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Effect of foliar application of iron on seasonal changes of some physical and chemical properties in berries of Halwani Lebanon grape cultivar (*Vitis vinifera* L.)

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A field experiment was conducted in 2009 and 2010 growing seasons, to study the effect of foliar application of iron- chelated "Fe-EDTA" (0, 100 and 200 mg.l^{-1}) on the seasonal dynamic of some physical and chemical properties of berries of Halwani Lebanon grape cultivar, grown on a calcareous soil in Mosul region, Iraq. The results revealed that the foliar application of 100 mgFe.l^{-1} caused a significant increase of berry weight, TSS, glucose and malic acid in berries while spraying with 200 mgFe.l^{-1} caused a significant increase in the total acidity (TA), tartaric acid and fructose in juice berries compared to the control for both seasons. Additionally, berry weight, TSS, glucose and fructose were increased from the beginning of berry growth to véraison and ripening stage in both seasons; the TA, malic acid and tartaric acid increased from berry set to véraison whereas they decreased towards the end of the growth seasons in both seasons. On the other hand, the interaction between iron levels and times on growth and development of berries were also discussed.

Key word: Iron spraying, seasonal changes, grape berry.

INTRODUCTION

Grapes are high in carbohydrates and are useful source of many minerals and vitamins B_6, C, E and K. They are also a source of antioxidant compounds through the phenolic in their skins and possibly seeds (Yilmaz and Toledo, 2004). Halwani Lebanon is considered one of the most important grape cultivars grown successfully in Iraq. Seasonal changes occur in many physical and chemical characteristics of the grapes during growth and development from beery set to maturity. Among micronutrients, iron plays a vital role in synthesis of chlorophyll, carbohydrates production, cell respiration and nitrogen assimilations. In addition to the important function in photosynthesis, it is involved in the biosynthesis of plant hormones (Mengel et al., 2001; Greasy and Greasy, 2009). The protoporphyrin synthesized as a precursor of hem is also a precursor of chlorophyll (Bould et al., 1983). Iron deficiency causes marked changes in the ultrastructure of chloroplast, with thylakoids grana being absent under extreme deficiency and the chloroplast being smaller (Bould et al., 1983; Kirkby and Romheld, 2004). The availability of iron in soil, a function of a number of properties viz., texture, $CaCO_3$

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Table 1. Analysis of the tested soil according to (Page et al., 1982).

Depth (cm)	Clay (%)	Silt (%)	Sand (%)	O.M. (%)	$CaCO_3$ (%)	HCO_3 (meq/L)	Soil pH
0-25	22.3	55.6	22.1	1.36	18.3	2.26	7.63
25-50	19.2	58.4	22.4	0.96	19.6	2.62	7.74
50-75	18.8	59.1	22.1	0.64	19.9	2.69	7.79
Depth (cm)	Available		K (meq/L)	P (ppm)	Total N (%)	CEC (meq/L)	EC (ds/m)
	Zn (ppm)	Fe (ppm)					
0-25	1.00	1.83	0.211	4.0	0.08	23.60	1.20
25-50	1.10	1.70	0.216	3.7	0.08	23.63	1.22
50-75	0.92	1.69	0.214	3.0	0.04	23.50	1.24

content, organic matter, physiological pH range and amount of iron in the soil form which is in equilibrium with these in the soil solution (Lindsay, 1976; Mengel, 1994). The lime induced iron chlorosis is a common problem when crops are grown on calcareous soils. Some of the crops which are sensitive to iron deficiencies are citrus, grapes, vegetable, ornamentals, strawberries and avocado (Tendon, 1998). Furthermore, the presentation of chelated iron increases the possibility of foliar absorption favoring photosynthesis processes.

The objectives of this experiment were to: 1) Investigate the effect of foliar application of Fe-EDTA on berry weight and its some bio-chemicals composition in grape berry juice and to study the effect of seasonal changes (weekly intervals) of berry weight and its some bio-chemical composition of berry growth and development during the growing seasons.

MATERIALS AND METHODS

This experiment was carried out during 2009 - 2010 in the growing seasons on 20-year old vines (*Vitis vinifera* L.) of Halwani Lebanon grapevines cultivar grown at private orchard located at 36.19 N, 43.09 E and at latitude of 222.6 m above mean sea level in the city of Mosul, Nineveh governorate, Iraq. The vines were planted at 2.25 m × 3 m apart. Full description of the tested soil is given in Table 1 according to Page et al. (1982). The vines trained to the cane system were chosen as uniform in vigor. The experimental vines were pruned in mid- February (Al-Imam and Altalib, 1995); left four canes (each with 12 buds) and six spurs (each with 2 buds) per vine. The chosen vines were divided into a different treatment, including the control. Foliar application of Fe-EDTA at three levels (0, 100 and 200 mg.l^{-1}) was carried out three times per season; the first time before the start of bloom at April 20, the second time after berry set on May 20, and the third time, 30 days later using Tween-20 as a wetting agent at 0.1% was added to the spraying solution of Halwani Lebanon cultivar. Seasonal changes of the berry weight, total soluble solids (TSS), glucose, fructose, total acidity (TA), tartaric acid and malic acid during the growth phases of berries were studied. Grape berries of Halwani Lebanon cultivar were sampled 14 times separately. The present investigation is a factorial experiment split in time; each treatment was replicated three times with two vines per each and randomized complete block design (RCBD) was arranged. Data obtained throughout this study were statically analyzed using analysis of variance and subjected to Duncan's multiple range test; 0.5 P level was used to differentiate means (Roger and Hasted, 2003).

Grape berries were sampled at 14 weekly intervals from berry set on May 29 throughout fruit ripening on September 1. TSS was determined with hand refract meter; quantity determination of glucose and fructose was done using enthrone (Plummer, 1974). The per cent absorbance was then read at 620 nm by Spectrophotometer with the reagent blank set at zero absorbency. Total acidity was determined against NaOH 0.1 N as tartaric acid (Ranganna, 1986). Quantity determination of tartaric acid was done by the spectrophotometer at 520 nm (Zoecklein et al., 1980) using Sodium meta vanadate material. Quantity determination of Malic acid was done (Jakobs, 1958) by using Calcium acetate.

RESULTS AND DISCUSSION

Berry weight

Data in Figure 1 shows that the berry weight of Halwani Lebanon grape was positively affected in response to foliar application of iron-chelated "Fe-EDTA". The highest value of berry weight was obtained by spraying with 100 mgFe.l^{-1} of iron (3.964 and 4.160 g) compared with the control (3.645 and 3.701 g) in both seasons respectively.

