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EFFECT OF NUTRITIONAL STATUS ON FRUIT CRACKING OF FIG (*Ficus carica* L. cv. Sarılop) GROWN IN HIGH LEVEL BORON CONTAINED SOILS

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Abstract

Fruit cracking is one of the important quality parameter in dried fig marketing. Two different research have been carried out to determine the effect of nutritional status on fruit cracking of fig (Ficus carica L. cv. Sarilop) grown in high level boron (B) contained soils of Aydın, Turkey. In the first research, fig trees were grouped depending on cracked fruit ratio. Nutrient contents of soil, leaf and fresh fruit taken from each group were evaluated by cracked fruit ratio of fig trees. In the second study, K_2SO4, NH_4NO_3, $CaCl_2$, $MgSO_4$ and H_3BO_4 fertilizers were sprayed to the trees. Comparing with reference values of leaf and fruit, calcium (Ca) content was low but B content was high while other nutrient contents were in normal range in both experiments. Cracked fruit ratio was given positive correlation coefficients by soil B , leaf B and peel B contents; and negative correlation by soil potassium (K), leaf Ca and peel Ca contents, soil Ca/B, leaf Ca/B, soil Ca/(K+Mg+Na) and fruit Ca/(K+Mg+Na) ratios.

Key words: *Fig tree, fruit cracking, calcium, boron.*

INTRODUCTION

More than 50% of world dried fig is produced in Turkey. Especially Sarılop cultivar is very suitable for drying due to high sugar content, thick pulp and thin skin features (Işın et al., 2003). Some of important quality features in dried fig can be enumerated as disease damage, spots due to excessive moisture or radiation, fruit cracking, eaten by bird or insect (Anonymous, 2006).

Fruit cracking may result from the fluctuation of soil moisture and relative humidity, dry wind or heavy irrigation following a dry spell (Aksoy and Akyüz, 1993; Hepaksoy et al., 2007). Plant cell wall thickness and stability were affected by calcium and also nitrogen, potassium, magnesium and fruit size. In general, these elements were deficient in fig plantation of Great Meander Valley (Aksoy and Anaç, 1993; Aşkın et al., 1997).

Cracked fruit ratio in dried fig is reduced with calcium fertilization (Aksoy and Anaç, 1994). Because, calcium stabilizes cell walls, maintains membrane stability and permeability, alleviates damage that is caused by freezing and thawing stress. Calcium also plays an essential role in all of the basic categories of plant defense against diseases; maintenance of membrane integrity; signalling multiple pathways of defense through enzyme activation; release of phytoalexin, an antimicrobial agent; repair and reinforcement of damaged membranes and cell walls; and synthesis of structural barriers (Marschner, 1995; McLaughlin et al., 1999).

Ficus carica is known as a sensitive crop on boron toxicity (Adriano, 1986). In the saturation extracts of soils, 0.7 mg B kg^{-1} was indicated as the approximate safe limit for sensitive crops including fig tree (Anonymous, 2007). One of the most widespread dried fig plantation area in the world is Germencik-Incirliova belt of Aydin in Turkey. However, this area is under the boron toxicity threaten. In the lowland of Germencik, high (2.0-4.99 mg B kg^{-1}) and toxic level boron (>5 mg B kg^{-1}) contained soil ratio was 75% and 25%, respectively. On the other hand ground water boron content ranged from 0.35 mg B L^{-1} to 4.98 mg B L^{-1} with the mean of 3.3 mg B L^{-1}. This water is not suitable for sensitive and moderately sensitive crops. Nevertheless, it was used in agriculture because of scarcity in irrigation water (Aydın and Seferoğlu, 1999).

Biochemical role of boron is implicated in three main processes: keeping cell wall structure, maintaining membrane function, and supporting metabolic activities (Bolanos et al., 2005). Although considerable agronomic importance, our understanding of B toxicity mechanism is still not completely understood, and remains an open question (Ruiz et al., 2003). Boron toxicity may appear in three ways: (1) disruption of cell wall development; (2) metabolic disruption by binding to the ribose moieties of ATP, NADH or NADPH; and (3) disruption of cell division and development by binding to ribose, either as the free sugar or within RNA (Stangoulis and Reid 2002). Under B toxicity, reactive oxygen species formation and antioxidant enzyme activities are not critical factors of the tolerance mechanism (Karabal et al., 2003).

Increasing Ca content or decreasing B content in fruit skin directly depends on mainly available Ca or B content in soil and transpiration rate (Goldberg, 1993; Tadesse et al., 2001).

