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Effect of soil mineralogical composition on fruit quality of sweet cherry cultivars

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Abstract

Leaf nutrient concentration of sweet cherry (*Prunu savium*. L) cultivars was affected by mineralogical composition of soil and tree requirements. Thus, the main objective of this study was to evaluate and choose the performance of the most sweet cherries cultivars in two different pedoclimatic orchards through weight, acidity, firmness, soluble solids content, ripening index and mineral analysis of leaves at 60 days after full bloom (DAFB). This study was carried out in two experimental sites in the North-West of Tunisia (Tibar and Ain-Drahem), with the main purpose of investigating the foliar macronutrient content of four cultivars which are Napoleon, Van, Moreau and Sunburst. The physic-chemical analysis of the soil shows that Tibar's soil was heavy, while Ain Drahem's was light. The mineral leaf analysis shows that the four cultivars presented deficiency on leaf P, K, Ca and Mg concentration but nutrional balance on N concentration. The best fruit weight was found in Sunburst in Ain-Drahim (4,81g) and Van (6,49g) in Tibar. Titratable acidity of Tibar's cultivars was more important than those of Ain Drahem. At both orchards, Moreau showed the balanced nutritional values (∑DOP index), whereas the poorest were found in Napoleon, Van and Sunburst.

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Introduction

Sweet cherry (*Prunu savium* L.) is a fruit crop with a high economic importance, due to the nutritional, technological and commercial value of its fruits (Pérez *et al*., 2010). In Tunisia, despite the favorable conditions, sweet cherry is a poorly valued species and only some regions practice this culture in small-scale. The reason for this situation are numerous, but the most important are the poorly chosen of adequate cultivars for the proper soil, new cultivars with better fruit quality, heavy soil and outdated growing technology. In spite of cultivars are grown in the same conditions, mineral concentrations of plants may change (Bergmann 1992; Kacar 1995; Marshner 1995). Studies have shown that rootstocks can affect root and tree growth, yield and quality of sweet cherry fruits (Betran *et al* 1997; Sitarek *et al* 1998; Roversi *et al* 2010; Sotirov 2011). From the perspective of supply management in quantity and quality, in these conditions, we found it useful to assess the cropping techniques primarily by controlling mineral nutrition by foliar diagnosis method and physico-chemical soil analysis. Physico-chemical soil analysis should be made on the orchard to control their fertility (German *et al*,. 1999) and to adapt gradually the femur to the couple soil/orchard (Lichou Et Aubert, 1989). In order to better knowledge about cherry trees nutrient status, some authors propose earlier leaf chemical analysis as a better prognosis tool for optimal, insufficient or excessive leaf macronutrients level (Moreno *et al*., 1996; Betran *et al*., 1997). Withal, information on leaf nutrient composition of sweet cherries especially those grown on typical heavy and acidic soil in many regions, is not available in literature (Milosovic *et al*., 2014). It will be necessary to establish the relationship between the nutritional status of the trees and soil factors based on soil sampling and to establish a relationship between minerals and some quantitative parameters. Sweet cherries are highly appreciated by the consumer and their acceptance is mainly based on soluble solids content, acidity, firmness's, and overall appearance (Crisisto *et al*., 2003). There are many factors that are included in the term fruit quality in the sweet cherry. However, only fruit weight, fruit firmness and soluble solids can be measured whereas the top level of each of these factors is correlated with the best fruit quality (Folge, 1975). Leaf nutrient status can measure the elements actually taken by the tree from the soil and in a well determined climate. The method of production has a significant influence on the leaves' levels of nutrients (Neilsen *et al*., 1995**).** The soil and climate interaction acts on the vegetative growth and promoting fruits quality. At different levels, changes may interfere with this process. The aim of this study was to select the most tolerant cultivar(s) for nutrient deficit conditions to minimize nutritional disorders of sweet cherry orchards through fruit quality, nutritional status of trees and physico-chemical soil analysis.

