

Relations among Boron Status and Some Soil Properties of Isparta Region Apple Orchards

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Abstract: This study was conducted to determine the boron (B) status of apple orchards and examine the relations among B nutrition and some soil properties in Isparta province. For this purpose 250 gardens from the seven districts of the region were determined and soil and leaf samples were collected. In order to determine soil and leaf B status and relations among these some soil properties were determined. Similarly, other leaf nutrient concentrations were analyzed. According to the soil analysis it was seen that most of the soils are B-sufficient. If soil B concentrations were evaluated depending on the district, the lowest soil B (0.26 mg kg⁻¹) was measured from the gardens of Senirkent, the highest B concentration (3.44 mg kg⁻¹) was determined in Atabey. Looking at the individual districts, all apple orchards in Gönen and Keçiborlu have sufficient (0.5-2 mg kg⁻¹) soil B. Also in Yalvaç, Atabey, Gelendost and Eğirdir 71%, 95%, 96% and 97% of the soils had higher B concentration than B deficiency level (0.5 mg kg⁻¹). The most soil B deficiency problem was observed in Senirkent and Yalvaç. Average soil B levels for Atabey, Eğirdir, Gelendost, Gönen, Keçiborlu, Senirkent and Yalvaç orchards were calculated as 1.32, 0.96, 0.87, 0.67, 0.91, 0.49 and 0.62, mg kg⁻¹ respectively and general average were determined as 0.84 mg kg⁻¹. Depending on leaf analyze results, it was seen that 94.8% of the trees had sufficient B and only 5.2 percent of trees had B deficiency. According to the results, there is not B deficiency in 85 % of the soils. And this reflects the leaf analysis as well. Although this result, there was not seen any correlation between soil and leaf B concentrations. But, there were negative correlations among available soil B and soil pH and Ca. Positive correlations were determined among soil B concentrations and other micro nutrients. While a negative correlation between leaf B concentration and leaf P was found, there was a positive correlation between B and Mn.

Isparta Yöresi Elma Bahçelerinin Bor Durumlarıyla Bazı Toprak Özellikleri Arasındaki İlişkiler

**Anahtar
kelimeler**
Elma
bahçeleri,
Bor,
Isparta

Özet: Bu çalışma, Isparta yöresi elma bahçelerinin bor (B) beslenme durumlarını belirlemek ve B beslenmesiyle bazı toprak özellikleri arasındaki ilişkileri incelemek amaçlanmıştır. Bu amaçla yedi bölgeden 250 bahçe belirlenerek toprak ve yaprak örnekleri alınmıştır. Toprak ve yaprakların B durumları belirlenerek bunlar arasındaki ve diğer bazı toprak özellikleri arasındaki ilişkiler belirlenmiştir. Benzer şekilde diğer yaprak besin elementi içerikleri de belirlenmiştir. Toprak analiz sonuçlarına göre, çoğu toprağın B seviyesinin yeterli olduğu görülmüştür. Bölgelere göre bir değerlendirme yapılırsa, en düşük B düzeyi (0.26 mg kg⁻¹) Senirkent, en yüksek B düzeyi ise (3.44 mg kg⁻¹) Atabeyde belirlenmiştir. Bölgelere bireysel olarak bakılırsa, Gönen ve Keçiborlu da ki bahçelerin tamamının B bakımından yeterli (0.5-2 mg kg⁻¹) olduğu görülmektedir. Aynı zamanda, Yalvaç, Atabey, Gelendost ve Eğirdir bahçelerinin sırasıyla % 71, % 95, % 96 ve % 97' si nin eksiklik düzeyin (0.5 mg kg⁻¹) üzerinde B içerdiği görülmüştür. En fazla B eksikliği sorununa Senirkent ve Yalvaç ta rastlanmıştır. Atabey, Eğirdir, Gelendost, Gönen, Keçiborlu, Senirkent ve Yalvaç için ortalama toprak B düzeyleri sırasıyla 1.32, 0.96, 0.87, 0.67, 0.91, 0.49 ve 0.62, mg kg⁻¹ olarak belirlenirken genel ortalama 0.84 mg kg⁻¹ olarak hesaplanmıştır. Yaprak analizlerine göre ağaçların % 94.8' i B bakımından yeterli, sadece % 5,2lik kısmının yetersiz olduğu görülmüştür. Bu sonuçlara göre toprakların % 85'in de B eksikliğine rastlanmamakta ve bu durum yaprak analizlerinde de görülmektedir. Bu sonuçlara rağmen toprak ve yaprak analiz sonuçları arasında bir korelasyon görülmemiştir. Fakat toprak B konsantrasyonu ile toprak pH sı ve Ca arasında negatif ilişkiler belirlenmiştir. Toprak B konsantrasyonu ile diğer mikro elementler arasında pozitif ilişkiler görülmüştür. Yaprak B konsantrasyonu ile yaprak P konsantrasyonu arasında negatif, B ile Mn arasında ise pozitif ilişkiler belirlenmiştir.

