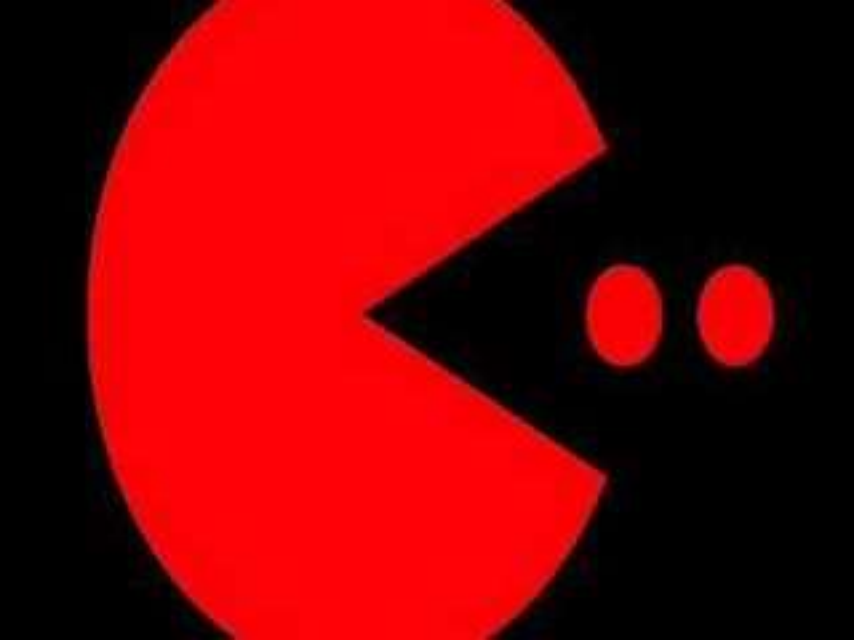


PACMAN

Jon Clements

Maine Preseason Tree Fruit Meeting
March 22, 2023

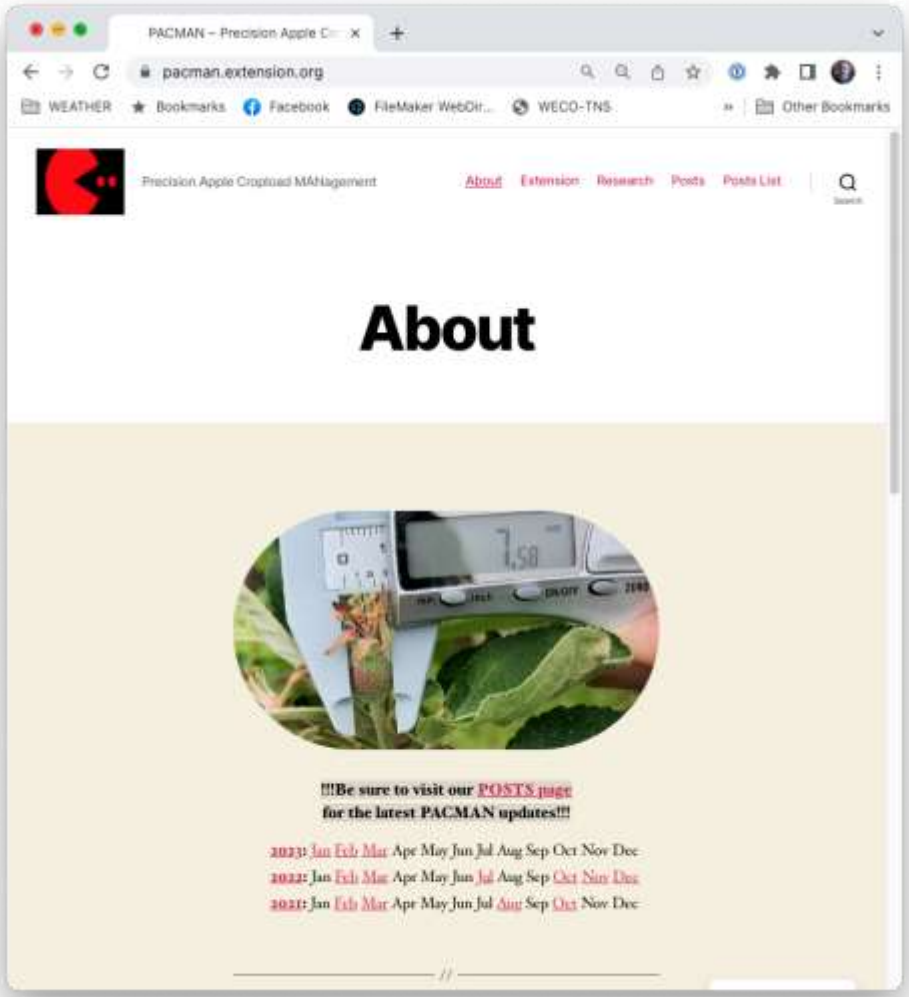
UMassAmherst | Extension Agriculture Program

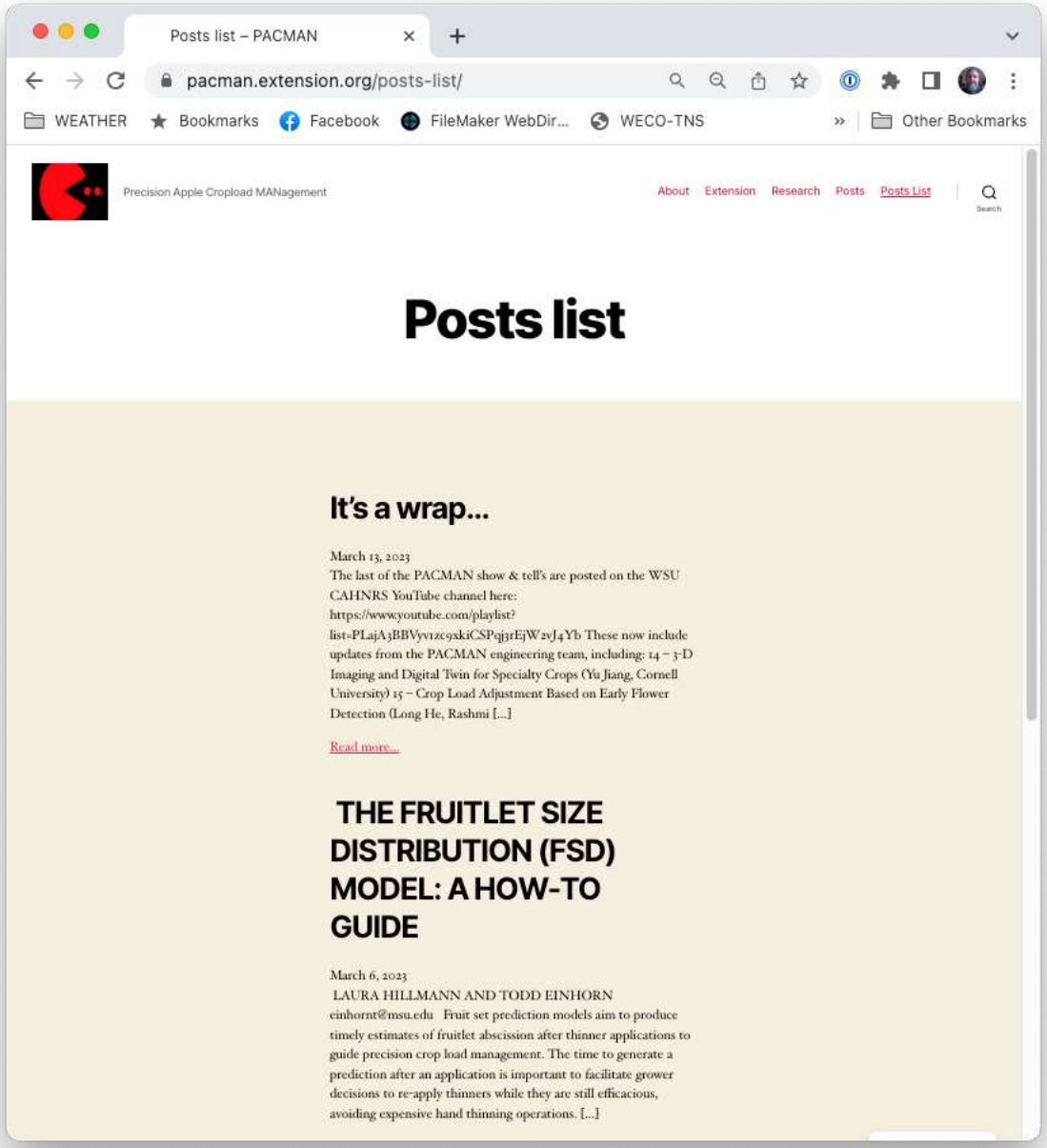
No, I don't mean this!!! ☺

Precision **A**pple **C**roploa**d** **MAN**agement

- Precision pruning
- Precision chemical thinning
- Hand thinning
- Result – achieve optimum economic crop load
- Most typically applies to tall-spindle system
- and higher value varieties (Honeycrisp, Gala, Fuji)

pacman.extension.org





pacman.extension.org

The PACMAN Extension team includes:

- Jon Clements, University of Massachusetts Amherst
- Karen Lewis, Washington State University
- Mario Miranda and Craig Kahlke, Cornell University
- Philip Schwallier (retired), Michigan State University
- Long He and Daniel Weber, Pennsylvania State University

Be sure to see our POSTS for the latest outputs/outcomes of PACMAN.

PACMAN's research team includes:

Terence Robinson (Project Director), Lailiang Cheng (Co-Project Director), Miguel Gomez, Greg Peck, and Yu Jiang, Cornell University

Stefano Musacchi, Washington State University

Todd Einhorn, Michigan State University

Long He, Paul Heinemann, and Dana Choi, Pennsylvania State University

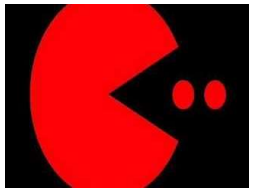
Tom Kon, North Carolina State University

Sherif Sherif, Virginia Tech University

Tory Schmidt, Washington Tree Fruit Research Committee

Chris Layer, MOOG Inc., Space Group

Roderick Farrow (Collaborator), Fish Creek Farms



Precision Crop Load Management of Apples:
USDA-NIFA-SCRI SREP 2020-51181-32197. 09/30/2019 – 08/31/2023.

Precision pruning

- Reduces number of flower buds to predetermined number using tall-spindle pruning rules and spur extinction (Robinson, et al., 2013. New York Fruit Quarterly, Volume 21, Number 2, Summer 2013.)

Precision Crop Load Management

Terence Robinson[1], Alan Lakso[1], Duane Greene[2] and Steve Hoying[1]
[1]Dept. of Horticulture, NYSAES, Cornell University, Geneva, NY 13345
[2]Dept. of Plant, Soil and Insect Sciences, University of Massachusetts, Amherst, MA 01003

This research was partially supported by the New York Apple Research and Development Program.

"The economic impacts of achieving the proper crop load each year are large (often $5,000-$10,000 per acre) and justify a more intense effort to manage crop load to achieve the optimum fruit number each year. Precision Thinning is a new strategy that begins with defining the optimum fruit number/tree (target fruit number) then applying sequential chemical thinning sprays (with rates and timing guided by the carbohydrate balance model to predict thinning efficacy and the fruit growth rate model to assess thinning efficacy in time to allow re-treatment when needed) with the goal of reducing fruit number per tree to close to the target fruit number to optimize crop value and reduce hand thinning costs."

Crop load management is the single most important yet difficult management strategy that determines the annual profitability of apple orchards. The number of fruit that remain on a tree directly affects yield, fruit size and the quality of fruit that are harvested, which largely determine crop value. If thinning is inadequate and too many fruits remain on the tree, fruit size will be small, fruit quality will be poor and flower bud initiation for the following year's crop may be either reduced or eliminated. Consequently, poor or inadequate thinning will reduce profitability in the current year and result in inadequate return bloom in the following year. Over thinning also carries economic perils since yield and crop value the year of application will be reduced and fruit size will be excessively large with reduced fruit quality due to reduced flesh firmness, reduced color and a much-reduced postharvest life. Thus, management of crop load is a balancing act between reducing crop load (yield) sufficiently to achieve optimum fruit size and adequate return bloom without reducing yield excessively (Figure 1).

