FINAL PROJECT REPORT
WTFRC Project Number: AP-06-601

Project Title: Flower bud development in apple

PI: Peter Hirst
Organization: Purdue University
Telephone/email: 765-494-1323 / hirst@purdue.edu
Address: Department of Horticulture and Landscape Architecture
Address 2: Purdue University
City: West Lafayette
State/Province/Zip IN 47907-2010

Cooperators: Felipe Castillo, WTFRC

Item	Year 1 (2006)	Year 2 (2007)	Total
Salaries[1]	3380	3481	6861
Benefits	1159	1194	2353
Wages	4893	4893	9786
Benefits	495	495	990
Supplies	200	200	400
Travel[2]	700	700	1400
Total	**10827**	**10963**	**21792**

[1] 5% of Hirst time spent on this project

[2] Travel to Washington state to set up the field study and establish the treatments.

Objectives:

The objective of this project was to further understand the root causes of biennial bearing by tracking the development of potential flower buds from early in the season through to dormancy. Bourse buds were selected with different histories:

- vegetative
- flowering but not fruiting
- fruiting

Our goal was to determine whether buds on vegetative spurs differed from those that flowered but did not set fruit, and whether in turn these differed from spurs that carried fruit. We were interested to learn not only whether spur history affected whether a flower developed, but how well developed the flower was by the end of the season. More highly differentiated buds are likely to result in larger fruit the following year.

Significant findings:

- Floral/fruiting status of spurs had no effect on whether they would form flower clusters for the following year
- Floral/fruiting status of spurs had little effect on the quality of flowers formed for the following year
- Overall tree crop load may be as important or more important than localized fruiting effects in determining biennial bearing
- Flower formation may start earlier in the season in Fuji than in Gala.

Methods:

On 10 mature trees each of Gala (regular bearing, small fruit size) and Fuji (biennial, larger fruit size), 20 buds from each of the following categories were selected at flowering.

- vegetative (Gala trees flowered very heavily in 2006 and insufficient vegetative buds could be found)
- flowering but not fruiting (flowers removed at full bloom)
- fruiting (thinned to the king flower at full bloom)

Buds were selected and tagged at full bloom and sampled throughout the season. After tagging buds for later sampling, the trees were hand-thinned to a light-moderate commercial crop load. On each sampling date, 2 buds per tree were sampled and stored in a fixative solution until later dissection.

During dissection, the number of bud scales, transition leaves, true leaves and bracts were counted. The degree of floral differentiation was measured using a 1-5 rating scale in 2006 where 1=vegetative and 5=highly differentiated floral bud (sepals clearly differentiated on king and lateral flowers. This scale was expanded slightly in 2007 so that 0=vegetative and 5=highly differentiated floral bud. We also measured the diameter of the king flower within the bud.

From these data, we determined:

- the degree to which the presence of a flower or a fruit on a spur inhibits floral bud formation for the following years crop.
- the degree to which the presence of a flower or a fruit on a spur affects the complexity of flower buds (and therefore fruit size potential).

Results and Discussion

Because temperature plays such a central role in tree development, we looked at the course of growing degree-day (GDD) accumulation over each growing season. During the period of our sampling, the accumulation of GDD was essentially linear. Therefore graphs of bud development appeared almost identical, whether they were plotted against days after full bloom or GDD. Since days after full bloom is more easily interpreted, plots presented in this report will use that basis.

As buds develop, they form (in order from the outside) bud scales, transition leaves (appearing as a cross between bud scales and true leaves), true leaves, then bracts. The true leaves represent the very small leaves that will first emerge from the buds the following spring. If the meristem of the bud appears flattened, this indicates that there is no visual sign that the bud has formed a flower therefore such buds are classified as vegetative. In floral buds however, the meristen becomes domed, then forms first the king flower then lateral flowers (see Fig. 1).