1. Introduction

Boron is one of the important nutrients playing role on sugar transport, cell wall synthesis, carbohydrate metabolism, RNA metabolism, respiration, IAA metabolism, phenol metabolism and etc. Because of many roles of boron on plant physiology, B deficiency can occur as different deficiency symptoms. Because B is a phloem immobile nutrient, B deficiency can result in numerous fruit disorders affecting fruit storability and quality. If a plant has B deficiency, cell wall structure damage and denaturing, cracking, decaying and softening can arise in the some fruits and tuber crops [1, 2]. It is known that apple trees require higher amount of B [3]. Boron is required for pollen germination and pollen tube growth resulting in fruit setting. Therefore, B fertilization may increase yield, particularly when plants are grown on sandy soil with a low content of available B. Although all mechanism of the B has not been well understood, the effect of B fertilization of apple trees on fruit quality can change with the several biological and environmental factors such as cultivar, orchard location, rainfall, air temperature has been well known for many years. Both low and excessive concentration of B in apple trees cause poor fruit quality. Apples with a low B concentration have a short storage life because of the high susceptibility to a break down. On the other hand, high B concentration in apples enhances the incidence of internal disorders, particularly water core and internal breakdown. Also, high B concentration in apples could result in increased decay and decreased fruit firmness [1, 4].

Boron uptake of the plants is in close relation with some soil, plant and environment factors. Even plants grown on a same soil there can have different characteristics for B using ability [5, 6]. Boron uptake by plants decreases with the increase of pH and lime [7]. Soil texture and clay type are other factors effecting plant B nutrition and it is recorded that plants can uptake better B from the coarse texture soils [8]. In regions having more rainfall, coarse texture with low organic matter containing soils don't have sufficient B. But increasing of organic matter in these soils contributes B nutrition of plants [9].

In plant production, yield and quality have close relation with plant mineral nutrient concentrations. So it is required to know sufficient levels of nutrients for desired production. Boron is a nutrient that deficiency and toxicity levels are close in the soils So, keeping the sufficient amount of soil B concentration needs close monitoring.

Soil and leaf analysis are used very often to determine nutritional status of plants and soils fertility status [1, 10, 11, 12, 13, 14, 15, 16, 17, 18]. Nutrient amounts determined with these analyses compare with previously determined standard values. Even sometimes these results completely not meet expected results; these analysis methods are the most trustable ways for determining nutritional status of plants and soils. In this study, it was aimed to investigate the nutritional status of apple orchards in Isparta district.

