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Factors Affecting Taste Scores of Early Season Seedless Table Grape Cv. Mystery and Prime

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Table grapes of cv. Mystery and Prime were harvested from 10 farms in two growing areas of Israel over two seasons. The grapes were separated on the basis of sucrose solutions from 12 to 18%; soluble solids content (SSC), titratable acidity (TA), and pH were determined; and taste tests were conducted. SSC gave the best correlation with taste tests, and multiple regression of SSC, TA, and pH improved the correlation. There were both seasonal and regional differences in the measured maturity parameters. Lower TA and higher pH were found in grapes from the Jordan Valley. Volatiles were predominantly C_6 compounds hexanal and 2-hexanal, contributing a fresh aroma to the grapes. It is concluded that Mystery and Prime grapes have good organoleptic quality if harvested at SSC levels of >14%.

KEYWORDS: pH; potassium; soluble solids content; titratable acidity; volatiles

INTRODUCTION

Grapes are nonclimacteric fruit and do not ripen further after harvest; therefore, they must be harvested at a stage of maturity suitable for consumption. To harvest at the ideal maturity, it is necessary to determine the true composition of the fruit in the field. Thus, it is necessary to make field tests of the grapes on the vine during their maturation. For various reasons it is not easy to establish the best method of measuring the maturity of grapes in the field. Grapes on the vine do not ripen at the same rate. Each berry and cluster differ in their rates of ripening (*1*, *2*). The position of the fruit on the vine, the location of the vine in the vineyard with respect to exposure, soil moisture, humidity, and temperature, the amount of crop, and soil differences all can affect the rate of berry maturation (*3*, *4*).

Nonetheless, the determination of indices of maturity are of considerable importance for deciding when to begin harvest. A great deal of research has been done to determine optimum maturity in different areas. Maturity criteria discussed include size, color, soluble solids solids (SSC), acidity (TA), and the sugar/acid ratio (SSC/TA) (*5*−*8*). In general, the sugar/acid ratio is used, although sugar concentration alone was found to be sufficient in certain cases and preferred because of its relative ease of determination (*6*). Guelfat-Reich and Safran (*7*) came to the conclusion that the maturity of cultivars with a naturally low acid concentration can be determined on the basis of soluble solids content, that of high-acid cultivars by acidity alone, and the medium-acid cultivars by both sugar and acidity. It seems that there are no general criteria applicable to all cultivars and that it is also quite possible that maturity standards may differ between regions and even between seasons (*6*).

Export of table grapes from Israel to Europe is limited to early summer, so an early harvest is of great economic importance. As a result, grape growers tend to harvest their fruit as early as possible, relying on the percentage of sugar in the fruit. Recently, two new cultivars, Mystery and Prime, have been introduced into various growing regions. Maturity standards for these two cultivars have not yet been established. In this study, the harvest maturities of these two cultivars were compared from two growing regions in Israel over two seasons. Taste tests were conducted to determine what was the contribution of SSC and TA to acceptable taste. Volatiles were measured as well because these components are an important aspect of overall taste perceptions (*9*).

MATERIALS AND METHODS

Grape Sampling. The experiments covered a period of two years during which two cultivars were tested, Prime and Mystery. Prime and Mystery are early season, white, seedless table grapes that ripen together with Perlette grapes but require fewer treatments to increase berry size than do Perlette. The grapes are grown on a Y-shaped trellis, are treated with a dormancy releasing spray in midwinter, and girdling and a GA_3 application after fruit set to increase berry size. Bunches are also hand-thinned to maintain a yield of 25−30 tons/ha.

