Precision Crop Load Management: Part 2

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Our Precision Crop Load management protocol, which was used by some growers in 2013, consisted of first defining the optimum fruit number/tree (target fruit number) and then pruning to reduce flower bud numbers to 1.5 times the target fruit number. Chemical thinning consists of applying sequential thinning sprays (with rates and timing guided by the carbohydrate balance model and the fruit growth rate model to assess thinning efficacy). The program was successful in guiding chemical thinning decisions in 2013.

Crop load in apple can be adjusted by three management practices: pruning, chemical thinning and hand thinning. In recent years growers have relied primarily on chemical thinning to adjust crop load with a lesser reliance on pruning and hand thinning to reduce crop load. In other countries hand thinning is still the primary means of adjusting crop load. A few progressive growers have also begun to utilize pruning as a means to adjust crop load.

Precision crop load management is a program we have developed which utilizes all three management approaches to adjust crop load. Managing crop load using "Precision" techniques is a multistep process that begins with precision pruning to leave a preset bud load on the tree, followed by precision chemical thinning to reduce initial flower number per tree to as close as possible to a pre selected fruit number per tree and ends with precision hand thinning to leave a precise number of fruits per tree.

Precision Pruning

Precision pruning is a strategy to reduce the flower bud number per tree to a pre-defined flower bud number through pruning. It begins with counting the number of flower buds on a few representative trees per orchard. In the past, the lack of uniformity of semi-dwarf trees and the massive number of buds on a tree made accurately counting buds impractical if not impossible. However, with adoption of the Tall Spindle growing system, which utilizes ~1000 trees per acre, it becomes practical to count the number of flower buds on representative trees in each orchard.

Knowing the number of flower buds per tree allows us to reduce initial flower bud numbers by pruning off excess fruit buds and only keep those needed to set an adequate crop. In addition, we have the ability to select individual buds through selective pruning retaining only those that are of the highest quality. By pruning to a specified bud number, we can start the process of fruit thinning to better target the specific fruit sizes of the highest value fruit. By reducing the number of fruit buds on the tree early through pruning, we can reduce competition among flower and fruitlets resulting in increased resources for the remaining fruit and improved fruit size and quality. Making accurate fruiting bud counts requires an investment in time, but this is a practice which can provide an immediate return on the investment of time.

Determining the "proper" bud numbers per tree depends both on the desired yield and fruit size but also on the level of risk the grower is willing to accept. Although it is possible to use pruning to reduce fruiting buds to nearly the exact level required to set a full crop, we suggest that additional buds be retained to account for natural factors that cause buds not to set such as frost or freeze, poor pollination, and poor flower viability. We could reduce the number of buds to exactly the number of final fruits we desire assuming we can produce 1 large fruit per fruiting spur. However we believe that we should leave additional buds in case we have miss counted or that we have a weather event that kills additional buds, prevents pollination and puts us below the target flower and fruit number to achieve the crop load that we desire. The additional buds that will be required to provide "insurance" will depend on the variety. For example, early blooming varieties may be more at risk for frost damage and you may want to keep more buds than ones that bloom late and have a lower risk of fruitlet loss. Thus the number of buds to leave after pruning is based on the target number of fruits adjusted by a bud load factor that will provide some insurance buds. Based on preliminary data we are currently suggesting that growers prune using a bud load factor of 1.5 flower buds for each final fruit number.

The practical method of doing this:

1. Select 5 uniform trees per variety per block. Select trees randomly in representative areas of the orchard. It is important to count each variety within the block separately since different cropping levels and growth habit will result in different number of buds per tree and the resulting pruning severity.
2. Count and record the entire number of fruit buds on each of the selected trees and calculate the average number of fruit buds per tree.
3. Calculate the target number of apples per tree to produce the yield of specific size fruit we have targeted.
4. Multiply the target number of fruits by 1.5 to determine the number of fruit buds that should be left on each tree to achieve the desired yield with some insurance buds.
5. Prune to remove excess buds above that target bud number. This can best be done by using the 3 rules of Tall Spindle pruning. 1) Cut the leader at the optimum height (90% of between row spacing) to a lateral branch; 2) remove 1-3 large limbs with a bevel cut for renewal; and 3) columnarize the remaining branches by cutting off large secondary lateral branches. This initial pruning should be followed with a more detail pruning of removing inferior buds to reduce bud level to target level. Removing buds should be done selectively by removing first those buds that are of poor quality or positioned so that they will produce lower quality fruit, such as those that are on pendant wood or small diameter wood.
6. After pruning, recount bud numbers of 5 representative trees to assess success of pruning and readjust pruning methods to better reflect target levels. Regularly reassess pruning to ensure that target bud levels are being achieved. Different people, weather conditions, etc. can result in drifting away from the original goal and pruning methods will need to be readjusted through time.

