency: Growth and yield measurements. In: Temperate zone Pomology, W. H. Freeman and Company (Sa Franscisco) 1978, pp. 119-120.
17. Wojcik P. Yield and "Jonagold" apple fruit quality as influenced by spring sprays with commercial Rosatop material containing calcium and boron. Journal of Plant Nutrition 2002;25(5):999-1010.
18. Wojcik P. Vegetative and reproductive responses of apple trees to zinc fertilization under conditions of acid coarse-textured soil. Journal of plant Nutrition 2007;30(10-12):1791-1802.