Fruit drop and HLB

By Tripti Vashisth and Lisa Tang

Fruit drop is a natural, physiological phenomenon that occurs in all citrus varieties. However, pre-harvest fruit drop often causes grower distress and concern as it can result in significant yield reduction as well as loss of tree resources into non-harvested fruit.

THREE PERIODS OF FRUIT DROP

In general, citrus trees bloom profusely in spring, but only a small number of flowers become fruit that stay on the tree and reach maturity until harvest. In sweet orange (*Citrus sinensis*), for example, less than 1 percent of flowers turn into harvestable mature fruit. The actual percentage of flowers to harvestable fruit will vary from year to year, with heavy-blooming years setting less flower to fruit than in years with lighter bloom. The low percentage of flowers turning to fruit can be attributed to fruit drop during different stages of growth and development.

The physiological process of fruit drop is called abscission. Naturally, citrus fruitlets and fruit generally detach from trees during the following three periods: post-bloom, June and pre-harvest.

Table 1. Pre-harvest fruit drop from 2009 to 2018, according to citrus production reports in Florida from the National Agricultural Statistics Service, U.S. Department of Agriculture (2018).

	Pre-Harvest Fruit Drop				
	Oranges			Grapefruit	
Season	Navel	Early-mid season	Valencia	White	Colored
2009–2010	10%	8%	14%	12%	10%
2010–2011	7%	7%	16%	11%	9%
2011–2012	17%	13%	19%	16%	18%
2012–2013	27%	18%	22%	22%	20%
2013–2014	19%	23%	31%	29%	25%
2014–2015	21%	22%	25%	24%	27%
2015–2016	24%	32%	29%	34%	40%
2016–2017	27%	26%	30%	44%	36%
2017–2018[1]	68%	62%	52%	66%	50%

[1]The dramatic increase in fruit drop from the 2016–2017 season to the 2017–2018 season was mainly due to the high winds of Hurricane Irma in September 2017.

Figure 1. June drop in sweet orange occurs at the abscission zone located at the branch and peduncle junction. Therefore, the peduncle remains attached to fruit (indicated by red arrow).

Post-bloom Drop

Shortly after bloom, a number of flowers and fruitlets of citrus abscise due to poor pollination or in response to nutrient shortages and/or inadequate environmental conditions. The infection of the fungus *Colletotrichum acutatum* also causes the drop of small fruitlets that set immediately after bloom. Eighty to 90 percent of all flowers drop their fruit in this period.

June Drop

Approximately one to two months after bloom, young developing fruit abscise from trees with excessive fruit set in June (often happens in May in Florida), consisting of about 10 percent of the total drop. The drop during this stage mainly results from the competition among young fruit for energy (carbohydrates) for growth and development. Although June drop of citrus fruit is typically considered a natural event during the course of fruit development, water-deficit in addition to warm temperatures in summer can exacerbate fruit drop (Figure 1).

Figure 2. Pre-harvest fruit drop in mandarin occurs after the fruit attains physiological maturity. Drop occurs at the peduncle and calyx junction (shown by blue arrow), leading to fruit drop without the peduncle attached.

Pre-harvest Drop

Another wave of fruit drop in citrus occurs starting at three to four months prior to harvest. Unlike earlier drops, the pre-harvest fruit drop occurs in mature fruit. In addition, these mature fruit abscise distinctly at the calyx abscission zone ("button"), instead of the peduncle (stem) abscission zone (Figure 2).

For citrus trees grown in Florida,

increased drop of mature fruit prior to harvest is one of the many symptoms of huanglongbing (HLB) disease, caused by *Candidatus* Liberibacter asiaticus. This HLB-associated pre-harvest fruit drop, in addition to tree decline, results in a reduction in yield (Figure 3). For example, for the late-season Valencia, pre-harvest fruit drop rose from 14 percent in the 2009–2010 production season to 30 percent during the 2016–2017 season (Table 1, page 6). To date, how HLB escalates pre-harvest drop in citrus remains unclear.

THE ROLE OF ENDOGENOUS PLANT HORMONES

The balance of two endogenous (growing from within) plant hormones, auxin and ethylene, plays an important role in signaling the process of abscission. A higher ratio of ethylene to auxin induces the enzymes responsible for the separation of the main body and fruit from the tree. Use of ethephon (ethylene) in abscission studies effectively loosens the fruit in healthy citrus.

