Effects of Calcium and Boron Foliar Application on Pomegranate *(Punica granatum* L.) Fruit Quality, Yield, and Seasonal Changes of Leaf Mineral Nutrition

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Keywords: Pomegranate, foliar application, nutrients, leaf analysis, vitamin C, cracking

Abstract

In this study, the effects of calcium and boron foliar sprays on yield, fruit quality and seasonal changes of leaf mineral nutrition were studied during 2011 in Mugla, one of the main pomegranate producing regions in Turkey. Calcium (calcium nitrate 2% and 4%), boron (boric acid 1.5% and 3%) were applied on two occasions (firstly, in full blossoming; secondly, one month post full blossoming). Yield (total yield per tree, total number of fruits, cracking fruit ratio, average fruit weight, average fruit size) and fruit quality (fruit juice pH value, total soluble solids, titratable acidity and vitamin C) were measured. The maximum yield (38.338 kg/tree) was recorded with the application of 2% calcium nitrate, while minimum yield was recorded under 1.5% boron application (20.764 kg/tree). All treatments resulted in increased fruit size, fruit length, fruit weight and fruit juice ascorbic acid content as compared to control.

Keywords: Pomegranate, foliar application, nutrients, leaf analysis, vitamin C, cracking

INTRODUCTION

Pomegranate (*Punica granatum* L.) is a very popular fruit all over the world, and year on year production is increasing. In Turkey, pomegranate features highly in both local consumption and, European exportation. It is a main attraction for foreign currencies. The popularity of new markets and suitable ecological conditions have promoted a rapid increase in pomegranate cultivation which now boasts some 26.90 hectares (Anonymous, 2012). Pomegranate production in Turkey has risen from 60.000 tons in 2002 to 315.150 tons in 2012 .The Mugla region in south west Turkey, produces 15% of total pomegranate output (Anonymous,2012) .

Pomegranate is a good source of protein (16%), carbohydrate (14.5%),minerals (Potassium> Phosphorus > Magnesium > Sulphur > Calcium > Chlorine > Iron > Sodium

> Zinc > Manganes) , antioxidants, vitamin (Vitamin C> Niacin > Riboflavin). (www.nhb.gov.in)

Calcium is an effective element of a fruit's physiological resistance (Faust,1989), increases cell turgor pressure (Mastrangelo et al., 2000) and stabilizes the cell membrane (Picchioni et al., 1995). Calcium disorders prevent physiological maturity before harvesting, such as delay and decrease in the quality of the fruit within many fruit species (Hernandez-Munoz et al., 2006). Foliar calcium applications may extend the ageing process significantly (Pooviah, 1979), however, little is known about the effect of foliar calcium application on yield and quality (Ramezanian et al., 2009).

Boron is an essential nutrient and although leaves can tolerate toxic levels of this element, boron deficiency can cause serious problems such as defective fruit development, less yield and poor fruit quality (Maurer, 1999). Boron foliar applications have also been applied successfully within a limited number of studies for reducing the breakdown of fruit, fruit cracking, controlling boron levels and plant bio regulators (PBR) applications (Singh et al., 2003).

Leaf-nutrient analysis is the best method for diagnosing the nutritional status of trees, and represents an important tool for determining future fertilization requirements Benton Jones (1985), Bar-Akiva et al. (1968). The criteria for determining optimum requirements include: seasonal accumulation of nutrients in plants, fruit quality and yield. Lack of or too much macro and micro elements cause undesirable changes in a wide range of deficits and surpluses.

MATERIAL AND METHODS

Forty five pomegranate (*Punica granatum* L.var. *Hicaz Nar*) trees were selected in an established orchard located within the Ortaca region of Mugla province, Turkey. The average annual rainfall in this area was 1070 mm for the year 2011. Soil character was alkaline. Trees were labeled with plastic tags. The experiment was laid out in randomized design in split plots, with tree replications.