Spraying with iron caused a significant increase in the percentage of pollen vitality, pollen grains germination, length of pollen tube, setting of berries, ovules fertilization and the number of seeds in the berry, in addition to, the increase of chlorophyll content of leaves, and leaf area per cluster used and foliar application of Fe-EDTA at four levels 0, 50, 100 and 200 mg.l^{-1} (Al-Imam, 1998). Increase in photosynthesis sufficiency, and its product is used for cell division and expansion, which has been positively reflected in increasing the berry weight. In general, micronutrient values (Table 1) were under the critical range in calcareous soil of orchard soils of vines. This indicates that the grapevines grown in this orchard might respond to Fe-fertilization, whereas a negative correlation between micronutrients with both pH and carbonate forms appeared. These relations indicated the significant effects of pH and carbonate forms upon the distribution of available micronutrients in calcareous soils (Seddyk et al., 1995). The soils of Nineveh orchards were characterized as calcareous with high $CaCO_3$ content and high pH values that result in decreasing the available

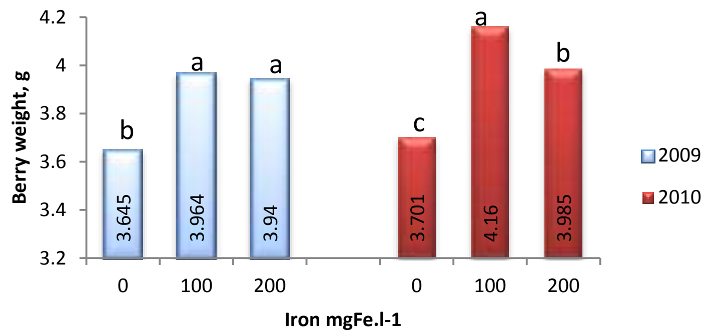

Figure 1. Effect of Fe-EDTA levels on berry weight. Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

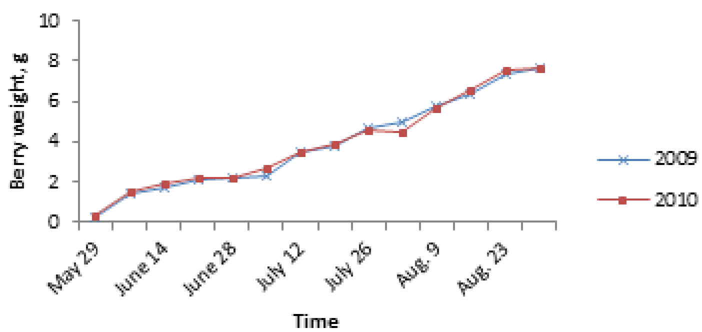

Figure 2. Changes in berry weight measured during the growth and development of Halwani Lebanon.

amount of some nutrients especially micronutrients whose deficiency symptoms appear on grapevines. The results in Figure 2 show that significant changes in grape berries were sampled at 14 weekly intervals and increased dramatically from berry set on May 29 (0.263 and 0.317g) throughout maturity on September 1 (7.603 and 7.640 g) in both seasons respectively.

In the first phase of the berry grape growth, the fertilization results in immediate and rapid cell division in more than approximately 200,000 cells in a thesis to a maximum of 600,000 at berry véraison. It is distinguished by a large change in gene expression (Harris et al., 1968; Davies and Robinson, 2000; Waters et al., 2005). The results of the investigation in Table 2 revealed that the combination of iron levels with sampling dates of berries, had a clear effect on berry weight, especially foliar sprays with 200 and 100 mgFe.l^{-1} of iron and their combinations with a final sampling date of Sept.1 caused a significant increase of berry weight (7.80 and 7.83g) in both seasons respectively. The growth and development of the grapevine berries are usually divided into three major and quite distinct phases. The first-phase shows in Table 2 a period of rapid growth and displays a very active metabolism and rapid cell division, which starts after fruit set on May 29 (0.23g) to June 21 (2.00g). In these 4 weeks there was a significant increase of berry weight. In the second phase-period of about 3 weeks there was a slow and slight increase in berry weight from June 21 (2.00 g) to July 12 (2.21g) at véraison. The French word véraison used to describe the change in berry skin color (Conde et al., 2007) indicates the beginning of ripening. After véraison, berries resume fast growth again from July 19 (3.48 and 3.51 g) to fruit maturity on Sept.1 (7.20 and 7.31 g) of berry weight in both seasons respectively. The berries start to accumulate water and carbohydrates especially sugars and other color levels bred to increase fruit size and weight. The most dramatic changes in the grape berry composition occur during this ripening phase (Winkler et al., 1974; Monselise and Raton, 1986; Conde et al., 2007). In addition to the development of fruit tissue represents the final phase of floral development and involves both cell division and cell expansion (O'Neill, 1997).

Foliar sprays is most effective, when soil nutrient availability is low (Table 1), topsoil dry and root activity during the reproductive stage is decreased (Wojcik, 2004). Data of soil analysis listed in Table 1 revealed that the soil of the experimental orchard contained high pH, percentage of $CaCO_3$ and low organic matter. The predominantly calcareous of high pH soils could limit the availability of micronutrient, including Fe, Mn, Cu and Zn, since they tend to precipitate in soil solution in a

Table 2. Interaction effect of Fe-EDTA and seasonal times on berry weight of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	0.23^{t}	0.33^{t}	0.23^{t}	0.27^{n}	0.40^{n}	0.28^{N}
June 7	1.01^{s}	1.58^{r}	1.63^{qr}	1.03^{m}	1.88^{l}	1.68^{L}
June 14	1.68^{p-r}	1.74^{o-r}	1.86^{n-r}	1.90^{l}	1.93^{l}	1.87^{L}
June 21	2.00^{n-r}	2.13^{n-q}	2.10^{n-q}	2.27^{l}	2.30^{l}	2.08^{L}
June 28	2.07^{n-r}	2.24^{no}	2.18^{n-p}	2.30^{l}	2.40^{l}	1.98^{L}
July 5	2.21^{no}	2.35^{n}	0.22^{no}	2.36^{l}	3.45^{jk}	2.18^{L}
July 12	3.18^{m}	3.53^{lm}	3.66^{k-m}	3.15^{k}	3.75^{i-k}	3.71^{i-k}
July 19	3.48^{lm}	3.73^{kl}	4.01^{k}	3.51^{jk}	3.81^{i-k}	4.27^{g-i}
July 26	4.55^{j}	4.72^{ij}	4.87^{j}	4.10^{h-j}	4.83^{fg}	4.91^{e-g}
Aug. 2	4.72^{ij}	5.00^{h-j}	5.11^{hi}	4.73^{f-h}	5.06^{ef}	5.08^{Ef}
Aug. 9	5.42^{gh}	6.03^{ef}	5.81fg	5.41^{ef}	6.10^{cd}	5.58^{De}
Aug. 16	6.12^{ef}	6.60^{d}	6.41^{de}	6.25^{c}	6.71^{bc}	6.69^{Bc}
Aug. 23	7.17^{c}	7.70^{ab}	7.27^{bc}	7.22^{ab}	7.78^{a}	7.70^{A}
Sept. 1	7.20	7.80^{a}	7.81a	7.31^{ab}	7.83^{a}	7.78^{A}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

