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Effects of Excessive Potassium Levels on pH, Acidity and Color of Fresh and Stored Grape Juice.

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Three excessive rates of potassium (K) were applied throughout the growing season to two-year-old container-grown Concord (Vitis labrusca L.) vines. Excessive K resulted in an increase in the K levels and a decrease in the magnesium (Mg) levels of leaves, petioles, canes, trunks and roots at fruit harvest and, to a lesser extent, during dormancy. Potassium levels in petioles correlated better with K and pH in fresh and stored juice than did the K levels in other plant parts. Excessive K levels in the juice were detrimental to fresh and stored juice pH and color quality. High juice pH levels, created by the excessive K fertilization, produced problems in color stability during storage.

In warm production regions high pH of grapes at harvest can be a problem for both the juice and wine industries. High pH values in grapes reduce color and stability of processed products. This condition can be exaggerated by high cation uptake from the soil, and excessive potassium (K) can contribute to the problem (1,9,10). The substitution of K+ cations for H+ in the grape tissue can increase the pH despite a high acidity (2,3,5). Additional information on this subject is needed. The objective of this study was to investigate the effects of three levels of excessive K fertilization on the K content of the plant and fruit and on the subsequent pH, acidity, color quality and color stability of the fresh and stored juice.

Materials and Methods

One-year-old Concord grapevines were planted in 1980 in commercial potting soil (Pro-Mix) in 19L containers. They were grown for one year, pruned and trained to a short bilateral cordon system with 1.5 m between plants and 1.8 m between rows. For the first year, vines were uniformly fertilized weekly with nitrogen, phosphorus, and potassium. Drip irrigation was used as required to maintain adequate soil moisture.

In 1981, three excessive rates of potassium fertilization (3, 6, and 12 g per plant in the form of K_2SO_4) were applied at weekly intervals to the containers from May 1 through September 1 (harvest). The potassium was spread evenly over the surface of each container and incorporated by flooding the containers with water. To these treatments and a control (0 g K), nitrogen was applied weekly during the growing season to maintain vine growth, and water was applied with drip-irrigation as needed. All vines were thinned to four clusters (2 on each cordon). The experiment was designed as a randomized complete block with 20 replications of single vine plots.

Plant Part Nutrient Analysis: At the time of fruit harvest (Sept. 1) petiole and leaf samples were taken from recently matured leaves of fruiting shoots exposed to the sun. The remaining plant part samples (canes, trunks, roots) were collected twice (at harvest and during dormancy), using half of the replications at each sampling time. Whole vines were removed from the containers; the roots, trunks, and canes were separated; and samples of each were collected. Cane samples consisted of 8 cm sections taken from the four fruiting canes, and 10 cm trunk samples were taken from the middle of the trunk. Approximately 50 g of root tissue were collected from different areas of the root system. All plant parts were dried at 80°C, ground in a Micro-Wiley mill to pass through a 40-mesh screen, and stored in tightly capped plastic vials. Before being weighed for analysis, the samples were redried at 80°C. Samples were digested using heat, H_2SO_4 and H_2O_2; cooled to room temperature; filtered; and brought to volume with deionized water. Potassium and magnesium contents were determined flame photometrically using a Beckman Model DU spectrophotometer.

Juice Analysis: The four clusters were destemmed, and the berries were frozen in polyethylene bags for storage. For quality analysis, the grapes were thawed and blended for 15 seconds in a laboratory blender. The samples were then heated for one hour at 85°C, allowed to cool to 25°C, and strained through two layers of coarse cheesecloth to remove the pulp. A portion of this juice was collected for immediate analysis, and the other portion was placed in 50-mL plastic tubes, capped, frozen, and stored for three days to crystallize potassium bitartrate.

For fresh juice analysis, percent soluble solids was determined using a Bausch and Lomb Abbe refractometer. Tristimulus color was determined by a Gardner Color and Color Difference Meter standardized to a dark red tile (L=23.1, a=22.0, b=7.1). A 5-mL aliquot of juice was placed in an optical cup, a white tile was placed over the cup, and CDM "L", "a", and "b" values were recorded. Approximately 20 mL of juice was centrifuged for 15 minutes at 15 000 rpm and used for the remaining quality determinations. A 5-mL sample was diluted to 125 mL with deionized water, the initial pH was recorded, and the sample was titrated to pH 8.4 with 0.1 N NaOH to determine acidity. A 2-mL aliquot of juice was diluted

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to 50-mL with deionized water, acidified to pH 1.5 with dilute HCl, and diluted further to 100-mL with deionized water. The absorbance at 520 nm of the sample was determined using a Bausch and Lomb Spectronic 20 spectrophotometer (Model 340). Potassium and magnesium contents of the juice were determined flame photometrically using a Beckman Model DU spectrophotometer.