Table 1. Sampling areas

Districts	Rates in the total apple planted areas in Isparta (%)	The number of the sample	Distribution in the total sample (%)
Atabey	2.2	20	8.0
Eğirdir	24.9	62	24.8
Gelendost	24.4	71	28.4
Gönen	4.0	14	5.6
Keçiborlu	1.0	12	4.8
Senirkent	18.0	21	8.4
Yalvaç	11.6	50	20.0
TOTAL	86.1	250	100.0

Table 2. Soil pH, EC, OM and CaCO₃ status of apple orchards

Districts	pH			EC (dS m ⁻¹)			O.M (%)			CaCO ₃ (%)		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Atabey	7.20	7.78	7.55	0.18	0.68	0.32	0.8	5.7	3.0	1.0	21	9.9
Eğirdir	6.80	7.82	7.47	0.13	0.55	0.23	0.6	6.5	2.9	1.0	46	8.6
Gelendost	7.24	8.07	7.69	0.17	0.68	0.28	0.5	5.8	2.3	1.0	50	17.4
Gönen	7.49	7.99	7.77	0.21	0.71	0.35	1.0	1.7	1.4	34	46	41.0
Keçiborlu	7.69	8.02	7.85	0.22	0.54	0.34	1.4	2.5	1.8	27	39	32.0
Senirkent	7.58	8.05	7.78	0.19	0.72	0.30	0.8	3.4	2.1	9.0	45	30.0
Yalvaç	7.39	8.26	7.82	0.15	0.83	0.24	0.6	4.4	2.4	8.0	46	30.0
Mean	7.71			0.29			2.3			24		

2. Materials and Methods

Study was carried on 250 apple gardens. For this, 7 districts, where intensive apple growing are made, were determined and gardens were tried to be chosen according to production area for each district (Table 1). From these gardens soils (0-30 cm) and leaf samples were taken and brought to the lab and prepared for the analysis as described by Kacar [19] and Jones et al. [10].

Table 3. Soil B variations for individual districts

Districts	B (mg kg ⁻¹)		
	Min.	Max.	Mean
Atabey	0.39	3.44	1.32
Eğirdir	0.32	2.49	0.96
Gelendost	0.39	2.51	0.87
Gönen	0.54	0.85	0.67
Keçiborlu	0.65	1.23	0.94
Senirkent	0.26	0.88	0.49
Yalvaç	0.19	2.08	0.62
Mean			0.84

Table 4. Soil Fe, Cu, Zn, Mn, Ca, Mg, K and P variations for individual districts (mg kg⁻¹)

Districts	Fe			Cu			Zn			Mn		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Ort.
Atabey	2.10	4.23	3.0	2.10	4.23	3.0	2.10	4.23	3.0	Min	Max	Ort.
Eğirdir	1.24	19.21	7.3	1.24	19.21	7.3	1.24	19.21	7.3	1.84	7.0	4.0
Gelendost	2.48	9.35	4.1	2.48	9.35	4.1	2.48	9.35	4.1	0.98	11.71	6.8
Gönen	0.72	3.11	1.9	0.72	3.11	1.9	0.72	3.11	1.9	2.98	12.8	6.6
Keçiborlu	0.88	3.04	1.7	0.88	3.04	1.7	0.88	3.04	1.7	0.6	4.6	2.1
Senirkent	1.83	4.17	2.8	1.83	4.17	2.8	1.83	4.17	2.8	0.8	5.9	2.1
Yalvaç	0.89	5.38	2.7	0.89	5.38	2.7	0.89	5.38	2.7	1.5	9.2	4.6
	Ca			Mg			K			P		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Atabey	2429	7257	4656	214	838	569	186	1403	763	17.2	103.5	60.6
Eğirdir	2086	8039	5102	161	1011	513	42	962	391	1.69	91.26	38.2
Gelendost	2408	9210	5505	134	1105	456	143	2085	559	0.56	104.4	33.8
Gönen	3984	6018	4792	239	936	394	195	1487	466	10.6	59.3	37.7
Keçiborlu	3848	7359	5082	347	1029	749	370	1300	728	0.28	65.9	33.4
Senirkent	4000	8364	5680	354	907	573	177	7316	1361	0.7	84.2	33.6
Yalvaç	4507	12884	6995	119	900	449	158	1124	482	0.28	89.4	21.2