Materials and methods

Plant material and experimental procedure

This study was carried out on a 7-years old sweet cherry orchard in two experimental sites. In Ain-Drahem experimental site (Longitude 8, 7; latitude 36,7832; Altitude 800m), the average rainfall is about 1040 mm /year. The lowest average temperatures are around 11°C during the month of February and the hottest ones are 26°C during July. At Tibar (longitude 9, 1; latitude 36,5167; altitude 328m), the average rainfall is about 540 mm/year. The lowest average temperatures are about 10°C during the month of February and the hottest ones are about 29°C during the months of July and August. This study was conducted over a period of two years, from 2013to 2014. Both orchards were established in late autumn 2007. 'Napoleon', 'Van', 'Moreau' and 'Sunburst' sweet cherry cultivars were grafted on Saint Lucie (SL) 64 (*Prunu smahaleb* L.) rootstocks in a randomized block design with three replications of five trees per plot of each experimental site. The planting distance was 4m×5 m. Orchards were not irrigated and not fertilized in the examined period. Fruit quality attributes were determined using the fruit weight (g) at repining from 2013 to 2014 annually. From five different trees, were used for each cultivar 15 fruits, in three repetitions.

For determining the weight of fruits we used an electronic balance (Radwag, 0.01 g sensitivity). Titratable acidity (TA) was determined by neutralization with a sodium hydroxide solution 0,1N, to the point of equivalence, using thymolphthalein as the indicator. The soluble solids content (SSC) was determined with the refract metrical method using a Zeiss hand refractometer according to Milošević *et al.* (2013). Fruit flesh firmness was determined non-destructively using the Durofel Index (ID) on two opposite cheeks in the equatorial zone, using a hand-held durometer (Durofel, Agrotechnologie, France) with a0.25 mm tip. The ripening index (RI) was calculated as the SSC/TA ratio.

Mineral analysis

Leaf mineral concentration was determined in 2013 and 2014. Leaf sampling was done at 60 DAFB (days after full bloom), approximately 1 to 2 weeks after harvest of all the varieties. Healthy, fully developed leaf samples were collected from the middle part of bearing shoots of the trees. Leaf samples were washed and dried outdoors in an airy place for a week. After drying samples in a well-ventilated drying oven for 6 hrs at 40°C, the whole sampled material was finely grounded and homogenized. Samples were then stored in paper bags in a dark and dry place until use. Totalnitrogen (N) was determined by Kjeldahl analysis; P was analyzed by ultraviolet spectrophotometer (Hewlett-Packard 8452 A); K by atomic emission spectroscopy; Ca and Mg by atomic absorption spectroscopy (Perkin-Elmer 1100).

Deviation from optimum percentage

The DOP index (deviation from optimum percentage) was estimated for the diagnosis of the leaf mineral status of the trees (Montanes *et al.*, 1993). The DOP index was calculated from the leaf analysis at 60 DAFB by the following mathematical expression:

$(DOP = (C_n/C_o -1) x100)$

Where C_n is the foliar content of the tested nutrient, and C_o is the critical optimum nutrient content for sweet cherry; both values were given on a dry matter basis.

The C_o was taken from optimum values for sweet cherry proposed by Leece (1975). Besides, it provided the general nutritional status of nutrients through the ∑DOP index, and obtained by adding the values of DOP index irrespective of sign. The lower the ∑DOP, the greater is the intensity of balance among nutrients evaluated.

Soil sampling and preparation

Three soil samples were collected from five layers (0-20, 20-40, 40-60, 60-80 and 80-100cm) of each treatment by using manual soil sampling equipment following the study of Nagy *et al.* (2006). The collection of soil sampling was done in December (winter rest period).