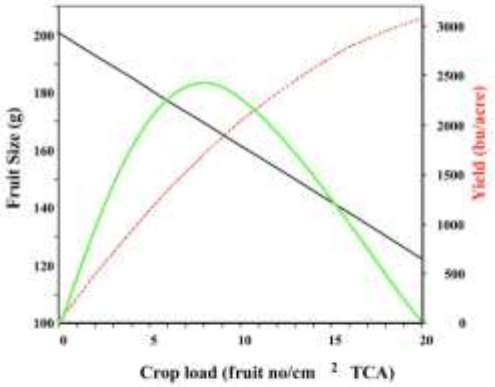


Figure 1. Counter balancing responses of Gala fruit size and yield to crop load with the curvilinear response of crop value to crop load showing an optimum crop value at a crop load of ~8-9 fruits/cm² TCA.

Economic Impacts of Crop Load

Calculations of crop value at various crop load levels using fruit size and yield as the main variables has shown in a number of experiments to that the relationship of crop value to crop load is curvilinear (Figure 1). At very high crop loads (unthinned Gala trees) fruit size is often very small but yield is very high. Crop value in this situation is almost zero since the value of the fruit is often exceeded by the packing and storage costs. When crop load is reduced to more moderate levels through thinning, then crop value rises dramatically even though yield is lower due to larger fruit size, which has greater value. At some point crop value peaks and then with further reductions in crop load crop value declines due to lower and lower yield. Although fruit size continues to increase it does not compensate for the loss in yield. It is striking how narrow the crop value peak is in many situations. Identifying and then achieving this optimum crop value is often very difficult for apple growers. It is difficult for fruit growers to know the economic impact of not achieving the optimum crop load without having various levels of thinning each year to construct the curves shown in Figure 1. The difference between the optimum crop load and under thinning or over thinning can sometimes be a difference of thousands of dollars per acre. Thus growers often fail to capture the full crop value possible without knowing how much "money they left on the table". More precisely managing crop load will help growers achieve the optimum crop load and maximize crop value.

Management Approaches to Precisely Managing Crop Load

There are 3 management practices that have a large effect on crop load: 1) pruning, 2) chemical thinning and 3) hand thinning. In recent years growers have relied primarily on chemical thinning to adjust crop load with a lesser reliance on hand thinning to reduce labor requirements. In other countries hand thinning is still the primary means of adjusting crop load.

Precision pruning

- 1 bud per final fruit number? – risky
- 1.5 to 2 buds per final fruit number? – yes
- 3+ buds per final fruit number – risk overcropping and biennial bearing
- 1.5 to 2 buds
- Tall-spindle rules; bud extinction
- Example: Honeycrisp, 80 apples per tree target, leave 120 to 160 buds (but see next slide)

Precision pruning

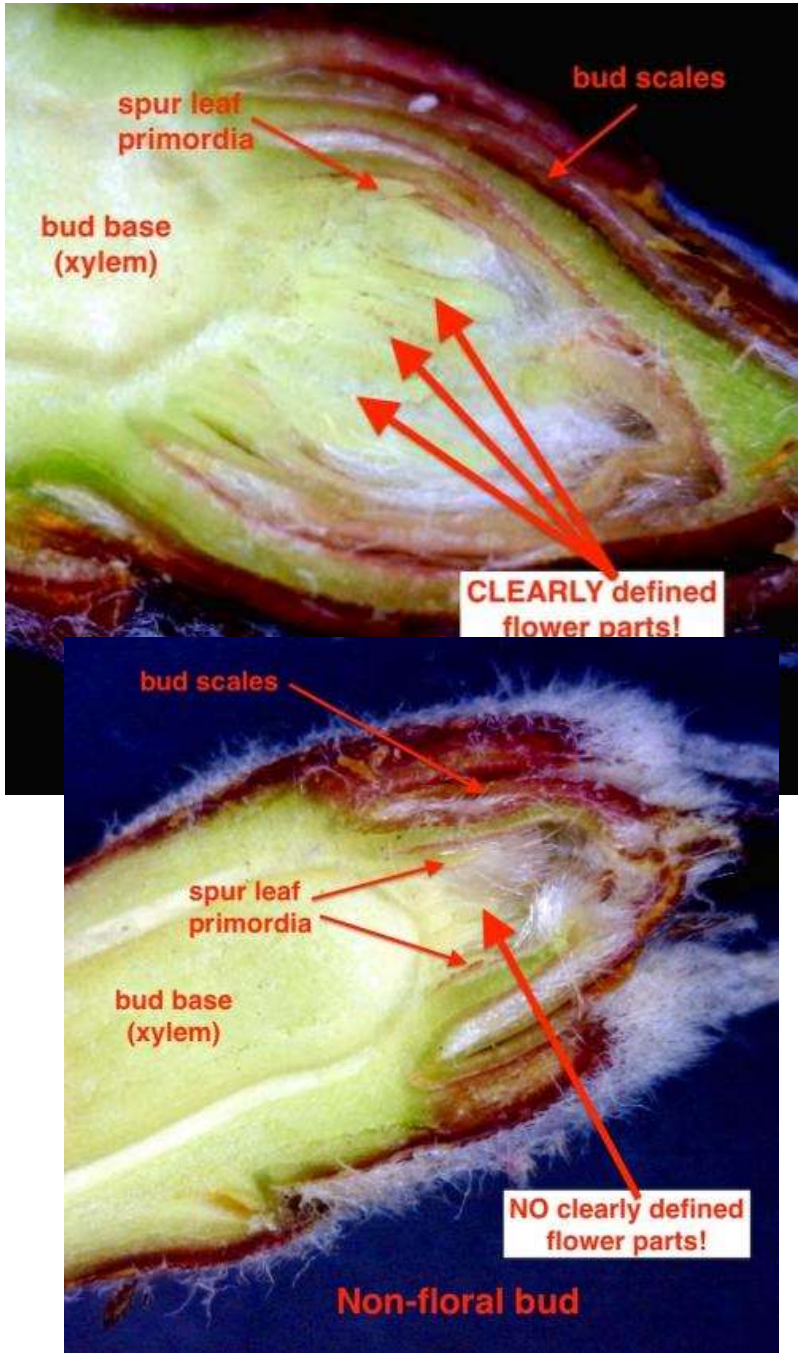
Ah, but there is a catch!

Honeycrisp: floral vs. non-floral buds?

We have a fact sheet for you!

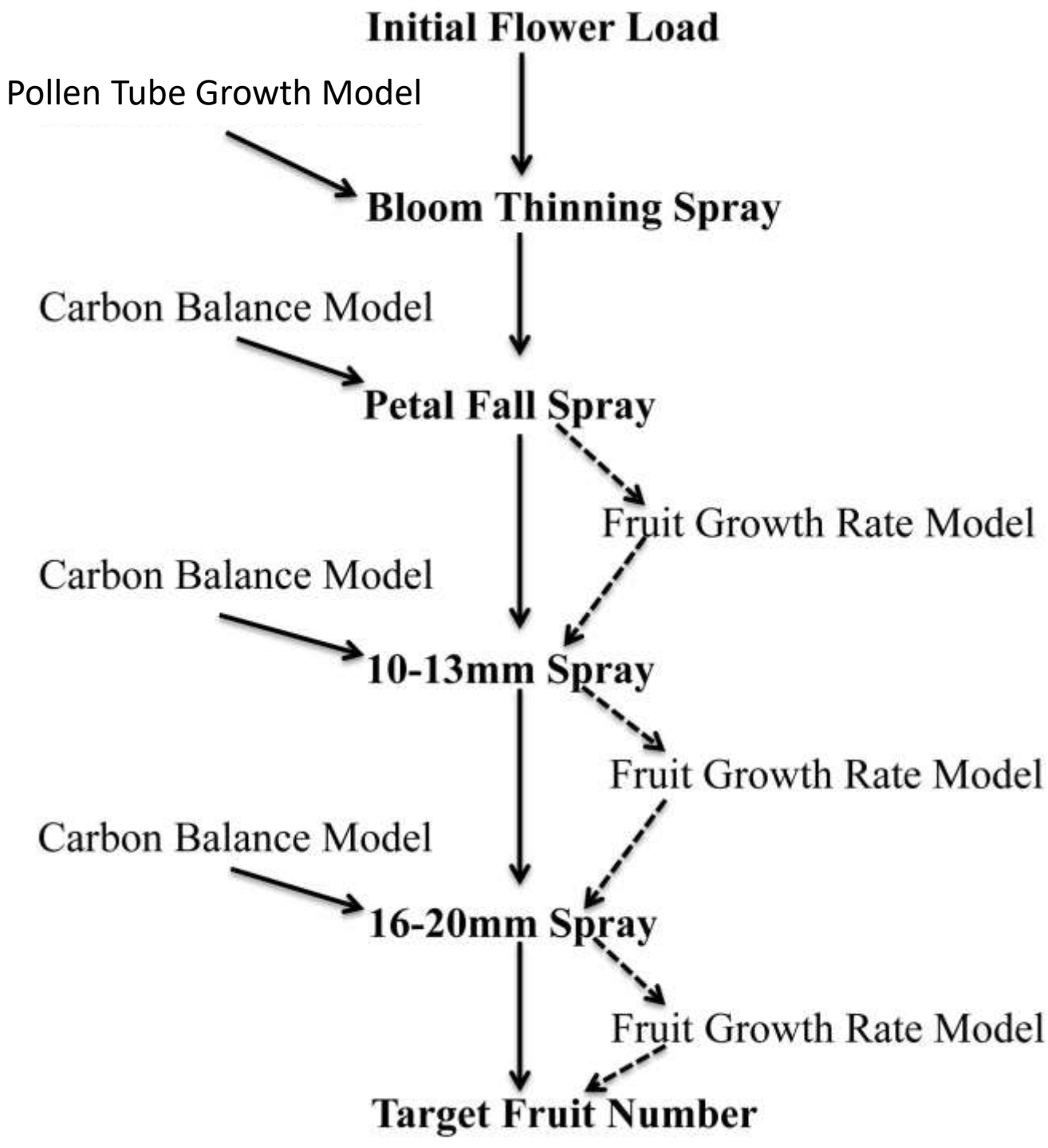
- HRT-Precision crop load management of Honeycrisp: flower bud identification and precision pruning

umassfruit.com→Publications→Fact Sheets



Precision chemical thinning

- Pollen tube growth model
- Carbon balance model
- Fruit growth rate model



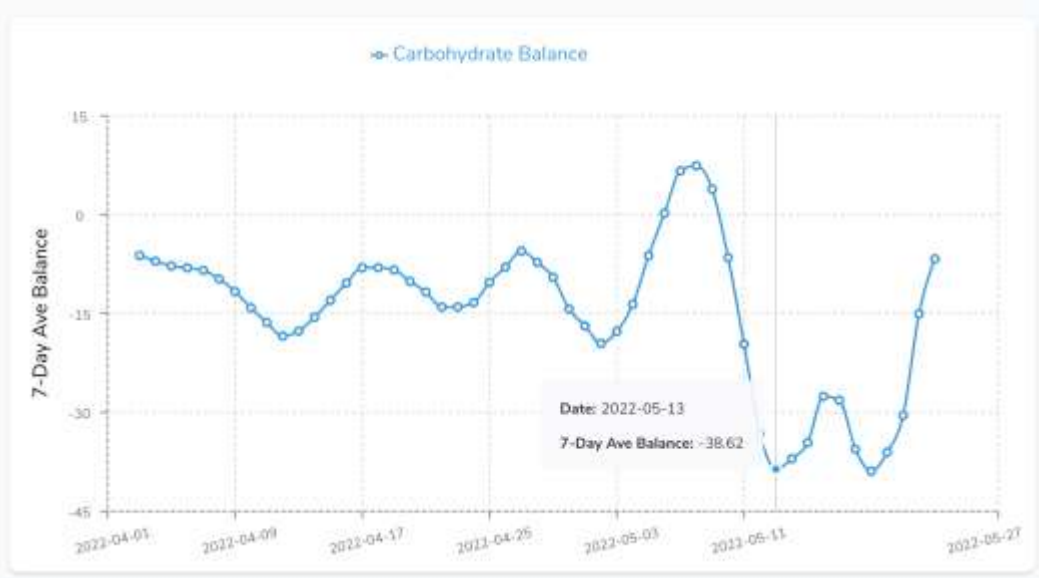
Pollen Tube Growth Model (PTGM)