Table 2. Interaction effect of Fe-EDTA and seasonal times on berry weight of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	0.23^{t}	0.33^{t}	0.23^{t}	0.27^{n}	0.40^{n}	0.28^{N}
June 7	1.01^{s}	1.58^{r}	1.63^{qr}	1.03^{m}	1.88^{l}	1.68^{L}
June 14	1.68^{p-r}	1.74^{o-r}	1.86^{n-r}	1.90^{l}	1.93^{l}	1.87^{L}
June 21	2.00^{n-r}	2.13^{n-q}	2.10^{n-q}	2.27^{l}	2.30^{l}	2.08^{L}
June 28	2.07^{n-r}	2.24^{no}	2.18^{n-p}	2.30^{l}	2.40^{l}	1.98^{L}
July 5	2.21^{no}	2.35^{n}	0.22^{no}	2.36^{l}	3.45^{jk}	2.18^{L}
July 12	3.18^{m}	3.53^{lm}	3.66^{k-m}	3.15^{k}	3.75^{i-k}	3.71^{i-k}
July 19	3.48^{lm}	3.73^{kl}	4.01^{k}	3.51^{jk}	3.81^{i-k}	4.27^{g-i}
July 26	4.55^{j}	4.72^{ij}	4.87^{j}	4.10^{h-j}	4.83^{fg}	4.91^{e-g}
Aug. 2	4.72^{ij}	5.00^{h-j}	5.11^{hi}	4.73^{f-h}	5.06^{ef}	5.08^{Ef}
Aug. 9	5.42^{gh}	6.03^{ef}	5.81fg	5.41^{ef}	6.10^{cd}	5.58^{De}
Aug. 16	6.12^{ef}	6.60^{d}	6.41^{de}	6.25^{c}	6.71^{bc}	6.69^{Bc}
Aug. 23	7.17^{c}	7.70^{ab}	7.27^{bc}	7.22^{ab}	7.78^{a}	7.70^{A}
Sept. 1	7.20	7.80^{a}	7.81a	7.31^{ab}	7.83^{a}	7.78^{A}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

carbonate-dominated environment (Epstein and Bloom, 2005). Foliar fertilization might be due to the beneficial effect of iron increase, iron availability and quicker direct uptake of ferrous iron (Fe-EDTA) by vine leaves resulting in better absorption and translocation of N, P, K, Fe and Zn (Al-Imam, 2014). These mineral statues affected the physiological performances of photosynthesis activity and its products and ultimately fruit quality.

Total soluble solids (TSS)

Figure 3 shows that foliar application of 100 mgFe.l^{-1} of iron caused a significant increase in TSS of berry juice (8.464 and 8.121%) compared to 200 and 0 mgFe.l^{-1} of iron in both seasons respectively. From the results shown foliar spraying especially with high level of iron-chelated caused (at 200 mgFe.l^{-1}) a significant decrease of sugar content in the berries, because there is an inverse relationship between the grapevine yield and the number of clusters and the decrease of sugar content in addition to increase tartaric and malic acids in berries (Bravdo et al., 1985; Al-Imam, 1998). The sugars of the vinifera grape are primarily glucose and fructose, generally accounting for 90% or more of the carbohydrates in the must and from 12 to 27% or more of the weight of the

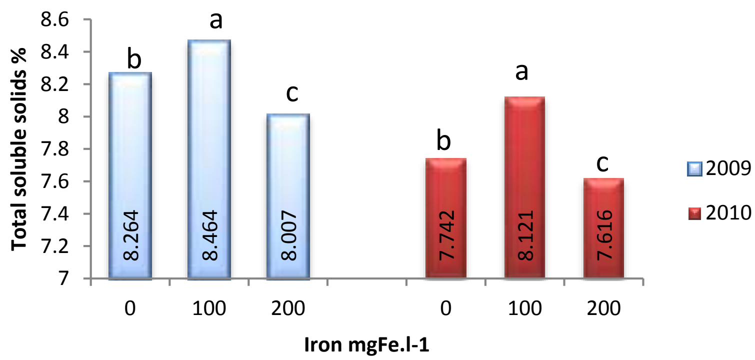

Figure 3. Effect of Fe-EDTA levels on Total Soluble Solids percentage. Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

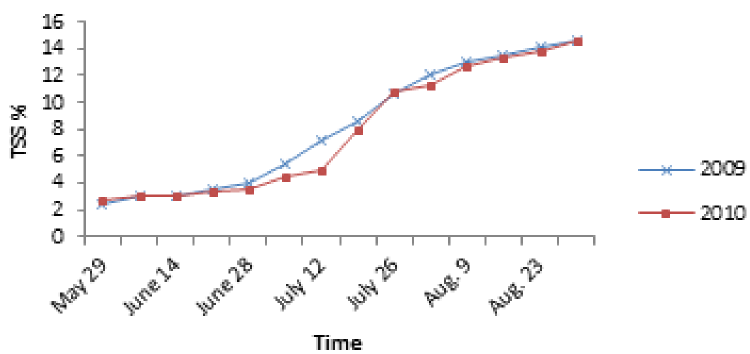

Figure 4. Changes in Total Soluble Solids percentage during the growth and development of cv. Halwani Lebanon grape berries.

mature berry. The trend lines of the berries were sampled at 14 weekly intervals from berry set on May 29 through fruit ripening on Sept.1 of TSS were presented in graphic form in Figure 4 in the berry juice.