An example of how to calculate the target fruit number and target flower bud number in steps 2 and 3 is presented for a Gala orchard on M.9 rootstock planted 3'X12' (1210 trees/acre). In this example, we set a target yield of 1500 bushels/acre of 100-count size or 100 apples per bushel.

1. Multiply the target yield of 1500 bushels/acre by 100 fruit per bushel to calculate the need for 150,000 apples per acre. By dividing the total number of fruit/acre by the number of trees per acre we calculate that we need 125 apples per tree.

2. Multiplying the desired fruit number by a bud load factor of 1.5 indicates we need to leave 180 flower buds per tree to achieve our desired yield and to have some insurance buds against frost and poor pollinations.
3. In this example lets assume our flower bud counts of 5 representative trees indicated we had 450 buds per tree before pruning. This means that through pruning we need to remove 270 buds.

The beauty of using precision pruning is that we can implement this practice today to achieve higher profit levels. And with higher density orchards and uniform trees it should be a simple procedure to tag, and count bud numbers for each variety in each orchard estimating the pruning that should be done with very little risk or cost. It becomes more difficult as orchard tree numbers decline and vigor increases.

Precision Chemical Thinning

Precision chemical thinning is the second leg of managing apple crop loads more precisely (Robinson et al., 2013). It utilizes sequential chemical thinning sprays guided by the use of the carbohydrate model and the fruit growth rate model. In the last 4 years we have developed the precision chemical thinning method to more consistently achieve a target crop load. It uses the carbon balance model as a predictive tool for predicting thinning response prior to application of thinners (Lakso et al., 2006; Robinson and Lakso, 2011) and the fruit growth rate model for early assessment of thinning response (Greene et al, 2013) immediately following application in time to re-apply another spray if needed.

The method begins with first calculating the final fruit number (target fruit number) per tree and secondly assessing the number of flower clusters on the trees (after pruning) by counting 5 representative trees (See example above in precision thinning section). The initial flower number can be estimated by multiplying the number of flower buds by 5 flowers/cluster. Once the initial number of flowers/tree is determined, sequential chemical thinning sprays are applied followed by rapid assessment of the results in time to apply a subsequent thinning spray and then an early re-assessment, followed by another spray if needed until the final target fruit number for each variety is achieved.

<u>In practice precision thinning begins with</u>:

1. One to two <u>bloom thinning spray</u> at 60 and 80% full bloom.
2. The first spray is followed by a <u>petal fall spray</u> applied 2-4 days after petal fall (about 1 week after the bloom spray) when fruits are 5-6mm in diameter. Before the petal fall spray the results of the carbohydrate model are used to guide the rate of chemical and the exact timing of the petal fall spray.
3. The first two sprays are followed by an assessment of the efficacy of those 2 sprays using the fruit growth rate model which indicates the percentage of thinning achieved with the first 2 sprays.
4. Then, if needed, <u>a third spray</u> is applied at 10-13mm fruit diameter (about 1 week after the petal fall spray). Before the petal fall spray the results of the carbohydrate model are used to guide the rate of chemical and the exact timing of the third spray.
5. The third spray is followed by an assessment of the effectiveness of all previous sprays using the fruit growth rate model, which indicates the percentage of thinning achieved with all 3 previous sprays.
6. Lastly, if still more thinning is needed, a <u>fourth spray</u> is applied at 16-20mm (about 1 week after the third spray) to achieve the target fruit number.

Figure 1 shows a decision making tree we envision being used by growers to achieve the optimum crop load.

Precision Hand Thinning

Precision hand thinning is the third leg of managing apple crop loads more precisely. The practice of hand thinning can be beneficial to increase fruit size and color by singling fruit within the cluster, by balancing the number of resting spurs with fruitful ones ensuring return bloom, by improving pest control by exposing clustered fruit, and in young trees by balancing continued growth with cropping to help fill out the canopy.