Furthermore, the application of 2,4-dichlorophenoxyacetic acid, an auxin, delays the abscission of mature fruit in healthy citrus trees. Nevertheless, the effects of ethylene biosynthesis and action inhibitors and auxins on preventing pre-harvest fruit drop are inconsistent in HLB-affected citrus trees. Based on recent studies, it is not recommended to apply plant growth regulators (PGRs) in order to reduce pre-harvest drop.

RECENT RESEARCH

A better understanding of mature fruit abscission associated with HLB is necessary to develop strategies to mitigate increased pre-harvest drop for HLB-affected citrus in Florida. Thus, a study on HLB-affected Valencia trees was set up in an experimental grove in Lake Alfred, Florida.

This study compared the effects of different HLB severities on fruit abscission, based on HLB symptom levels. Low, moderate and severe symptom levels were included in the study (Figure 4). For each tree in the study, mature fruit drop was monitored during the period of January through harvest at the end of May (Figure 5). Trees at the severe symptom level had a significantly higher fruit drop rate compared to low and moderate symptom trees.

A subset of mature fruit that was still attached to the trees was collected and further separated into "loose" and "tight" fruit based on the value of fruit detachment force (FDF), which determines how much force is required for a fruit to be pulled or detached from the tree. Loose fruit represented those fruit that would potentially drop shortly, whereas tight fruit were physiologically not ready to abscise yet (Figure 6). For severe symptom trees, 60 percent of the fruit were loose. At

Figure 3. Pre-harvest fruit drop of Valencia in February, two months before anticipated harvest.

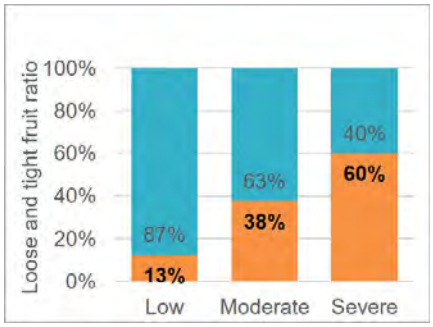

Figure 6. The ratio of tight and loose fruit for the subset of attached Valencia fruit. Severe symptom trees had a significantly higher number of loose fruit.

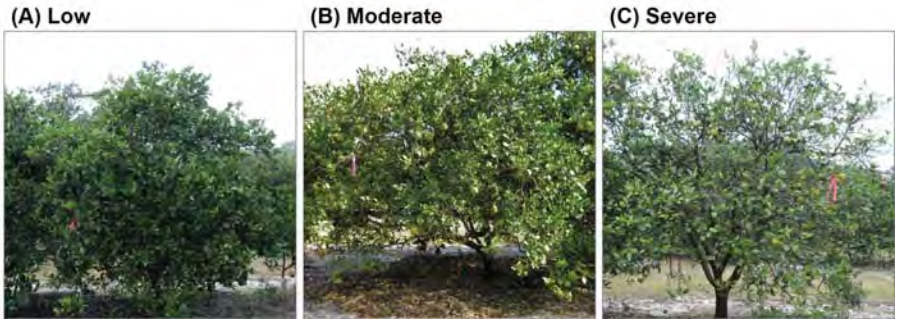

Photo courtesy of Shweta Chhajed

Figure 4. Valencia trees at three HLB symptom levels: low (A), moderate (B) and severe (C), at the Citrus Research and Education Center in Lake Alfred, Florida, were used for the study of HLB-associated pre-harvest fruit drop.

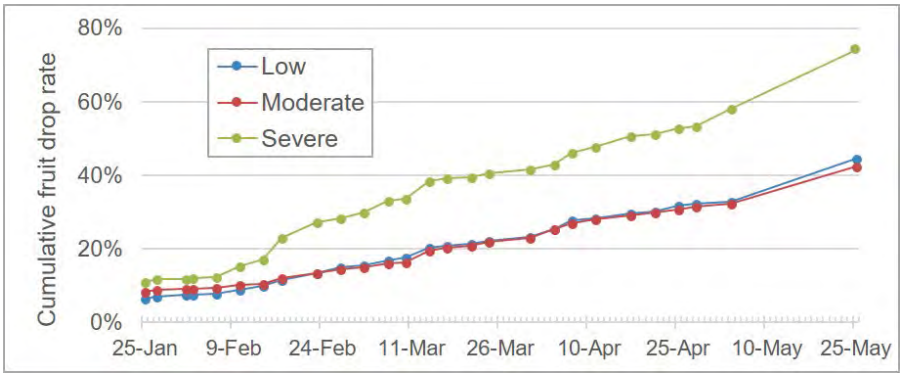

Figure 5. Cumulative fruit drop for Valencia trees at three HLB symptom levels during the period from January to May.