Data analysis

All results obtained were subjected to analysis of variance (ANOVA) with the statistical SAS, for normality, distribution, frequency, and means separation. (Test at P≤0.05)

Results and discussion

Soil

Cherries prefer light, well-drained soils. A silt loam is best, but cherries can tolerate soils ranging from sandy loam to clay loam as long as there is good drainage. According to the PAPEG texture triangle, the soils are different. The soil of Tibar is heavy having asilty clay layer of alternating silty clay loam with the middle 60-80cm being sandy clay. This texture tends to form a crust on the surface under the effect of rainfall and irrigation, which makes it impervious to water and air. They clog very easily, which has the effect of asphyxiating plant roots and soil organisms but the presence of sand in the middle makes it permeable and therefore not beating. The soil of Ain-Drahemis clayey sand (0-80cm) to sandy clay (80-100cm). It is a light soil. This is an excellent soil because it has good ventilation, standpoint of balance, drainage and retention of water and nutrients. It is suitable for the cultivation of cherries.

Both experimental sites have organic matter content lower than 2%, so they are poor in organic matter. Both soil regions are rich in nitrogen.

According to these guidelines and values of the C/N ratio of the soil studied mentioned in Table 2, we see that this soil with all its analyzed layers has a C/N ratio low by reference standards (Calvet, 1986) and this therefore reflects very favorable conditions for the strong mineralization of organic matter following good biological activity. In agricultural soils, the C/N ratio is lowered further and reflects good biological activity which leads to the mineralization of the organic material (C/N less than 10) (Soltner, 2000). This low ratio of all of the humus horizons reflects the rapid development of plant material fallen to the ground, so the speedy return of nutrients to the roots prospected horizons, and good opportunities for nitrogen nutrition which is the source of wealth of the two soils nitrogen. The Ain-Drahem Phosphorus soil had a variable rate. According to the P_2O_5 appreciation of comparable level of Soltner (2000), the surface portion (0-40cm) was high, then the 40-100cm phosphorus rate decreased and became medium. The soil of Tibar was poor relative to the soil of Ain-Drahem.

Table 1. Results of physical analysis of the soil in two orchards.

Orchards	Elements	00-20 (cm)	20-40 (cm)	40-60 (cm)	60-80 (cm)	80-100 (cm)
Tibar	Fin Silt	25	26	23	20	30
	Coarse silt	5	4	4	4	2
	Fin Sand	22	22	23	22	23
	Coarse sand	12	12	12	9	12
	Total Sand	34	34	35	31	35
	Total Silt	30	30	27	24	32
	Clay	34	34	35	42	30
AinDrahem	Fin Silt	9	11	11	12	12
	Coarse silt	9	7	7	7	3
	Fin Sand	36	37	38	30	32
	Coarse sand	27	27	23	25	25
	Total Sand	63	64	61	55	57
	Total Silt	18	18	18	19	15
	Clay	16	16	19	23	25

In the 0-40cm layer, we found almost the same level of phosphorus, while in the 40-60 cm layer it was low and the rate of the 60-100 cm rate became low on average. This may explain the difficult P migrates deep corroborating the work of Huguet (1978) which states that, whatever the content of the soil, phosphorus is a little variable component and migrates deep in small quantities. In acidic soil (Tibar and Ain Drahem), the phosphorus binds with aluminum and iron to form poorly soluble compounds, and therefore is less available to the plant. Level K_2O across the Ain Drahem soil layers was very poor while the soil layers of Tibar had satisfactory levels as determined by the level of K_2O (Soltner, 2000). The deficiency of this element may have an antagonistic effect caused by excess nitrogen. Potassium is retained in soils that have a reasonable clay and/or organic matter level. Ain-drahem was poor because the soil was sandy clay. Mg and K pose problems for farmers. They are indeed in dispensable to the life of the plant. Mg as part constituent of chlorophyll and an activator of certain enzymes, K as a catalytic agent in the synthesis of carbohydrates and proteins. K deficiency is rare in clay or silty clay soil (soil of Tibar) compared to soils containing sand (soil of Ain-Drahem).

The pH of a soil is a measure of its acidity, which influences the absorption of nutrients and crop yield. According to Russell (2003), cherry requires a soil pH between 6.6 and 7.8 while the two soils are acidic to slightly acidic. Except the 40-60 cm layer of Tibar's soil, this answers the cherrys requirements. The soil pH is outside the ideal range. Soils are acidic, so some modifications are possible. We can incorporate lime before planting to raise pH.