Table 5. Evaluation of the soils in terms of available nutrients

Nutrients	Levels (mg kg ⁻¹)	Evaluation	Number of the samples	Distribution (%)	Nutrients	Levels (mg kg ⁻¹)	Evaluation	Number of the samples	Distribution (%)
P	0-5	Very low	20	8.0	B	<0.5	Low	37	14.8
	5-10	Low	18	7.2		0.5-2.00	Enough	206	82.4
	10-15	Medium	20	8.0		2.0-5.0	High	7	2.8
	15-20	High	23	9.2		>5.0	Very high	0	0
	>20	Very high	169	67.6		Fe	<2.5	Low	60
K	<50	Very low	1	0.4	2.5-4.5		Deficiency can arise	128	51
	50-100	Low	2	0.8	>4.5		Enough	62	25
	100-300	Medium	60	24	Cu	0.2-0.25	Medium	2	0.8
	300-1000	Good	169	67.6		0.26-1.0	Enough	5	2
	>1000	Over	18	7.2		>1	High	243	97.2
Ca	<380	Very low	0	0.0	Zn	<0.2	Very low	0	0
	380-1150	Low	0	0.0		0.2-0.7	Low	73	29
	1150-3500	Medium	14	5.6		0.7-2.4	Medium	126	51
	3500-10000	High	234	93.6		>2.4	High	51	20
	>10000	Very high	2	0.8		Mn	<0.2	Very low	0
Mg	<50	Very low	0	0	0.2-0.7		Low	2	1
	50-160	Low	2	0.8	0.7-5		Medium	123	49
	160-480	Medium	130	52	>5		High	125	50
	480-1500	High	118	47.2					
	>1500	Very high	0	0					

Table 6. Leaf B variations for individual districts

Districts	B (mg kg ⁻¹)		
	Min.	Max	Means
Atabey	31	51	38.9
Eğirdir	26	44	33.1
Gelendost	21	58	32.3
Gönen	10	51	33.2
Keçiborlu	29	43	36.5
Senirkent	21	46	32.2
Yalvaç	20	51	29.6
Mean			33.7

To determine soil available nutrients, P extracted with NaHCO₃ [20], K, Ca, and Mg extracted with NH₄AOC [21] and Mn, Zn, Fe, and Cu extracted with DTPA [22]. Phosphorus measurement was done using spectrophotometer; others were measured with Atomic Absorption Spectrophotometer. Soil texture was determined using hydrometer [23] and CaCO₃ content was measured with calcimeter [24]. Soil organic matter was determined based on Walkley and Black [25]. Soil pH was measured using pH meter in suspension of soil and water at the rates of 1/ 2.5.

In order to determine soil extractable B, 20 g of soil was weighted in to 250 ml flask and 40 ml of 0,01M CaCl₂ solution was added. Suspension was boiled for

5 minutes using re-circulated cooling system. Then solution was cooled until room temperature and filtrated through the blue band filter paper. Boron concentration of filtrate was measured with ICP [19].

For leaf analysis, samples were dried at 65±5°C and were grounded. Afterwards, samples were wet digested with microwave oven and filled up to 50 ml with ultra-pure water. Total nitrogen was analyzed according to Kjeldahl method. Phosphorus concentrations of samples were determined with a spectrophotometer (Shimadzu UV-1208) at 430 nm according to the vanadomolybdo phosphoric acid method. Potassium, Ca, Mg, Fe, Cu, Zn, and Mn concentrations were determined using atomic absorption spectrophotometer. Boron concentration of the leaf was measured using the same filtrate with ICP [26].

For evaluating soil B level, 0.5 mg B kg⁻¹ was accepted as critical concentration [27]. Sufficient leaf B concentration was accepted as 25-40 mg kg⁻¹ [10]. Other classifications were made using the classification chard given in Alpaslan et al., [28]. for the soils and given in Jones et al. [10] for he leaves.