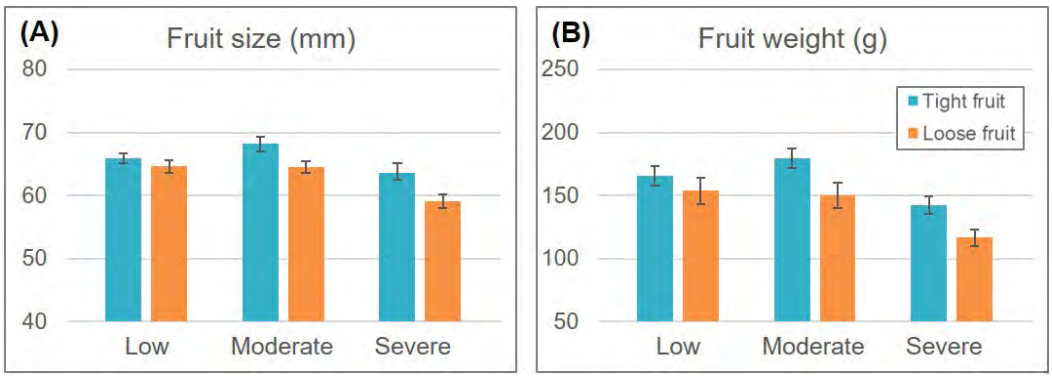

Figure 7. Size in diameter (A) and fresh weight (B) of loose and tight mature fruit of Valencia trees at three HLB symptom levels in May.

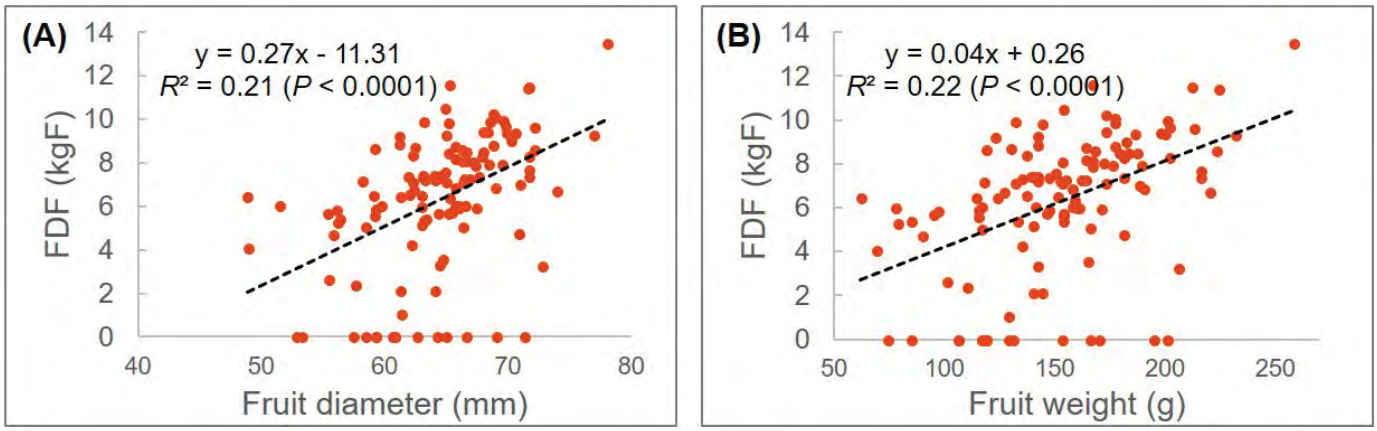

Figure 8. Regression of fruit detachment force (FDF) and the diameter (A) and weight (B) of individual fruit. A positive correlation means that with larger fruit size, higher FDF is required to remove the fruit. Fruit with high FDF is more likely to remain on the tree for a long time.