Mineral nutrients and DOP index

Leaf analysis of mineral content at 60 DAFB to allow the diagnosis of potential deficiencies or excesses in time to be corrected with more efficiency.

Table 2. Chemical analysis of soil in Tibar and Ain-Drahem.

Orchards		00-20 (cm)	20-40 (cm)	40-60 (cm)	60-80 (cm)	80-100 (cm)
Tibar	Carbone%	0 ,5	0,4	0,4	0,1	0,2
	N%	0,28	0,16	0,12	0,19	0,23
	C/N	1,78	2,38	3,17	5,10	0,84
	K_2Oassim/1000	0,28	0 ,22	0,17	0,13	0,14
	P_2O_5assim ppm(OLSEN)	22	7	13	15	11
	pH	5,6	6,3	5,8	5,7	5,8
AinDrahem	Carbone%	1,1	0,8	0,4	0,3	0,2
	N%	0,23	0,19	0,23	0,21	0,11
	C/N	4,62	4 ,08	1,68	1,37	1,78
	K_2Oassim/1000	0,08	0,07	0,06	0 ,07	0,06
	P_2O_5assim ppm(OLSEN)	42	49	12	23	13
	pH	6	5,4	6,6	5,6	6,1

In the present study and according to data in table 3, experimental sites significantly affect the leaf macronutrients level of all sweet cherries. The highest N level was found in three cultivars, Van, Moreau and Sunburst in Ain-Drahem. In Tibar, two cultivars presented the highest level, Napoleon and Moreau. However Napleon had the lowest level in Ain-Drahem.

This variation may be explained by the size of crop. Indeed, Dude (1978) reported that it has frequently been demonstrated that the leaves have a different composition than other trees depending on the abundance of the harvest. Differences between sites for leaf P content were not significant. All cultivars have the low level P. Cultivar had no effect on leaf P contents, which is in agreement with other studies (Nelsein *et al.*, 2010).

Table 3. Leaf macronutrients composition for sweet cherry trees of four cultivars in two orchards, based on mid-shoot leaves sampled at 60 DAFB. Values are the mean for 2013 and 2014.

Orchards	Cultivars	N	P	K	Ca	Mg
Ain-Drahem	Nap	2,00 b	0,10 a	0,86 b	0,54b	0,12b
	Van	2,27a	0,10 a	0,82 b	0,08b	0,25a
	Mor	2,19a	0,11 a	1,17 a	0,13a	0,24c
	Sunb	2,41a	0,10 a	0,89 b	0,15a	0,11a
Tibar	Nap	2,32 a	0,10 a	1,47 a	0,26b	0,062b
	Van	1,89 b	0,12 a	1,64 a	0,28b	0,12a
	Mor	2,45 a	0,11 a	1,77 a	0,38a	0,04b
	Sunb	1,74 b	0,12 a	1,38 a	0,42a	0,12a

Means in the same column followed by the same letter are not significantly different according to the LSD test ($P \leq 0.05$). Nap: Napoleon, Mor: Moreau, Sunb: Sunburst

All cultivars under Tibar conditions had no significant difference between levels of leaf K. Sunburst contained lower levels of leaf K and the same leaf K level as Summit. Napoleon also recorded the same level leaf Kas Heidlfinger in the study of Milosevic *et al.* (2014). This similarity can be explained that there wasn't an impact of rootstock in the accumulation of K. In Ain-Drahem, differences among cultivars for leaf K were not significant and they were deficient according to Leece (1975), except for Moreau which recorded a high amount. Our data is partially in accordance with the results obtained by Milosevic *et al.* (2014).

However, results of other authors confirmed the great variability of leaf mineral composition due to the genotype, year, rootstock and environment. The soil of Tibar is heavy, so fixation by clay particles decreased K availability, whereas Leece (1975) reported that K deficiency in sweet cherry orchards occurred mainly on sandy-loam and loamy soils which tended to be low in exchangeable bases, like our trial in Ain-Drahem. The K reduction in sweet cherry orchards can be associated with heavier cropping rootstocks for cherries (Neilsen and Kappel, 1996).