For stored juice analysis, the frozen samples were thawed overnight at, 10°C (duality determinations were identical to those used for fresh juice).

All data were subjected to analysis of variance and F tests. Duncan's Multiple Range Test was used to separate means.

Results and Discussion

Plant Part Analysis: The mineral composition of plant parts at harvest showed that, as the potassium (K) fertilization level was increased, there was an increase in the K content and a decrease in the magnesium (Mg) content in all plant parts (Table 1). Other researchers (1,6,8,10,13) have reported an increase in petiolar K and decreases in Mg due to K fertilization. In general, the petioles and leaves had the highest. K content of the plant parts analyzed. All levels of K fertilization resulted in a reduction of the Mg content of the petioles to deficiency levels (below 0.2%) as determined by Shaulis and Kimball (11). However, the foliage of these plants that received excessive K did not express Mg deficiency symptoms. In the control plots, petiole K at harvest was at an acceptable level (2.35% dry wt.) according to Shaulis and Kimball (11), and excessive K content was established at all other K fertilization levels. The K content of the canes had the highest correlation (r=0.84) with the level of K fertilization, followed closely by trunks (r=0.81), leaves (r=0.80). petioles (r=0.73), and roots (r=0.65).

High K fertilization resulted in increases in the K content of dormant canes and trunks, and all levels of K fertilization increased the K levels in dormant roots (Table 2). The same trends of Mg content that occurred in canes, trunks and roots at harvest were present in the dormant plants. The correlations for the K level of dormant plant parts and level of potassium fertilization were not as good [canes (r=0.55), trunks (r=0.44) and roots (r=0.45) as correlations obtained at harvest.

The only significant, correlation with the K contents of the plant parts at harvest and the K content, of the fresh juice was with the petiole K level (Table 3). However, K levels of all the plant parts correlated significantly with stored juice K, with the K content of the trunks and petioles having the highest correlation values. There were no significant correlations between the K levels of the plant parts and the acidity levels of the fresh or stored juice. Significant correlations existed for petiole K and pH of the fresh and stored juice. The only other significant correlation for the K content in a plant part with juice pH was with the K content of the trunks and the pH of the fresh juice. Overall, the K levels of the petioles had more significant correlations with juice K and pH than any other plant part. Therefore, petiole K gives the best indication of the K level and pH in the fresh and stored juice.

Table 1. Effects of potassium fertilization on the K and Mg content of plant parts at harvest.

Plant part	Potassium fertlization (g/plant)[z]	Potassium content (% dry wt.)	Magnesium content (% dry wt.)
Petioles	0	2.35c[y]	0.33a
	3	4.07b	0.15b
	6	5.35a	0.11c
	12	5.79a	0.10c
Leaves	0	1.25d	0.23a
	3	2.05c	0.17b
	6	2.81b	0.15c
	12	3.50a	0.13d
Canes	0	0.48d	0.09a
	3	0.76c	0.06b
	6	0.84b	0.06b
	12	1.00a	0.06b
Trunks	0	0.35c	0.08a
	3	0.48b	0.06b
	6	0.49b	0.06b
	12	0.65a	0.06b
Roots	0	0.71c	0.16a
	3	1.15b	0.13d
	6	1.06b	0.14c
	12	1.48a	0.15b

[z]K fertilizer was applied weekly from May 1 through Sept. 1 (harvest).
[y]Means separated within columns and plant parts by Duncan's Multiple Range Test at the 5% level.

Juice Analysis: Increasing the K fertilization resulted in an accumulation of K in the fresh and stored juice (Table 4). Previous reports on K fertilization present similar results (9,10). Excessive levels of K fertilization increased the pH and lowered the acid content of fresh and stored juice. Similarly, Abdalla and Sefick (1), Mattick *et al.* (9) and Morris *et al.* (10) have reported that high K fertilization increased the pH and lowered the acid levels of Concord juice. These increases in pH due to excessive K were due to the direct exchange of K canons for protons derived from the organic acids (2,3,5). This exchange is probably due to the activity of adenosine triphosphatases (4).

These high rates of K fertilization also resulted in a reduction in CDM "b" values and an increase in CDM hue (a/b) values of the fresh and stored juices. Consequently, juice color was more

Table 2. Effects of potassium fertilization on the K and Mg content of dormant plant parts.

Plant part	Potassium fertilization (g/plant)^z	Potassium content (% dry wt.)	Magnesium content (% dry wt.)
Canes	0	0.62b	0.09a
	3	0.65b	0.08b
	6	0.72ab	0.07c
	12	0.80a	0.06d
Trunks	0	0.53b	0.09a
	3	0.53b	0.08b
	6	0.54b	0.08b
	12	0.66a	0.07c
Roots	0	0.64b	0.11a
	3	0.84a	0.08b
	6	0.77a	0.08b
	12	0.84a	0.07b

^{z}K fertilizer was applied weekly from May 1 through Sept. 1 (harvest).
^{y}Means separated within columns and plant parts by Duncan's Multiple Range Test at the 5% level.