There is little research on the nutritional status of dried fig. Effect of Ca and other nutrients on cracked fruit formation in soil contained high level boron is not well understood. Interpretations on this subject were explained mainly by some assumption and clear data were not available. The purpose of this research is to explain effect of nutritional status on cracked fruit formation in dried fig tree.

MATERIALS AND METHODS

Soil Conditions and Fruit Cracking Experiment

This research has been carried out at Erbeyli, Incirliova district of Aydın in Turkey in August 2006. Fig plantation (*Ficus carica* L. cv Sarılop) was about 4 ha and 40-45 years old. Cracked fruit was defined as cracking length was higher than 1/3 of fruit dimension (Anonymous, 2006). Fig trees were grouped depending on cracked fruit ratio as <0.2%, 10-12% and >20% with namely low, moderate and high, respectively at the onset of fruit ripening period in August. Six trees from each group were marked.

Samples were taken as soil from 0-30 cm, leaf from third node and fresh fig fruits with six replications. Physical and chemical properties of soil samples were analyzed by Kacar (1972). For nutrient element analyses, leaf and fruit samples were dried in a forced-air oven at 70°C for 72 hours. The dried leaf samples were ground in a stainless steel Wiley mill. The dried leaf samples were dry ashed in a muffle furnace at 500 °C for 6 h for the determination of P, K, Ca, Mg, and B. The concentrations of Ca and Mg were determined by atomic absorption spectrophotometry (Varian SpectrAA 220FS), K and Na by flame photometry (Jenway PFP7) and P by spectrophotometry (Shimadzu UV-160A) (Kacar, 1972). Total N content of dried leaf samples was analyzed by Kjeldahl digestion method (Kacar, 1972). Boron was determined by azomethine-H method (Wolf, 1974).

Some soil characteristics range of the experimental area were as follows: texture loamy, total salt 0.021-0.024%, organic matter 1.19-1.25%, $CaCO_3$ %2.01-2.84 and pH (1:2.5 water) was 7.58-7.71.

Foliar Fertilizer Experiment

Foliar fertilizer application experiment was established at Tekin, Germencik district of Aydın in Turkey. About 1 ha and 25-30 years old fig plantation was chosen. Average cracked fruit ratio was over 20% in the recent years. Some soil characteristics of the experimental area were as follows: texture loamy, $CaCO_3$ 2.55%, pH (1:2.5 water) 7.76, total salt 0.032%, organic matter 1.31%, total N 0.029 mg kg^{-1}. The concentrations of NH_4OAC extractable K, Ca, Mg and Na were as follows (mg kg^{-1}): 334, 3116, 449 and 41.2 respectively. $NaHCO_3$-available P was 7.76 and Azomethine-H extractable B was 3.72 mg kg^{-1} (Kacar, 1972).

Experimental design was completely randomized with four replications. Treatments were control, K_2SO4, NH_4NO_3, $CaCl_2$, $MgSO_4$ and H_3BO_4. Elemental concentrations of N, P, Ca, Mg and B in the solution were arranged as 0.25% (w/v) and added sodium carboxymethyl cellulose (2.5 mL L^{-1}). Applications were done three times with 8-day intervals starting from 28th of June. Leaf and fruit sampling were taken at the onset of fruit ripening period in August 2007 and carried to the laboratory in cool box. Fruits were peeled manually with a knife, paying attention not to include the fruit pulp. Leaf and peel analysis were done same ways as the first experiment.

Statistical analysis

Data collected from soil and plant samples were analysed with a completely randomized treatment structure. The statistical analysis was performed with the JMP statistical software system (JMP 5.0.1a 1989-2002 SAS Institute Inc.). Mean separations were performed by the LSD-test at a significance level of 0.05.

RESULTS AND DISCUSSIONS

Some chemical properties of soil, leaf and fresh fruit depending on cracked fruit ratio of fig trees are given in Table 1. Soil taken from the first experimental area where fig trees having a high cracked fruits ratio had higher ($p<0.05$) B contents while they have lower in K and Ca contents. In terms of N, P, Mg and Na contents there was no difference among the soil groups.