Level leaf Ca significantly varied among cultivars in two orchards and they recorded a more deficient level than accorded by Leece (1975). In the two orchards, the lowest level of Cawas found in Napoleon and Van, they were statistically similar. Whereas, the highest was found in Moreau and Sunburst, these too, were statistically similar. Cultivar had no effect on leaf Ca contents, which is in agreement with other studies (Neilsen *et al*., 2010). Sunburst had higher Ca level than other cultivars in Tibar which is in accordance with the results obtained by Milosevic *et al.* (2014).

Leaf Mg concentration for all cultivars in both orchards was below the reference. The breakdown in Mg in all cultivars and in both study sites can be explained by poor absorption by the rootstock. The deficiency of this element is generally induced by antagonism with some elements such as Ca.

Insufficiency of leaf Ca and Mg status was high in our trial. This can be explained by soil acidity in the five depths and their low contents in the soil (table 2). This tendency has also been detected in previous study on sweet cherry, although deficiencies of these nutrients are rarely seen in fruit orchards (Johnson and Uriu, 1989). Leaf Ca deficiency can be explained also by its very low mobility in the plant, whereas Mg deficiency is generally induced by antagonism with some nutrients such as Ca and K (Johnson and Uriu, 1989).

Generally, these results indicated that scions of Sunburst, Moreau, Van, and Napoleon had low capacity to accumulate most of the macronutrients at 60 DAFB which is in agreement with result of Neilsen *et al.* (2010). This is a bad accumulation, due to their poor adaptation to the growing conditions. In addition, in the study of Milosevic *et al.* (2014), which collected sweet cherry leaves at the same sampling time as ours, leaf N, P, K, Ca and Mg contents were higher than our results, indicating that, besides rootstock and cultivar, pedo-climatic conditions play an important role in leaf nutrients composition.

To assess the optimum mineral nutrition, the DOP index was determined from leaf mineral elements at 60 DAFB. This index is used to indicate if an element tends to be deficient (DOP < 0), optimal (DOP = 0), or in excess (DOP > 0) (Montanes *et al*., 1993).

In the present study, cultivars on both orchards tended to have an insufficient range of all nutrients, except leaf N which were higher than the optimum, as compared with reference values for sweet cherry proposed by Leece (1975). Additionally, the positive DOP_N was observed in Sunburst in Ain-Drahem. The negative DOP indexes indicate a general problem with soil availability of these nutrients or with nutrient uptake (Leece, 1975).

DOP indexes for macronutrients highlights the significant differences between cultivars within same rootstock at both orchards (Table 4). Probably, other rootstocks can show more balanced nutritional values for macronutrients than SL64, due to adequate uptake of these nutrients.

Leaf N level in Van, Moreau and Sunburstin Ain-Drahem, as well as, Napoleon and Moreau in Tibar tended to be closer to the optimum N level ($DOP_N \approx 0$). All these data imply that Van in AinDrahem and Napoleonin Tibar could be less susceptible to N deficiency in these conditions. In the present study, leaf N in Sunburst in Ain-Drahem, leaf N in Moreau and Napoleon respectively were almost normal attributing to relatively high N_{TOT} content in the soil because of the decomposition of organic matter or/and the presence of a basal application brought before planting.

The negative DOP indexes indicate a general problem with soil availability of these nutrients or with nutrient uptake (Leece, 1975). The negative DOP_P indicated a very high P deficiency in Napoleon, Van, Moreau and Sunburst leaves at both orchards, although the P soil level is very high in Ain-Drahem and normal at Tibar. P is not mobile in plant tissues at 60DAFB and deficiencies can be associated with its lack of solubility. Also, P insufficiency could be due to the poor uptake of this element from this soil type. The negative DOP_K, DOP_{Ca} and DOP_{Mg} indicated the tendency of K, Ca and Mg deficiency in cherries in both orchards.

Table 4. The DOP index and ∑DOP determined from leaf macronutrients content at 60 DAFB of four sweet cherry cultivars in the two different orchards. Values are the mean for 2013 and 2014.

