The Effects of Foliar Applications of Nitrogen, Boron, and Zinc on the Fruit Setting and the Quality of Almonds

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Abstract: Fruit drop in orchards of almonds (*prunus amygdalus L.*) is one of the major problems encountered by producers of fruit in Iran. Nutritional elements, particularly nitrogen and boron, have an effective role in this issue. To study the effect of these elements, a factorial experiment was done based on randomized complete blocks with 18 applications and three repetitions – altogether, 108 8-year-old Azar trees were tested in the county of Shabestar during 2002 and 2003. The first factor was nitrogen supplied from a urea source in two levels (zero and 5000 ppm), the second factor was boron from a boric acid source in three levels (zero, 2000 ppm and 4000 ppm), and the third factor was zinc supplied by a source of zinc sulfate in three levels (zero, 2000 ppm and 4000 ppm). The highest percentage of fruit setting (24 percent) was measured at the third levels of boron and zinc. The highest final fruit setting percentage (15 percent) was obtained for second- and third-level boric acid. Also, the highest single kernel weight (2.4 grams) was measured for combined foliar application with 5000-ppm urea and 4000-ppm boric acid. The highest kernel percentage (14 percent), on the other hand, was achieved with third-level boron. The highest fruit length (4.4 centimeter) was also obtained for third-level boron. Furthermore, second- and third-levels of boric acid led to the highest fruit width (3.1 centimeter). The highest oil percentage measured (53 percent) was observed for third-level zinc without applying nitrogen. The highest hard shell percentage (22 percent) was obtained when combined foliar applications of second-level nitrogen and second- and third-level boric acid were used. On the other hand, the highest protein percentage (23 percent) was measured for the combined foliar application of urea and third-level boric acid. No significant simple or interactive year by location effects were obtained for any of the fertilization applications.
[Mohammad Taher Nezami. **The Effects of Foliar Applications of Nitrogen, Boron, and Zinc on the Fruit Setting and the Quality of Almonds.** *Life Sci J*:9(4):1979-1989]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 297

Keywords: nitrogen, boron, zinc, initial fruit setting, final fruit setting, almonds

Introduction:

Despite ranking fourth in the world in the production of almonds, Iran lacks in performance and quality in this field. Therefore, considering the role this product can have in increasing exports and bringing in foreign currencies, ways to enhance performance should be examined and determined. One of the factors leading to decreased performance is mismanagement particularly in the case of the lack of nutrients, a problem that crucially needs to be resolved. As Vezvaee and Ghaderi (1999) have reported in Karaj, autumn foliar applications of boric acid and zinc sulfate brought about an increase in fruit setting from 18.5 percent in the control application up to 39.5 percent in the combined application of boron and zinc. As reported for Italian plums by Hanson (1985), autumn foliar applications of boron led to 15 percent increases in fruit setting as well as lowered ovary lengths in trees without boron deficiency. Mahyoub et al. (1993) brought about considerable increases in apricot yields by means of combined foliar applications of boron along with nitrogen. Ahmad and Abddel (1995) reported that foliar applications of boron, nitrogen and zinc on oranges leads to higher product yield, fruit weight and diameter, extent of dissolved solid matter and total sugar content. As reported by Salem (1996), the application of iron, zinc and nitrogen raises the number and amount of tangerine yields. This researcher reported that autumn applications of 5000-ppm zinc sulfate and urea causes noticeably higher fruit settings. Nyomora et al. (1999) concluded that foliar applications of 1 percent boric acid in the autumn following harvest – when active green surfaces for sufficient boron intake existed – led to considerably higher amounts of boron in the almond plants' internal organs as well as 22 percent increases in fruit setting and 15 percent raises in product yield.

Furthermore, Nyomora et al. (1995 and 1997) concluded that autumn foliar applications of boron upon the flower leaves and stigmas led to 20 and 25 percent increases of the concentrations of this element respectively as compared to the control application. These researchers concluded that boron deficiency brings about slower growth and thus delayed flowering in almonds. When boron deficiencies occur, the stamen loses its spore tissue, and part of the plant's reproductive organs is injured. In such circumstances, the stamens have lower capacities for producing pollen, and the size and the growth of the pollens is thus affected. Chaplin et al. (1977) presented a theory based upon which boron exists in the pollen tube along with callose compounds. With boron deficiencies, callose increases, and pollen tubes grow and evolve with difficulty. Furthermore, nitrogen and carbohydrates accumulate in the leaves when there is insufficient boron. They concluded that autumn foliar applications of boron at concentrations of 5000 milligrams per kilograms upon Italian plum trees had no effect upon spring fruit setting, when the amount of fruit wetting was already high (12.2 percent) with suitable temperature; however, in early cold springs, when temperatures ad also fruit settings are low (3.2 percent), there was a 32 percent increase in fruit setting. The amount of boron existing in plum fruits is often insufficient for appropriate fruit setting. Autumn foliar applications of boron led to 115 percent increases in fruit settings and 40-100 percent performance enhancements in Italian plums; no signs of boron deficiencies were observed in the leaves, either. Using foliar applications of boron and zinc on oranges, Quin (1996) brought about considerable increases in pollen tubes, fruit settings, product yield and fruit sugar contents. Moreover, as indicated by the findings made by Supriya et al. (1995) on lemons, foliar application with zinc decreased the amount of potassium in the leaves. Spark (1998) also observed that foliar application with zinc lowered the amount of magnesium in the leaves. This research has endeavored to examine the effect of foliar applications of nitrogen, boron and zinc upon the fruit setting and some other characteristics of almonds.