- Measure style length
- Note date of king bloom
- Apply caustic thinner* when NEWA PTGM model shows king flowers have been pollinated

* ATS or lime sulfur

Carbon Balance Model

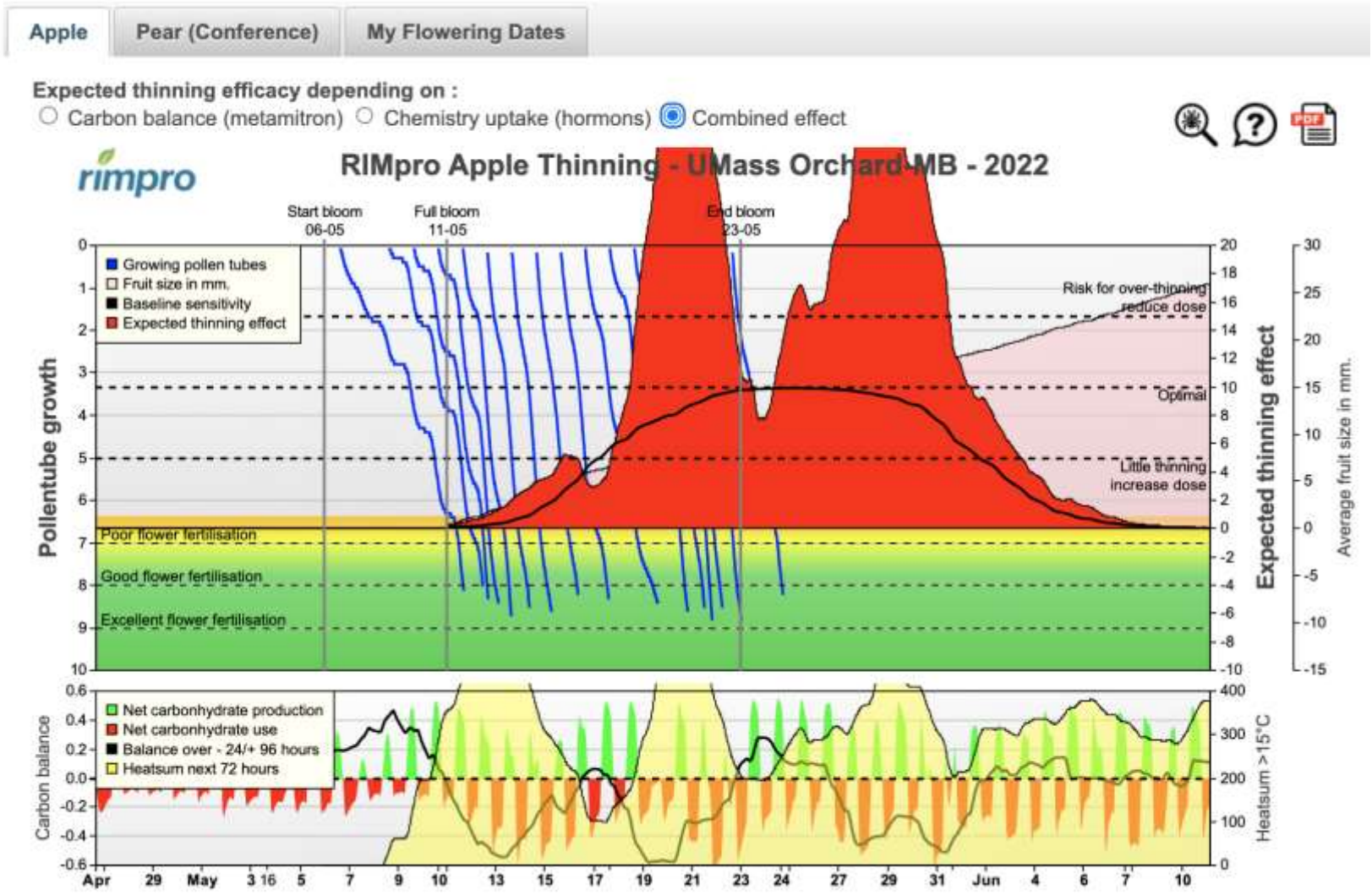
- Apple carbohydrate thinning model on NEWA
- Timing and rate adjustment
- Solar radiation and temperature dependent
  - *More light = more difficult to thin*
  - *Higher temperature (particularly at night) = easier to thin*



Apple Carbohydrate Thinning Model (on NEWA)

Date (2022)	Max Temp (°F)	Min Temp (°F)	Solar Rad (MJ/m2)	Tree Carbohydrate Status (g/day)		Accum 4°C DD since bloom	Thinning Recommendation
				Daily	7-Day Weighted Ave	≥ 200 & ≤ 250	L = Low Risk of Overthinning C = Caution D = Danger of Overthinning
May 16	80	61	19.1	-55.86	-27.59	106	Apply Standard Chemical Thinning Rate L
May 17	68	52	19.2	-10.55	-28.16	117.3	Apply Standard Chemical Thinning Rate L
May 18	70	48	27.1	9.73	-35.6	128.4	Apply Standard Chemical Thinning Rate L
May 19	56	50	3.4	-44.06	-38.96	135.9	Apply Standard Chemical Thinning Rate L
May 20	77	46	20.2	-9.7	-36.06	148.2	Apply Standard Chemical Thinning Rate L
May 21	88	62	18.9	-81.02	-30.47	168	Decrease Chemical Thinning Rate by 15% L
May 22	90	66	21.4	-90.41	-15.05	189.3	Apply Standard Chemical Thinning Rate L
May 23	72	56	26.5	4.71	-6.72	202.9	Apply Standard Chemical Thinning Rate L

Fruit thinning (on RIMpro.cloud)



Fruitlet growth rate model

- Tag trees and mark clusters (5 x 14 = 70)
- Count flower clusters
- Begin measuring fruitlets at 6-7 mm
- Measure at 4-5 day intervals post chemical thinner application
- Number of apples per tree and % set

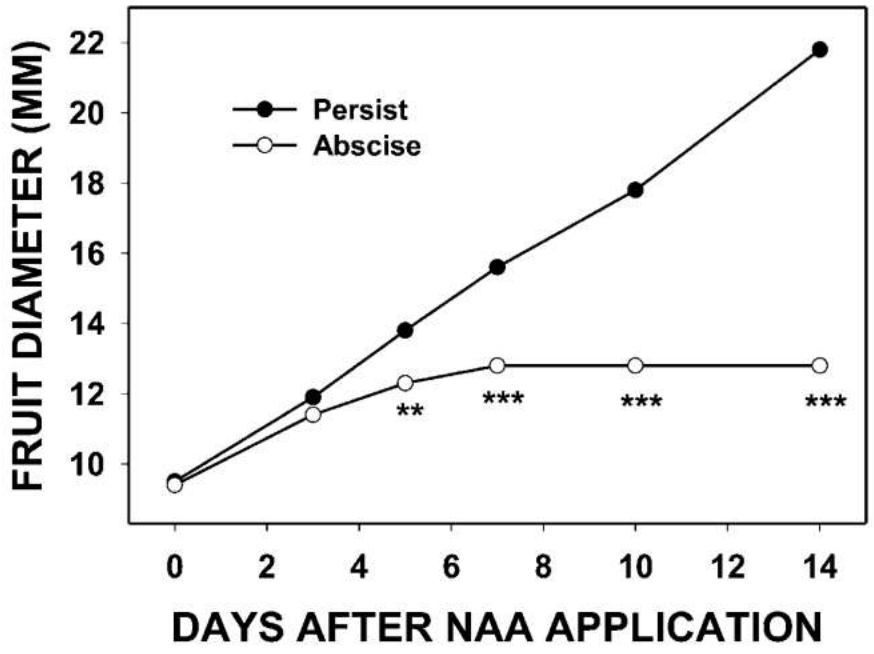
HortScience 48(5):584–587. 2013.

Development of a Fruitlet Growth Model to Predict Thinner Response on Apples

Duane W. Greene[1]
Stockbridge School of Agriculture, University of Massachusetts, Bowditch Hall, Amherst, MA 01003

Alan N. Lakso and Terence L. Robinson
New York State Agricultural Experiments Station, Cornell University, Geneva, NY 14456

Phillip Schwallier
Michigan State University, East Lansing, MI 48824



Fruit: HRT-RECIPE - Predicting

ag.umass.edu/fruit/fact-sheets/hrt-recipe-predicting-fruit-set-using-fruitlet-g...