Fruits were harvested in two growing regions: the Jordan Valley, where the cultivars ripened in early to mid June; and the Central Valley, where the same cultivars ripened from mid to late June. Samples were taken from the first harvest for export. From each vineyard five export cartons were harvested. Each carton contained 5 kg of fruit made up of 8−12 grape bunches. Five farms were sampled from each growing

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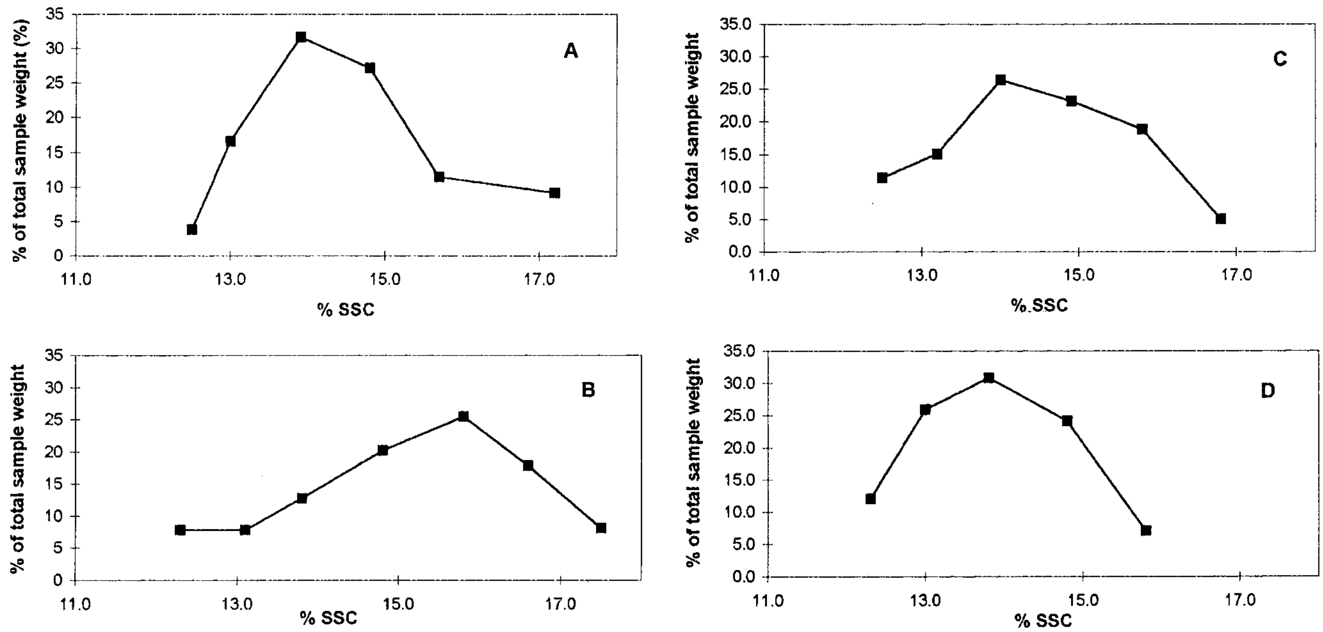

Figure 1. SSC of berries from five bunches separated according to sucrose solutions: (A, B) Mystery berries from the Jordan and Central Valleys, respectively; (C, D) Prime berries from the Jordan and Central Valleys, respectively.

area. Grapes were either sampled directly after harvest or held for a few days at 0 °C before sampling. No antifungal treatments were given to the grapes during this brief storage.

Two sampling systems were used for maturity analyses. In the first, the grapes from one 5 kg box were separated from the bunches and passed through a series of sugar concentrations from 11 to 18% as described by Guelfat-Reich and Safran (*7*). There was a 1% difference between the sugar solutions. The berries that sank in each solution were collected, washed, and weighed, and their juice was extracted with an electric juicer. This method was compared to taking five replicates of 20 berries from the center of the clusters from another 5 kg box of fruit and juicing them.

SSC, TA, and pH Analysis. SSC was determined on the juice with a digital refractometer (Atago, Tokyo, Japan). TA and pH were determined with an automatic titrator (Metrohm, Munich, Germany). Two milliliters of juice was diluted with distilled water, the pH measured, and then the juice titrated with 0.1 N NaOH to pH 8.2; the result was calculated as percent tartaric acid.