The applied treatments were calcium as calcium nitrate at concentrations of 0 %, 2%,4% and boron as boric acid at concentrations of 0 %, 1.5%, 3%. All treatments were applied at full bloom (16 May 2011) and one month after full bloom (16 June 2011). All solutions were applied in the afternoon (6-7 p.m) using a hand pressure sprayer with a capacity of 15 liters. Leaf samples were collected approximately monthly starting in the period May to October. Ripe fresh fruits were picked on 16 October 2011. Leaf samples from each plot were combined as samples of 100 -120 leaves for the determination of nutrient concentration. Nine fruits per each replicate were selected to calculate mean fruit weight, fruit length and diameter.

Fruit weight was measured electronically. Average fruit length and diameter was measured with a digital calliper averaged for each replicate. Fruit juice pH value was measured by a digital pH meter. Total soluble solid content was measured using a hand-held refractometer. Titratable acidity was determined by titrating an aliquot of juice against 0.1 N NaOH and expressing the result as percentage of anhydrous citric acid. Ascorbic acid content was measured by spectrophotometric methods (Pearson ,1970). The methods used by the laboratory for the determination of the leaf elements were: for nitrogen Kjeldahl procedure, for phosphorus spectrophotometry, for potassium flame photometry, for calcium, magnesium, iron, zinc and copper using the atomic absorption spectrophotometry.

Collected data were analysed with the TARIST analysis programme, to detect statistically significant differences with at 5% confidence level (Açıkgöz et al.,1994).

RESULTS AND DISCUSSION

Total Yield Per Tree, Total Number Of Fruits, Average Fruit Weight, Fruit Length, Diameter, Cracking Fruit Ratio

CN1 (Ca_2NO_3 2%), CN2 (Ca_2NO_3 4%) and B2 (B_2O_3 3%) applications had increased yield but foliar application of B1(B_2O_3 1.5%) did not affect the yield of ' Hicaznar' pomegranate**.** External CN1 (Ca_2NO_3 2%) and B2 (B_2O_3 3%) increased fruit set. Fruit number per tree exhibited highest increase with CN1 (85 fruit per tree) and B2 (80 fruit per tree),but not significantly. All application had increased fruit weight and fruit size (diameter and length) as compared to control fruit. Ullah 2012 said that as the levels of foliar application of boric acid increased the yield of 'Kinnow' mandarin ,it might be due to increased fruit set and fruit retention by the B. Results were supported by Abd-Allah (2006) who stated that foliar application of boric acid and calcium chelate produced the highest number of fruits in 'Washington' navel orange. All applications reduced the cracking contrast to control , but not significantly. The ratio of fruit cracking was reduced to a maximum with the application of B1 (boric acid 1.5%) and CN2 (calcium nitrate 4%).

Fruit Juice pH Value, Total Soluble Solids, Titratable Acidity, Vitamin C

pH, TSS, TA and vitamin C (control) concentration of fruit juice are show in Table 2 and all fruit quality parameters are not significant by treatments. Effect of calcium and boron increased vitamin C concentration.

Foliar application of B1affected the pH (3.46) and ascorbic acid (18.70), but not significantly. Total soluble solids (TSS) (16.18), titratable acidity (TA) (2.53) were highest affected by the foliar applications of B1 (Table 2). Our results confirmed the finding of Ullah et al.(2012) who stated that foliar application of B1 treatment had the highest TSS and TA in 'Hicaznar 'pomegranate as compared to C, but not significantly .

Leaf Nutrition Concentration And Seasonal Changes

Leaf N concentrations varied 0.86-2.45%, P 0.04 -0.13 %, K 0.56-1.07%, Ca 0.84-5.66%, Mg 0.28-1.92%, Cu 6.63-16.20 ppm, Mn 6-24 ppm, Fe 52.53-143.3 ppm and Zn 6.25-16.10 ppm changed during the growth period in the leaves of all applications (Figure 1).