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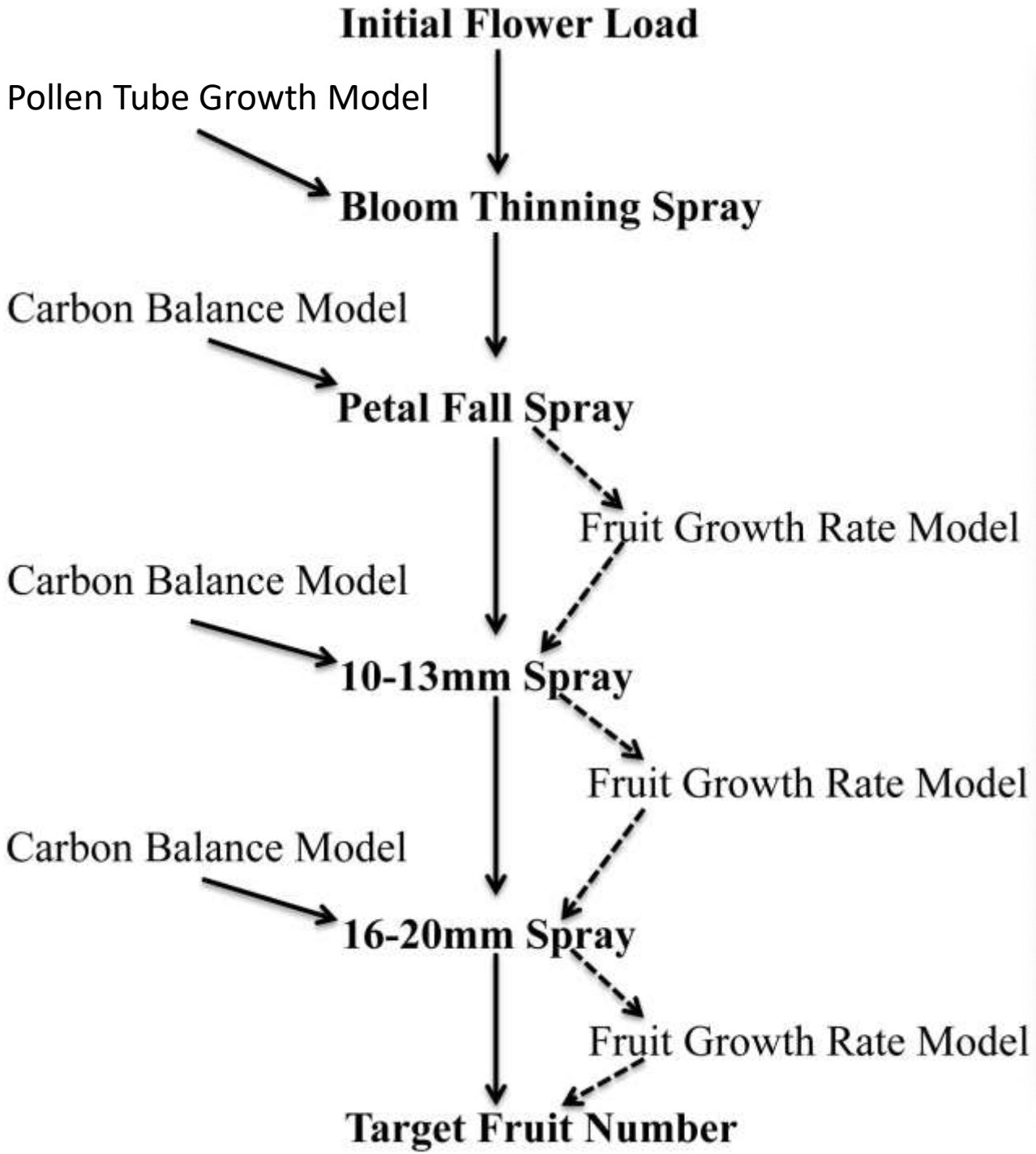
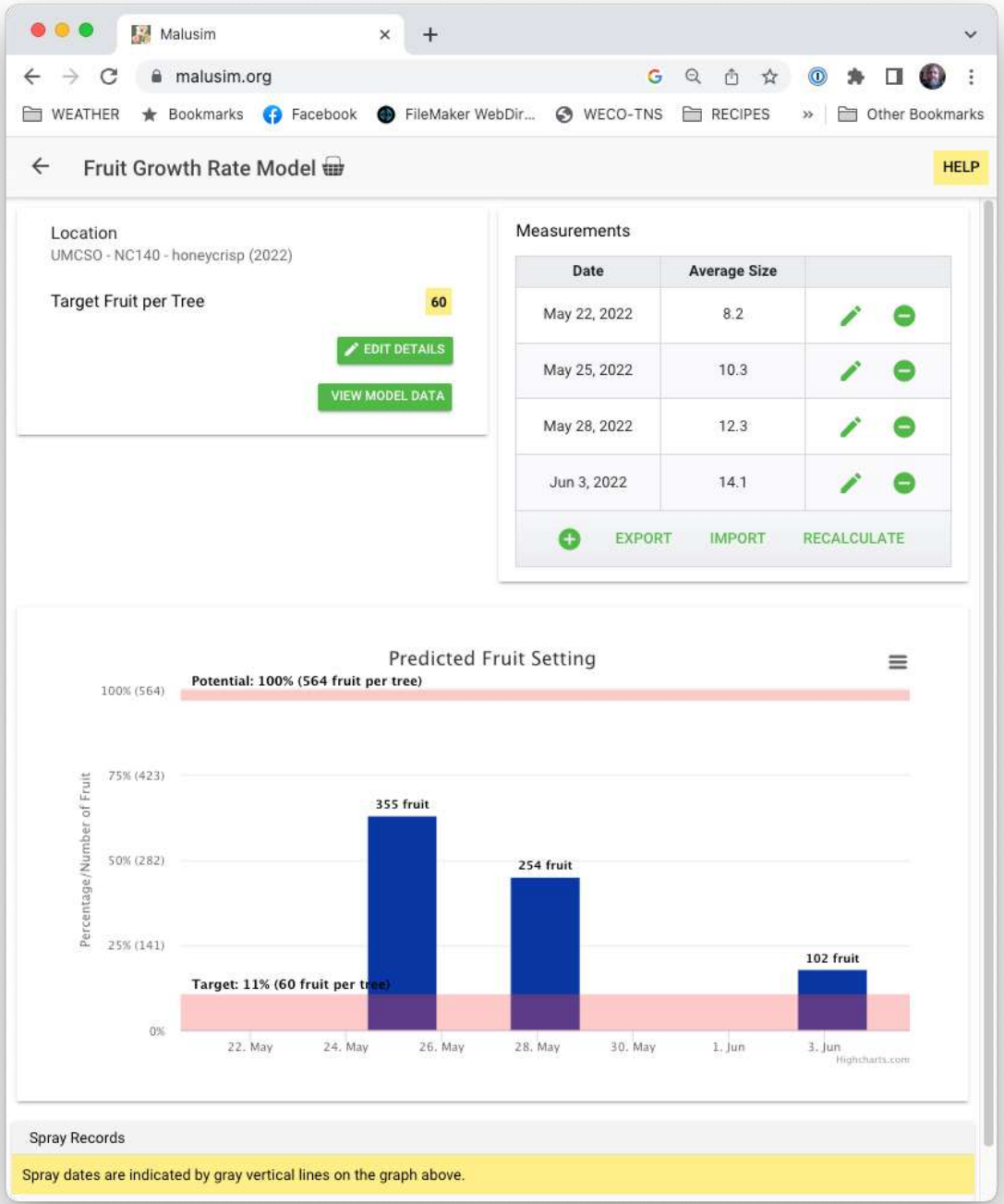
- IPM Berry Blast

HRT-RECIPE - Predicting fruit set using the fruitlet growth rate model

These are the basic INGREDIENTS and DIRECTIONS for predicting apple fruit set using the fruitlet growth rate model. If using the recommended "Ferri" spreadsheet, download it using the link below. Also note "for more information." Any questions or comments, contact Jon Clements.


Initial Flower Load
Pollen Tube Growth Model
Bloom Thinning Spray
Carbon Balance Model
Petal Fall Spray
Fruit Growth Rate Model
Carbon Balance Model
10-13mm Spray
Fruit Growth Rate Model
Carbon Balance Model
16-20mm Spray
Fruit Growth Rate Model
Target Fruit Number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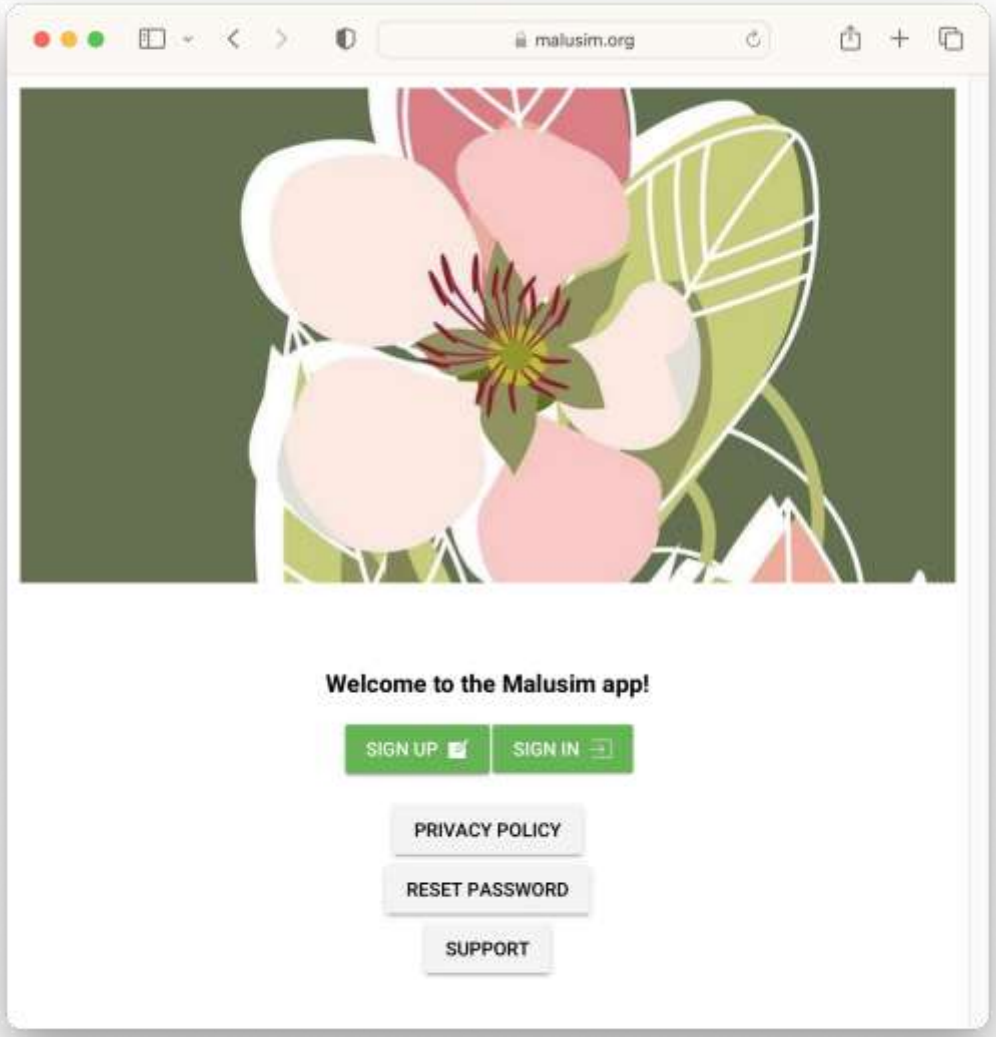
Other Bookmarks
Fruit Growth Rate Model
HELP
Location
UMCSO - NC140 - honeycrisp (2022)
Target Fruit per Tree
60
EDIT DETAILS
VIEW MODEL DATA
Measurements
Date
Average Size
May 22, 2022
8.2
May 25, 2022
10.3
May 28, 2022
12.3
Jun 3, 2022
14.1
EXPORT
IMPORT
RECALCULATE
Predicted Fruit Setting
Potential: 100% (564 fruit per tree)
100% (564)
75% (423)
50% (282)
25% (141)
0%
Percentage/Number of Fruit
355 fruit
254 fruit
102 fruit
Target: 11% (60 fruit per tree)
22. May
24. May
26. May
28. May
30. May
1. Jun
3. Jun
Highcharts.com
Spray Records
Spray dates are indicated by gray vertical lines on the graph above.

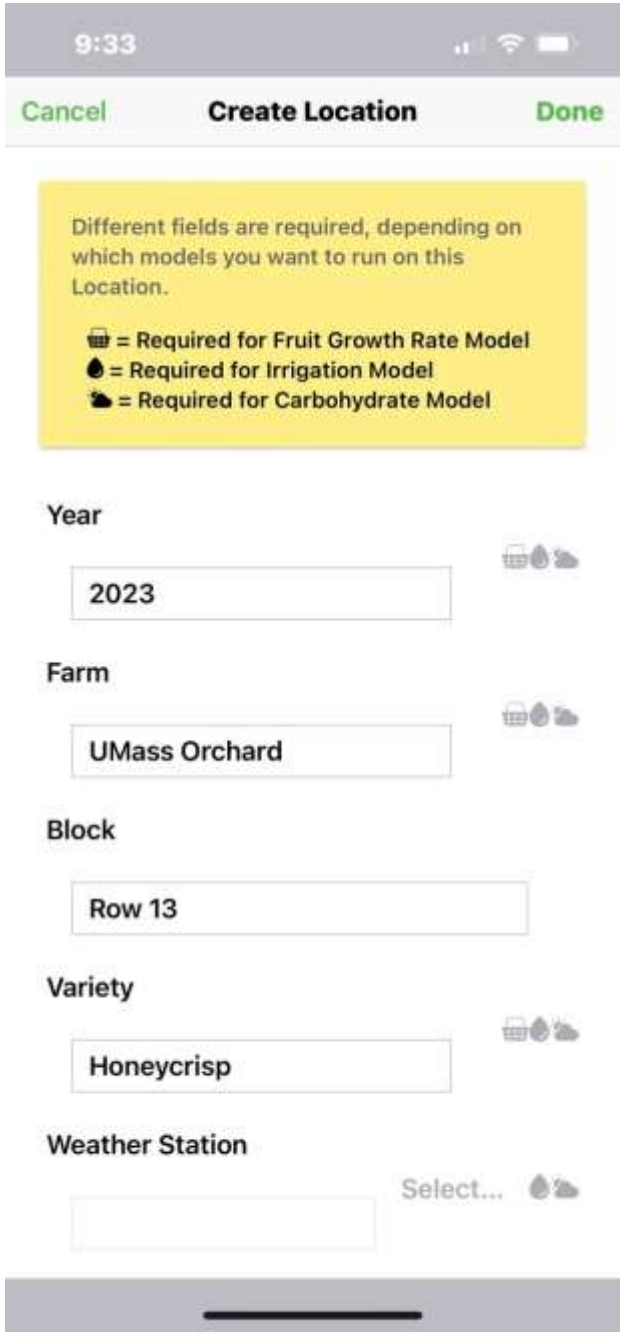
Malusim

- App (iPhone or Android) or web (malusim.org)
- Create an account on malusim.org
- Set up your variety(s) and block(s)
- Enter fruitlet growth measurements
- Review predicted fruit set, make chemical thinning decisions