Table 1. Nutrient contents of soil, leaf and fruit depending on cracked fruit ratio of fig trees

Nutrient content		**Cracked fruit ratio**			**Mean**
		Low (>2%)	**Moderate (8-12%)**	**High (>20%)**	
Soil	N, mg kg^{-1}	0.030	0.029	0.033	0.031
	P, mg kg^{-1}	8.35	9.56	8.23	8.71
	K, mg kg^{-1}	151 a	163 a	115 b	143
	Ca, mg kg^{-1}	1902 a	1840 b	1661 b	1801
	Mg, mg kg^{-1}	299	336	345	327
	Na, mg kg^{-1}	13.2	18.3	15.0	15.5
	B, mg kg^{-1}	2.01 c	2.59 b	3.69 a	2.76
Leaf	N, %	1.52	1.58	1.54	1.55
	P, %	0.076	0.081	0.080	0.079
	K, %	1.273 a	1.062 b	1.165 b	1.167
	Ca, %	1.371 a	1.198 b	1.200 b	1.256
	Mg, %	1.110	1.110	1.168	1.129
	Na, %	0.037	0.048	0.051	0.045
	B, mg kg^{-1}	475 c	527 b	563 a	522
Fruit	N, %	0.631	0.653	0.654	0.646
	P, %	0.105	0.112	0.107	0.108
	K, %	0.632	0.601	0.711	0.648
	Ca, %	0,253	0,207	0,269	0.243
	Mg, %	0,196	0,211	0,185	0.197
	Na, %	0,0082	0,0084	0,0078	0.0081
	B, mg kg^{-1}	169 b	206 a	195 a	190

* Different letters in the same row indicate significant differences ($p<0.05$)

In the leaf samples, K and Ca contents having a high cracked fruit ratio were higher ($p<0.05$) while they were lower in B content. There was no difference ($p<0.05$) among the leaf sample groups for Mg and Na contents. On the other hand, in the fresh fruit sample analysis, statistically differences ($p<0.05$) were found among the B content while K, Ca, Mg and Na contents were not found statistically different.

Evaluation of K, Ca, Mg and Na content in plant tissue is required not only for their specific concentrations but also for their ratio. Mean nutritional problems in the experimental area are low calcium content and toxic level of B supply in soil. Correlation coefficients between cracked fruits ratio and measured observations were given in Table 2. Cracked fruit ratio has a positive correlation coefficient with soil and leaf B contents ($p<0.01$); and negative correlation with soil K and leaf Ca contents, soil Ca/B, fruit Ca/(K+Mg+Na) ratio ($p<0.01$), leaf Ca/B and soil Ca/(K+Mg+Na) ratio ($p<0.05$).

Table 2. Correlations between some nutritional status components and cracked fruit ratio of fig trees

Correlations with cracked fruit ratio	Correlation coefficients		
	Soil	Leaf	Fruit
N	0.386	0.012	0.126
P	-0.081	0.076	0.125
K	-0.508*	-0.133	0.279
Ca	-0.751**	-0.596**	0.184
Mg	0.219	0.297	-0.199
Na	0.170	0.218	-0.011
B	0.899**	0.577**	0.145
K/Ca	-0.398	0.102	0.188
K/B	-0.914	-0.451	0.136
Ca/(K+Mg)	-0.206	-0.307	-0.022
Ca/(K+Mg+Na)	-0.536*	-0.389	-0.639**
Ca/B	-0.932**	-0.520*	0.146

* and ** denote significant r values at $p<0.05$ and $p<0.01$ respectively

In the second study, there were some boron toxicity symptoms in leaf blades at the beginning of the experiment. However, foliar fertilizer applications did not result in any extra damage on leaf and fruit in fig trees. The fruit maturity delayed about 4 days in ammonium nitrate applied trees. Effect of foliar fertilizer applications on nutrient content of leaf and fresh fruit peel was shown in Table 3. In generally, N, K, Ca, Mg, B content of leaf and peel increased statistically in respect to relevant nutrient source as ammonium nitrate, potassium sulphate, calcium chloride, magnesium sulphate and boric acid respectively. Only peel Mg concentration was not changed statistically.

Table 3. Effect of foliar fertilizer applications on the leaf and peel nutrient content and cracked fruit ratio of fig trees

Nutrients	Control	NH_4NO_3	K_2SO_4	$CaCl_2$	$MgSO_4$	H_3BO_4
			Leaf nutrient contents			
N, %	1.38 b*	1.54 a	1.36 b	1.30 b	1.33 b	1.32 b
K, %	1.59 b	1.52 b	1.87 a	1.54 b	1.64 b	1.52 b
Ca, %	1.89 b	1.96 b	1.92 b	2.45 a	1.98 b	1.95 b
Mg, %	0.98 b	0.98 b	1.03 b	1.04 b	1.36 a	0.99 b
B, mg kg^{-1}	418 b	382 b	315 b	391 b	412 b	570 a
			Peel nutrient contents			
N, %	0.49 b	0.53 a	0.47 b	0.47 b	0.44 b	0.48 b
K, %	0.99 b	1.16 b	1.23 a	1.09 b	1.19 b	1.18 b
Ca, %	0.63 b	0.63 b	0.67 b	0.80 a	0.67 b	0.61 b
Mg, %	0.11	0.12	0.11	0.11	0.14	0.11
B, mg kg^{-1}	33.1 b	33.2 b	33.0 b	29.7 c	33.0 b	35.7 a
			Cracked fruit ratio			
	33.7 b	29.1 bc	28.6 c	10.0 d	30.0 bc	42.9 a