In all treatments, maksimum leaf nitrogen concentration were observed in July, but , in B2 and CN2 applications maximum concentration was observed in August. Especially, after second foliar application , leaf N concentrations showed an increase in all treatments. Vegetation in contrast to previous studies in chestnut (Toprak et al.,2013), in kiwifruit (Smith et al.,1987) analysing Fig.1. Towards the end of vegetation, leaf nitrogen concentration was observed to decrease before stabilising. Highest leaf concentrations of N (2.45%) were obtained from leaves of trees sprayed with CN1. Trees were sprayed with B1 and B2 showed higher increases in N levels (2.34%, 2.26%, 2.21%) than C trees in the last three months. These results were in line with Ullah (2012).

The trees were sprayed with B2 revealed maximum increase in leaf P contents of ' Hicaznar' pomegranate trees (0.13%) about 30% higher than control trees in May. In all applications , phosphorus concentration decreased in June compared to other months.

The reason for this decrease in the amount of phosphorus in all applications, could be attributed to the transportation of phosphorus to growth centers (Haiyan,2002).

At the beginning of vegetation, K levels were at their maximum levels and showed a decreasing trend towards the end of vegetative growth. These results were similar to those of Toprak et al, (2013). In general, boric acid applications hadn't increased the leaf K contents. The highest leaf K contents were exhibited by the foliar application of B1 in May over those trees sprayed with B2 because, according to Gupta (1979), low levels of B are associated with an increase in K contents of plants and, similarly, (Sotiropoulos et al., 2006) determined that foliar applications of B did not increase the leaf K contents of Cherry trees budded on 'Gisela5' root stock (Ullah et al. ,2012).

It was observed that leaf Ca concentrations ranged from 0.84-5.66% in all vegetation for all applications. From month to month, leaf calcium concentration showed an increasing trend. Maximum calcium concentration measured 5.66% in October. Ca concentrations of 'Hicaznar' pomegranate leaves showed an increase after the foliar application of B and Ca . These results confirm the findings of Ullah et al.(2012).

Mg concentrations ranged between 0.27-1.92 % in old leaves, (Figure 2). Magnesium concentrations were higher from young leaves within all applications. Four peaks of Mg concentrations were observed in the leaves of the five applications during fruitlet, growth and fruit enlargement, respectively. The first highest peak of Mg was reached with the CN1 application in September. Mg concentration had reached maximum levels in CN2 ,B1 and B2 possibly because calcium and boron applications had increased the Mg uptake (Bonomelli,2010).

For seasonal Fe concentration , higest value was observed CN1 applications in July and August (131.2ppm -143.3ppm) (Figure 3). For seasonal Zinc concentration , higest values were observed for B1application in May (16.1ppm) and CN1 application in August (15.8 ppm).For seasonal Cu concentration, higest values were observed CN1 application in August (14.6 ppm) and with with B2 application in September (16.03 ppm) (Fig.3.). For seasonal Mn concentration , higest values were observed for CN1 application in August (24ppm). Foliar calcium nitrate and boric acid applications had increased microelement uptake. Bonomelli et al. (2010) stated that the application of calcium can increase the uptake of other nutrients. One peak of Mn and Zinc concentrations were observed in the leaf of all treatments during fruit enlargement in August. In september significant decreases were found in the leaves. For seasonal B concentration, higest value was observed for B1 application in June (40.77 ppm) (Figure 4). Those results were similar to the work done by Xiao, 2007 in the 'Newhall' and 'Skagg's Bonanza' navel oranges.

Boron and calcium had effects on some measured characters on pomegranate, however, were not significant. The application of boron (1.5% and 3%) and calcium (2% and 4%) increased fruit yield significantly. The application of boron at both levels (1.5 and 3%) increased the characters such as fruit number (per tree), weight, fruit size (length and diameter), pH, TSS, TA, and ascorbic acid content, but was not significant. Ca was also significant for tree yield whereas the calcium treatments had no statistically significant effects on fruit number (per tree), weight, fruit size (length and diameter),pH, TSS,TA, and ascorbic acid content. All applications had affected on reduction of fruit cracking.

CONCLUSIONS

Foliar sprays of boric acid 1.5% increased N, Mg, Zn concentration, and foliar sprays of boric acid 3% enhanced P, Mg, Fe, Cu, Mn. Foliar sprays of calcium nitrate 2% increased, N, P, K, Ca, Mg, Fe, Zn, Cu and Mn concentration, and foliar sprays of calcium nitrate 4% increased K, Ca, Fe concentration.