Volatile Measurement. Volatiles were determined from juice by using the method of solid-phase microextraction (SPME) as detailed by Yang and Peppard (*10*). Volatile compounds (0.8 mL of sample) were trapped for 10 min using a poly(dimethylsiloxane)-coated SPME fiber assembly (Supelco, Bellefonte, PA). The compounds were analyzed by SPME headspace GC-MS (Varian Star 3400 CX GC equipped with a 30 m × 0.25 mm i.d., DB-5MS column and interfaced with a Varian Saturn 3 MS). The fiber was placed by a 8200cx autosampler into a 1077 splitless injector for 3 min (injector temperature was 210 °C). Helium was the carrier gas, and the GC temperature was programmed for 2 min at 40 °C, increasing to 250 °C at 10 °C/min for 21 min and then held for 2 min at 250 °C. Ionization energy was 70 eV. Compounds were identified on the basis of the Wiley library (*Wiley Registry of Mass Spectral Data*, 6th ed.; Wiley: New York, 1994). Three samples from three different farms in each growing area were analyzed for each cultivar.

Organoleptic Tests. Taste tests were conducted with a panel of 20 trained persons on the berries segregated in the sucrose solutions, as well as a pooled sample of berries from the center of bunches. Each taste series contained four to six samples. The taste panel graded the samples according to three descriptors: sweetness, sourness, and general grape taste. The ratings were from 1 to 3: 1 = poor (not sweet, very sour, not tasty) and 3 = good (sweet, not sour, tasty). The value of 2.2 for general taste was chosen as the minimum value for good-tasting grapes.

Statistical Analysis. Data were analyzed on an SAS statistical program, for standard deviation, Duncan's multiple-range test, correlations, and multiple regression (*11*).

RESULTS

SSC and TA. The SSC of the berries separated according to sucrose solutions ranged from 12 to 18% with generally a normal distribution curve (Figure 1). Occasionally a harvest would be skewed toward the top or bottom end of the sucrose concentrations, but in general they showed a bell curve distribution. More than 70% of the berries on a bunch were within 2% of the peak sugar distribution. However, within an individual bunch there was also a range of SSC values from 14 to 18%, and the pH of the individual berries showed a distribution as well, varying from pH 3.8 to 5.3 (data not shown).

Comparison of Sampling Methods. When the groups of berries from the various sucrose solutions were combined and averaged, the values for the measurements performed were similar to those taken from random bunches (Table 1). Grapes from Jordan Valley farms were lower in TA and higher in pH than those from the Central Valley. The SSC of the harvests from the Jordan Valley showed more variation from farm to farm, with three being >15% and two farms harvesting grapes of <15% SSC. In contrast, all of the farms in the Central Valley harvested their fruit at ~14% SSC.

Correlation of Taste and Maturity Parameters. Taste tests were performed on the berries of the two cultivars separated in sucrose solution and correlations run between taste, SSC, TA, and pH (Figure 2). The best correlation between overall taste and a maturity parameter was SSC, which gave R^2 values of 0.62 for both Mystery and Prime grapes. The samples that fell below the 2.2 taste score were 14% SSC or lower for both cultivars. Neither TA nor pH showed a good correlation with taste. Examining the correlation of the ratio of SSC/TA and taste did not improve the correlation over SSC alone, nor did SSC × pH give a better correlation (Table 2).

The lack of involvement of TA or pH in overall taste was surprising in that the tasters could discriminate between grapes

Table 1. Comparison of Prime Grape Maturity Measured on Random Bunches or According to Berries Separated on Sucrose Solutions[a]