*Different letters in the same row indicate significant differences ($p<0.05$)

Cracked fruit ratio was affected significantly by foliar fertilization (Table 3). It was lowest (10.0) in $CaCl_2$ and highest (42.9) in H_3BO_4 treatments. The order was $CaCl_2$< K_2SO_4< NH_4NO_3< $MgSO_4$< Control<H_3BO_4 with the values of 10.0, 28.6, 29.1, 30.0, 33.7 and 42.9, respectively. Comparing with the control, cracked fruit ratio was decreased significantly in Ca and K applications. According to Duncan's multiple range test, boric acid placed in the first place followed by control and the last group was formed by ammonium nitrate, potassium sulphate, and magnesium sulphate.

Using the mean values of treatments, cracked fruit ratio was positively correlated by peel B content as Y= 5.530B-153.2 (R^2=0.965), and negatively correlated by peel Ca content as Y=-146.9Ca+127.2 (R^2=0.895). Similar trends were found for leaf Ca and B concentrations. Nevertheless, their determination coefficient values were lower than that of fruit skin's.

The mean values of the experiment were evaluated as similar for N, K and Mg; low for Ca; high for B when they compared with the relevant studies in the region. For example, reference values of mineral elements in dried fig leaf were found for N, P, K, Ca, Mg as 1.695-1.709%, 0.088%, 1.070-1.161%, 3.568-3.614%, 0.658-0.721%, respectively (Aksoy et al., 1987). Calcium concentration in the fig leaf varied 0.68-2.98 % from April to November (Ersoy et al., 2003) and 2.22-5.78% at the fruit maturity (Anaç et al., 1987).

Several researchers showed that cracked fruit ratio in fig was decreased by Ca applications (Aksoy and Anaç, 1994; Hepaksoy et al., 2007). However, calcium movement into the fruit decreases as the season progresses. Mg, K, P, and N increase along with the translocation of photosynthesis. This reduces the ratio of Ca with other elements, particularly Mg and K that it may result in the physiological disorder (Tadesse et al., 2001).

Fig plant is known as sensitive to boron toxicity (Anonymous, 2007). In the experimental area soil boron concentration ranged from 1.60 to 3.94 mg kg^{-1} that is quite high for sensitive crops (Silanapaa, 1990; Anonymous, 2007). Soluble B concentrations play a major role in the occurrence of B toxicity symptoms (Wimmer et al., 2003). The intercellular soluble B concentrations of basal leaf parts of nonsalt-stressed wheat plants closely reflected the external B supply. The slight tendency towards higher intercellular soluble K^+ concentrations might indicate some membrane damage resulting in higher K^+ leakage into the apoplastic space (Wimmer et al., 2003).

Molassiotis et al. (2006) reported that boron toxicity resulted in increasing ROS activities in apple. Excess boron applications enhanced lipoxygenases (LOX) activity, lipid peroxidation (measured as MDA content) and H_2O_2 accumulation and resulted in diminution of the proline (PRO) content. This kind of processes was likely happened in our study. Besides, Ca deficiency in plant tissue decreased cell wall strength. Thus, fruit cracking increased.

In this study, Ca concentrations were about half of the reference values while B concentrations were was about 4/3 of toxic level in the fig leaves (Jones et al., 1991). In terms of cell wall stability, both cases had a negative effect. Thus, Ca and B contents with Ca/B ratio in soil and plant tissue are main factors on fruit cracking. Although available K content of soil range was close to optimum level, it was effective on fruit cracking. In addition, low tissue Ca content resulted in negative significant correlations between Ca/(K+Mg+Na) ratio and fruit cracking. Because there are antagonistic relations between Ca and other alkalines such as K, Mg and Na (Marschner, 1995).

CONCLUSIONS

The result of present study indicates that Ca and B contents with Ca/B ratio in soil and plant tissue are probably main factors on fruit cracking. Increasing B, K, Mg and Na uptake increases severity of Ca deficiency with the result of higher cracked fruit ratio. These parameters with biochemical composition of fruit skin can be further investigated and tested in screening for cracking.

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