Table 3. Correlations between potassium in plant parts at harvest and K, acidity, and pH of fresh and stored juice.

	Potassium				
	Root	Trunk	Cane	Petiole	Leaf
K in juice					
Fresh	0.24	0.27	0.36	0.57*	0.35
Stored	0.55*	0.71**	0.54*	0.66**	0.58*
% Acid in Juice					
Fresh	0.14	0.10	0.11	−0.01	0.09
Stored	0.17	0.06	0.03	0.13	0.27
pH of Juice					
Fresh	0.36	0.52*	0.40	0.54*	0.41
Stored	0.30	0.44	0.39	0.53*	0.39

* Significant at 0.05.
** Significant at 0.01.

blue and less desirable. This change in color was probably due to the increases in pH due to high K fertilization. High pH values have been shown to alter the color of anthocyanin solutions by changing the structure of the anthocyanin molecule (7,12,14). As in previous findings (10), these color changes occurred even though the excessive levels of K in the juice had little or no effect on the anthocyanin content (as determined by the acidified absorbance at 520 nm).

Little change occurred in the pH of the juice during storage if excessive potassium had not been applied, but excessive K fertilization resulted in greater pH increases during storage (Table 4). This change in pH occurred even though excessive K fertilization had no effect on acid and little influence on potassium loss during juice storage. Excessive K fertilization resulted in a greater change in CDM "b" and hue (a/b) values during storage. Although these undesirable color changes occurred, there were no differences in the changes of the anthocyanin content (acidified absorbance at 520 nm) during storage as a result of high K fertilization.

The K contents of the fresh and stored juice had significant correlations with fresh and stored juice pH, hue, and chroma (a^2+b^2, an indication of the strength of the color), but not with the acidified absorbance at 520 nm (Table 5). Although the correlation values between K in the fresh juice and the pH of the fresh and stored juice were the same, the slopes of the regression lines show a higher and more rapid increase in stored juice pH as the K level of the fresh juice increased (Fig. 1). The K levels in the stored juice had higher correlation values with juice pH, hue, and chroma than did the fresh juice K levels (Table 5). The pH values of both the fresh and stored juice had similar correlations with hue and chroma. As the pH of the fresh juice increased, there was an increase in the hue (a/b) values of both the fresh and stored juice, but the increases in hue during storage was greater at high pH (Fig. 2). In contrast, the chroma values were lower in the stored juice at all pH levels of the fresh juice (Fig. 3). The pH values of the fresh and stored juice did not correlate with the acidified absorbance (Table 5).

Conclusions

Excessive K fertilization increased the K content and lowered the Mg content of petioles, leaves, canes, trunks and roots when sampled at fruit harvest and, to a lesser extent, during dormancy. The K level of petioles had better correlations with fresh and stored juice K and pH than did the other plant parts.

Fresh and stored juice K levels and pH were increased when excessive K fertilization was applied. Highly significant, positive correlations existed between juice K and juice pH. The color quality and acidity of the fresh and stored juice were lowered by excessive K fertilization. Color quality of the fresh and stored juice was significantly and negatively correlated with fresh juice pH. This demonstrated the effect of pH on the color expressed by the anthocyanins. Excessive K fertilization also resulted in a greater increase of juice pH and a greater loss in color quality during storage.

Table 4. Effects of potassium fertilization and storage on the quality and changes of grape juice.

Potassium fertilization (g/plant)[z]	Juice K (ppm)	pH	Acidity (% tartaric)	CDM Color b	CDM Color a/b	Acidified absorbance @ 520 nm[x]
			Fresh			
0	2730c[y]	3.43c	0.58a	3.7a	5.7b	0.629a
3	2977bc	3.52b	0.56ab	3.8a	5.6b	0.539b
6	3266ab	3.58b	0.54b	3.4ab	6.0ab	0.574ab
12	3343a	3.67a	0.54b	3.0b	6.5a	0.620ab
			Stored			
0	1504c	3.44c	0.42a	3.1a	6.2c	0.528a
3	1642c	3.59b	0.38b	2.8ab	6.6bc	0.459a
6	1891b	3.70b	0.37b	2.4bc	7.2ab	0.503a
12	2378a	3.82a	0.38b	2.1c	8.0a	0.506a
			Change in Storage			
0	−1226ab	−0.01c	−0.17a	−0.6a	+0.5a	−0.101a
3	−1335ab	+0.07b	−0.18a	−1.1b	+1.1b	−0.080a
6	−1375a	+0.11a	−0.16a	−1.0b	+1.2b	−0.071a
12	− 965b	+0.15a	−0.16a	−1.0b	+1.5b	−0.114a

[z]K fertilizer was applied weekly from May 1 through Sept. 1 (harvest).
[y]Means separated within columns and storages by Duncan's Multiple Range Rest at the 5% level.
[x]Juice sample was acidified to pH 1.5 before determining absorbance.