There was a slow rise in TSS from May 29 samples (2.5 and 2.667%) to July 5 samples (4.033 and 3.478%) in both seasons respectively. After July 5 the increase in TSS was very rapid in berries and this trend continued up to maturity (14.633 and 14.567%) which were significantly superior to all sample dates in both seasons respectively. The analysis of variance of TSS (Table 3) showed highly significant iron levels × sampling dates interaction. During the first period of rapid growth of the berries the percentage of sugar present is low. During the second stage of growth and development of berries the sugars increase rapidly. During early summer the vines are growing rapidly, most of the sugars are then being used in the growth of the vine and in the increase of berry weight and size. The carbohydrate (Sugar and Starch) that begins to accumulate in the leaves and woody parts of the vine are translocated to the fruits, where there is a rapid buildup of sugars. Another possible source of the sugars in grape berries is from transformation of organic acids from malic and tartaric acids (Winkler et al., 1974; Conde et al., 2007; Greasy and Greasy, 2009).

The summer season in Iraq is hot and the heat summation is rapid, the grapes ripen faster. The amount of TSS content of berries at different iron levels significantly increased during the berry growth season. A significantly greater content of TSS in berries was recorded on September 1 collected from spraying the vines with 0 mgFe.l-1 of iron (15.10%) in the first season and from the spraying the vines with 0 and 200 mgFe.l-1 of iron (14.90 and 14.90%) in the second season respectively; while the lowest amount of TSS was recorded in May 29 from all the three iron levels.

Glucose and fructose in berry juice

The major carbohydrate compounds of the grape berry are glucose and fructose. During ripening glucose and fructose accumulate in roughly equal amounts in the vacuole (Agaeorges et al., 2000). The results in Figure 5

Table 3. Interaction effect of Fe-EDTA and seasonal times on total soluble solids (TSS) percentage in berry juice of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	2.50^{w}	2.40^{w}	2.60^{vw}	2.60^{uv}	2.50^{V}	2.90^{t-v}
June 7	3.10^{tu}	3.00^{uv}	3.00^{uv}	3.20^{st}	3.00^{Tu}	3.00^{tu}
June 14	3.20^{s-u}	3.10^{tu}	3.10^{tu}	3.10^{st}	3.20^{St}	3.10^{st}
June 21	3.50^{r-t}	3.60^{rs}	3.50^{r-t}	3.20^{st}	3.50^{Ro}	3.20^{st}
June 28	3.90^{qr}	4.30^{q}	3.90^{qr}	3.50^{rs}	3.70^{R}	3.23^{st}
July 5	5.40^{p}	5.50^{p}	5.30^{P}	4.30^{q}	4.50^{Pq}	4.50^{pq}
July 12	7.50^{n}	7.00^{o}	7.00^{O}	4.80^{p}	5.50^{O}	4.80^{p}
July 19	8.00^{m}	9.80^{l}	8.10^{M}	7.80^{n}	8.10^{N}	7.90^{n}
July 26	10.50^{k}	11.50^{j}	10.00^{L}	10.50^{m}	11.50^{K}	10.50^{mn}
Aug. 2	12.10^{i}	12.00^{i}	11.90^{Ij}	11.00^{l}	11.90^{Jk}	11.00^{l}
Aug. 9	13.00^{gh}	13.60^{ef}	12.70^{H}	12.40^{i}	13.50^{e-g}	12.10^{ij}
Aug. 16	13.50^{ef}	13.70^{de}	13.20^{fg}	13.20^{gh}	13.80^{d-f}	12.90^{h}
Aug. 23	14.40^{be}	14.30^{bc}	13.70^{de}	13.90^{c-e}	14.30^{Bc}	13.40^{op}
Sept. 1	15.10^{a}	14.70^{ab}	14.10^{cd}	14.90^{a}	14.70^{Ab}	14.90^{a}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

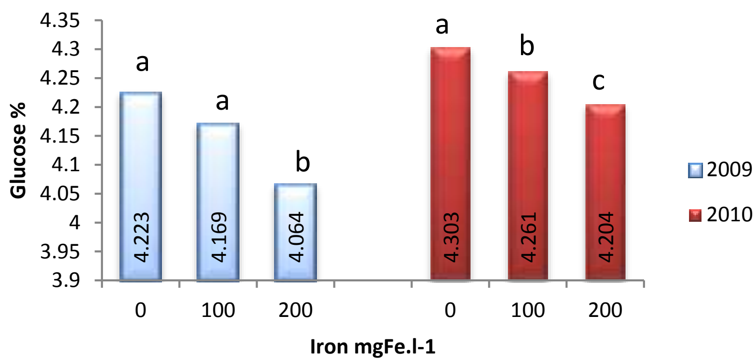

Figure 5. Effect of Fe-EDTA levels on Glucose percentage. Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

showed that spraying the grapevines with 200 mgFe.l^{-1} caused a significant decrease in the glucose content of berry juice as compared with 0 mgFe.l^{-1} in both seasons while in Figure 6 it showed a significant increase of fructose content by increasing the level of iron in the spaying solution especially in the first season.

Spraying with 200 mgFe.l^{-1} caused a highest amount of fructose (3.284 and 3.195%) in the both season respectively. Figures 7 and 8 clearly show that the seasonal changes in glucose and fructose percentage in berries by the time from berry set May 29 to maturity in September 1. Figures 7 and 8 clearly show that the concentration of glucose was higher than fructose from May 29 to July 5 collected and glucose amount significantly increased gradually to maturity. While, the fructose amount increased rapidly after August 9 to maturity (Figure 8). The ratio of glucose to fructose in the grape changes considerably between fruit set until fruit maturity.