Table 1. The results for leaf analysis made for major almond production in the province

element region	percentage			milligrams per kilogram			
	nitrogen	phosphorous	potassium	iron	manganese	zinc	boron
Azarshahr	2.2	0.32	1.4	96	46	15	25
Bonab	1.9	0.33	1.5	86	72	14	46
Shabestar	1.8	0.30	1.7	97	66	13	23
Maragheh	2.2	0.32	1.9	79	71	19	24

It should be noted that the figures for each column have been derived from the means for 10 orchards.

As seen in Table 1, most groves in the province show deficient or average amounts of nitrogen, zinc and boron. In the regions of Bonab and Shabestar, there is lack of nitrogen, and the amount of nitrogen in the region of Azarshahr is also at the minimum desirable level. In the regions of Azarshahr, Bonab and Shabestar, zinc exists at desirable levels. Boron, on the other hand, proves to be lacking in the regions of Azarshahr, Shabestar and Maragheh, whereas it is at a desirable level in the region of Bonab. Thus, the region studied is lacking in fertilizers, and greater need than before for the area to be studied (Malakouti and Gheibi, 2000). There clearly must be a correlation between the consumption of these elements and enhanced fruit settings. Nevertheless, despite the desirable amount of some elements, the foliar applications of nitrogen, boron and zinc have proved to be influential upon fruit setting percentage. This research has merely attempted to study and compare the effects of the consumption of nitrogen, zinc and boron upon the amount of fruit setting. The aim of the present study has been focused only on the effects of the elements concerned in the study rather than quantitative factors.

Methods and Materials

This project was conducted as a factorial experiment based upon randomized complete blocks with 18 applications and three repetitions – altogether, 108 8-year-old Azar trees were tested in the county of Shabestar (the Teel Production Cooperative) during 2002 and 2003. The trees included in the study were 8 years old. The orchard studied included Sahand, Nonperiel and Monagha almonds, and was a combination of pollinating and pollen-accepting. The first factor was nitrogen, supplied by an urea source in two levels (zero and 5000 ppm), the second factor was boron supplied from a source or boric acid in three levels (zero, 2000 ppm and 3000 ppm), and the third factor was zinc from a source of zinc sulfate in three levels (zero, 2000 ppm and 4000 ppm). The trees were first selected and labeled based upon the research plan and the applications. Around a month after harvesting the product, foliar applications of boric acid, zinc sulfate and urea were carried out. Applications were done in the evening to facilitate better absorption. About 0.05 percent of Citowett solution was added to nutrient solutions as foliar wash. The control application was sprayed with water and washing material. About 10 liters of solutions was consumed for each tree. Half of the nitrogen fertilizer was used in Esfand, and the other half was applied in Khordad. For each tree on the first location, 800 grams of urea, 500 grams of triple superphosphate, 600 grams of potassium sulfate, 50 grams of iron chelate and 1500 grams of manganese sulfate were used; 350 grams of urea, 250 grams of triple superphosphate, 100 grams of iron chelate and 300 grams of manganese sulfate were used for the second location. During the growth season, measures were taken to contest pests, diseases and weeds. The soil the almond trees were planted in and also the irrigation water used on location were analyzed (Tables 2 and 3). In this experiment, trees of almost the same size were selected in rows, and one branch of each was marked. Thus, even branches located on geographically equal sides of the trees in the experiment were chosen; five fertile branches with diameters of approximately 2.5 centimeter and from the same geographical side were selected from each tree. Equal numbers of pollinating and pollen-accepting trees of the orchard have been used. Counting was carried out 30 days after initial fruit setting and 60 days after final fruit setting, thus determining the number of flowers, and subsequently, the number of fruit formed and the percentage of fruiting. The concentration of nutrients in the nitrogen fertilizer applications were measured using wet ash methods and Auto Kjeldal; for phosphorous, spectrophotometers were used, whereas flame photometry was used for potassium and dry-ash methods along with atomic absorption were used to measure trace elements. Furthermore, quantitative factors such as single fruit weight, kernel percentage, fruit length and width, oil percentage (using the Soxhlet method), single kernel weight, hard shell percentage and protein percentage were also measured.