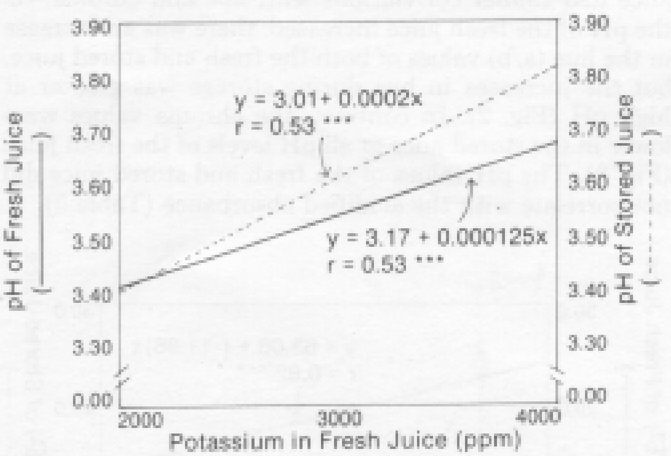

Fig. 1 Relationship between potassium in the fresh juice and the pH of the fresh and stored juice.

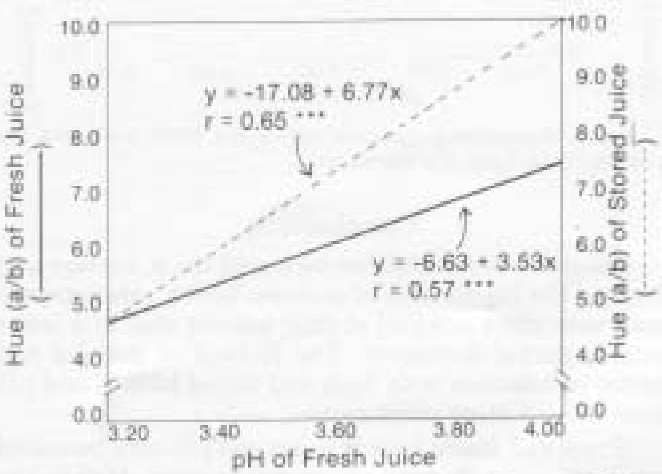

Fig. 2. Relationship between pH of the fresh juice and the hue of the fresh and stored juice.

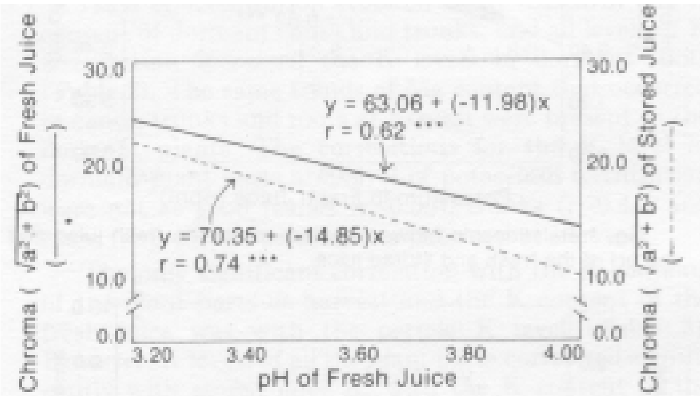

Fig. 3. Relationship between pH of the fresh juice and the chroma of the fresh and stored juice.

Table 5. Correlations between K, pH and color of fresh and stored juice.

	K in juice		pH of Juice	
	Fresh	Stored	Fresh	Stored
K in juice				
Fresh	1.00			
Stored	0.41 **	1.00		
Loss	0.65 ***	-0.41 ***		
pH of juice				
Fresh	0.53 ***	0.76 "**	1.00	
Stored	0.53 ***	0.75 *"	0.94 ***	1.00
Increase	0.44 ***	0.61 *'*	0.72 ***	0.90***
Hue (a/b) of juice				
Fresh	0.34 *	0.43 **	0.56***	0.63***
Stored	0.42 **	0.59 *'*	0.64 ***	0.69***
Increased	0.28 *	0.44 ""	0.40 **	0.42**
Chroma (a^2+b^2 of juice				
Fresh	-0.31 *	-0.47 ***	-0.61 ***	-0.71***
Stored	-0.35 **	-0.57 ***	-0.74 ***	-0.79***
Loss	0.11	0.24 *	0.28 *	0.21
Acidified Absorbance (520 nm)				
Fresh	-0.17	0.16	-0.22	0.27*
Stored	-0.12	0.07	-0.09	0.23
Loss	0.13	0.16	0.25	0.14

* Significant at 0.05. ** Significant at 0.01. *** Significant at 0.001.

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