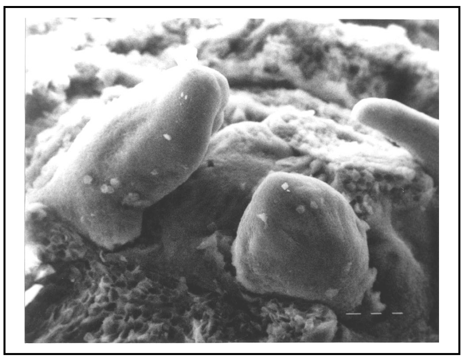


Fig. 1. Developing apple buds showing a flattened meristem indicating a vegetative status (left) and a highly developed flower cluster (right).

As buds develop over the course of the season, the number of appendages (bud scales, transition leaves, true leaves and bracts) increased markedly (Figs. 2-3), although the floral/fruit status of the bud had no effect in either Gala or Fuji in either year. In both years, Gala buds had approximately 27 appendages by the end of the season, compared with 17-21 for comparable buds of Fuji. Most of this difference was due to the presence of more bracts in Gala buds. The function of bracts in buds is unknown.

In 2006, the first visible signs of flower formation in Gala buds appeared just after 90 DAFB (Fig. 4). which coincides with the timing of floral differentiation we have found in our previous work with Red Delicious buds in Ohio and Gala buds in New Zealand. Buds of Fuji however formed flowers earlier giving a wider window during which flowers could form. Flowers formed earlier (40-80 DAFB) in 2007, and very rapidly (Fig. 5). The timing of flower formation was similar in Gala and Fuji, with almost all buds of both cultivars forming flowers by 80 DAFB. From our earlier work with Red Delicious in Ohio, flowers formed during the period 90-120 days after full bloom, and after this period essentially no more flowers formed. This is the earliest we have seen flowers form in any of our many studies examining flower formation.

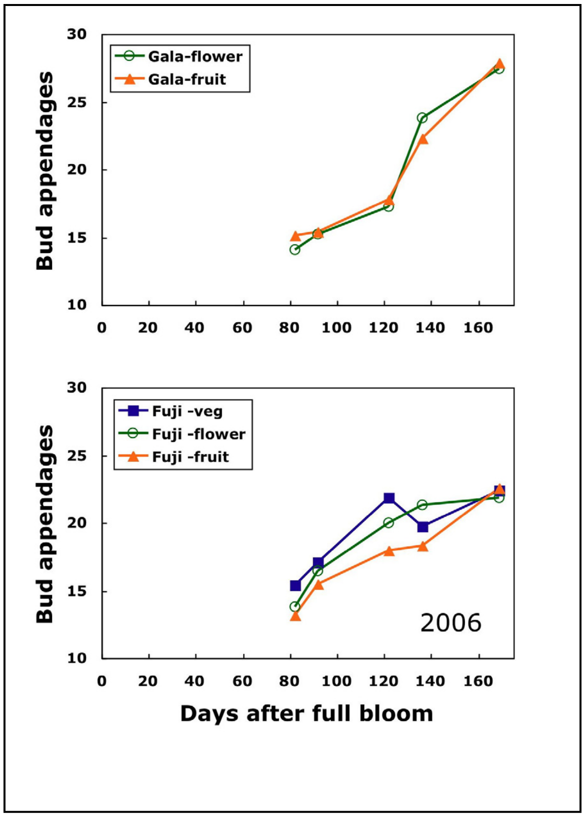


Fig. 2. Total number of appendages (bud scales + transition leaves + true leaves + bracts) in buds of Gala and Fuji in 2006. Full bloom was April 30, 2006.