Table 2. The results of analyses made on the soil of the study locations during 2002-3 at the Shabestar Teel Cooperative

year	soil depth (cm)	EC dS/ m^{-1}	pH	Percentage of neutralized material	organic carbon (%)	**milligrams per kilogram**						soil tissue
						phosphorous	potassium	iron	manganese	zinc	boron	
The 1st location	0-30	1.2	8.1	10	0.62	11	200	4.9	5.2	0.28	0.4	L.S
The 2nd location	0-30	1.1	8.2	12	0.41	5	120	4	3.6	0.20	0.31	L.S
The 1st location	0-30	1.7	8.2	14	0.51	10	220	4.8	4.9	0.22	0.39	S.L
The 2nd location	0-30	1.6	8.2	23	0.38	4	110	3.5	3.2	0.18	0.22	S.L

Table 3. The results for the chemical analysis of the irrigation water

EC ($dS.m^{-1}$)	milliequivalents per liter				pH
	bicarbonate	chlorine	calcium	magnesium	
0.120	2.7	0.5	2.6	0.5	8.1

Results:

The soil of the region had no salinity problems, was highly alkaline, and moderate in lime; on the other hand, organic compounds, phosphorous, potassium, iron and manganese were at moderate levels, whereas deficiencies were seen in trace elements such as zinc and boron. The water in the region had no salinity problems, and was to some extent alkaline.

Table 4. The effect of various applications upon the concentrations of various nutrients in almond tree leaves

Milligrams per kilogram of dry plant matter					**Percentage in dry plant matter**					**Factor / Application**
boron	copper	zinc	manganese	iron	Mg	Ca	K	P	N	
26 C	4/8 A	8/5 C	39 A	46 AB	0/42 A	3/21 AB	1/56 A	0/24 A	1/86 B	$N_0B_0Zn_0$
25 C	5/1 A	25 B	40 A	45 AB	0/39 A	3/20 AB	1/52 A	0/21 B	1/97 B	$N_0B_0Zn_1$
27 BC	5 A	25 A	42 A	46 AB	0/45 A	3/33 A	1/50 A	0/21 B	1/87 B	$N_0B_0Zn_2$
30 B	4/9 A	10 C	40 A	45 AB	0/42 A	3/28 AB	1/52 A	0/25 A	1/98 B	$N_0B_1Zn_0$
39 B	5 A	15 C	42 A	40 B	0/45 A	3/29 AB	1/48 AB	0/22 AB	1/96 B	$N_0B_1Zn_1$
40 AB	5/1 A	27 A	40 A	42 B	0/43 A	3/30 AB	1/49 AB	0/20 AB	1/87 B	$N_0B_1Zn_2$
42 AB	5/5 A	11 C	41 A	45 AB	0/44 A	3/32 A	1/51 A	0/26 A	1/88 B	$N_0B_2Zn_0$
42 AB	5/2 A	17 C	42 A	47 A	0/45 A	3/31 AB	1/50 A	0/22 AB	1/78 B	$N_0B_2Zn_1$
43 AB	4/9 A	26 A	41 A	48 A	0/43 A	3/30 AB	1/49 A	0/20 B	1/82 B	$N_0B_2Zn_2$
29 BC	4/8 A	14 C	39 A	45 AB	0/45 A	3/66 A	1/48 AB	0/24 A	2/1 A	$N_1B_0Zn_0$
28 BC	4/7 A	21 B	40 A	47 A	0/44 A	3/52 A	1/47 AB	0/21 B	2/15 A	$N_1B_0Zn_1$
30 B	4/6 A	27 A	42 A	48 A	0/43 A	3/48 A	1/49 A	0/19 B	2/12 A	$N_1B_0Zn_2$
40 AB	4/5 A	13 C	41 A	46 AB	0/42 A	3/36 A	1/50 A	0/23 A	2/15 A	$N_1B_1Zn_0$
42 AB	4/7 A	19 B	41/5 A	45 AB	0/45 A	3/42 A	1/51 A	0/21 AB	2/17 A	$N_1B_1Zn_1$
43 AB	4/9 A	24 A	42 A	46 A	0/43 A	3/5 A	1/52 A	0/20 AB	2/19 A	$N_1B_1Zn_2$
45 A	4/6 A	14 C	41 A	47 A	0/42 A	3/52 A	1/51 A	0/24 A	2/11 A	$N_1B_2Zn_0$
48 A	4/7 A	21 B	39 A	46 A	0/45 A	3/6 A	1/51 A	0/23 A	2/12 A	$N_1B_2Zn_1$
49 A	4/8 A	29 A	40 A	45 AB	0/44 A	3/5 A	1/50 A	0/22 AB	2/18 A	$N_1B_2Zn_2$