area	farm	sample method	berry wt (g)	SSC (%)	TA (%)	pH	SSC/TA	SSC × pH
Central Valley	1	random	6.7 ± 0.43	14.9 ± 0.66	0.64 ± 0.04	3.25 ± 0.03	23.3 ± 1.5	48.7 ± 2.6
		sucrose	6.3 ± 0.95	15.1 ± 1.5	0.65 ± 0.02	3.26 ± 0.05	23.4 ± 2.2	49.3 ± 5.7
	2	random	6.2 ± 0.27	14.4 ± 0.7	0.59 ± 0.05	3.21 ± 0.04	24.5 ± 3.1	46.3 ± 2.6
		sucrose	6.1 ± 0.27	13.9 ± 0.9	0.57 ± 0.05	3.20 ± 0.04	24.5 ± 3.9	44.3 ± 3.5
	3	random	7.5 ± 0.40	13.8 ± 0.5	0.60 ± 0.04	3.27 ± 0.05	23.0 ± 1.2	45.1 ± 2.0
		sucrose	7.5 ± 0.95	13.3 ± 1.4	0.59 ± 0.07	3.27 ± 0.07	22.9 ± 4.3	43.5 ± 5.5
	4	random	4.7 ± 0.11	14.3 ± 0.4	0.44 ± 0.02	3.42 ± 0.04	32.3 ± 1.8	48.7 ± 7.4
		sucrose	4.5 ± 0.42	13.4 ± 1.1	0.42 ± 0.01	3.42 ± 0.03	31.6 ± 4.2	45.7 ± 4.2
	5	random	6.2 ± 0.27	14.4 ± 0.7	0.59 ± 0.05	3.20 ± 0.04	24.5 ± 3.1	46.3 ± 2.6
		sucrose	6.3 ± 0.95	14.3 ± 0.4	0.57 ± 0.05	3.27 ± 0.05	24.5 ± 3.9	44.3 ± 3.5
Jordan Valley	1	random	5.5 ± 0.26	14.7 ± 1.62	0.38 ± 0.03	3.69 ± 0.12	39.0 ± 7.3	54.3 ± 7.3
		sucrose	5.7 ± 0.32	14.5 ± 1.67	0.38 ± 0.02	3.65 ± 0.09	38.4 ± 5.9	53.0 ± 7.3
	2	random	5.6 ± 0.25	15.4 ± 0.90	0.33 ± 0.03	3.60 ± 0.05	46.3 ± 4.9	55.4 ± 3.9
		sucrose	4.9 ± 0.56	15.9 ± 1.4	0.34 ± 0.01	3.66 ± 0.01	47.3 ± 3.9	58.1 ± 4.5
	3	random	6.2 ± 0.22	16.1 ± 1.0	0.57 ± 0.02	3.47 ± 0.03	28.2 ± 2.3	55.8 ± 3.8
		sucrose	5.8 ± 0.42	16.0 ± 1.6	0.56 ± 0.02	3.46 ± 0.05	28.3 ± 3.3	55.4 ± 3.2
	4	random	6.4 ± 0.45	17.3 ± 0.57	0.55 ± 0.03	3.60 ± 0.05	31.3 ± 2.1	62.3 ± 2.3
		sucrose	6.0 ± 0.38	17.1 ± 1.4	0.55 ± 0.04	3.57 ± 0.09	31.3 ± 4.7	61.5 ± 6.6
	5	random	4.7 ± 0.53	13.3 ± 1.0	0.40 ± 0.03	3.72 ± 0.08	33.2 ± 4.9	49.5 ± 5.8
		sucrose	4.5 ± 0.24	13.5 ± 1.5	0.41 ± 0.01	3.74 ± 0.10	33.4 ± 3.9	50.5 ± 7.1

[a] Data are the average of five grape bunches for each measurement ± standard deviation.