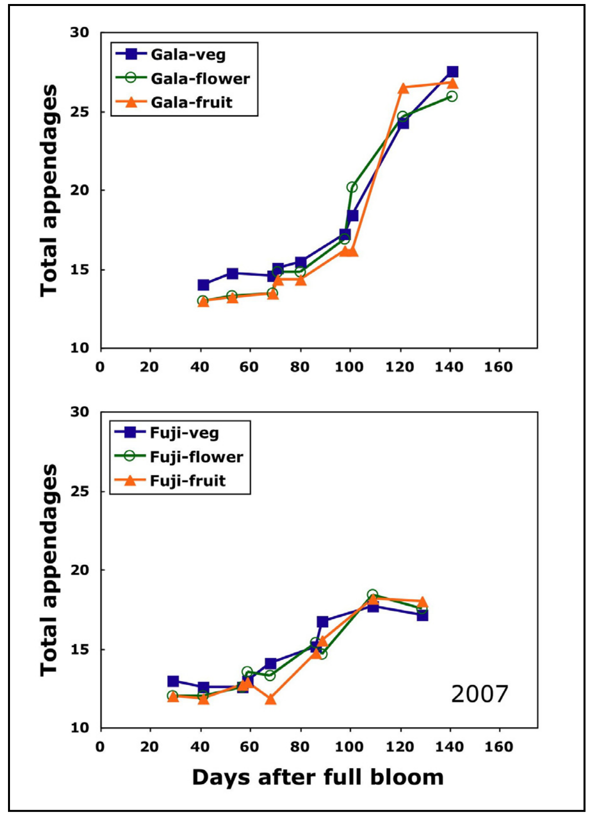
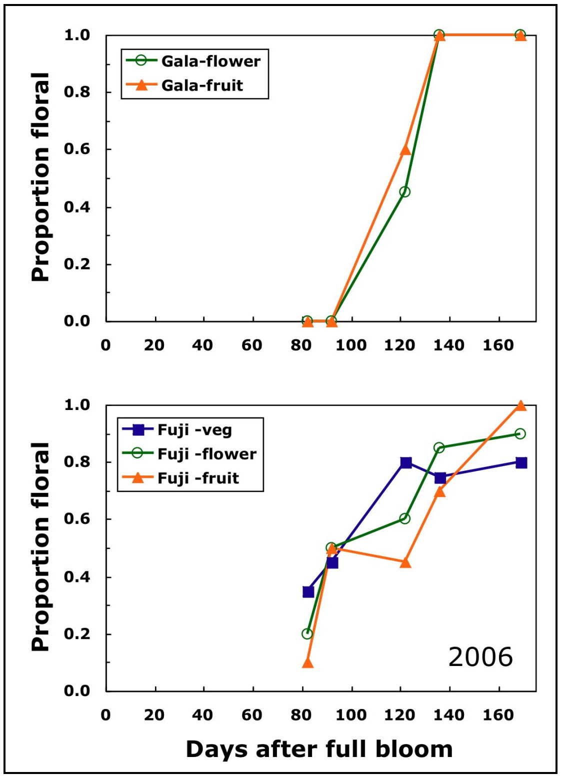


Fig. 3. Total number of appendages (bud scales + transition leaves + true leaves + bracts) in buds of Gala and Fuji in 2007. Full bloom was May 1 (Gala) or May 13 (Fuji).

Interestingly, at least 80% of all buds sampled eventually formed flowers, including those from fruitful spurs. This challenges the simple text-book idea that the presence of a fruit on a spur inhibits flower initiation in the bourse bud of that spur, especially in cultivars with a propensity for biennial bearing such as Fuji. This did not happen in either year in this study. The trees used for this study were hand-thinned to a reasonable commercial crop load, so it appears that the overall crop load of the trees may have been more important in determining flower formation that localized fruiting effects on particular spurs.

The level of complexity a bud attains before flowers are formed can be determined by linear discriminant analysis and is called the critical appendage number. Basically this analysis determines the threshold level in terms of number of bud appendages that must be reached before a flower is formed. This analysis predicts the critical appendage number, then gives a measure of what proportion of all buds would have had their floral status predicted correctly using this model.