The analysis of variance of glucose and fructose (Tables 4 and 5) showed the effect of interaction of iron levels × sampling dates. It was shown that the highest value of glucose (Table 4) shown at the vines sprayed with 0 and 100 mgFe.l^{-1} (7.87 and 7.70%) respectively in the first season and at 0 mgFe.l^{-1} of iron (7.93%) in the second season, were significantly superior to other treatments. While the data in Table 5 clearly shows that the highest amount of fructose at foliar application of 200 mgFe.l^{-1} on Sept.1 at maturity (7.31 and 7.28%) in both seasons respectively, were significantly superior to other

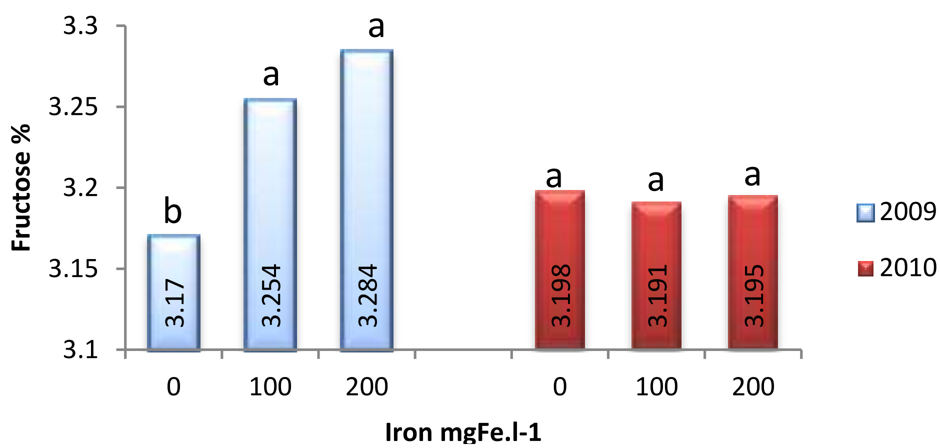

Figure 6. Effect of Fe-EDTA levels on fructose percentage. Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

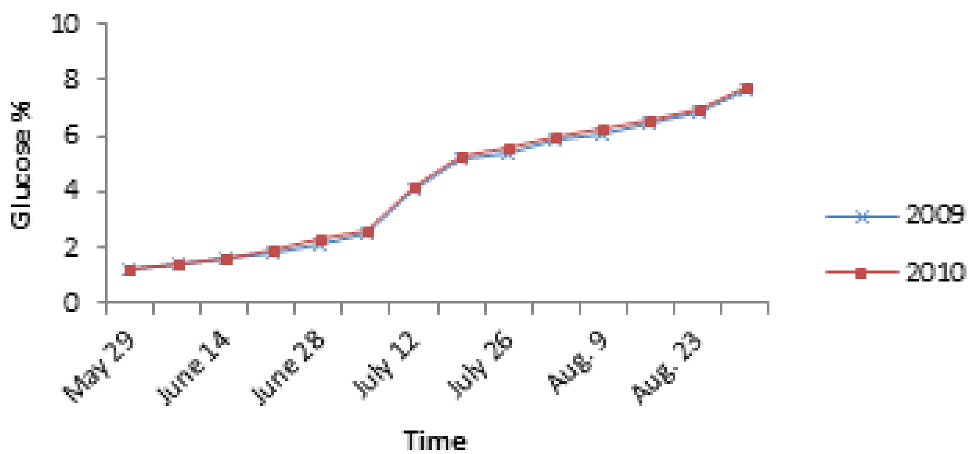

Figure 7. Changes in glucose percentage during the growth and development of cv. Halwani Lebanon grape berries.

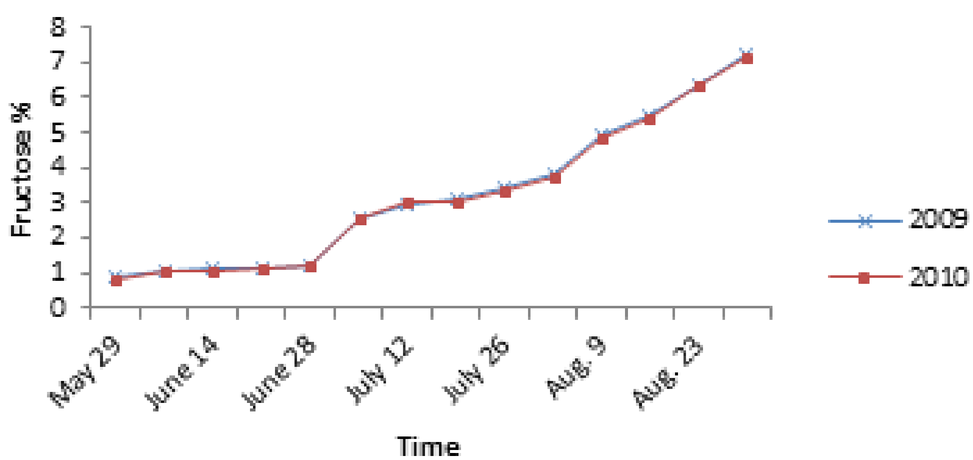

Figure 8. Changes in Fructose percentage during the growth and development of cv. Halwani Lebanon grape berries.

Table 4. Interaction effect of Fe-EDTA and seasonal times on Glucose percentage in berry juice of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	1.27^{rs}	1.22^{s}	1.33^{s}	1.28^{w}	1.24^{w}	1.28^{w}
June 7	1.42^{q-s}	1.40^{q-s}	1.39^{q-s}	1.44^{v}	1.49^{v}	1.40^{v}
June 14	1.59^{pq}	1.55^{p-r}	1.56^{pq}	1.67^{u}	1.60^{u}	1.59^{u}
June 21	1.80^{p}	1.83^{p}	1.81^{p}	1.90^{t}	1.91^{t}	1.87^{t}
June 28	2.1^{o}	2.20^{no}	2.10^{o}	2.19^{s}	2.39^{r}	2.20^{s}
July 5	2.5^{m}	2.60^{m}	2.40^{mn}	2.61^{q}	2.68^{q}	2.45^{r}
July 12	4.35^{k}	4.0^{l}	4.03^{l}	4.40^{o}	4.11^{p}	4.10^{p}
July 19	5.19^{ij}	5.21^{ij}	5.0^{j}	5.30^{n}	5.33^{mn}	5.31^{n}
July 26	5.28^{i}	5.41^{i}	5.33^{i}	5.41^{m}	5.60^{l}	5.75^{k}
Aug. 2	5.93^{gh}	5.87^{h}	5.80^{h}	5.99^{j}	5.91^{j}	5.91^{j}
Aug. 9	6.23^{f}	6.17^{fg}	5.77^{h}	6.31^{h}	6.21^{i}	6.21^{i}
Aug. 16	6.61^{de}	6.40^{ef}	6.31^{f}	6.70^{f}	6.48^{g}	5.91^{j}
Aug. 23	6.98^{c}	6.80^{cd}	6.74^{cd}	7.11^{d}	6.91^{e}	6.89^{e}
Sept. 1	7.87^{a}	7.70^{a}	7.43^{b}	7.93^{a}	7.80^{b}	7.5^{c}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