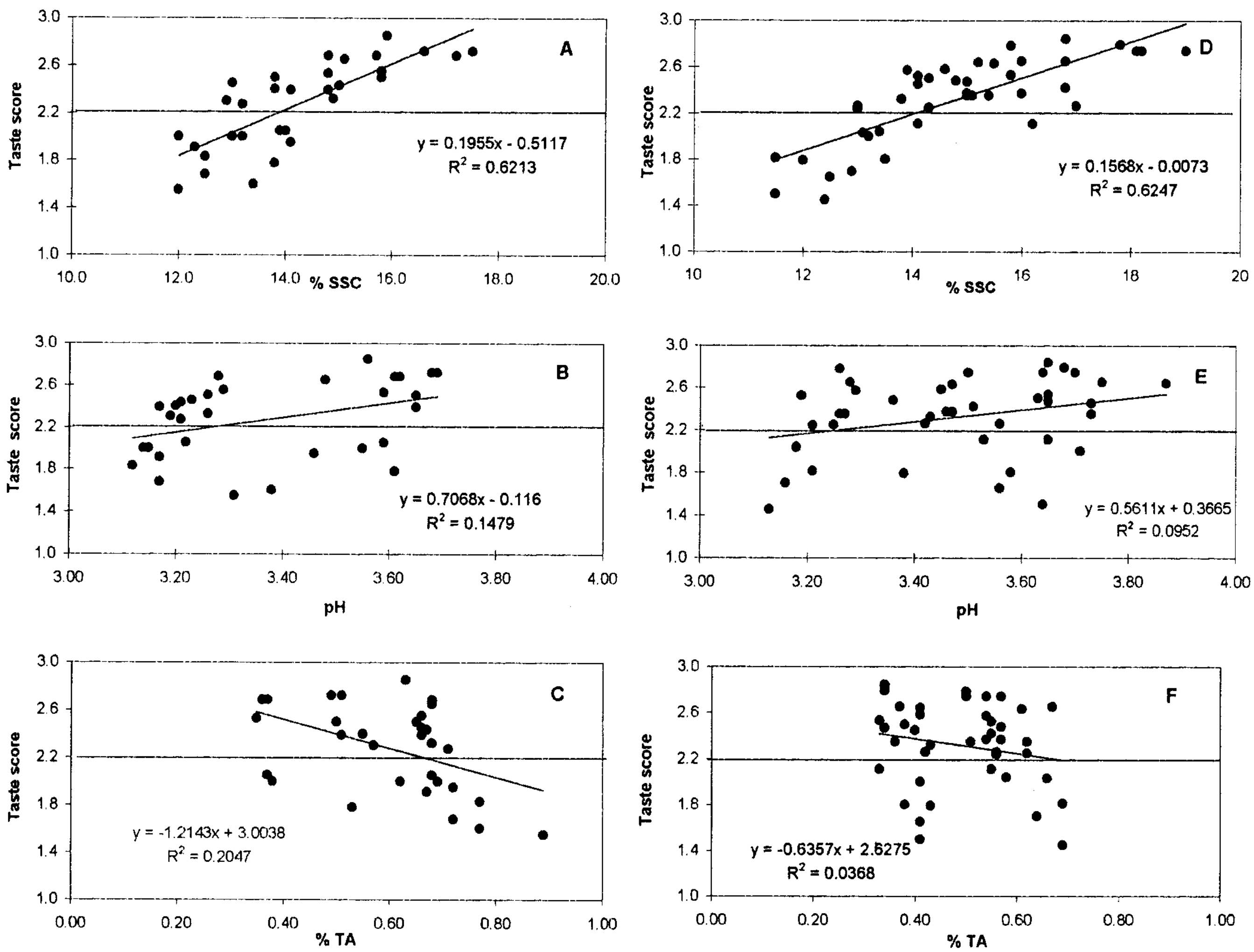

Figure 2. Correlations between the taste score and (A, D) SSC, (B, E) pH, and (C, F) TA. Panels A–C are correlations for Mystery grapes and panels D–F for Prime grapes.

that were more or less sour and this played a role in their rating of overall taste (Figure 3). The correlations were better between sweetness (R^2 of 0.92 for Mystery and 0.93 for Prime) than sourness (R^2 of 0.64 for Mystery and 0.57 for Prime). However, the correlations for discriminating sour grapes as being less tasty were much higher than those discriminating low pH or high