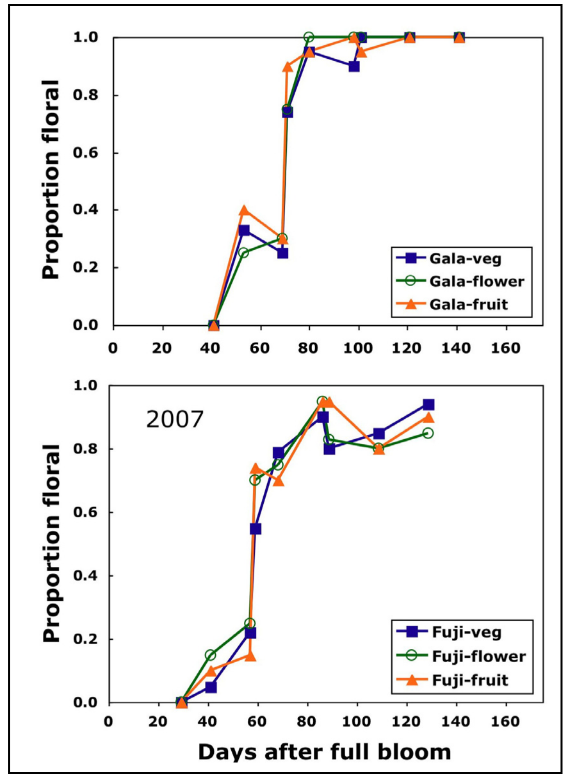


Fig. 4. The proportion of buds in which the commitment to flowering (doming of the meristem) was visible in 2006.

Fig. 5. The proportion of buds in which the commitment to flowering (doming of the meristem) was visible in 2007.

The models used to predict the floral status of buds performed well in 2006, in all cases classifying over 80% of buds correctly (Table 1). However in 2007 results were not as clear, with descriminant models only predicting the floral status of 60-70% of buds correctly based on their number of appendages (Table 2). With Gala (2007) and Fuji (2006 and 2007) there were slight trends suggesting that buds from fruiting spurs formed flowers at a lower level of complexity than vegetative spurs. Although there is some suggestion here that the floral/fruiting status of a bud may have had a slight influence on the complexity at which the switch from vegetative to floral was made, caution should be used in in interpreting this result since only about 65% of buds were classified correctly by these models in 2007. Furthermore, the floral/fruiting status of buds did not affect the timing of bud differentiation (Figs. 4-5) or the rating of meristem development (Figs. 6-7).

Table 1. The critical appendage number prior to flower formation and proportion of buds correctly classified as vegetative or floral using linear discriminant models in 2006.

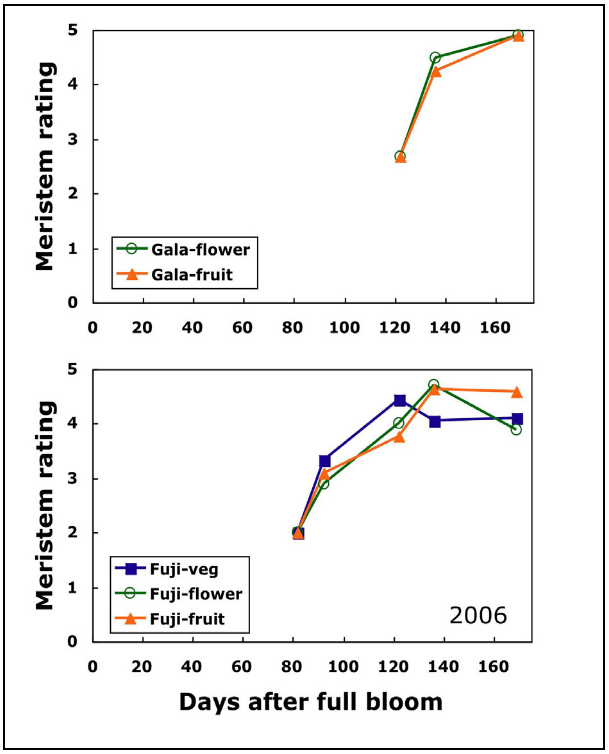
Cultivar/bud type	Critical app. No.	% correct
Gala		
Flowering	18.5	88.8
Fruiting	18.2	87.5
All Gala	18.3	88.1
Fuji		
Vegetative	18.0	81.3
Flowering	17.7	81.3
Fruiting	16.6	88.8
All Fuji	17.4	83.3

Table 2. The critical appendage number prior to flower formation and proportion of buds correctly classified as vegetative or floral using linear discriminant models in 2007.

Cultivar/bud type	Critical app. No.	% correct
Gala		
Vegetative	17.0	61.0
Flowering	16.1	67.6
Fruiting	15.9	65.2
All Gala	16.3	63.7
Fuji		
Vegetative	14.5	65.7
Flowering	14.0	65.0
Fruiting	14.0	69.8
All Fuji	14.2	65.9

Obviously not only the number or proportion of buds that flower is important, but also the "quality" of those flowers since this is likely to affect fruit size the following year.