Orchards	Cultivars	N	P	K	Ca	Mg	∑DOP
AinDrahem	Nap	-15,5a	-46,97a	-62,53b	-71,47a	-77,45b	273,92 a
	Van	-5,16a	-47,07a	-64,34b	-95,36b	-54,18a	272,80 a
	Mor	-8,41a	-40,30b	-49,04a	-92,84b	-56,14a	251,58 b
	Sunb	+0,91a	-48,30a	-61,2b	-91,68b	-78,65b	257,12a
Mean							255,67B
Tibar	Nap	-3,917a	-47,38a	-36,00a	-86,31	-88,65b	269,44a
	Van	-23,91b	-36,10a	-28,04a	-85,15	-76,45a	250,52a
	Mor	+2,25a	-40,61a	-24,43a	-79,78	-91,74b	245,61a
	Sunb	-27,33b	-34,46a	-39,82a	-77,68	-77,60a	257,12a
Mean							271,43A

Sign (-) indicates lower content than optimum, while sign (+) indicates higher content than optimum. The different small letters indicate significant differences among ∑DOP indexes within each cultivar at P indexes 0.05 by LSD test. The different capital letter indicates significant differences among ∑DOP indexes in each orchard at P≤ 0.05. Nap: Napoleon; Mor: Moreau; Sunb: Sunburst.

The *C*o was taken from optimum values for sweet cherry proposed by Leece (1975). Besides, it provides the general nutritional status of nutrients through the ΣDOP index, obtained by adding the values of DOP index irrespective of sign. The lower the ΣDOP, the greater is the intensity of balance among nutrients. Analysis of DOP indexes for macronutrients highlights the significant differences between orchards and cultivars within the same rootstock (Table 4). Hence, Ain-Drahem showed more balanced nutritional values for macronutrients than Tibar, due to suitable ground and the adequate uptake of these nutrients. Among cultivars in Ain-Drahem, the widest imbalance in nutritional values was observed in Napoleon, Van and Sunburst, and the lowest in Moreau. In both orchards, Moreau showed the best balanced nutritional values, whereas the poorest found in Napoleon, Van and Sunburst.

Fruit quality attributes

In the present study, all fruit physical features were very different among the cultivars (Table 5), Sunburst in Ain-Drahem, Van in Tibar had the highest weight, and Moreau in Ain-drahem, Sunburst in Tibar had the lowest. Sunburst behaves differently at the two experimental sites. In two orchards, fruit weight of four cultivars was very small; therefore Van and Moreau in Tibar were admitted into the first category of quality with a fruit weight of at least 5 g, which was in accordance with the work of Sîrbu *et al.* (2008). Fruit weight is generally lower, ranging between 2 g and 5.5 g (Petre, 2006). It should be noted that rootstock and crop load may also influence fruit weight (Goncalves *et al.*, 2006). But the availability of minerals in the soil, and their removal can be responsible for the weight of fruit.

The soluble solids content (SSC) varies between 11 and 25° Brix in sweet cherry (Serrano *et al.*, 2005). In the present study, mean SSC ranged between 14.2 and 16.8° Brix in Ain-Drahem, 12,4 and 17° Brixin Tibar for the same cultivars. Sunburst had the lowest SSC in both orchards. The highest were Napoleon in Ain-Drahem and Van in Tibar with almost similar SSC levels (Table 5). The Sunburst SSC level was lower than that found by Miloševići1 *et al.* (2013) but almost the same SSC level as that found by Milosevic (2014) on Mazzard rootstock.

This level was higher than those mentioned in our study, due to different local environment, farming practice and rootstock used. It seems that, beside cultivar, region, weather conditions during harvest period, maturity stage, season and rootstock play an important role in SSC (Serrano *et al.*, 2005). As known, soluble solids level is related with the fruit quality. Cultivars with SSC > 15° Brix are considered to be acceptable for sweet cherry (Kappel *et al.*, 1996), which is the case in our study for Napoleon, Van and Moreau in both orchards.