Table 7. Leaf Fe, Cu, Zn and Mn variations for individual districts (mg kg⁻¹)

Districts	Fe			Cu			Zn			Mn		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Atabey	94.1	203.0	135.0	1.4	11.4	5.6	27.3	115.2	49.3	44.4	137.0	85.7
Eğirdir	50.8	205.5	119.2	2.9	19.6	10.3	17.6	158.7	55.6	21.3	254.1	85.1
Gelendost	23.8	280.3	68.0	0.4	12.3	4.9	7.0	129.4	35.3	18.3	122.3	59.3
Gönen	27.6	161.8	65.5	5.4	11.0	7.9	10.9	57.8	21.1	68.1	150.0	107.4
Keçiborlu	43.4	83.4	60.7	7.4	12.8	9.7	6.3	28.1	12.3	101.8	279.9	180.0
Senirkent	27.9	151.6	78.7	8.5	33.1	13.0	5.9	77.5	21.6	60.3	243.8	103.2
Yalvaç	22.1	136.1	71.9	2.5	236.8	13.5	5.4	46.4	18.0			

Table 8. Leaf P, K, Ca, Mg and N variations for individual districts (%)

Districts	P			K			Ca		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Atabey	0.11	0.28	0.17	1.24	2.29	1.78	0.47	1.08	0.84
Eğirdir	0.12	0.31	0.19	0.79	3.15	1.80	0.44	1.98	0.89
Gelendost	0.05	0.47	0.21	0.81	3.63	1.80	0.67	1.97	1.22
Gönen	0.11	0.29	0.15	1.18	2.45	1.74	1.02	2.17	1.38
Keçiborlu	0.09	0.22	0.12	1.18	3.89	2.21	0.97	2.24	1.44
Senirkent	0.12	0.32	0.18	1.29	3.47	2.06	1.23	2.40	1.60
Yalvaç	0.13	0.33	0.20	1.16	2.98	1.88	0.73	2.36	1.21
Districts	Mg			N					
	Min.	Max.	Mean	Min.	Max.	Mean			
Atabey	0.25	0.42	0.35	1.7	3.0	2.5			
Eğirdir	0.24	0.75	0.37	1.7	3.0	2.5			
Gelendost	0.23	0.64	0.39	1.7	3.2	2.5			
Gönen	0.36	0.61	0.44	1.4	2.6	2.2			
Keçiborlu	0.34	1.22	0.71	1.4	2.2	1.86			
Senirkent	0.31	0.72	0.46	1.7	2.8	2.3			
Yalvaç	0.20	0.81	0.36	1.8	3.1	2.4			

Table 9. Evaluation of the leaf nutrient concentrations

Nutrients	Levels	Evaluation	Number of the samples	Distribution (%)
P, %	<0.15	Low	36	14.4
	0.15-0.30	Enough	214	85.6
	>0.30	High	0	0
K, %	<1.0	Low	3	1.2
	1.0-1.6	Enough	69	27.6
	>1.6	High	178	71.2
Ca, %	<1.2	Low	139	55.6
	1.2-2.0	Enough	107	42.8
	>2.0	High	4	1.6
Mg, %	<0.20	Low	0	0
	0.20-0.40	Enough	165	66
	>0.40	High	85	34
N, %	<2	Low	18	7.2
	2-3	Enough	230	92
	>3	High	2	0.8
B, mg kg ⁻¹	<25	Low	13	5.2
	25-40	Enough	214	85.6
	>40	High	23	9.2
Fe, mg kg ⁻¹	<50	Low	60	24
	50-100	Enough	104	41.6
	>100	High	86	34.4
Cu, mg kg ⁻¹	<6	Low	51	20.4
	6-20	Enough	196	78.4
	>20	High	3	1.2
Zn, mg kg ⁻¹	<20	Low	91	36.4
	20-50	Enough	115	46
	>50	High	44	17.6
Mn, mg kg ⁻¹	<30	Low	9	3.6
	30-100	Enough	174	69.6
	>100	High	67	26.8

3. Results and Discussion

3.1. Soil analysis

There is not salinity (EC) problem of the apple orchards and pH of the soils was between 6.80 and 8.26. Lime and organic matter (OM) content of the soils showed wide variation between 1-59% and 0.5-6.5% respectively. Mean values of pH, EC, OM and CaCO₃ was calculated as 7.71 0.29 ds m⁻¹, 2.3% and 24% respectively (Table 2).