The averages with similar letters in each column show no significant difference at a 5 percent level (Duncan's multiple range test)

As seen in Table 4, the amount of nitrogen in the leaves shows a significant increase in level N_1 compared to N_0. The amounts of phosphorous, potassium, manganese and copper in the leaves, on the other hand, show no significant difference in all applications. Enhanced levels of zinc and boron, however, leads to considerably higher concentrations of these elements in the leaves. The main effects of nitrogen, zinc and boron on product performance became significant at one percent probability levels, and the highest performances (4.6 and 4.9 tons per hectare) were obtained through the third-level foliar applications of zinc and boron, respectively. As seen in the results displayed in the variance analysis table, the main effects of nitrogen, zinc and boron levels at one percent probabilities upon initial almond fruit setting prove to be significant. The highest initial fruit setting was measured at third-level zinc (4000 ppm) (Figure 3). Moreover, the highest initial fruit setting was measured at third-level zinc (4000 ppm) (Figure 4). The main effects of nitrogen and boron levels upon final fruit setting percentage became significant at a one-percent probability. Furthermore, the highest percentages of final fruit settings were obtained by second- and third-level boric acid (Figure 5). The main effects of nitrogen and boron upon the weight of single almond fruits became significant at the probability of one percent. The second and third levels of boric acid showed the highest weight for a single fruit in grams (Figure 6). Furthermore, the main effects of nitrogen and boron levels upon shelled almond percentages proved significant at a one-percent probability. The highest shelled percentage (15.6 percent) was obtained at third-level boron (4000 ppm) (Figure 7). The main effects of nitrogen and boron levels upon the length of almond fruits became significant at the probability of one percent. The highest fruit length (4.4 centimeter) was measured at third-level boron (Figure 8). Moreover, the main effects of nitrogen and boron levels on the width of almond fruits became significant at a one-percent probability. The highest width obtained for almond fruits was for second- and third-level boric acid (Figure 9). The main effects of nitrogen and boron levels for shelled almond percentages also proved significant at a one-percent probability. The highest percentage of shelled fruit was obtained for third-level zinc (4000 ppm zinc sulfate) as compared to control (Figure 10). The main effects of nitrogen and zinc levels upon almond oil percentage were shown as significant at the probability of one percent. The highest oil percentage was measured as compared to control at second and third levels of zinc (Figure 11). The main effects of nitrogen and boron levels at a one-percent probability and the mutual effects of nitrogen and boron at 5-percent probabilities proved to be significant upon the weight of a single shelled almond. The highest weight of single shelled almond fruits were obtained by simultaneous foliar applications of 5-per-thousand concentrations of urea and 4000-ppm concentrations of boric acid (Figure 12). The main effects of nitrogen at a one-percent probability, the main effect of boron, and the mutual effect of nitrogen and boron at a 5-percent level of probability upon hard almond shell percentage also proved to be significant. The highest percentage of hard shell was obtained for foliar application simultaneously with second-level nitrogen alongside second- and third-level boric acid (Figure 13). The main effect of nitrogen and boron levels and also the mutual effects of nitrogen and boron upon almond protein percentage became significant at a probability level of one percent. The highest percentage of protein was resulted in by simultaneous foliar applications of urea and boric acid (Figure 14). The main effects of nitrogen and zinc at one-percent probability levels and the mutual effect of nitrogen and zinc at a 5-percent probability level showed to be significant.

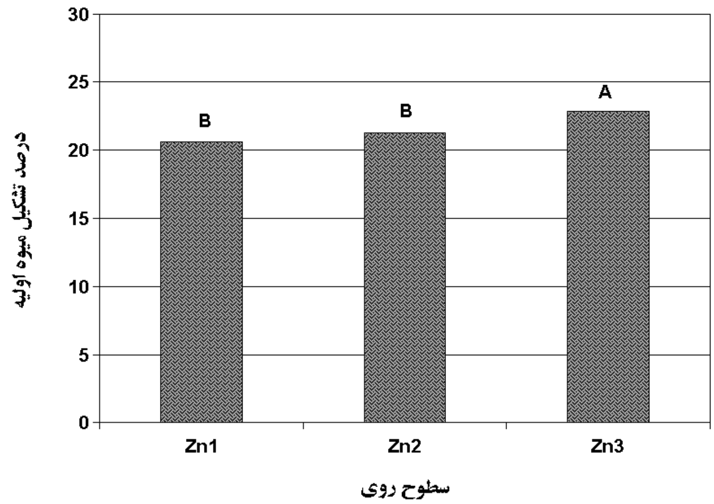

Figure 1. The effect of various levels of zinc upon initial almond fruit setting percentage