Hand thinning can take place anytime during the growing season between fruit set and harvest. Early hand thinning, within 6 weeks of bloom and before fruit bud initiation, will both help prevent biennial bearing and give the maximum fruit size improvement. Hand thinning later in the growing season only helps to marginally increase fruit size and can be used to grade fruit by removing damaged fruit but will not contribute to return bloom.

Procedures for precision hand Thinning

1. Select 5 representative trees throughout the block to be hand thinned and count all the fruit that remain on the tree after chemical thinners have had their effect.
2. Determine the total number of apples desired per tree to achieve the fruit size and yield desired (See the calculation example above).
3. Subtract the desired number of fruit from the total number of fruit counted per tree to determine the number of fruit that need be removed from each tree.
4. Hand thin the trees down to the desired fruit number by first removing any small, misshapen or imperfect fruit and then singling all fruit on the tree.

The simplest method for thinning is to use "zone thinning" and a multi-level platform. In this system each person who is hand thinning is assigned a zone (bottom, middle or top) to hand thin and assigned a specific number of fruit to remove. In trellised blocks this might be the area between two adjacent trellis wires. For example, a four-wire trellis will have 3 sections between wires and a 5 wire trellis will have 4. It is very simple to count the number of apples in each section and adjust the amount of hand thinning to achieve this target.

Another method of precision thinning would be divide the total number of apples per tree by the number of shoots per tree to determine how many apples should be on each shoot. The typical tall spindle will have ~20 fruiting shoots per tree. Therefore if our target is 125 fruit per tree there should be ~5 apples per shoot. Simply have people who are hand thinning reduce fruit numbers to 5 per shoot by first singling fruit on spurs then by spacing fruit where they are touching along each shoot.

Hand thinning is not new and is widely practiced however implementing a procedure to count fruit and reduce fruit number to a targeted number is new for most growers. Improving precision by counting and targeting fruit numbers will improve profitability. Fruit growers could implement this or a similar method to accurately count fruit immediately and see an immediate impact on their profitability.

Materials and Methods

Group Thinning Project: During the chemical thinning period of 2013 (May) we organized a statewide group effort to manage chemical thinning of Gala and Honeycrisp more precisely. We enlisted the cooperation of 19 growers and 2 private consultants along with the extension field staff from Cornell to manage fruit chemical thinning according to the precision crop load

management protocol which we have developed. A list of the persons who participated in this group precision thinning effort is given in Table 1.

At each location the cooperator counted the number of flower buds on 5 representative trees at pink and then calculated the target number of fruits per tree needed to achieve a desired high yield. The cooperators then tagged 17 representative spurs per tree on the 5 test trees. At petal fall each fruit in each cluster was marked with a number or dot to identify its position in the cluster. After the petal fall spray the fruit diameter of each fruit in the 17 tagged clusters on each of the 5 trees (425 fruits) was measured 3 days after spraying and then again 7 or 8 days after spraying. These diameter data were sent electronically to Terence Robinson who analyzed the data with the fruit growth rate model and within 24 hours sent the cooperator the results with his recommendation for the next spray. The cooperators then sprayed the test blocks sequentially with one of two spray protocols (bloom + PT +12mm +18mm sprays or PF +12mm+18mm sprays). After each spray the cooperators measured fruit diameters at 3 and 7 days after spraying and the data was analyzed by Terence Robinson and a new recommendation was sent back to the cooperators.

Sequential Application Experiment at Geneva: In the spring of 2013, we organized a field experiment at Geneva, NY with Gala to compare thinning efficacy of various timings of thinning sprays and various chemicals (Promalin, Maxcel and Sevin). Treatments were either a 2 spray-thinning programs (bloom + 12mm sprays or petal fall + 12mm sprays); 3 spray programs (bloom + PF + 12mm or PF + 12mm + 18mm) and a 4 spray program (bloom + PF + 12mm + 18mm).

We measured fruit set on 3 branches per tree and final fruit number and fruit size on the whole tree. Data were analyzed by ANOVA and means were compared using Least Significant Difference (P=0.05).