Table 5. Interaction effect of Fe-EDTA and seasonal times of Fructose percentage in berry juice of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	0.85^{j}	0.87^{j}	0.88^{j}	0.80^{m}	0.81^{m}	0.83^{m}
June 7	1.07^{ij}	1.10^{ij}	1.10^{ij}	1.00^{l}	1.08^{l}	1.09^{l}
June 14	1.08^{ij}	1.11^{ij}	1.11^{ij}	1.00^{l}	1.09^{l}	1.09^{l}
June 21	1.08^{ij}	1.11^{ij}	1.11^{ij}	1.09^{l}	1.10^{l}	1.10^{l}
June 28	1.21^{i}	1.24^{i}	1.26^{i}	1.18^{l}	1.20^{l}	1.20^{l}
July 5	2.50^{h}	2.00^{h}	2.63^{h}	2.51^{k}	2.50^{k}	2.58^{k}
July 12	2.91^{g}	3.00^{g}	3.02^{g}	3.23^{gh}	2.91^{j}	2.95^{ij}
July 19	3.11^{g}	3.16^{g}	3.17^{g}	3.10^{hi}	3.00^{ij}	3.00^{ij}
Aug. 2	3.78^{e}	3.83^{e}	3.87^{e}	3.80^{f}	3.80^{f}	3.71^{f}
Aug. 9	4.88^{d}	4.95^{d}	4.99^{d}	4.91^{e}	4.90^{e}	4.80^{e}
Aug. 16	5.33^{c}	5.50^{c}	5.58^{c}	5.38^{d}	5.41^{d}	5.40^{d}
Aug. 23	6.28^{b}	6.31^{b}	6.45^{b}	6.30^{c}	6.37^{c}	6.33^{c}
Sept. 1	7.10^{a}	7.31^{a}	7.31^{a}	7.09^{b}	7.11^{b}	7.28^{a}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

combination treatments.

Total acidity (TA) in berry juice

Figure 9 clearly shows that spraying with 200 mgFe.l^{-1} of iron chelated caused a significant increase in total acidity (TA) as tartaric acid with the increase of iron concentration in the spraying solution in both seasons.

The total acidity of berries of Halwani Lebanon grape increased fast from berry set on May 29 to June 21 in the first season, and on June 14 in the second season. After these sampling dates the TA decreased slowly until July 19. After that, there was a sharp decrease in TA until Sept.1 at maturity in both seasons (Figure 10).

Tartaric acid was synthesized most rapidly by young developing leaves and immature fruits in the first phase of berry growth. These explain the higher amounts of total acidity found early in the seasons in immature fruits (Kliewer and Lider, 1968). Malic acid is rapidly lost during

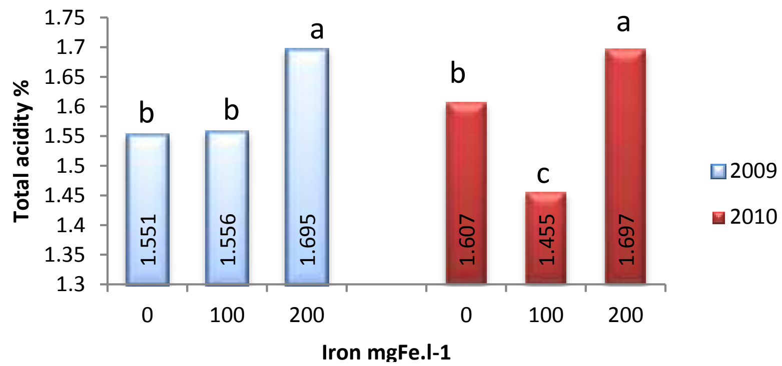

Figure 9. Effect of Fe-EDTA levels on total acidity percentage. Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

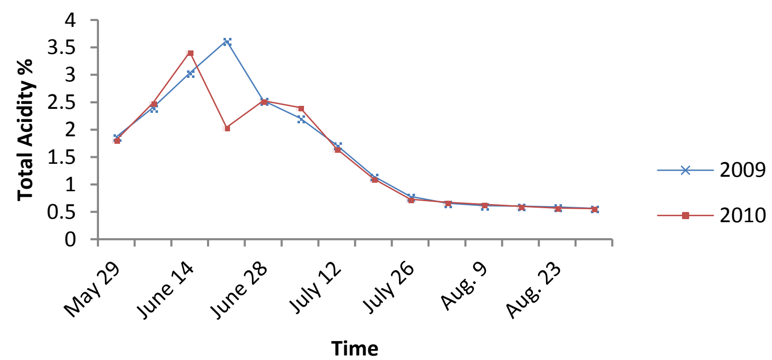

Figure 10. Changes in Total Acidity percentage during the growth and development of cv. Halwani Lebanon grape berries.

warm temperatures and during ripening, while tartaric acid salts are more stable. The decrease in acid concentration is due to an increase in membrane permeability allowing more acid to be metabolized. A reduction in the amount of acids translocated from the leaves, and the formation of salts, mainly potassium salts. A reduced synthesis of acid, the berries, finally, has a dilution effect, due to the rapid increase in berry volume during ripening (Monselise and Raton, 1986). The changes in total acidity in grape berries were evident from means of iron levels × sampling dates interaction (Table 6) and there was a significant increase in TA for 200 mgFe.l^{-1} on June 21 (3.83 and 4.13%) for both seasons respectively. After these sampling dates the TA decreased through Sept.1 at maturity.

Tartaric acid in berry juice

The results over two seasons indicated that foliar application with 200 mgFe.l^{-1} of iron showed a significant increase in tartaric acid in berry juice as compared with the 0 and 100 mgFe.l^{-1} of iron treatments (Figure 11). Seasonal changes of tartaric acid were found in Figure 12 to increase up to the 6th week of berry development during green berry stage to véraison in both seasons.

The highest amount of tartaric acid obtained at the véraison July 12 of berry development was 1.00 and 0.869% in both seasons. After July 12 there was a continuous decrease in the rate of tartaric acid till maturity on Sept.1 in both seasons. The analysis of variance between iron levels × sampling dates was evident from means of the combination in Table 7 and there were significant differences between iron levels in tartaric acid for all sampling dates; especially, the berries sampled of July 12 (1.11 and 0.93%) which were sprayed with 200 mgFe.l^{-1} of iron had a significantly greater amount of tartaric acid in both seasons respectively. The lower amount of tartaric acid (0.29%) was recorded on Sept.1 which was sprayed with 0 mgFe.l^{-1} (control) for both seasons.