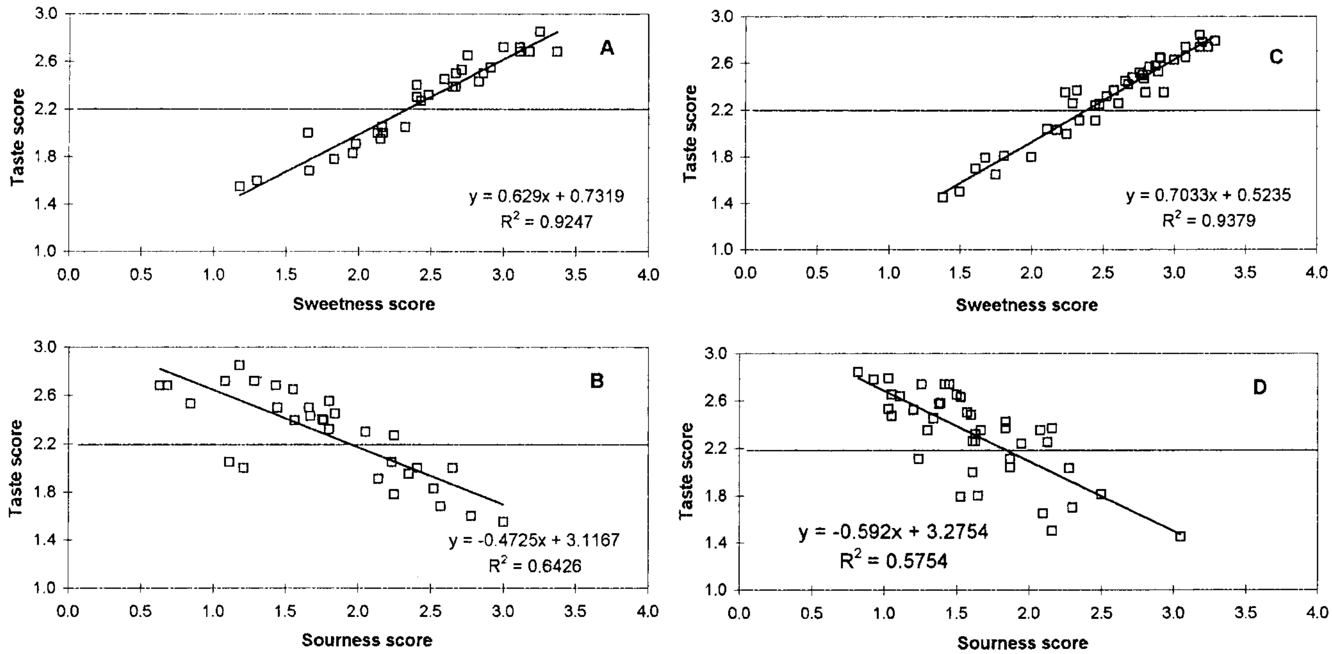

Figure 3. Correlations between (A, C) sweetness score and (B, D) sourness score of (A, B) Mystery grapes and (C, D) Prime grapes.

Table 2. Simple and Multiple Regression Analysis of Taste and Maturity Parameters SSC, TA, and pH of Mystery and Prime Grapes

	R^2			
cultivar	SSC	SSC/TA	SSC × pH	SSC, TA, pH
Mystery	0.62	0.27	0.48	0.80
Prime	0.62	0.25	0.54	0.77

Table 3. Comparison of Seasonal Differences in Mystery Grapes over Two Seasons[a]

season	SSC (%)	TA (%)	pH	SSC/TA	SSC × pH	taste score (1–3)
1	15.6a	0.62a	3.48b	26.1b	54.3a	2.30b
2	14.9b	0.42b	3.59a	32.2a	53.8a	2.66a

[a] Columns with different letters indicate significant differences at the $p = 0.05$ level according to ANOVA.

TA as being less tasty (Figure 2 compared to Figure 3). Similarly, the correlation between sweetness and good taste was better than that of SSC and taste. It was found that by using multiple regression the correlation between taste and the three parameters of SSC, TA, and pH was better than just SSC (Table 2).

Seasonal Differences. Taking the average of the grapes from the 10 farms (5 from each growing area) over two seasons showed that seasonal differences in maturity development occurred (Table 3). All parameters measured except the value of SSC × TA were significantly different between the two seasons. Interestingly, although the average SSC of the grapes was lower in season 2, the taste score was higher than for season 1. The explanation is probably that although SSC was lower in season 2, so was the TA of the grapes and so the taste was rated high, an additional indication that acidity is important in the taste score.

Volatiles. The major volatiles of both Mystery and Prime grapes were the C_6 volatiles, hexanal and 2-hexanal (Table 4). These two comprised >70% of the total volatiles. Of 22 major volatiles identified only 2, linalool and nerol, were monoterpenes, which are important in volatiles of wine grapes. The content of volatiles of the grapes from the Jordan Valley was similar to that of grapes from the Central Valley, but two volatiles, linalool and camphor, were significantly lower, and a number of volatiles were missing entirely from the samples of both cultivars from the Jordan Valley.