Results

Group Thinning Project: The 2013 season brought an intense apple bloom in most of NY State resulting from the low crop in 2012. In the group thinning project, estimates of bud load for Gala indicated that blocks ranged from a low of 1.1 flower buds/final fruit number to a very high 5.8 flower buds/final fruit number (Table 2). With Honeycrisp the flower bud loads ranged from 1.5 to 5.8 (Table 3). The average bud loads were about 2.4 for Gala and 3.0 for Honeycrisp which were both excessively high in 2013 indicating a need for greater pruning severity in most blocks in 2013.

In general it was difficult to thin adequately in most Gala and Honeycrisp orchards. Part of the problem was the very high initial flower bud loads. Multiple thinning sprays gave better results than just one spray with the hard to thin varieties.

The results of fruit diameter measurements made after petal fall thinning sprays around May 19th or 20th show that the bloom and petal fall sprays provided significant thinning on Gala and Honeycrisp but that additional thinning was still needed. In general fruit set was reduced from 100% down to about 30% by those two sprays (Table 4). The 12mm spray gave little thinning partially due to a high carbohydrate balance. The 18mm spray gave significant thinning in 2013. In general the thinning efficacy was loosely correlated to the estimated carbohydrate balance at the time of the thinning applications. Even with 4 sprays the fruit number per tree with Gala remained above the target fruit number which required significant hand thinning. This was the case with all but 2 of the Gala orchards and all but 3 of the Honeycrisp orchard used in the study.

The sequential application experiment at Geneva: The purpose of this experiment was to compare several sequential thinning programs. All thinning spray programs reduced fruit set, fruit number and yield while increasing fruit size with Gala. The greatest reduction in fruit set occurred with the 4 spray program (Promalin at bloom followed by Maxcel/Sevin 3 times or Maxcel at bloom followed by Maxcel/Sevin 3 times). The 4 spray programs reduced fruit number close to the target fruit number of 330 fruits/tree and achieve the target fruit size of 100 count fruit.

The 2 spray programs gave intermediate reductions in fruit set, fruit size and yield and intermediate increases in fruit size. The bloom +12mm sprays program tended to perform a little better than the PF+12mm spray program.

Among the 3 spray programs the best performance was from the 3 successive sprays of Maxcel/Sevin beginning at PF, then 12mm and 18mm with some oil added to the last spray.

Among bloom sprays, Promalin and Maxcel performed similarly. Among 18mm sprays Ethrel/oil performed poorly while Maxcel/Sevin+oil performed better.

Discussion

At each location participating in the group precision thinning project, the fruit diameter measurements gave good estimates of the thinning effect of the previous thinning spray. The real-time recommendations allowed cooperating growers to make real time decisions about the next spray. That information combined with the results of the carbohydrate model gave much greater confidence concerning the timing and dosage of thinning sprays in 2013.

At almost all locations the final cropload of Gala was still too high despite 3 or 4 sprays and this required significant hand thinning during the summer. The precision protocol gave many growers confidence to keep applying more sprays which then gave results closer to the target and resulted in less hand thinning.

Precision thinning measurements at Geneva, indicated that bloom sprays with either Promalin, Maxcel or ATS were helpful in reducing crop load compared starting thinning at PF. Although bloom thinning carries risks, in 2013 it was a valuable tool and should be considered in other high crop years.

Sequential applications of thinning sprays was the best approach to thinning Gala in 2013. It was a year with very heavy bloom and poor thinning efficacy. Starting the thinning program with a bloom spray was beneficial. Promalin and Maxcel worked equally well as a bloom spray. For the PF spray either NAA/Sevin or Maxcel/Sevin worked equally well. For the 18mm spray Maxcel/Sevin+oil worked better than Ethrel+oil. The improvements in fruit size with multiple Maxcel sprays were better than when other chemical were sprayed at 18mm.

Conclusions

The new precision thinning program for managing apple crop load allows growers to first determine a target fruit number and the initial fruit number per tree and then apply sequential thinning sprays beginning at bloom to reduce fruit number per tree in a step wise manner down to the target fruit number. The program utilizes the Cornell Apple Carbohydrate Thinning model and the Fruit Growth Rate model to provide real time information to growers of the progress in this step wise thinning process. The program gives growers confidence to thin when appropriate and sound information about when not to thin. The economic implications of optimum crop load

and optimum fruit size are large and justify this more intensive management approach required by the Precision Thinning program.

Lastly, precision thinning will be more easily applied to the simple trees in high-density orchards such as the Tall Spindle or Super Spindle where counting of whole trees is easier than large trees.