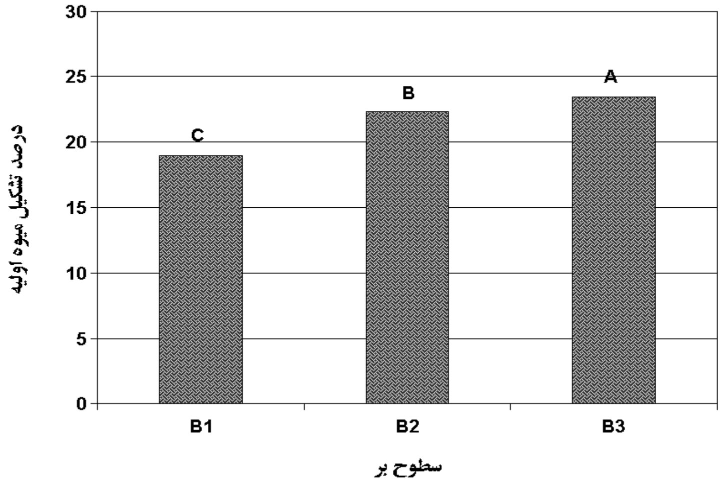

Figure 2. The effect of various levels of boron upon initial almond fruit setting percentage

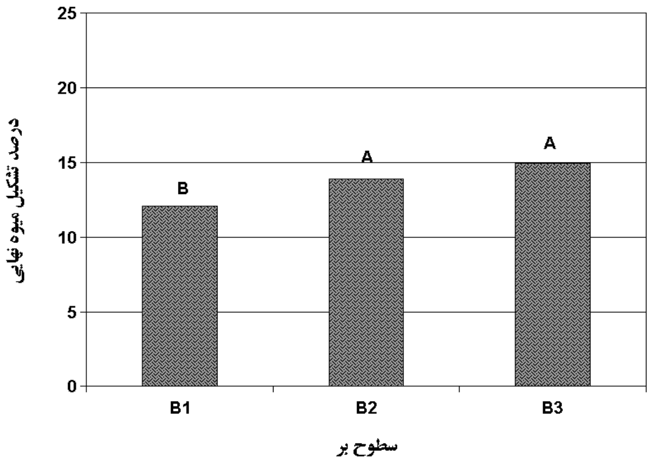

Figure 3. The effect of various levels of boron upon final almond fruit setting percentage

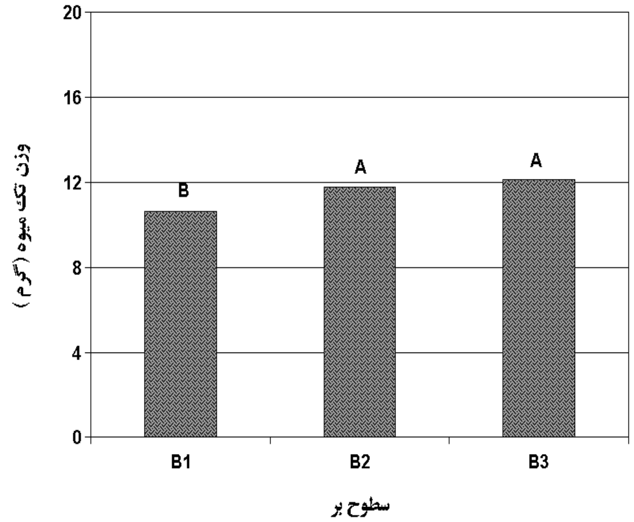

Figure 4. The effect of various levels of boron upon the weight of a single shelled almond