Although Gala flowers started differentiating later than Fuji in 2006, they developed rapidly and were highly differentiated by the end of the season (Fig. 6). Fuji buds on the other hand, showed a much more gradual development, but nonetheless were well developed by the end of the season. The floral/fruiting status of spurs did not influence bud development of either Gala or Fuji in 2006 or 2007 (Figs. 6-7). In 2007, flowers started becoming apparent in buds much earlier than in 2006 or in previous studies. Gala buds however, appear to have made the first step to becoming floral (doming of the meristem) but did not undergo further differentiation until about 50 days later. Data for Fuji buds was more variable (Fig. 7) , but it is clear that they did not differentiate to the same extent as Gala buds. It is possible that the Fuji buds may differentiate further before budbreak in the spring, and we will attempt to sample more buds at that time to check for further differentiation of floral buds.



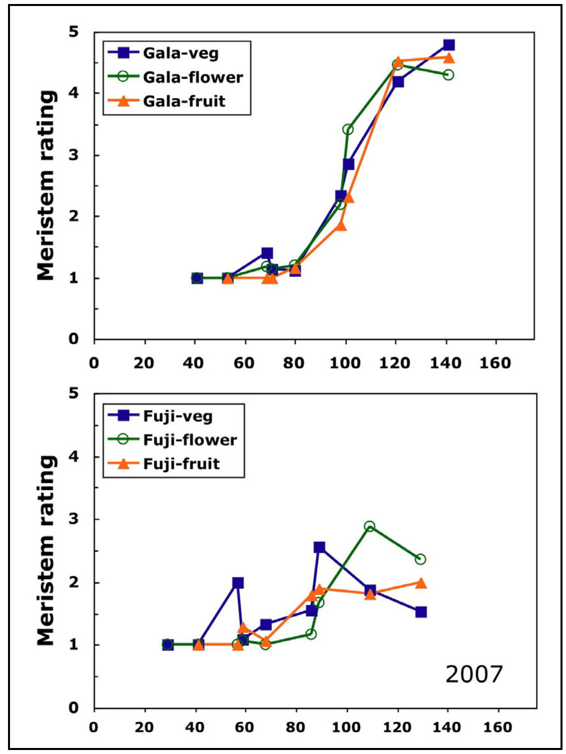


Fig. 6. The complexity of floral meristems in 2006, where 1=vegetative and 5=highly differentiated.

Fig. 7. The complexity of floral meristems in 2007, where 0=vegetative and 5=highly differentiated.

Another measure of the extent of floral bud differentiation is king flower diameter, which was measured in 2007. Obviously such data can only be collected after buds have become floral and developed to a point where the king flower is obvious. Again, the floral/fruiting status of a spur did not affect flower bud quality, as measured by king flower diameter (Fig. 8). King flowers in well developed Gala and Fuji buds were approximately 0.4-0.5 mm by the end of the season. Although the Fuji data presented in Fig. 7 may seem to contradict those in Fig. 8, in must be borne in mind that Fig. 7 includes all buds that have made the first visible step towards a floral status, whereas Fig. 8 only includes well-developed buds on which the king flower was obvious and could be measured. While the diameter of king flowers within buds doubled in diameter as they developed (0.25-0.5 mm), the external diameter of sampled buds did not change during the course of the season (Fig. 9). Generally, sampled buds of both cultivars ranged from 3-4 mm in diameter. For buds sampled at the end of the 2007 season, there was no relationship between the external dimensions of a bud and the diameter of the king flower contained within the bud (Fig. 10). This is not to say that large buds do not have larger flowers and higher fruit size potential than smaller buds, but within the narrow range of buds selected for this study, there was no relationship between bud size and flower quality.