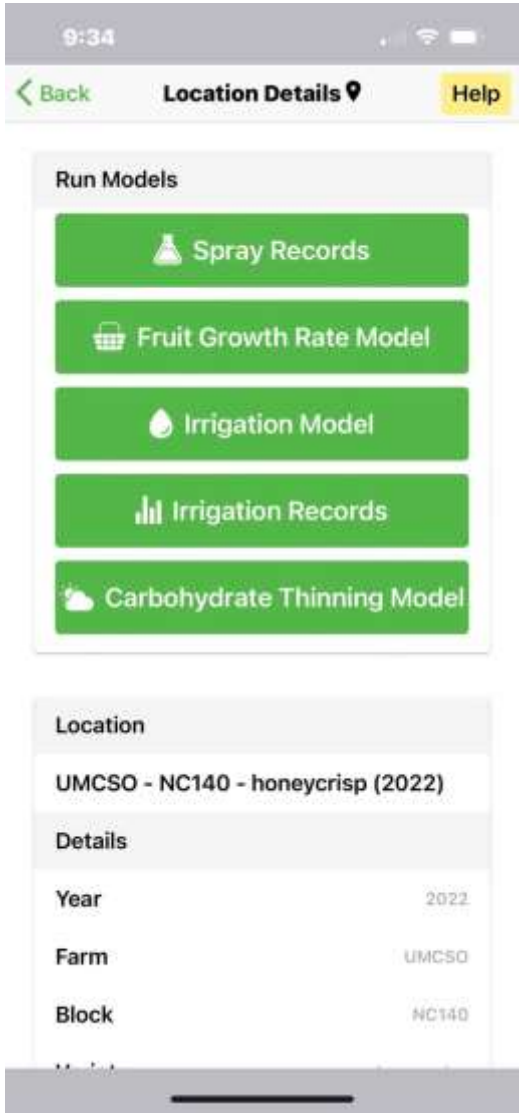
Malusim

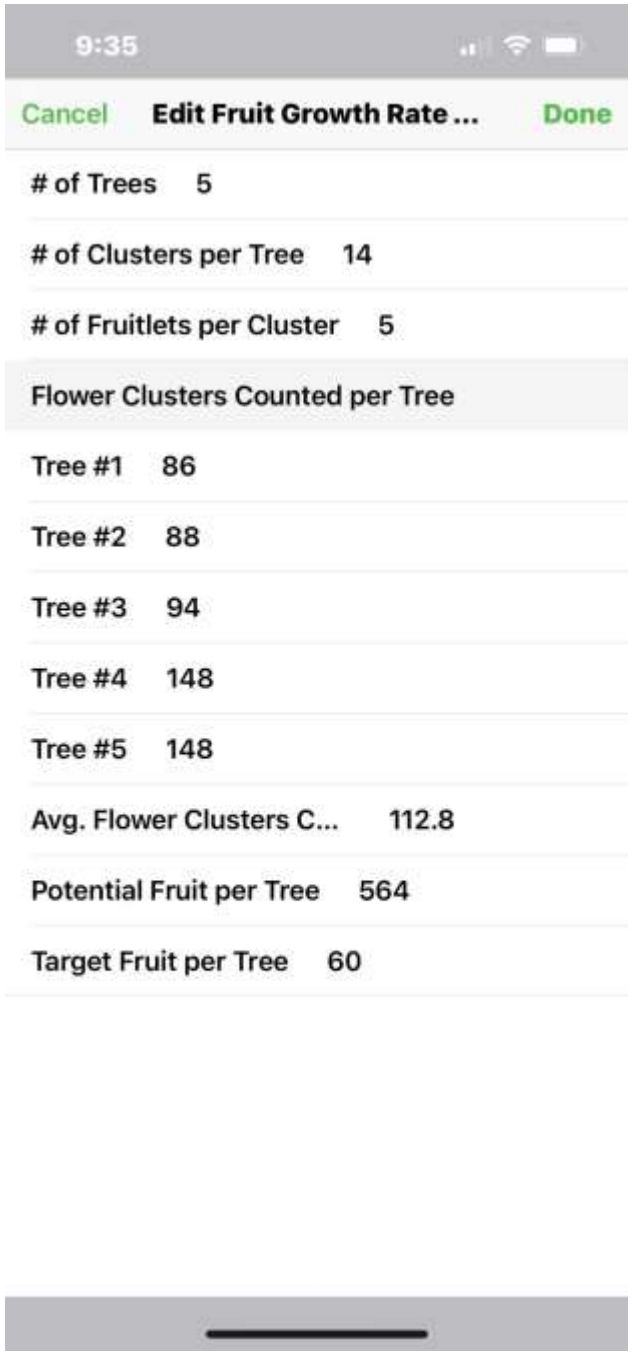

9:31
Locations
jacextman@gmail.com
Help
Existing Locations
This Year
Last Year
All
+ Add a Location
Build: 22-05-27
Privacy Policy

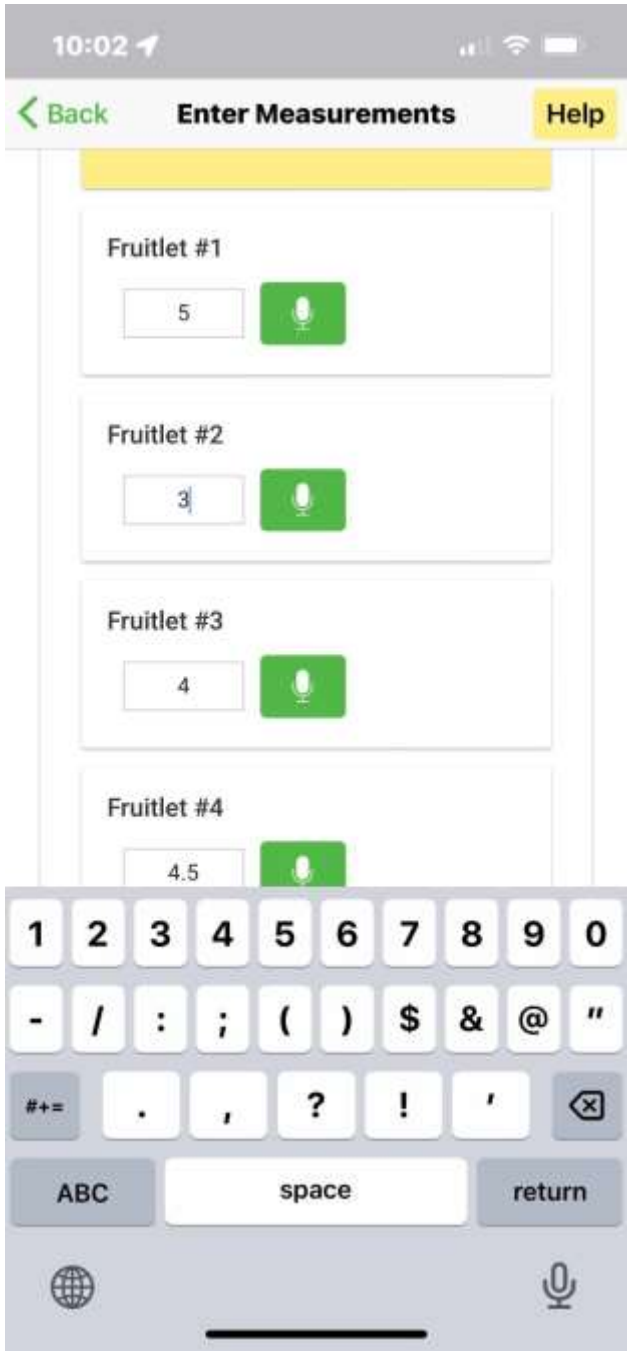

9:33
Cancel
Create Location
Done
Different fields are required, depending on which models you want to run on this Location.
= Required for Fruit Growth Rate Model
= Required for Irrigation Model
= Required for Carbohydrate Model
Year
2023
Farm
UMass Orchard
Block
Row 13
Variety
Honeycrisp
Weather Station
Select...


9:34
Locations
jacextman@gmail.com
Help
Existing Locations
This Year
Last Year
All
UMCSO - - gala (2022)
TFF - - evercrisp (2022)
UMCSO - NC140 - honeycri...
TFF - - gala (2022)
UMCSO - - fuji (2022)
TFF - - honeycrisp (2022)
+ Add a Location
Build: 22-05-27
Privacy Policy

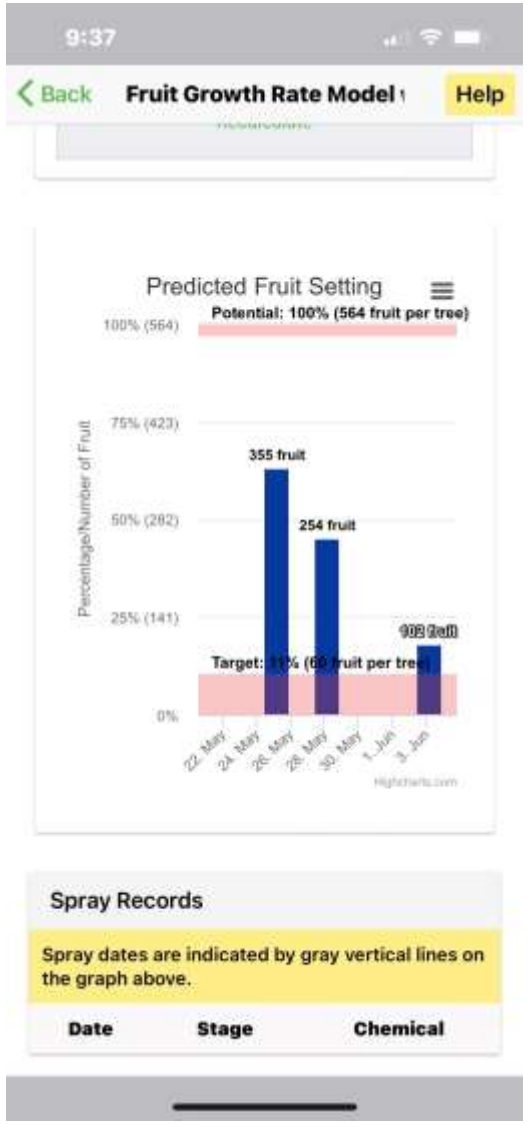
Malusim


9:34
Back
Location Details
Help
Run Models
Spray Records
Fruit Growth Rate Model
Irrigation Model
Irrigation Records
Carbohydrate Thinning Model
Location
UMCSO - NC140 - honeycrisp (2022)
Details
Year
2022
Farm
UMCSO
Block
NC140