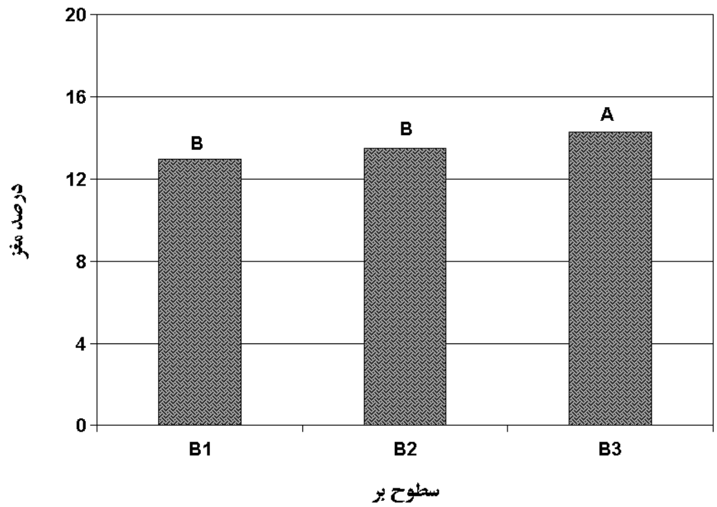

Figure 5. The effect of various levels of boron upon shelled almond percentage

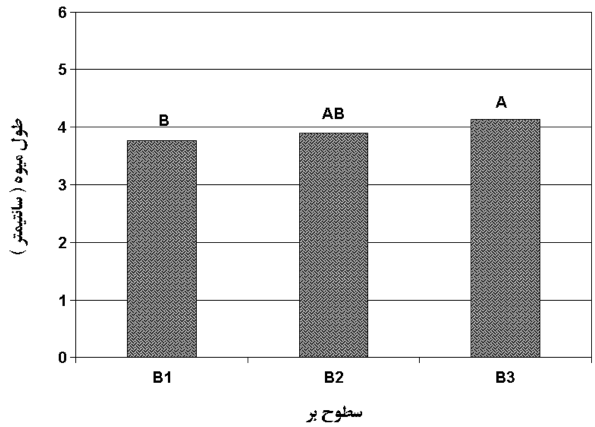

Figure 6. The effect of various levels of boron upon the length of the almond fruit

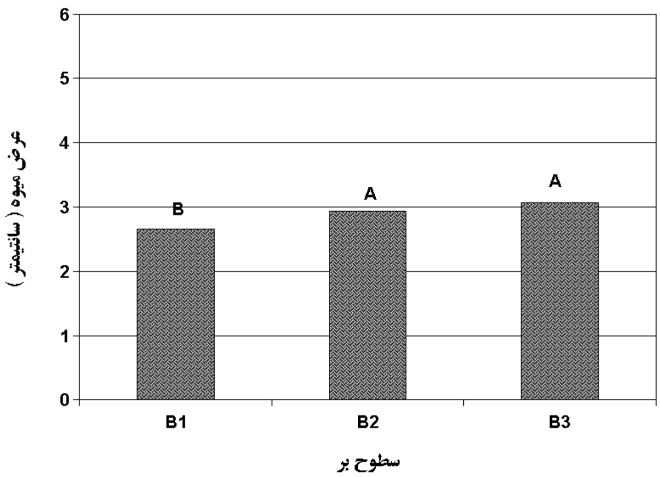

Figure 7. The effect of various levels of boron upon the width of the almond fruit

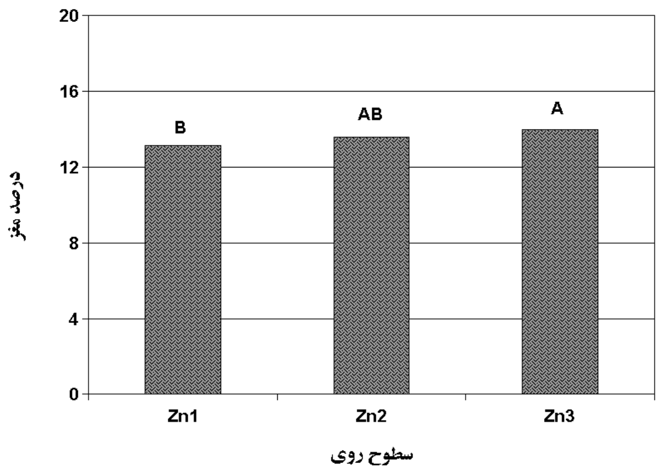

Figure 8. The effect of various levels of zinc upon shelled almond percentage

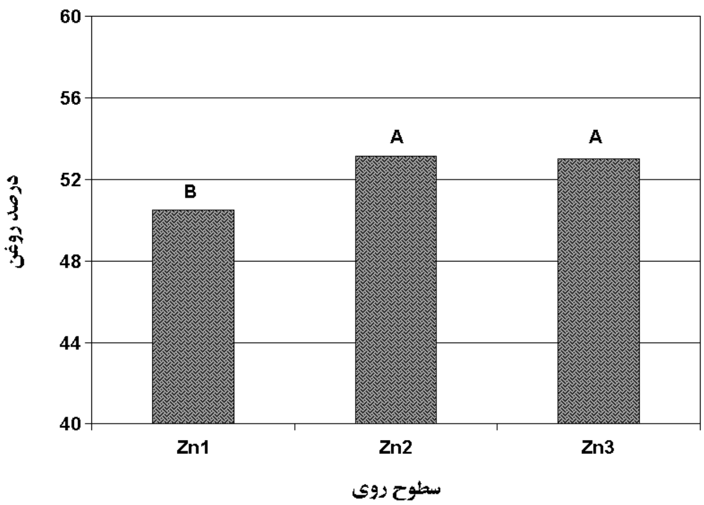

Figure 9. The effects of various levels of zinc upon shelled almond oil percentage