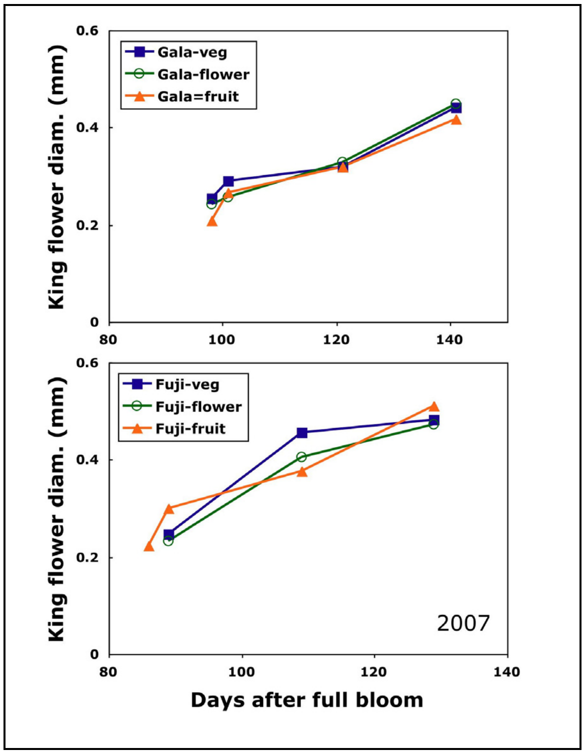


Fig. 8. The diameter of king flowers in buds during 2007.

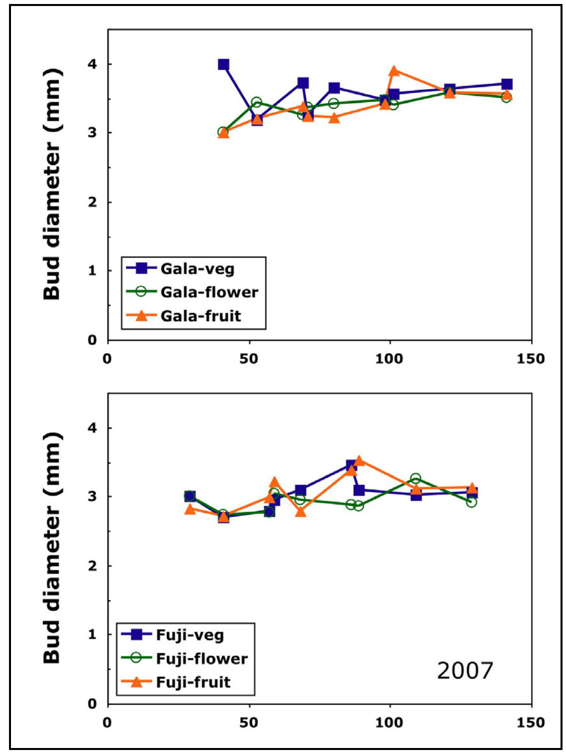


Fig. 9. The external diameter of buds sampled during 2007.

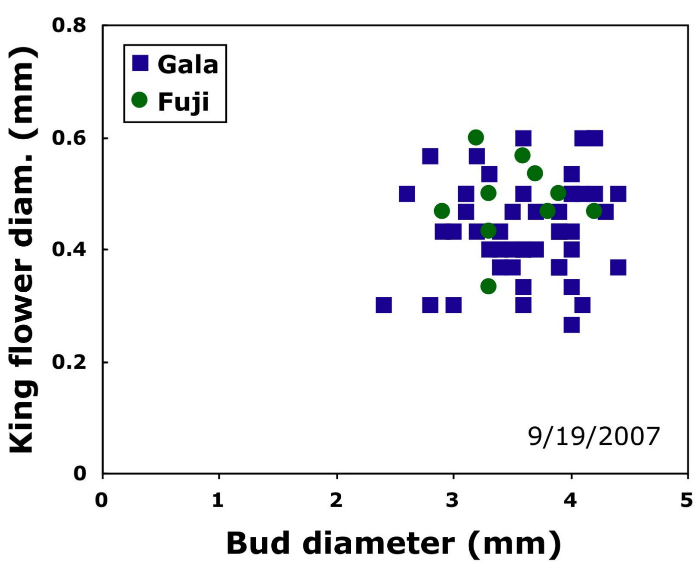


Fig. 10. Graph showing no relationship between bud external diameter and king flower diameter in 2007.