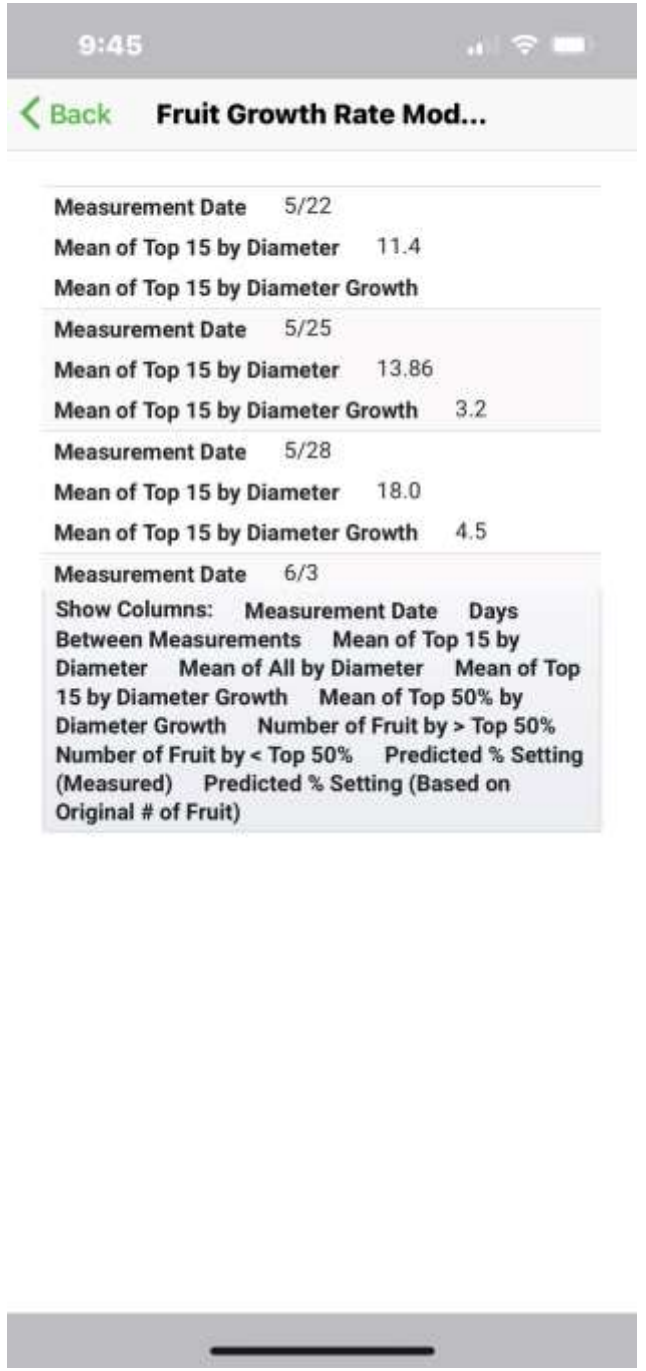

9:35
Cancel
Edit Fruit Growth Rate ...
Done
# of Trees 5
# of Clusters per Tree 14
# of Fruitlets per Cluster 5
Flower Clusters Counted per Tree
Tree #1 86
Tree #2 88
Tree #3 94
Tree #4 148
Tree #5 148
Avg. Flower Clusters C... 112.8
Potential Fruit per Tree 564
Target Fruit per Tree 60


10:02
Back
Enter Measurements
Help
Fruitlet #1
5
Fruitlet #2
3
Fruitlet #3
4
Fruitlet #4
4.5
1 2 3 4 5 6 7 8 9 0
- / : ; ( ) $ & @ "
#+= . , ? ! '
ABC
space
return

Malusim


9:37
Back
Fruit Growth Rate Model
Help
Predicted Fruit Setting
Potential: 100% (564 fruit per tree)
100% (564)
75% (423)
50% (282)
25% (141)
0%
Percentage/Number of Fruit
355 fruit
254 fruit
22. May
24. May
26. May
28. May
30. May
1. Jun
3. Jun
Spray Records
Spray dates are indicated by gray vertical lines on the graph above.
Date
Stage
Chemical

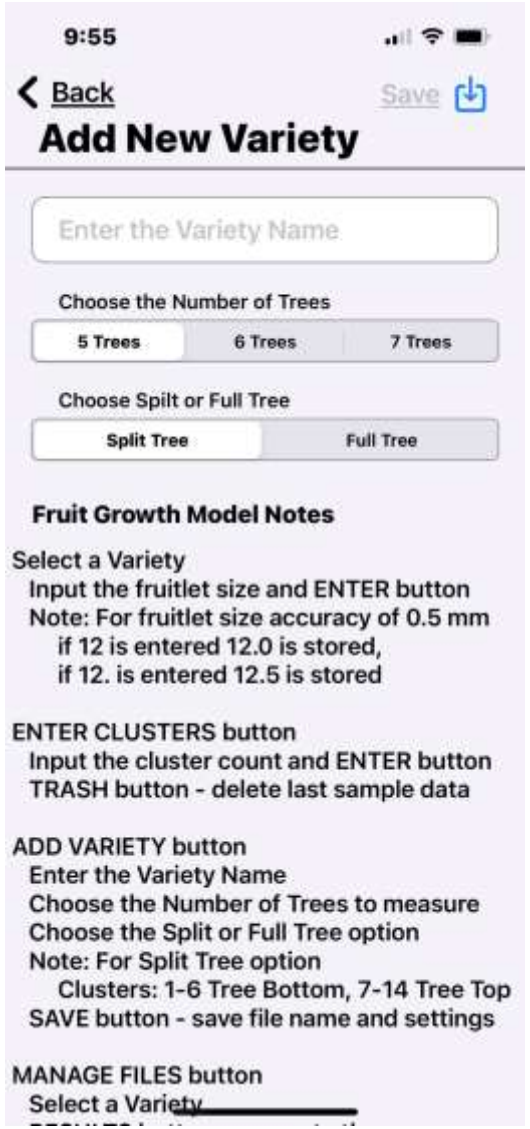

9:35
Back
Fruit Growth Rate Model
Help
View Model Data
Measurements
Date
Average Size
May 22, 2022
8.2
May 25, 2022
10.3
May 28, 2022
12.3
Jun 3, 2022
14.1
Export
Import
Recalculate

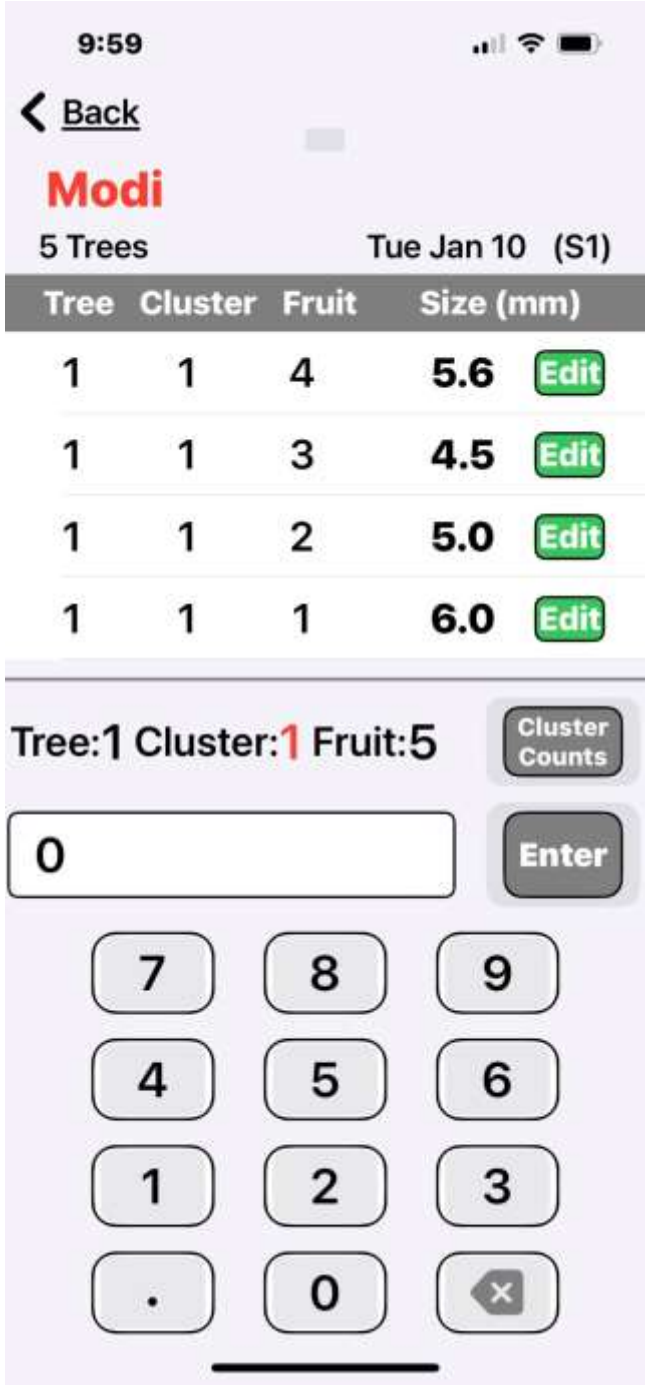

9:45
Back
Fruit Growth Rate Mod...
Measurement Date 5/22
Mean of Top 15 by Diameter 11.4
Mean of Top 15 by Diameter Growth
Measurement Date 5/25
Mean of Top 15 by Diameter 13.86
Mean of Top 15 by Diameter Growth 3.2
Measurement Date 5/28
Mean of Top 15 by Diameter 18.0
Mean of Top 15 by Diameter Growth 4.5
Measurement Date 6/3
Show Columns: Measurement Date Days Between Measurements Mean of Top 15 by Diameter Mean of All by Diameter Mean of Top 15 by Diameter Growth Mean of Top 50% by Diameter Growth Number of Fruit by > Top 50% Number of Fruit by < Top 50% Predicted % Setting (Measured) Predicted % Setting (Based on Original # of Fruit)

Fruit growth model (Ferri app)

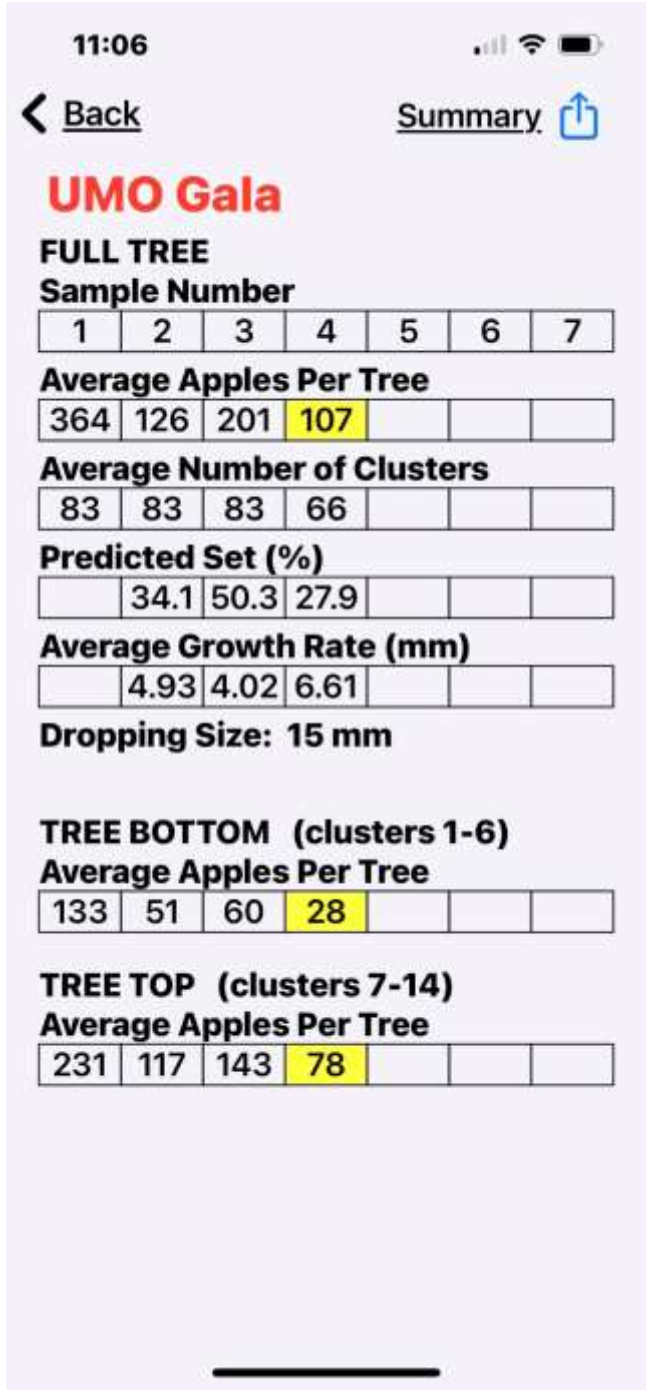
- App, iPhone only (no website)
- No account needed, all data kept on iPhone
- Add variety
- Enter flower cluster counts
- Enter fruitlet growth measurements
- Review predicted fruit set/make chemical thinning decisions