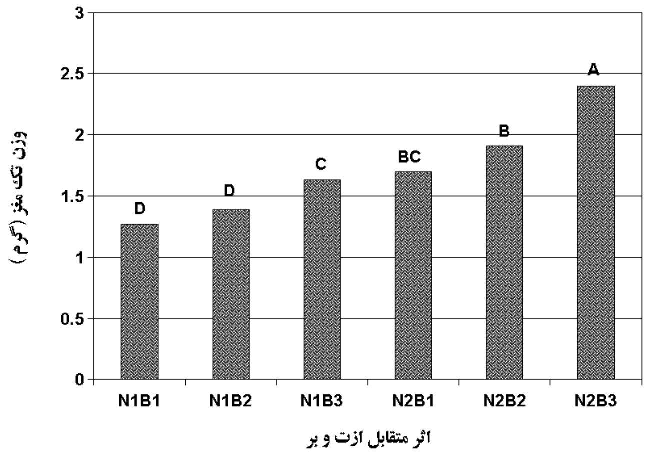

Figure 10. The effect of various levels of nitrogen and boron on the weight of a single kernel

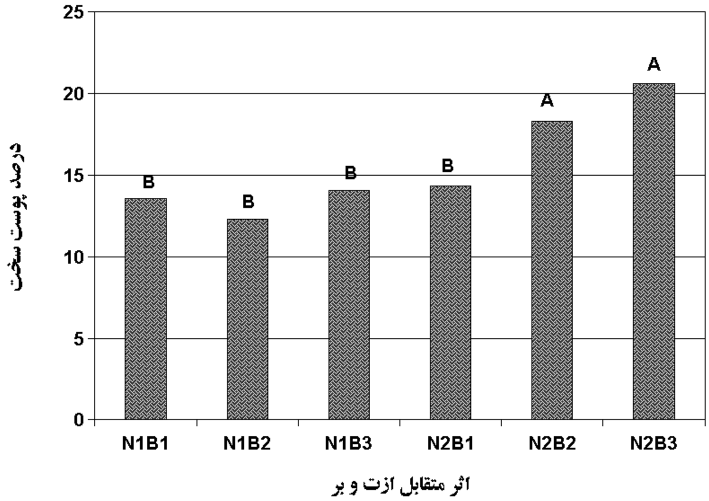

Figure 11. The effect of various levels of nitrogen and boron on the percentage of hard almond shell

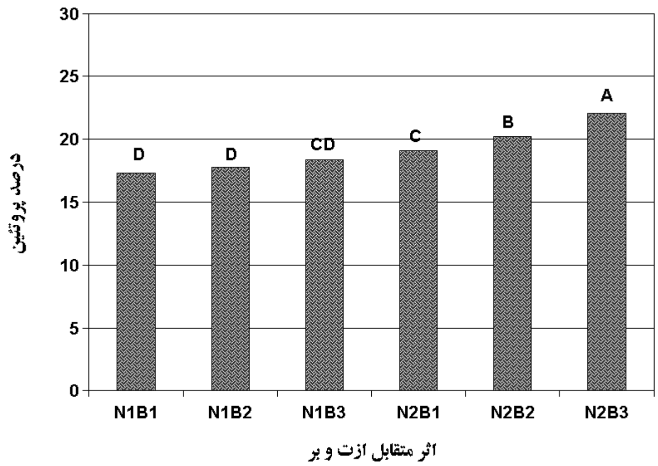

Figure 12. The effect of various levels of nitrogen and boron on almond protein percentage

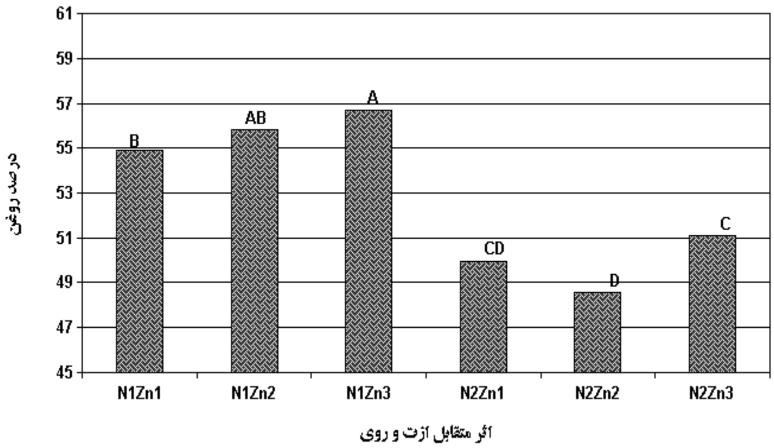

Figure 13. The effects of various levels of nitrogen and zinc upon the percentage of almond oil