If an evaluation was made for each district, the lowest B concentration in the soils was determined in Yalvaç, the highest was determined in Atabey district (Table 2). According to the average values of each district for Atabey, Eğirdir, Gelendost, Gönen, Keçiborlu, Senirkent and Yalvaç, B levels of districts was 1.32, 0.96, 0.87, 0.67, 0.94, 0.49 and 0.62 mgkg⁻¹ respectively. The general mean B value of the all areas was calculated as 0.84 mgkg⁻¹ (Table 3). The other available nutrient variations for each district are given in Table 4. Plant available nutrient concentrations and their evaluations were given in Table 5. As indicated there, all of soils for Ca and most of the soil for P, K, Mg, Mn and Cu are sufficient [28]. Also about 85% of the soils

are sufficient for available B, 15% of the soil is B-deficient [27]. These results represent the 85% of the total apple growing area in Isparta region [29].

3.2. Plant analysis

Boron variations of the apple orchards in each district were given in Table 6. As seen there, while the lowest B concentration was determined in Gönen, the highest was determined in Gelendost orchards. An average B concentration for all orchards was calculated as 33.7 mg kg⁻¹. Variation of leaf Fe, Cu, Zn and Mn concentrations were 22.1-280.3, 0.4-236.8, 5.4-158.7 ve 18.3-279.9 mg kg⁻¹ and the means of them were 87.7, 9.1, 35.0 ve 82.7 mg kg⁻¹ respectively (Table 7). Leaf macronutrient concentrations of the orchards varied between 0.05-0.47% for P, 0.79-3.89% for K, 0.44-2.4% for Ca, 0.20-1.22% for Mg and 1.4-3.2% for N with the means of same orders 0.19%, 1.86%, 16%, 0.40% and 2.42% (Table 8). Looking at the all nutrient values from the all orchards it was seen that only 5.2% of the orchards had B deficiency while the rest had sufficient and high. However, 24% 20.4%, 36.4% and 3.6% of the orchard had Fe, Cu, Zn and Mn deficiency, respectively. At the same time all orchards are rich for Mg, and 85,6% for P, 98,8% for

Table 10. Correlations among some soil properties and soil and leaf B concentrations

	Soil properties											
	pH	EC	OM	CaCO ³	Fe	Cu	Zn	Mn	Ca	Mg	P	Mg
Soil B	-0.49***	ns	0.35***	-0.18**	0.38***	0.36***	0.19**	0.24***	-0.32***	0.17**	ns	ns
Leaf B	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

** : p<0.05, ***: p<0.001, ns: non-significant

K and 92,8% for N are sufficient. The highest nutritional problem was seen in terms of Ca and it was seen that 55,6% of the trees has Ca deficiency [1, 10] (Table 9).

3.3. Relations of B analysis results with the other factors

According to the results obtained there is a significant (p<0.001) relation between soil and leaf B concentrations (Figure 1). Looking at the soil B levels and other soil factors there are negative correlations between B-pH, B-Ca and B- CaCO³. Positive correlations between soil B and other micronutrient were found and this can be expressed that B and Fe, Cu, Zn and Mn are being affected from the same soil conditions [1, 2, 30]. There were not any correlations among leaf B concentration and other parameters (Table 10).

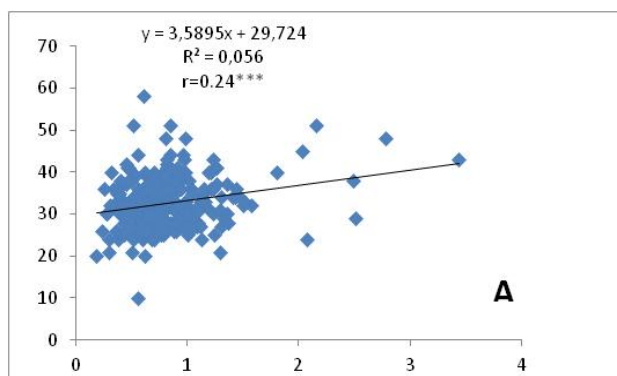


Figure 1. Correlations between soil and leaf B concentration

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