Malic acid in berry juice

The data in Figure 13 indicated that spraying with 100

Table 6. Interaction effect of Fe-EDTA and seasonal times of Total Acidity (TA) percentage in berry juice of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	2.00^{h}	1.71^{Ij}	1.89^{hi}	1.95^{i}	1.73^{j}	1.75^{Ij}
June 7	2.53^{c-f}	2.56^{c-e}	2.34^{fg}	2.51^{e-g}	2.55^{e-g}	2.40^{f-h}
June 14	2.60^{cd}	3.17^{B}	3.33^{B}	3.65^{b}	3.15^{d}	3.45^{C}
June 21	3.29^{b}	3.75^{A}	3.83A	2.59^{ef}	2.40^{f-h}	4.13^{A}
June 28	2.48^{d-f}	3.40^{e-g}	2.71^{C}	2.50^{e-g}	2.38^{f-h}	2.70^{E}
July 5	2.27^{g}	1.71^{Ij}	2.65^{cd}	2.33^{gh}	2.25^{h}	2.63E
July 12	1.75^{i}j	1.69^{J}	1.71^{ij}	1.84^{ij}	1.31^{k}	1.80^{Ij}
July 19	1.14^{l}	0.98^{Lm}	1.33^{K}	1.43^{k}	$0.90l^{m}$	0.98^{L}
July 26	0.72^{n-p}	0.78^{No}	0.84^{mn}	0.74^{mn}	0.70^{n}	0.75^{Mn}
Aug. 2	0.63^{op}	0.67^{n-p}	0.68^{n-p}	0.66^{n}	0.67^{n}	0.69^{Mn}
Aug. 9	0.60^{op}	0.62^{Op}	0.62^{op}	0.61^{n}	0.64^{n}	0.66^{N}
Aug. 16	0.59^{op}	0.61^{Op}	0.61^{op}	0.58^{n}	0.60^{n}	0.62^{N}
Aug. 23	0.57^{op}	0.59^{Op}	0.60^{op}	0.56^{n}	0.55^{n}	0.60^{N}
Sept. 1	0.54^{p}	0.56^{P}	0.59^{op}	0.55^{n}	0.54^{n}	0.59^{N}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

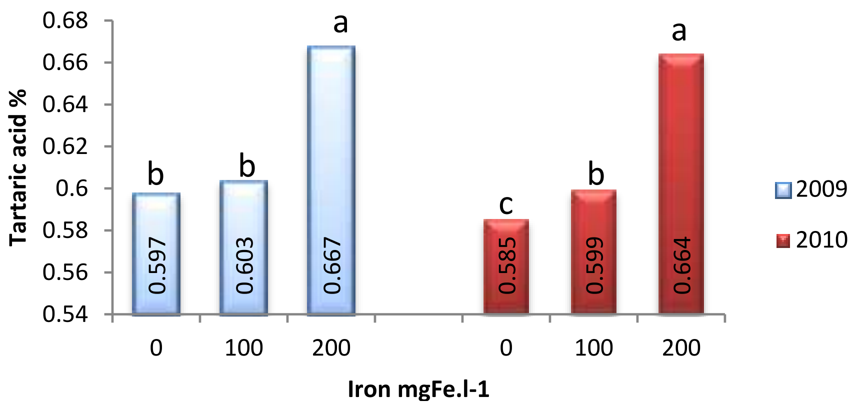

Figure 11. Effect of Fe-EDTA levels on Tartaric acid. Means with the same letter are not significantly different at p=0.05 according to Dancan's test.

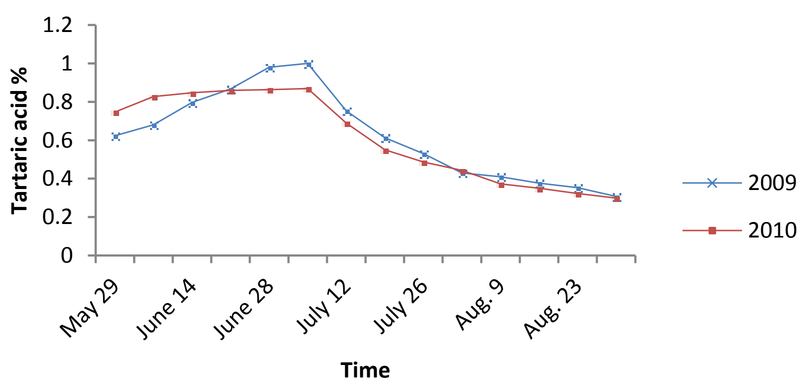

Figure 12. Changes in Tartaric acid percentage during the growth and development of cv. Halwani Lebanon grape berries.

Table 7. Interaction effect of Fe-EDTA and seasonal times of Tartaric acid percentage in berry juice of cv. Halwani Lebanon grape.

Iron (mg.l^{-1})	2009			2010		
	0	100	200	0	100	200
May 29	0.61l^{m}	0.62^{k-m}	0.64^{j-l}	0.70^{ij}	0.74^{g-i}	0.80^{f}
June 7	0.70^{g-i}	0.66^{i-k}	0.68^{h-j}	0.75^{gh}	0.85^{e}	0.88^{b-e}
June 14	0.78^{f}	0.80^{Ef}	0.81^{ef}	0.78^{fg}	0.86^{de}	0.90^{a-d}
June 21	0.88^{cd}	0.84^{De}	0.88^{cd}	0.80^{f}	0.87^{c-e}	0.91^{a-c}
June 28	0.89^{c}	0.97^{B}	1.08^{a}	0.80^{f}	0.87^{c-e}	0.92^{ab}
July 5	0.90^{c}	0.99^{B}	1.11^{a}	0.79^{f}	0.88^{b-e}	0.93^{a}
July 12	0.73^{g}	0.63^{Kl}	0.90^{c}	0.73^{h-j}	0.65^{kl}	0.69^{jk}
July 19	0.60^{lm}	0.53^{N}	0.71^{gh}	0.62^{l}	0.65^{kl}	0.55^{m}
July 26	0.51^{n}	0.50^{N}	0.58^{m}	0.51^{mn}	0.43^{o}	0.52^{mn}
Aug. 2	0.40^{p-r}	0.44^{Op}	0.45^{o}	0.42^{o}	0.41^{op}	0.50^{n}
Aug. 9	0.38^{rs}	0.42^{o-r}	0.43^{o-q}	0.35^{qr}	0.37^{pq}	0.40^{op}
Aug. 16	0.36^{s-u}	0.38^{Rs}	0.39^{q-s}	0.33^{q-t}	0.35^{qr}	0.37^{pq}
Aug. 23	0.33^{t-v}	0.36^{s-u}	0.37st	0.31^{r-t}	0.32^{r-t}	0.34^{q-s}
Sept. 1	0.29^{v}	0.31^{V}	0.32^{uv}	0.29^{t}	0.30st	0.31^{r-t}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