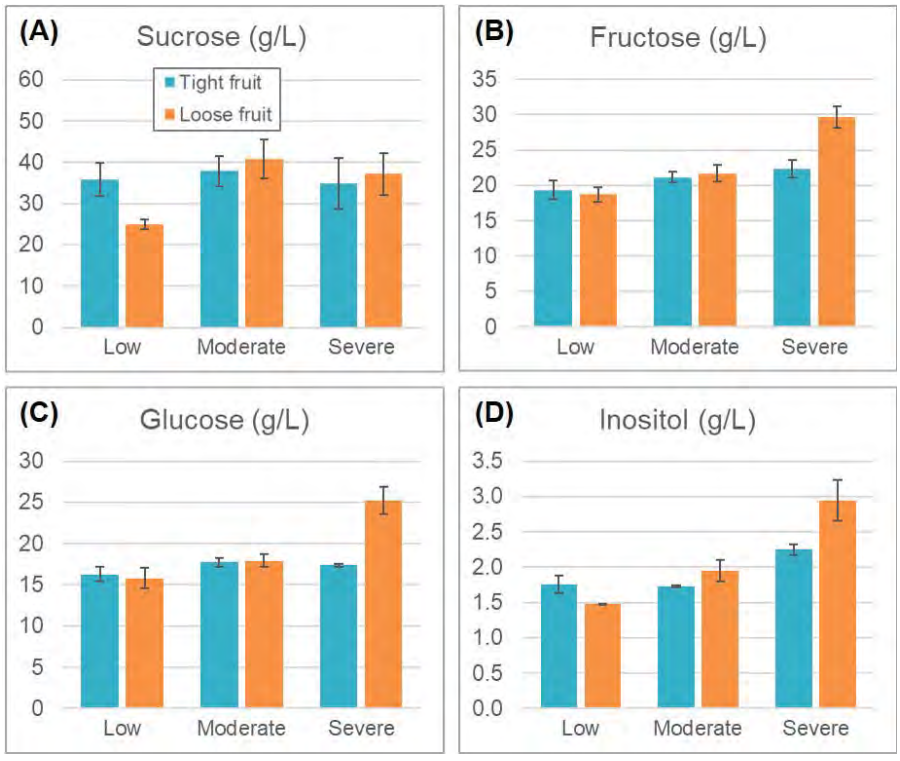

Figure 9. Concentration in grams per liter (g/L) of sucrose (A), fructose (B), glucose (C) and inositol (D) in juice of loose and tight mature Valencia fruit at three HLB symptom levels. Fruit from severe symptom trees and loose fruit consistently showed greater or equivalent levels of fructose, glucose and inositol as compared to tight fruit or fruit from other HLB disease levels.

the low symptom level, only 13 percent of fruit were loose.

For HLB-affected Valencia, fruit harvested from severe symptom trees was significantly smaller and lower in weight as compared to low and moderate symptom trees. Overall, the loose fruit were smaller in size (diameter) and weight than tight fruit (Figure 7). Across all three HLB symptom levels, the FDF value was positively correlated with the fruit size and weight, respectively (Figure 8). This suggests that smaller fruit require less force to be removed from the trees compared to the larger ones. Thus, it is possible that small fruit have a higher tendency to drop. With the arrival of HLB, a decrease in fruit size has been observed throughout the state in addition to increased pre-harvest fruit drop. This suggests that these two observations are correlated.

Between the two types of fruit, there were no consistent patterns of ethylene-related gene expression in May, but the possibility of early ethylene activity prior to the triggering

of citrus fruit abscission (before May) cannot be excluded. Interestingly, for trees at each of the HLB symptom levels, the carbohydrate concentration in juice of loose fruit was either greater than or equal to those of tight fruit.

Overall, fruit juice from severe symptom trees had the highest concentrated sugars as compared to the juice harvested from low and moderate symptom trees (Figure 9, page 10). This preliminary result, that loose fruit did not have lower carbohydrate content than tight fruit, suggests that the carbohydrate stress, which triggers June drop, is not likely to be the dominant cause of pre-harvest fruit drop in HLB-affected trees. The generally accepted hypothesis on the carbohydrate stress as the primary cause of pre-harvest fruit drop in HLB-affected trees needs further scrutiny.

The current focus in horticultural grove management should be on reducing any type of stress on the tree while intensively managing irrigation and nutrition.

CONCLUSION

To conclude, HLB-associated pre-harvest fruit drop is a complex phenomenon. Use of PGRs to reduce HLB-associated pre-harvest fruit drop is not currently being recommended. The current focus in horticultural grove management should be on reducing any type of stress on the tree while intensively managing irrigation and nutrition. Trees displaying less HLB symptoms or less decline tend to have less pre-harvest fruit drop and can hold on to fruit for a longer time.

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