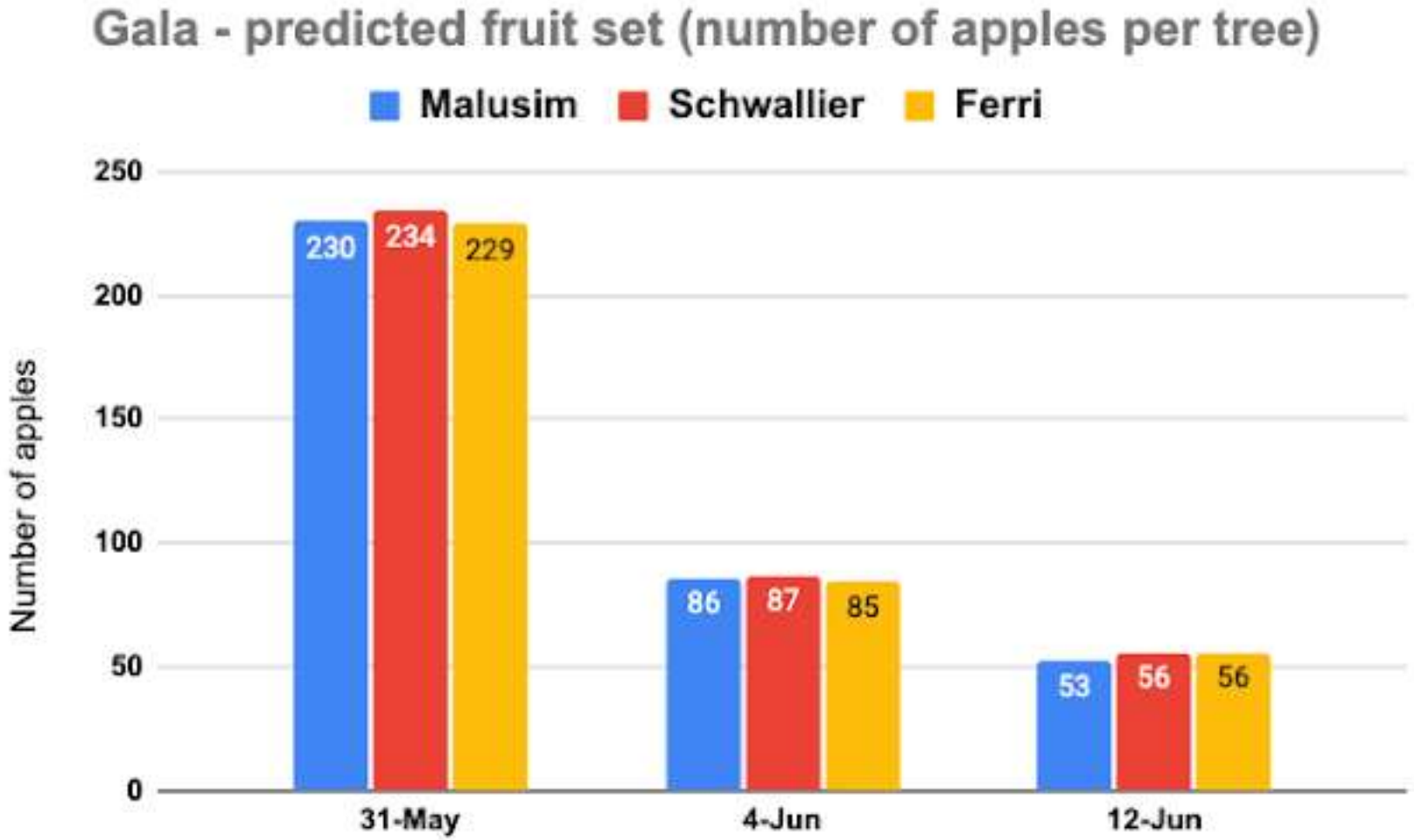
Fruit growth model (Ferri app)



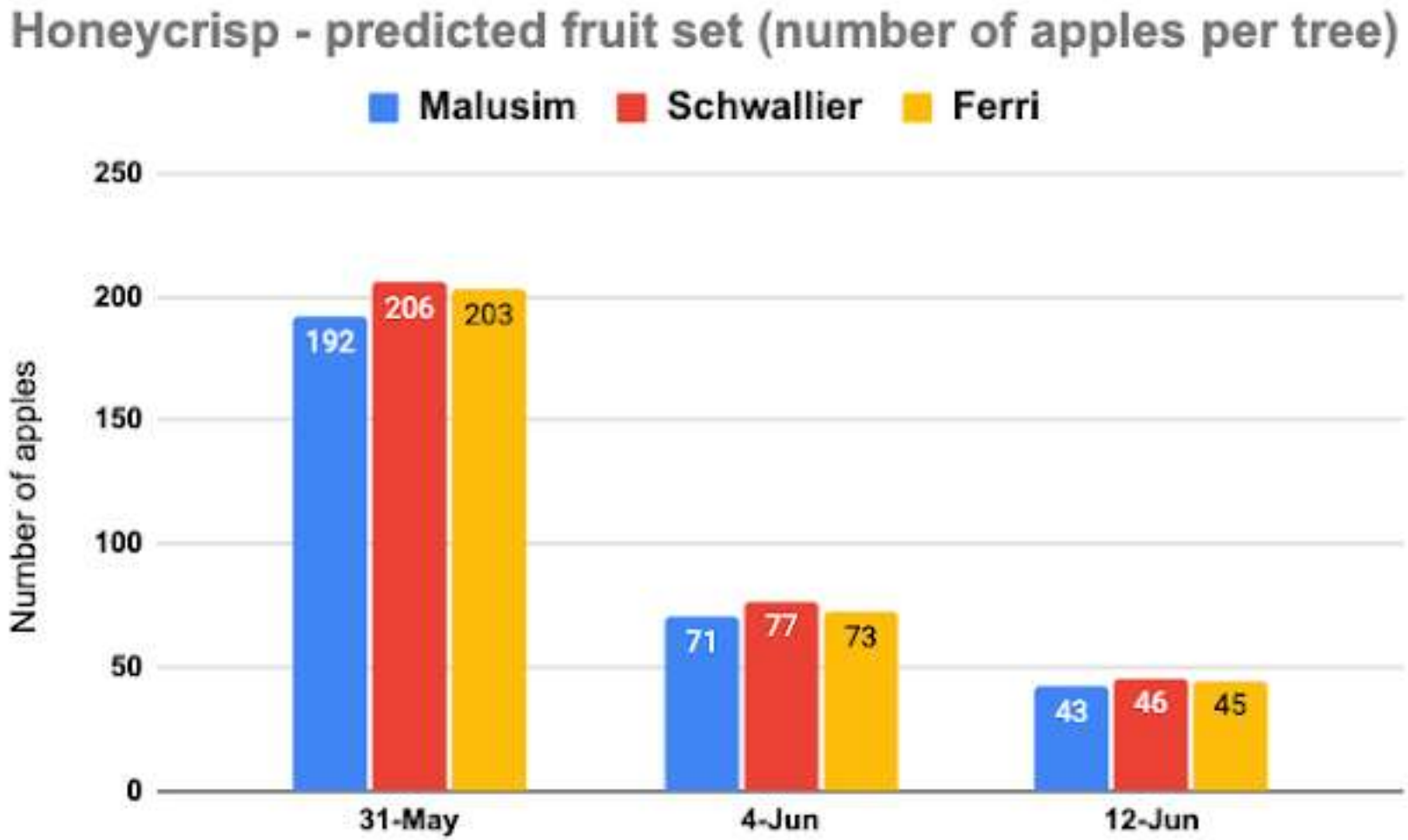


Fruit growth model (Ferri app)





Gala predicted fruit set. Target was 80 fruit per tree, actual at harvest was 45 apples.



Honeycrisp predicted fruit set. Target was 70 fruit per tree, actual at harvest was 26 apples.

Fruit: HRT-RECIPE - Predicting

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HRT-RECIPE - Predicting fruit set using the fruitlet growth rate model

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ag.umass.edu/fruit/fact-sheets/hrt-recipe-predicting-fruit-set-using-fruitlet-g...

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New England Grape Notes

NC-140 Massachusetts State Reports

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INGREDIENTS

1. 5 tall-spindle trees of same variety
2. Flagging tape and permanent marker
3. Flower cluster labels (https://www.avery.com/products/labels/5201)
4. 14 flower clusters per tree, times 5 trees = 70 flower clusters total
5. Digital caliper
6. Malusim app (Google Play or Apple Store)
7. or Fruit Growth Model (iOS only, search App Store on your iPhone)
8. or Ferri spreadsheet (Ferri spreadsheet 2023 Master v 2.1.2 for predicting fruit set w/ macros) and Perennia: Orchard Tools app