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Terence Robinson is a research and extension professor at Cornell's Geneva Experiment Station who leads Cornell's program in high-density orchard systems and plant growth regulators. Steve Hoying is a senior extension associate who is located at Cornell's Hudson Valley Lab who specializes in orchard management. Mario Miranda Sazo is an Extension Associate who specializes in orchard management with the Lake Ontario Fruit Program of Cornell Cooperative Extension. Andrea Rufato is a research scientist from EMBRAPA Brazil who is spending a year sabbatical at Geneva working with Terence Robinson.

Table 1. Participants in the 2013 Precision Thinning Group Effort.

Person	Location	Variety
Andrea Rufato (visiting scientist)	Geneva	Gala
Craig Kahlke/Pete Russell	Niagara	Gala
Craig Kahlke/Bill Gerling	Orleans	Honeycrisp
Mario Miranda/Jeff Smith	Orleans	Gala
Jim Misiti/Eric Brown	Orleans	Gala and Honeycrisp
Jim Misiti/Patrick Woodworth	Orleans	Gala
Rod Farrow	Orleans	Gala and Honeycrisp
Jim Eve	Wayne	Gala
JD Fowler	Wayne	Gala and Honeycrisp
Todd Furber	Wayne	Gala
Scott Vandewalle	Wayne	Honeycrisp
Steve Hoying/Joe Porpiglia	Ulster	Gala
Steve Hoying	Ulster	Gala
Mike Fargione/Bob Fix	Columbia	Gala
Jay Tuhill	Clinton	Honeycrisp
Seth Forrence	Clinton	Honeycrisp
Tom Everett	Clinton	Honeycrisp
William Abbott	Onondaga	Gala and Honeycrisp
Mike Biltonen	Ontario	Gala and Honeycrisp
Rick Reisinger	Schyler	Gala and Honeycrisp
Jon Clements	Massachussetts	Honeycrisp
Win Cowgill	New Jersey	Gala
Barney Hodges	Vermont	Honeycrisp

Table 2. Flower Bud Load of 18 Gala Orchards in NY State in 2013.

Orchard	Ratio of Floral Buds : Final Target Fruit Number
1	1.13
2	1.31
3	1.47
4	1.64
5	1.74
6	1.82
7	1.83
8	1.85
9	1.94
10	2.05
11	2.11
12	2.64
13	2.70
14	2.88
15	3.26
16	3.48
17	4.38
18	5.80
Average	2.39

Table 3. Flower Bud Load of 14 Honeycrisp Orchards in NY State in 2013.

Orchard	Ratio of Floral Buds : Final Target Fruit Number
1	1.49
2	1.83
3	2.00
4	2.43
5	2.44
6	2.50
7	2.72
8	2.88
9	2.88
10	3.25
11	3.44
12	3.46
13	5.22
14	5.80
Average	3.02

Table 4. Effect of Precision Thinning on Fruit Number per Tree of Gala/M.9 Apple Trees at Geneva, NY 2013.

Treatment	Initial Fruit Number	After Bloom Spray	After PF Spray	After 10mm Spray	After 18mm Spray	At 22mm	Target Fruit Number
Untreated Control	4430	1536	1217	1299	980	1288	335
Maxcel then 3 Maxcel/Sevin	4430	1051	992	981	579	567	335

Table 5. Effect of Promalin, Maxcel, NAA, Sevin and Ethrel and Combinations on Yield, Fruit Size of Gala/M.9 Apple Trees at NYSAES, Geneva, NY in 2013.

Full Bloom Spray	Petal Fall Spray (5mm)	12mm Spray	18mm Spray	Fruit No/ tree	Fruit Size (g)	Fruit set (# fruits/ cluster)
Untreated Control	-	-	-	700.6	125.11	0.76
Promalin 1pt /100 gal	-	Maxcel 64oz + 1pt Sevin/100 gal	-	469.2	155.92	0.51
Promalin 1pt /100 gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal	-	464.6	142.07	0.59
Promalin 1pt /100 gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal + 1 pt oil/100gal	333.4	175.27	0.47
Maxcel 64oz/100gal	-	Maxcel 64oz + 1pt Sevin/100 gal	-	416.2	155.19	0.50
Maxcel 64oz/100gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal	-	335.4	143.59	0.35
Maxcel 64oz/100gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal + 1 pt oil/100gal	326.8	160.13	0.37
-	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal	-	484.8	138.86	0.43
-	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal	Maxcel 64oz + 1pt Sevin/100 gal + 1 pt oil/100gal	284.6	162.31	0.31
			LSD P≤0.05	194.8	30.02	0.38
			Significance	***	***	**