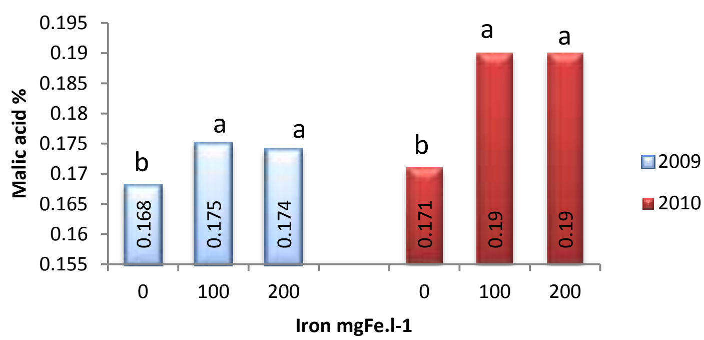

Figure 13. Effect of Fe-EDTA levels on Malic acid. Means with the same letter are not significantly different at p=0.05 according to Dancan's test.

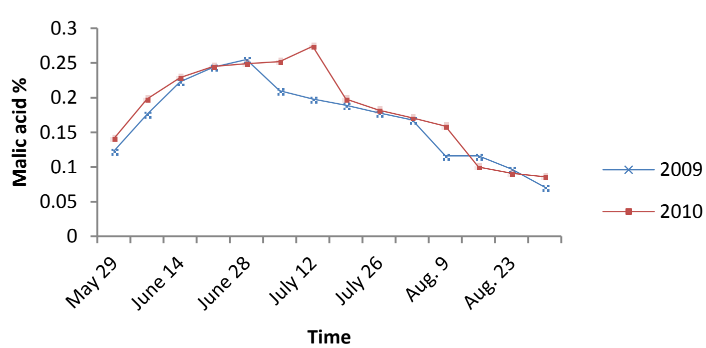

Figure14. Changes in Malic acid percentage during the growth and development of cv. Halwani Lebanon grape berries.

and 200 mgFe.l^{-1} of iron significantly increased the malic acid in berry juice compared to 0 mgFe.l^{-1} of iron treatments. Figure 14 clearly showed that malic acid gradually increased until July 5 (0.255%) in the first season and July 19 in the second season, and then started to decrease at maturity. Malic acid decreases

Table 8. Interaction effect of Fe-EDTA and seasonal times of Malic acid percentage in berry juice of cv. Halwani Lebanon grape.

Iron ($mg.l^{-1}$)	2009			2010		
	0	100	200	0	100	200
May 29	0.129^{o}	0.12^{op}	0.121op	0.13^{n}	0.145^{m}	0.147^{M}
June 7	0.17^{l-n}	0.18^{i-l}	0.177^{j-m}	0.16^{lm}	0.215^{hi}	0.22^{Hi}
June 14	0.20^{fg}	0.224^{cd}	0.246^{b}	0.205^{i}	0.24^{d-f}	0.242^{c-f}
June 21	0.233^{c}	0.249^{ab}	0.251^{ab}	0.230^{f-g}	0.25^{b-e}	0.255^{b-d}
June 28	0.25^{ab}	0.25^{ab}	0.26^{a}	0.236^{e-g}	0.255^{b-d}	0.256^{b-d}
July 5	0.22^{de}	0.254^{ab}	0.201^{fg}	0.24^{d-f}	0.258^{bc}	0.258^{bc}
July 12	0.196^{gh}	0.21^{ef}	0.199^{fg}	0.265^{ab}	0.278^{a}	0.28^{a}
July 19	0.185^{h-k}	$0.199f^{g}$	0.192^{g-i}	0.185^{jk}	0.221^{gh}	0.188^{j}
July 26	0.173^{k-m}	$0.19g^{-j}$	0.182^{i-l}	0.18^{jk}	0.182^{jk}	0.183^{jk}
Aug. 2	0.164^{mn}	0.169^{l-n}	0.172^{k-m}	0.17^{kl}	0.171^{kl}	0.172^{j-l}
Aug. 9	0.157^{n}	0.163^{mn}	0.164^{mn}	0.16^{lm}	0.16^{lm}	0.160^{lm}
Aug. 16	0.113^{p}	0.117^{op}	0.117^{op}	0.100^{op}	0.100^{op}	0.11^{o}
Aug. 23	0.093^{q}	0.100^{q}	0.100^{q}	0.095^{op}	0.095^{op}	0.100^{op}
Sept. 1	0.07^{r}	0.090^{q}	0.054^{s}	0.091^{pq}	0.091^{pq}	0.095^{op}

Means with the same letter are not significantly different at p=0.05 according to Duncan's test.

more rapidly than tartaric acid.

The analysis of variance (Table 8) showed a significant interaction between iron levels × sampling dates for data on malic acid in berry juice. The highest value of malic acid is shown in the vines sprayed with 200 $mgFe.l^{-1}$ of iron in June 28 in the first season. While the highest amount of malic acid was obtained on the vines sprayed with 200 $mgFe.l^{-1}$ of iron on July 12 at véraison in the second season. The lower amount of malic acid in the berry juice was obtained at maturity on Sept.1 and sprayed with 200 $mgFe.l^{-1}$ of iron (0.054%) in the first season and in the vines sprayed with 0 or 100 $mgFe.l^{-1}$ of iron in the second season. Grape berries are characterized by large amount of tartaric acid together with malic acid. The two organic acid accounts for more than 90% of the total acidity of the grape berry (Monselise and Raton, 1986).

Conclusion

Foliar application of iron level increased grapevine berry weight, TSS, TA, tartaric acid, malic acid and fructose in berry juice. Berry weight and its bio-chemical products were changed according to the physiological seasonal growing stage. There was high increase in berry weight, TSS, glucose and fructose from berry set to fruit maturity. High concentrations of total acidity, tartaric acid and malic acid to vréraison decreased in mature berries stage especially at ripening.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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