The values recorded in our study were intermediate compared with previous similar studies. Our result in Tibar was almost the same as that found by Hegedus *et al.* (2013) and Ballistreri *et al.* (2013).

These sweet cherry fruits are Ukrainian, so, there probably is a relationship between the genetic potential of our cultivars and the Ukrainian ones.

Table 5. Fruit physico-chemical features in two different orchards (Ain-Drahem and Tibar).

Orchards	Cultivars	Weight (g)	Soluble Solids Content (°Brix)	Titratable acidity (%)	Firmness (Kg/cm²)	Ripening index
Ain-Drahem	Nap	3,68b	16,8a	1,64b	2,86a	10,19b
	Van	3,81b	15,5b	1,70a	2,78a	9,09c
	Mor	3,23b	15,1b	0,93c	2,09b	16,23a
	Sunb	4,81a	14,2c	0,83d	2,85a	16,52a
Tibar	Nap	4,68 b	15,2 b	1,34b	1,90b	11,30b
	Van	6,49a	17a	1,27c	2,62a	13,43a
	Mor	5,49b	15,3b	1,50a	1,80b	10,18c
	Sunbt	4,66b	12,4c	1,15d	2,49a	10,78c

Means in the same column followed by the same letter are not significantly different according to the LSD test ($P \leq 0.05$), Nap: Napoleon, Mor: Moreau, Sunb: Sunburst.

In our work, Van in AinDrahem and Moreau in Tibarpromoted significantly higher acidity than other cultivars in both orchards. Titratable acidity was higher than that found with Milosevic (2014) on different rootstocks, so, SL 64 may be responsible for provoking higher acidity than others. Our results in Ain-Drahem are in accordance with those of Kuden and Kaska (1995), when analyzing a total of 21 cultivated sweet cherries mostly from Turkey, Europe, and the USA. Ballistreri *et al.* (2013) reported a range of 0.56–1.34 % for the TA of Italian sweet cherries which is the same as our work due to the similarity of Mediterranean conditions, the exception were Napoleon and Van in Ain-Drahem and Moreau in Tibar with a higher value.

Fruit flesh firmness is also an attribute very appreciated by consumers, although there are considerable genotypic differences. Softening in the last days of the ripening of cherries has been attributed to increases in ß-galactosidase activity, unlike most fruits, in which softening is dependent on pectin depolymerization due to polygalacturonase activity (Batisse *et al.*, 1996; Gerardi *et al.*, 2001). In Ain-Drahem, the highest fruit flesh firmness was observed in Napoleon and the least in Moreau genotype with a significant difference. Napoleon and Moreau in Tibar had the soft fruit flesh, while the fruit flesh was firm in Van and Sunburst.

Perez *et al.* (2008) also observed that sweet cherry genotypes showed great variability in fruit parameters such as flesh firmness. This is the same as our results in Tibar.

The ripening index (RI) is commonly used as a quality index for sweet cherry, and higher ratios are usually preferred (Cantín *et al.*, 2010). Moreau and Sunburst in Ain-Drahem, and Van in Tibar had higher RI.

Correlations among variables

There are many factors that are included in the term fruit quality in the sweet cherry. However, only fruit weight, fruit firmness and soluble solids can be measured, whereas the top level of each of these factor are correlated with the best fruit quality (Folge, 1975).

The correlation between some fruit quality parameters and some mineral elements leads us to distinguish a simple correlation coefficient analysis among characteristics (Table 6). The fruit weight showed positive correlation (at $p \leq 0.01$) with K level leaf (r = 0,61). Gautier (1987) explained that this element promotes the quality of fruit, caliber and taste. However, negative correlation with Mg level leaf (r= -0,55 at $p \leq 0.01$). Heller *et al.* (1998) reported that serious deficiencies affect yields with a lower average fruit weight and especially quality and storability. In both study area, the soil level of Mg is very low which has a negative effect on fruit weight.