Little information is available about the use of calcium with foliar spray for improving quantitative and qualitative aspects of pomegranate fruit (Ramezanian et al.,2009). However, within the last decade, the studies of pomegranate regarding macro and micro elements on the effects of fruit yield and quality with the application of foliar sprays have increased. As a result, this work would assist the studies related to determination of macro and micro nutrients role in fruit yield and quality.

ACKNOWLEDGEMENTS

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Tables

Table 1. Effect of calcium nitrate and boron on yield, fruit number, weight, length, diameter and cracking ratio of pomegranate fruits.

Treatment	Yield	Fruit Number	Weight	Lenght	Diameter	Cracking(%)
C	32.69ab	64	515.8	89.8	101.9	28.08
CN1	38.34a	85	565.4	90.4	105.3	22.30
CN2	35.55a	77	554	89.3	104.3	18.75
B1	24.47b	55	535.4	90.8	102.5	18.19
B2	38.11a	80	580.2	91.5	104.0	24.55
Lsd 0.05	**8.30***	**ns**	**ns**	**ns**	**ns**	**ns**

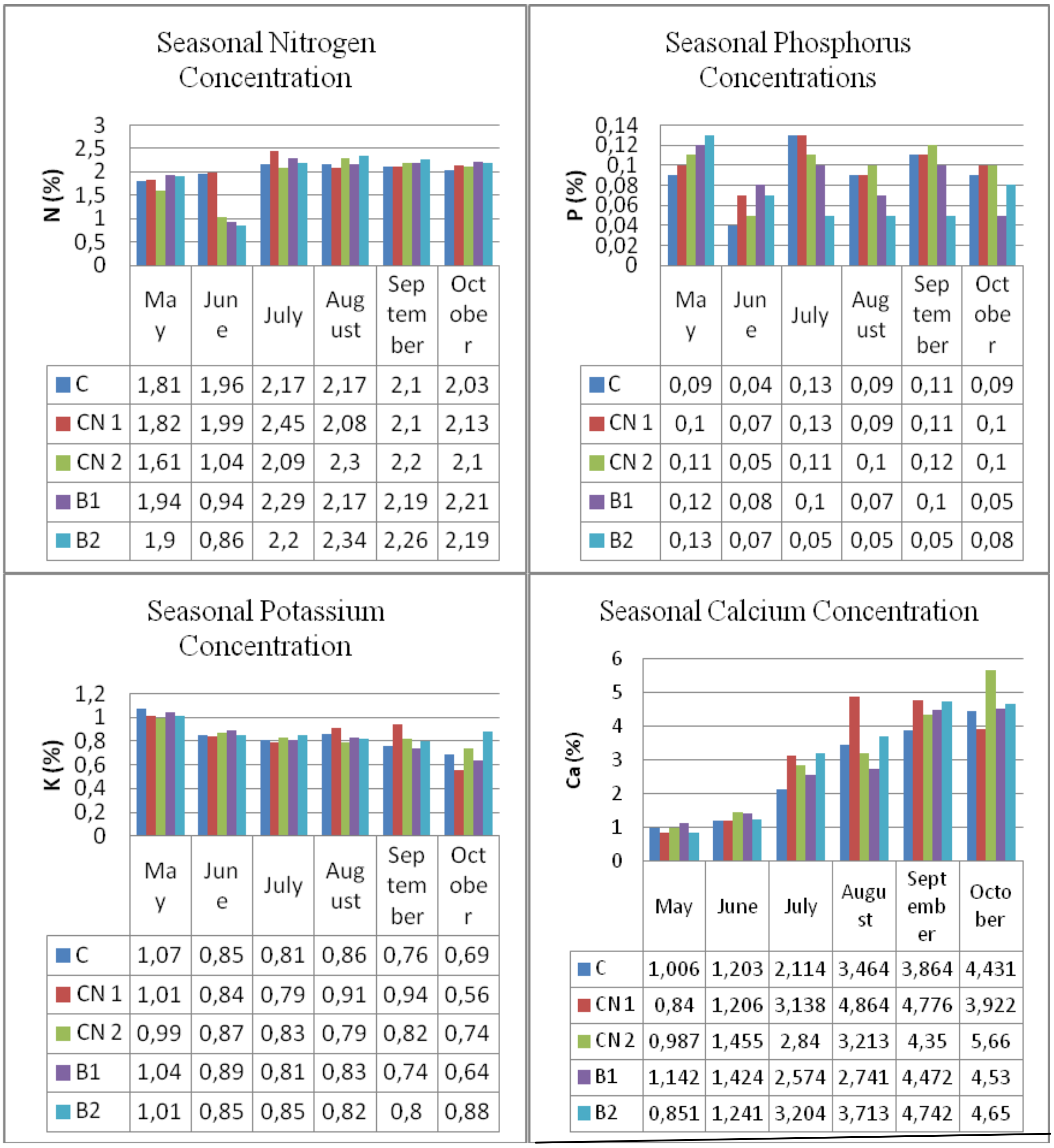
C: Control, CN1: Ca_2NO_3 2%, CN2: Ca_2NO_3 4%, B1: B_2O_3 1.5%, B2: B_2O_3 3%