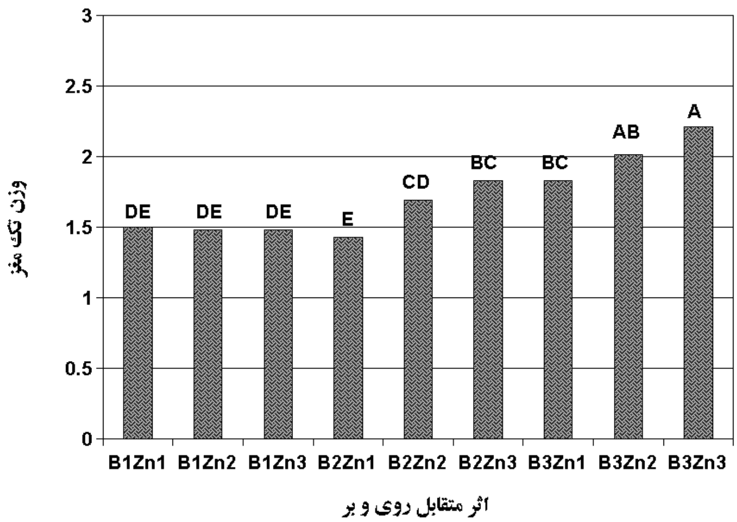

Figure 14. The effects of various levels of boron and zinc upon the weight of a single kernel

The main effects of nitrogen and boron levels at a one percent level of probability and the mutual effects of nitrogen and zinc at a 5 percent probability level proved to be significant upon the percentage of almond oil. The foliar application of third-level sulfate without nitrogen consumption provided the highest percentage of oil (Figure 13). Higher nitrogen consumptions do not seem to have decreased almond oil percentages. Furthermore, the variance analysis table shows that the main effects of nitrogen, boron and zinc amounts as well as the mutual effects of nitrogen and boron upon the weight of a single shelled almond became effective. As seen in Figure 14, the highest weight for a single shelled almond was obtained through simultaneous foliar applications of zinc sulfate (4 per thousand) and boric acid (4 per thousand). No significant simple or mutual effects of years or locations brought about by fertilization applications were observed.

Discussion and Conclusion

based on the results obtained, the foliar application of boron led to a significant increase in the amount of final fruit setting, which was not unexpected given the low amounts of this element in the soil and in the sample leaves of the location studied. It is obvious that sufficient amounts of boron are vital for fruit setting, and the existence of this element is necessary for pollen tube growth. In some cases, pollen budding depends only upon the existence of sufficient amounts of boron in the stigma. Boron also increases nectar amounts and decreases the length of the calyx tube, thus making it easier for bees to be attracted to flowers (Agarwala and Sharma, 1981). Moreover, foliar applications of sulfate showed significant effects on the amount of initial fruit setting. In their studies upon the effects of foliar applications of zinc and boron on cherry fruit setting, Usenik and Stampar (1999) concluded that simultaneous foliar applications of zinc sulfate and boric acid led to significant increases in initial fruit settings. These researchers attributed the impact of these elements to pollen tube growth, the existence of sufficient pollen and longer fertilization time. Third-level foliar application of boron also led to enhanced quantitative factors such as single fruit weight, almond kernel percentage, almond fruit length and almond fruit width. With deficient boron, the process of cell division is disrupted in all plants, including almonds, and does not occur fully. This indicates irregular, incomplete cell division, which leads to weak leaf development, resulting in lower photosynthesis rates and hence decreased carbohydrates, certainly impacts the qualitative factors of the product. Considering the low amount of boron in the soil of the location studied and as shown in leaf analyses, the intake and supplying of this element seems to have been carried out with difficulty. Sotomayor and Castro (1999) concluded that if the amount of boron in flower stigmas is lower than 35 milligrams per kilogram, fruit setting decreases considerably. Sotomayor et al. (2000) also reported that in Nonpareil almonds, foliar applications of boric acid with 4000 ppm concentrations enhanced final fruit setting by 27.7 percent, and by 23.4 percent for zinc foliar applications. Moreover, combined foliar applications of zinc and boron brought about 38.1 percent increases in final fruit setting and 15 percent increases in almond performances. Carol (2000) stated that autumn 5000 ppm foliar applications of zinc sulfate after harvesting the product led to 17 percent enhancements of fruit setting in the following year. The role of boron and zinc in increasing the amounts of oil and protein in almond fruits probably lies in the positive effects of these elements in nucleic acid compounds, perimidine and some cellular reactions such as starch biosynthesis. It seems that foliar applications of urea have also led to slightly significant positive effects upon fruit setting percentage and other quantitative factors.

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11/8/2012