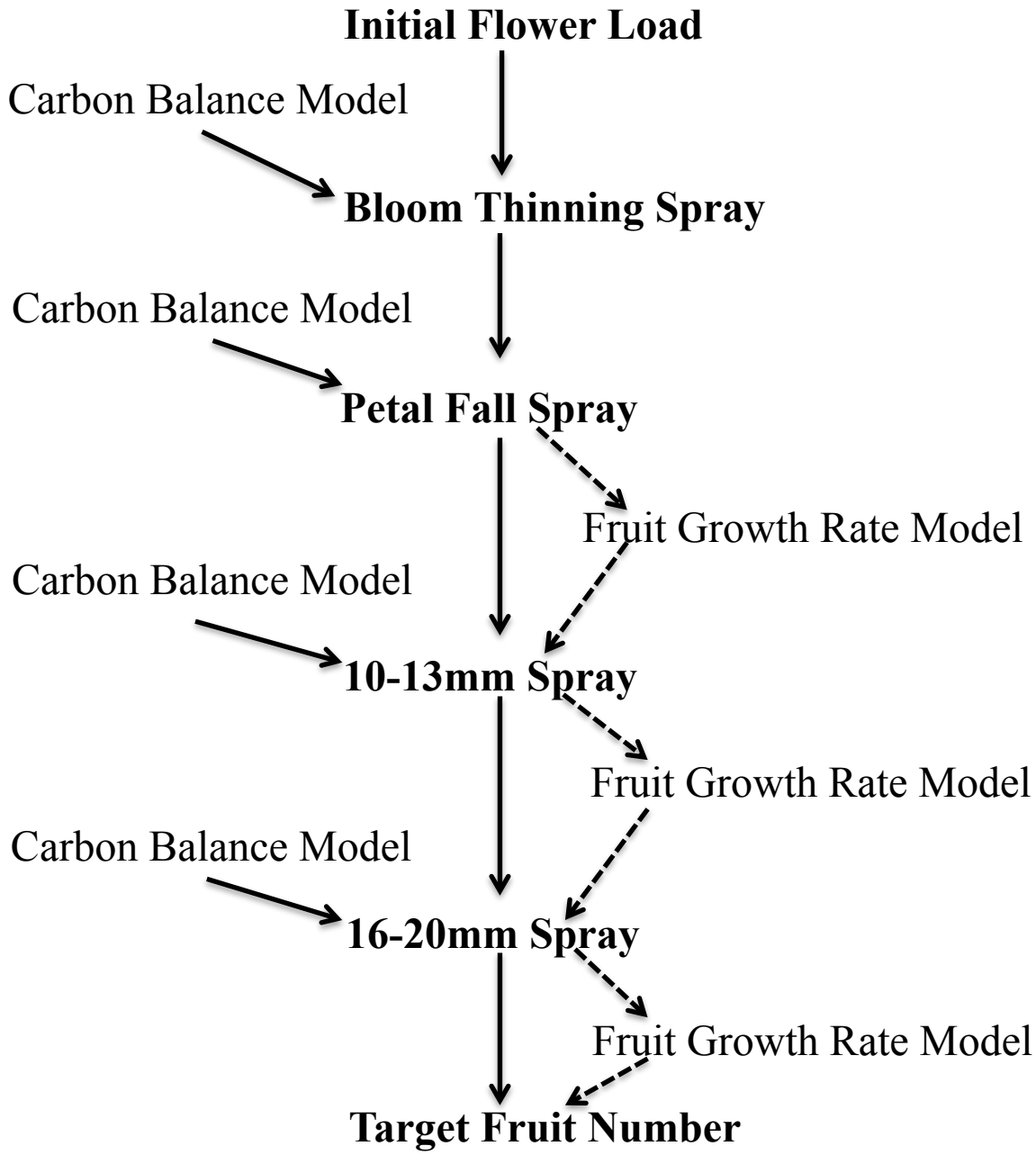

Fig. 1. Flow chart of precision thinning program to achieve a target crop load