Table 2. Effect of Calcium nitrate and boron on pH value, total soluble solids, titratable acidity, vitamin C of pomegranate fruits.

Treatment	pH	TSS (%)	TA (%)	Vitamin C (mg/100g juice)
C	3.38	15.93	2.10	5.85
CN1	3.39	16.01	2.06	10.17
CN2	3.41	16.07	2.53	12.33
B1	3.37	16.18	2.53	16.10
B2	3.46	15.80	2.10	18.70
Lsd 0.05	**ns**	**ns**	**ns**	**ns**

C: Control, CN1: Ca_2NO_3 2%, CN2: Ca_2NO_3 4%, B1: B_2O_3 1.5%, B2: B_2O_3 3%

Figures



	May	June	July	August	September	October
C	1,81	1,96	2,17	2,17	2,1	2,03
CN 1	1,82	1,99	2,45	2,08	2,1	2,13
CN 2	1,61	1,04	2,09	2,3	2,2	2,1
B1	1,94	0,94	2,29	2,17	2,19	2,21
B2	1,9	0,86	2,2	2,34	2,26	2,19

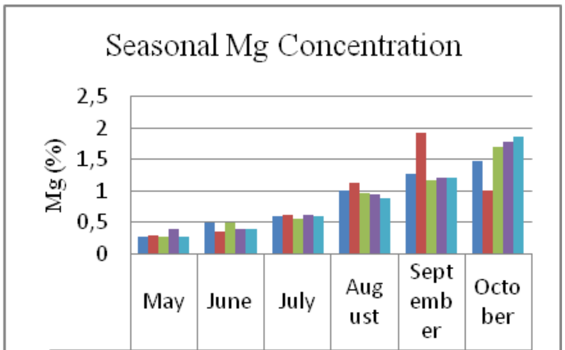
	May	June	July	August	September	October
C	0,09	0,04	0,13	0,09	0,11	0,09
CN 1	0,1	0,07	0,13	0,09	0,11	0,1
CN 2	0,11	0,05	0,11	0,1	0,12	0,1
B1	0,12	0,08	0,1	0,07	0,1	0,05
B2	0,13	0,07	0,05	0,05	0,05	0,08

	May	June	July	August	September	October
C	1,07	0,85	0,81	0,86	0,76	0,69
CN 1	1,01	0,84	0,79	0,91	0,94	0,56
CN 2	0,99	0,87	0,83	0,79	0,82	0,74
B1	1,04	0,89	0,81	0,83	0,74	0,64
B2	1,01	0,85	0,85	0,82	0,8	0,88

