Testing Correlations between Honeycrisp Apple's Leaf Chlorosis and Senescent Breakdown by Measuring Soluble Sugar Concentrations

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Introduction

Apple senescent breakdown (SB) is a disorder in which the inside of the fruit turns brown with tissue breakdown (Figure 1) while the exterior of the fruit remains normal. Leaf chlorosis is yellowing of leaf tissue due to a lack of chlorophyll, the green pigment found in leaves (Figure 2). Both fruit SB and leaf chlorosis happen in Honeycrisp apples.

Figure 1. Honeycrisp fruit senescent breakdown: the brown tissues developed over the storage while the exterior of the fruit appeared to be normal.

Figure 2. Honeycrisp leaf chlorosis: regional yellowing of leaf tissue due to the lack of chlorophyll.

Minnesota apple growers suggested a possible negative correlation between fruit SB and leaf chlorosis. According to the apple growers, chlorotic leaves appearing in mid-July indicate healthy Honeycrisp apple trees, and non-chlorotic leaves could indicate a future high percentage of SB during apple storage. Based on a previous study[1], Honeycrisp leaf chlorosis is caused by a high accumulation of starch in leaves. According to Palmer (2011), leaves photosynthesize and produce sugars. Some of them are converted to starch, then reconverted to soluble sugars that are exported to fruit (Figure 3). Chlorotic leaves may export less soluble sugar to fruit than non-chlorotic leaves. However, very little study has been done on how leaf soluble sugar concentrations correspond to those in fruit and senescent breakdown. This study hypothesized that there is an inverse relationship between soluble sugar concentration in chlorotic Honeycrisp leaves and fruit with senescent breakdown. To explore this relationship, the major sugar contents of both Honeycrisp leaves and fruits from two orchards were measured, and correlation tests were applied to the results.

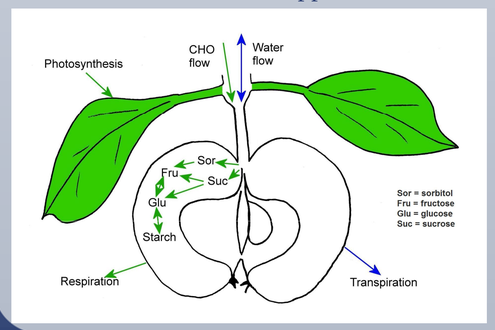

Figure. 3 Key fluxes into and within apple fruit (Palmer, 2011). The two primary soluble sugars transported from leaves to fruit are sorbitol and sucrose. Then sucrose and sorbitol are further converted to fructose and than glucose. The fruit stores excessive sugars as starch during growth.

Results

Starch analysis of Honeycrisp leaf tissue supported previously published studies; non-chlorotic leaves had a significant higher starch content than those of normal leaves (Table 1). However, the soluble sugar concentrations did not differ much between chlorotic and normal leaves.

Table.1 Mean (n=5) sugar and starch contents of chlorotic and non-chlorotic (normal) leaves in 2015. Starch measured using Megazyme starch kits. Sugars measured using High Pressure Liquid Chromatography with Refractive Index Detection (HPLC-RID)

Orchard	Chlorosis	Fructose (mg/g)	Sorbitol (mg/g)	Glucose (mg/g)	Sucrose (mg/g)	Starch (mg/g)
1	Normal	2.42	48.38	11.35	8.14	9.68*
1	Chlorotic	2.33	44.91	8.88*	6.92	70.51
2	Normal	0.87*	46.91	11.52	7.15	10.80*
2	Chlorotic	3.35	47.12	13.02	3.52*	63.09

- Different from other values within column at p = 0.05.

As for the soluble sugar concentrations in leaves, no major difference was detected. Fruit sugar concentrations varied with harvest years and orchard locations (Table 2). The two years of sugar analysis for apple fruit are presented in Table 2, and the data in 2014 showed more difference between browning and normal fruits than those in 2015.

Table 2. Mean (n = 5) sugar content comparison between brown and normal fruit in 2014 and 2015.

Year	Orchard	Browning	Fructose (mg/mL)	Sorbitol (mg/mL)	Glucose (mg/mL)	Sucrose (mg/mL)
2014	1	Normal	97.61	3.64	17.57	61.82
2014	1	Brown	81.76*	5.89	12.96*	64.17
2014	2	Normal	108.60	5.33	21.73	62.33
2014	2	Brown	83.50*	4.37	13.29*	66.98
2015	1	Normal	69.90	4.10	9.09	57.94
2015	1	Brown	69.63	4.42	10.04	59.16
2015	2	Normal	71.50	5.85	9.80	61.85
2015	2	Brown	72.16	4.10	9.09	58.23

- Different from other values within column at p = 0.05

Some correlations were found in sugar contents between normal leaves and brown fruits, and chlorotic leaves and normal fruits (Table 3). Sucrose and sorbitol concentrations of normal leaves were positively correlated with those of the browning fruits. The positive correlations were also tested between chlorotic leaves and normal fruits. Fructose concentration in chlorotic leaves and normal fruits also were positively correlated.

Table 3. Correlations between sugar concentrations of normal leaves vs. browning fruits and chlorotic leaves vs. normal fruits.

		Normal Leaves				Chlorotic Leaves			
		Fruc[a]	Suc[b]	Sorb[c]	Gluc[d]	Fruc	Suc	Sorb	Gluc
Browning Fruits	Fruc	-0.789							
	Suc		0.763**						
	Sorb			0.643*					
	Gluc				0.563				
Normal Fruits	Fruc					0.515*			
	Suc						-0.3		
	Sorb							0.152	
	Gluc								-0.08

*Fruc: fructose. [b]Suc: sucrose. [c]Sorb: sorbitol. [d]Gluc: glucose

*p < 0.1. **p < 0.05.

It is possible that the normal leaf sugar metabolism resulted the browning fruits sugar concentrations.

Conclusion

In this UROP project, moderate correlations between sugar concentrations of normal Honeycrisp leaves and apple tissues with SB, and chlorotic leaves and normal apple tissues were found. Due to the small sample sizes, very little difference was detected in the soluble sugar concentrations. Therefore, more evidence is needed to conclude that an inverse relationship exists between leaf chlorosis and fruit SB Future studies can be done on scoring the browning severities in order to provide parametric data for analysis. Also, since apple flesh browning has been associated with polyphenol oxidation, testing phenolic compound concentrations and polyphenol oxidase levels may also help to explain the senescent breakdown in Honeycrisp apples.

References

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