Bretaudeau and Faure (1992) reported that potassium ensures the fruit's sugar content. Sunburst in both experimental sites marks a low level of SSC because the breakdown of the soil in this element, it is not recommended to cultivate this variety in the same soil. On the other hand Ca was negatively correlated with ripening index ($r = - 0,44$ at $p \leq 0,05$). So Calcium is not the most important element that determines the firmness which contradicts other researches.

There was not any relationship between the fruit weight and fruit firmness which is in disagreement with results of others in cherries (Christensen, 1996; Demirsoy and Demirsoy, 2004). The nutrient requirements of young cherry trees *(Prunu savium* L.) increase during the period of fruit formation, and they continue to increase annually until the trees reach full production. In addition, the nutrient requirements can vary according to training systems, planting density, soil type, climatic conditions and genetic potential of the cultivar.

Many authors have discussed the relationship between plant calcium and potassium content. Andziak *et al.* (2004) has indicated that in apples, an increase in potassium concentration was associated with a decrease in calcium content in contrast to our results where the correlation was positive but not significant. There was not a meaningful relationship between leaf N content and ripening index. This was in contradiction with the result of Coutanceau (1962). There was a negative correlation but not significant among leaf N and Mg levels. This result was in accordance with those of Lichou and Audubert, (1989). P is negatively correlated but not significant with SSC and TA. This, corroborates the work of Khalil (1989). Also, there was positive correlation between AT and leaf Ca levels (Table 6), which means that the higher the leaf Ca level, the higher the titratable acidity. Firmness was negatively correlated with leaf K content (at $p \leq 0,01$; $r= - 0,53$). The firmness varies depending on the cultivar. The compounds of pectocellulosic walls and activity of tissue degrading enzymes during maturation are under genetic control. We found that there was a significant negative relationship between AT and IM (Table 6). Maturity is a very important step for fruit quality because it is the continuation of reserve accumulation in the fruit, loss of firmness, a reduction in acidity and an increase in sugar content.

Table 6. Correlation among leaf macronutrients, weight, firmness, SSC, TA and RI.

	N	P	K	Ca	Mg	Weight	Firmness	SSC	TA	RI
N	1.00000	ns	ns	ns	ns	ns	ns	ns	ns	ns
P		1.00000	ns	ns	ns	ns	ns	ns	ns	ns
K			1.00000	ns	-0.54(**)	0.61(**)	-0.53(**)	ns	ns	ns
Ca				1.00000	-0.53(**)	ns	ns	ns	0.33(*)	-0.44(**)
Mg					1.00000	-0.54(**)	ns	ns	ns	ns
Weight						1.00000	ns	ns	ns	ns
Firmness							1.00000	ns	ns	ns
SSC								1.00000	0.46(**)	ns
TA									1.00000	-0.88(**)
RI										1.00000

Significant at $p \leq 0,05$ (*) or at $p \leq 0,01$ (**); ns: not significant.

Conclusion

The physicochemical properties of sweet cherry depend on the culture area and the cultivars. Furthermore, irrigation can modify or overcome some of this fruit quality.

The poverty of both organic matter soils may be the cause of poverty in cultivar elements P, K, Ca, and Mg. Soil management is a key to improving nutrient retention and water infiltration in order to enhance fruit quality.

So we need effective soil management with fertilizers. It's preferable to apply most of yearly nitrogen requirement after harvest. Phosphorus can be incorporated in the autumn as a single band along the tree line. Daily K fertigation from mid-June to mid-August at a per tree rate of 15g/year in Ain-Drahem orchards maintain a higher K concentration in the soil solution. Sunburst in both areas behaves the same way and saves weight that responds to reference values with a low SSC. Moreau showed the balanced nutritional values, so it can absorb as many nutrients in deficient soil. Napoleon and Van behaved differently. They are sensitive to nutrient deficient soils, so, their culture required a lot of attention. We made an assumption on the rootstock role. These rootstock Saint Lucie 64 had a low efficiency in the absorption of some macronutrients from the soil such as N, P, K, Ca and Mg by a worst flow of nutrients in the leaves. We can choose the right rootstock for sweet cherry which is most suitable for each of the two grounds.

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