	May	June	July	August	September	October
C	1,006	1,203	2,114	3,464	3,864	4,431
CN1	0,84	1,206	3,138	4,864	4,776	3,922
CN2	0,987	1,455	2,84	3,213	4,35	5,66
B1	1,142	1,424	2,574	2,741	4,472	4,53
B2	0,851	1,241	3,204	3,713	4,742	4,65

C:Control ; CN1: 2 % Calcium Nitrate; CN2: 4% Calcium Nitrate; B1: 1.5% Boric Acid; B2: 3% Boric Acid

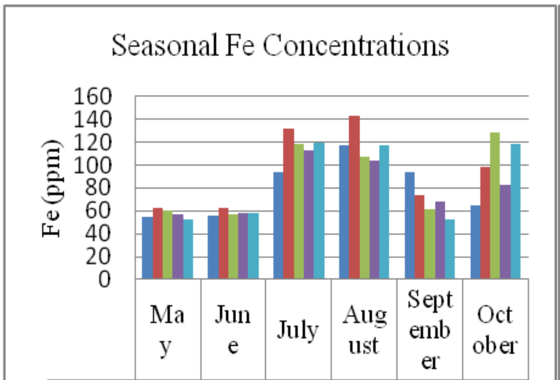
Fig.1. Seasonal trends of N, P, K, Ca concentrations in pomegranate leaves



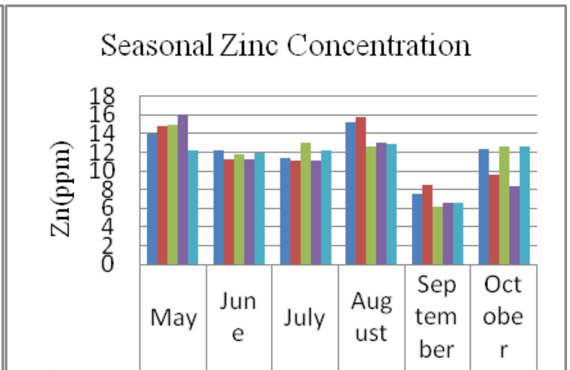
	May	June	July	August	September	October
C	0,28	0,49	0,59	1,01	1,26	1,47
CN 1	0,3	0,35	0,62	1,12	1,92	1
CN 2	0,27	0,49	0,56	0,96	1,17	1,69
B1	0,39	0,4	0,62	0,95	1,21	1,77
B2	0,28	0,4	0,6	0,88	1,2	1,85

C:Control ; CN1: 2 % Calcium Nitrate; CN2: 4% Calcium Nitrate;
B1: 1.5% Boric Acid; B2: 3% Boric Acid

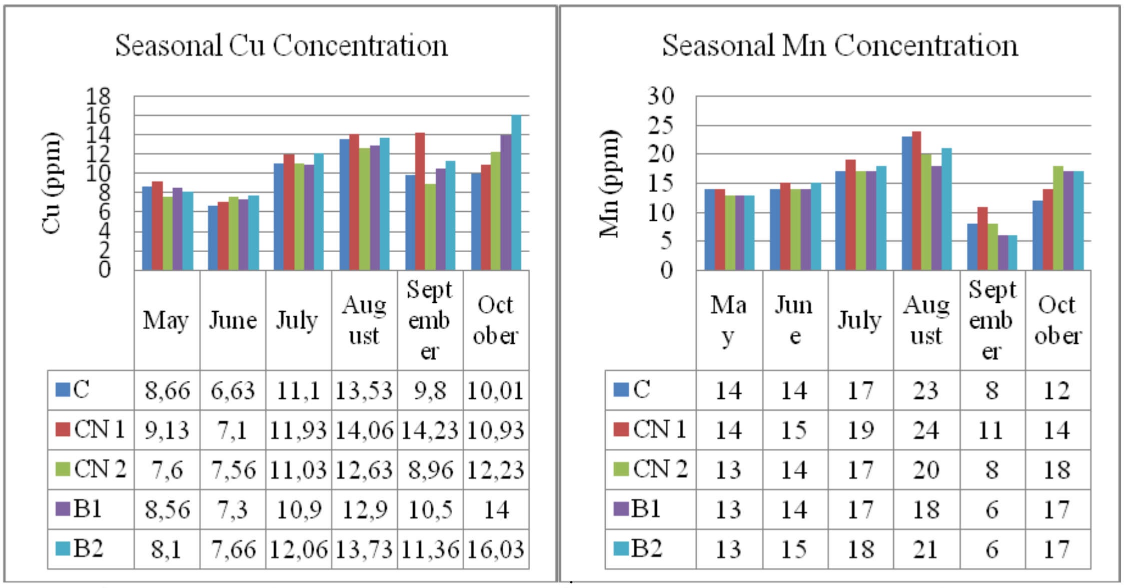
Fig.2. Seasonal trend of Mg concentrations in pomegranate leaves