Table 4. Volatiles of Mystery and Prime Grapes from the Jordan and Central Valleys[a]

	% area			
	Mystery		Prime	
compound	Jordan	Central	Jordan	Central
hexanal	48	55	51	46
2-hexanal	29	34	24	30
phenol	3.5	2.3	2.9	3.6
cyclododecane	0.7	3.7	5.1	2.5
2-ethylhexanol	2.4	1.2	3.6	1.9
1-hexanol	4.3	1.2	2.7	0.7
5,9-undecadien-2-one	0.2	0.3	1.0	0.4
linolool	1.8	1.8	0.7	1.5
nerol	2.6	1.0	1.4	1.5
camphor	0.6	1.6	0.4	1.3
nonanal	0.8	1.3	0.8	1.4
decanal	0.8	0.5	1.4	1.3
isoamyl decanoate	0.6	0.5	1.3	1.7
2-hexen-1-ol	1.8	0.3	0.8	0.2
2-hexyn-1-ol	0.5	0.5	0.5	0.5
octanal	0.4	0.2	0.4	0.5
theaspirane B	0	0.2	0	0.6
theaspirane A	0	0.2	0	0.8
6-methyl-5-hepten-2-one	0	0	0.3	0.3
β-damascenone	0	0.2	0	0.2
1,8-cineole	0	0.3	0	0.5
endobornyl acetate	0	0.1	0.1	0.2

[a] Values are the average of three samples and expressed as percent area of total volatiles.

DISCUSSION

It is necessary to determine maturity standards for each grape cultivar. In this study SSC was found to give the best correlation with organoleptic tests, but accounted for only ∼60% of the variability (Figure 2). However, including the acidity as either the ratio of SSC/TA or SSC × pH did not improve the correlation (Table 2), and only multiple regression of all three parameters gave a better correlation with taste than SSC alone. SSC is often used as a major criterion for harvest, but many researchers try to take into account the acidity as well. In most cases the ratio of SSC/TA is used. However, this was not appropriate for Mystery and Prime grapes. Combrink et al. (*5*) found that acid may vary from season to season, and although two samples may have the same SSC/TA ratio, they may differ considerably when tested organoleptically. In a number of cultivars grown in South Africa SSC was a more reliable indicator than SSC/TA (*8*, *12*). In the current research both SSC and TA varied from season to season, and with lower acidity the taste values were higher (Table 3).

The TA of Mystery and Prime grapes is in the range of what was defined as low acid by Guelfat-Reich and Safran (*7*). They showed that sugar alone is a good parameter for measuring optimum maturity in these low-acid cultivars. Only if the SSC was 14% or lower did acidity become important in determining if the berry was tasty or not. Mystery and Prime grapes had good organoloptic quality if harvested at SSC levels of 14% or higher. In addition, SSC/TA ratios of 30 or an SSC × pH value of 50 guaranteed good taste.

Grapes from the two growing areas examined showed differences in acidity and pH (Table 1). This difference may be due to the very hot climactic conditions of the Jordan Valley. It is known that high pH and low acidity are problems of warm climates (*4*, *13*). Even in grapes grown in temperate climates, a warm summer affected pH and TA more than SSC (*14*).

Aroma volatiles of table grapes have been less studied than those of wine grapes. Grapes are divided into floral and nonfloral (*15*) or aromatic and nonaromatic (*16*). In the aromatic or floral cultivars it is recognized that monoterpenes are important aroma compounds (*17*, *18*). In Mystery and Prime grapes only linalool and nerol were present from this class of volatiles (Table 4).

A group of volatile compounds that are quantitatively very important in nonaromatic grapes are the C_6 compounds (*16*). They arise from the action of lipoxygenase on the fatty acids of the berry (*19*). These volatiles were the prominent ones in Mystery and Prime grapes. In wine grapes they impart a characteristic green odor, which is not beneficial to the wine, but in table grapes these volatiles indicate freshness.

The volatile compounds in nonaromatic grapes are not much use as a parameter for maturity due to their low concentrations. Cultural practices and climate affect their levels, as was seen in the differences between volatile levels of Mystery and Prime grapes grown in the Jordan Central Valleys. In addition, the levels of volatiles continued to increase the longer the fruits were kept on the vine after the sugar and acid vales were suitable for harvest (*18*). Hardy (*20*) concluded that aroma ripeness and SSC and TA do not coincide. Therefore, although the volatiles contribute to the organoleptic quality of the grapes, they cannot be used as a harvest indicator.

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