	May	June	July	August	September	October
C	55,07	56,27	94,17	117	93,6	65,23
CN 1	62,9	62,57	131,2	143,3	73,33	98,07
CN 2	60,3	56,77	118,1	107,1	61,37	128,7
B1	56,53	57,9	112,6	103,9	68,57	82,6
B2	52,53	57,93	118,9	117,2	51,9	118,3



	May	June	July	August	September	October
C	14,04	12,23	11,4	15,16	7,56	12,36
CN 1	14,82	11,23	11,08	15,81	8,54	9,61
CN 2	14,94	11,81	13	12,67	6,25	12,64
B1	16,06	11,28	11,12	13,05	6,58	8,35
B2	12,21	11,96	12,26	12,9	6,57	12,58

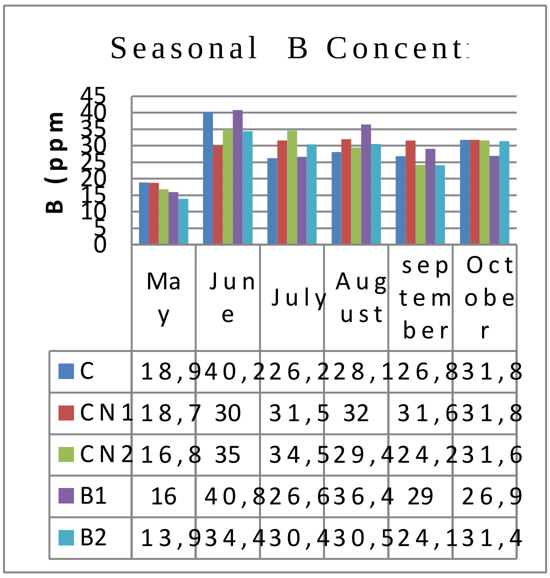


Cu	May	June	July	August	September	October
C	8,66	6,63	11,1	13,53	9,8	10,01
CN 1	9,13	7,1	11,93	14,06	14,23	10,93
CN 2	7,6	7,56	11,03	12,63	8,96	12,23
B1	8,56	7,3	10,9	12,9	10,5	14
B2	8,1	7,66	12,06	13,73	11,36	16,03

Mn	May	June	July	August	September	October
C	14	14	17	23	8	12
CN 1	14	15	19	24	11	14
CN 2	13	14	17	20	8	18
B1	13	14	17	18	6	17
B2	13	15	18	21	6	17

C:Control ; CN1: 2 % Calcium Nitrate; CN2: 4% Calcium Nitrate; B1: 1.5% Boric Acid; B2: 3% Boric Acid

Fig.3. Seasonal trends of Fe, Zn, Cu, Mn, concentrations in pomegranate leaves



B	May	June	July	August	september	October
C	18,9	40,2	26,2	28,1	26,8	31,8
CN1	18,7	30	31,5	32	31,6	31,8
CN2	16,8	35	34,5	29,4	24,2	31,6
B1	16	40,8	26,6	36,4	29	26,9
B2	13,9	34,4	30,4	30,5	24,1	31,4

C:Control ; CN1: 2 % Calcium Nitrate; CN2: 4% Calcium Nitrate;
B1: 1.5% Boric Acid; B2: 3% Boric Acid

Fig.4. Seasonal trend of B concentration in pomegranate leaves