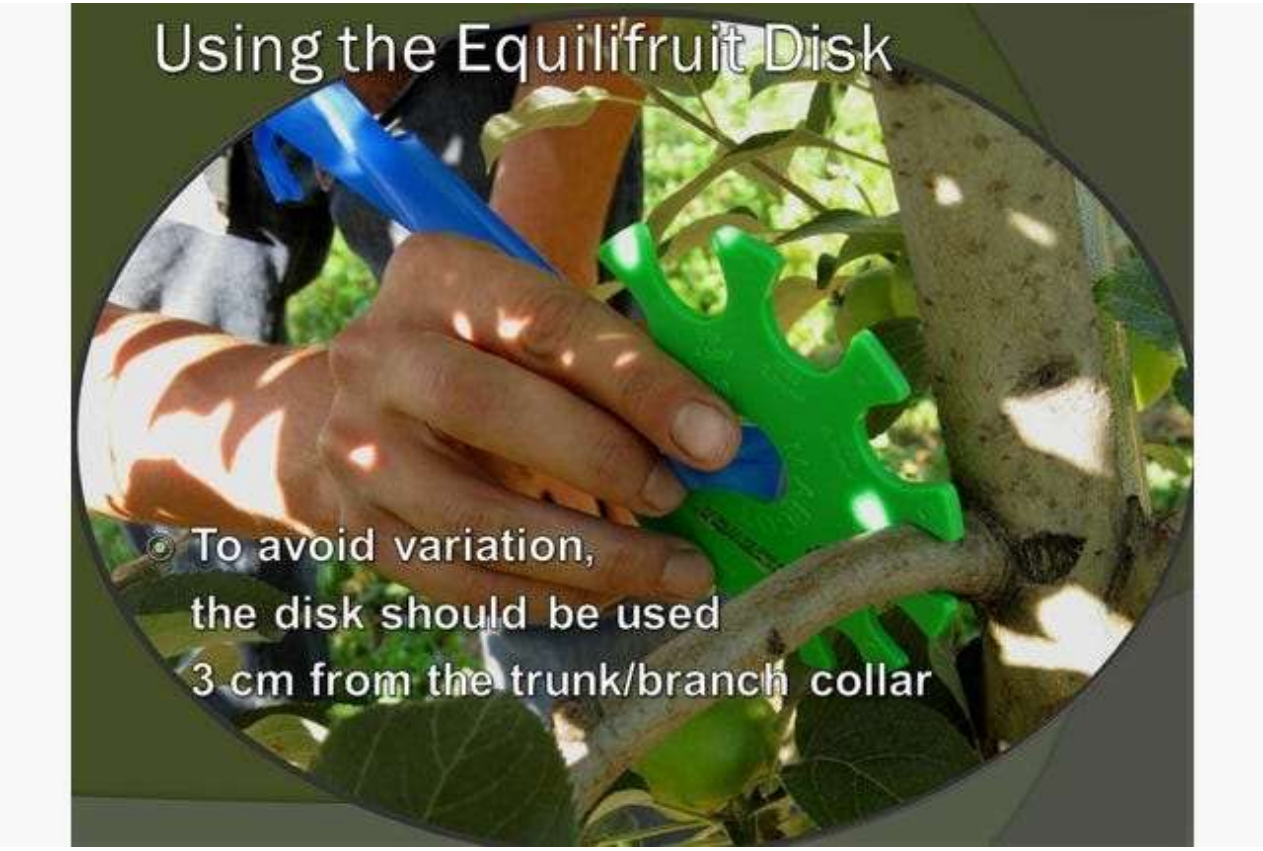
DIRECTIONS

1. Tag trees 1-5, count total number of blossom cluters per each tree, and determine desired crop load at harvest
2. Tag clusters (1-14)
3. Begin measuring fruitlets at app. 6-7 mm
4. Measure fruitlets at 4-7 day intervals, entering measurements into Malusim app or Orchard Tools. Measurement interval will depend on temperature and/or chemical thinner application(s), both of which affect fruitlet growth rate
5. Run fruitlet growth rate model in Malusim app
6. Or export data from Orchard Tools and copy into Ferri spreadsheet and run fruitlet growth rate model. (A reminder, if using the Ferri spreadsheet, on each measurement date, the number of remaining clusters with fruitlets on each tree must be counted for the model run to be most accurate.)
7. Use predicted fruit set to determine need for further chemical thinning sprays
8. Enjoy!

Hand thinning

- What can I say other than it is expensive?
- Can hand thin down to target crop load
- Do as soon as possible…

https://extension.psu.edu/apple-crop-load-management-a-hand-thinning-gauge



Arghh…Honeycrisp

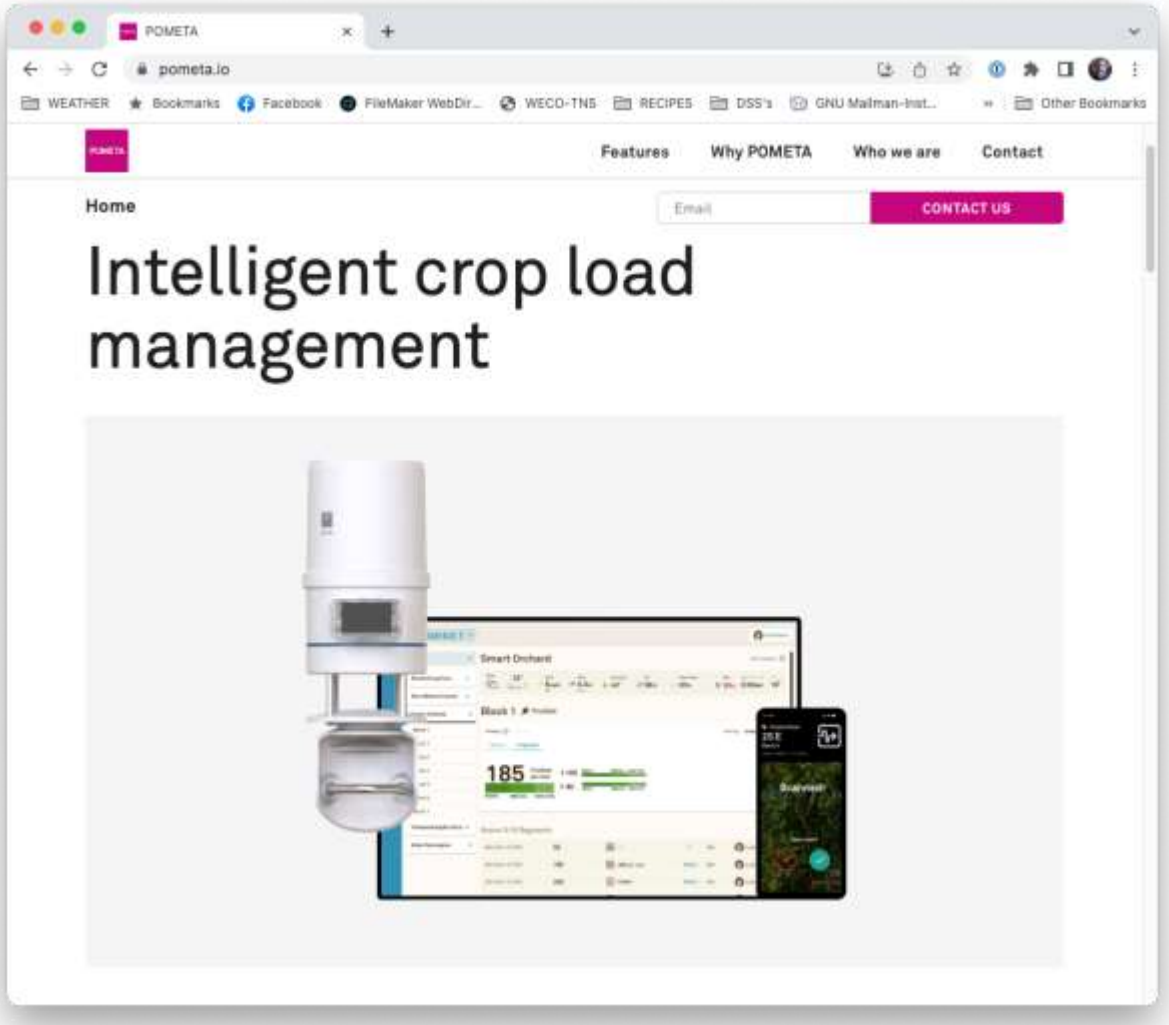
- NAA at bloom
- NAA at petal fall
- NAA at 30, 45, 60 days after petal fall
- Why? Initiates flower bud development early, as soon as 30 days post-petal fall
- Also need to hand thin 30 to 45 days post-petal fall

Precision Apple Croploa d MANagement

- Precision pruning
- Precision chemical thinning
- Hand thinning
- Goal: achieve optimum economic crop load
- But THERE'S GOT TO BE AN EASIER WAY???!!!

Pometa.io
(formerly Farm Vision Technologies)

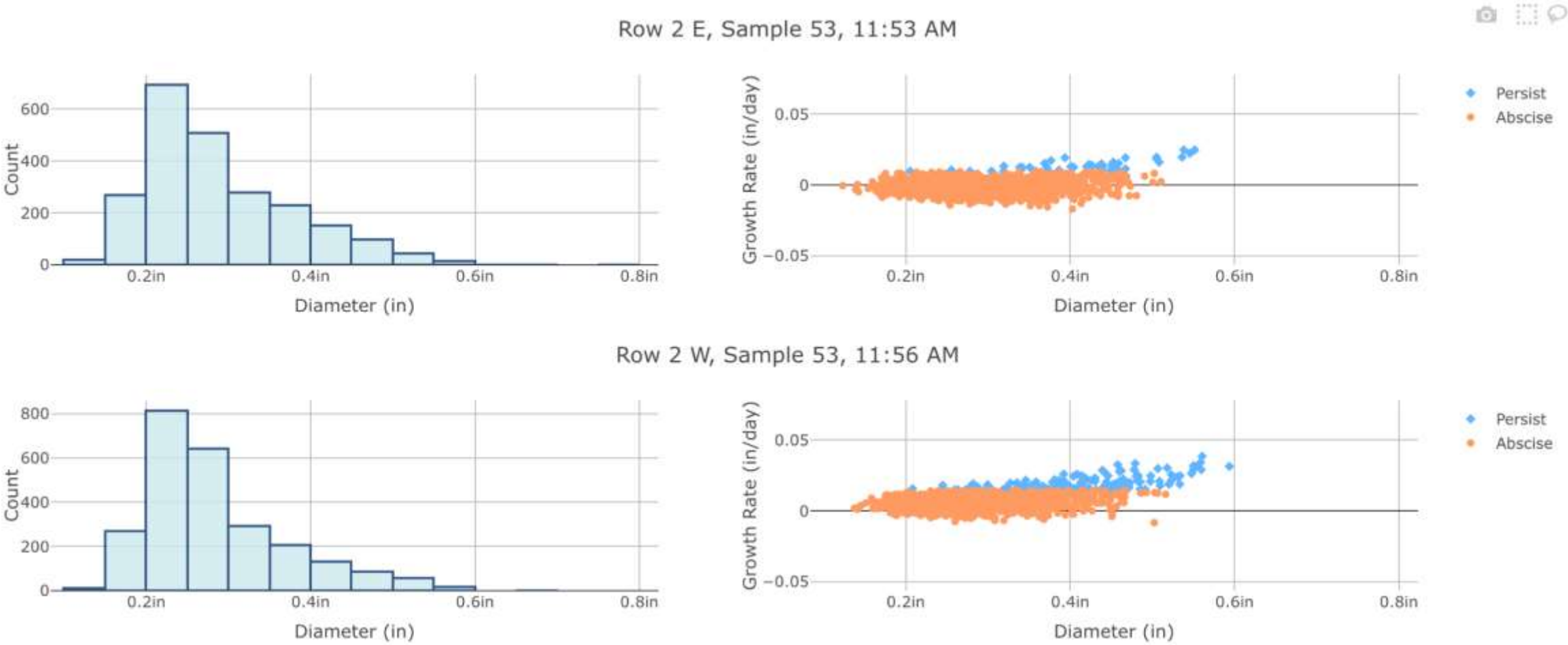
- Fruitlet growth rate model
- Yield estimation
- Crop size distribution
- iPhone 13 or 14 PRO only!
- Cost???



FVT in 2022

- Gala, Fuji, Honeycrisp
- 2 locations
- In collaboration with MSU, WSU, and Cornell

FVT in 2022


Row 2 E, Sample 53, 11:53 AM
Count
600
400
200
0
0.2in
0.4in
0.6in
0.8in
Diameter (in)
Growth Rate (in/day)
0.05
0
−0.05
Persist
Abscise
Row 2 W, Sample 53, 11:56 AM
800


FARM VISION


FARM VISION

Fruit Quarterly, Vol. 31, No. 1, Winter 2023

Digital Technologies for Precision Apple Crop Load Management (PACMAN) Part I: Experiences with Tools for Predicting Fruit Set Based on the Fruit Growth Rate Model

Anna Wallis[1], Jon Clements[2], Mario Miranda Sazo[3], Craig Kahlke[3], Karen Lewis[4], Tom Kon[5], Luis Gonzalez[6], Yu Jiang[6] and Terence Robinson6

[1]Michigan State University Extension, Grand Rapids, MI | [2]University of Massachusetts, Amherst, MA | [3]Cornell Cooperative Extension, Lake Ontario Fruit Program, Newark and Lockport, NY | [4]Washington State University Extension, Quincy, WA | [5]Dept. of Horticulture, North Carolina State University, Mills River, NC | [6]Horticulture Section, School of Integrative Plant

This research was supported by the New York Apple Research and Development Program

We are working with several companies to evaluate methods to streamline the use of the fruit growth rate model to manage crop load more precisely. In this article we report on our evaluations of a smart phone camera system of measuring fruit size distribution to determine fruit set after a thinning spray that was developed by Pometa company. We also evaluated their method of yield estimation.

el, computer vision

CMAN (Pre-
an extremely
g crop load.
ect on yield,
an orchard's
ent practices:
nning, which
(Robinson et
endations for
national proj-
s a follow-up
n this project

ent is the fruit

the time the work was conducted.

The trials presented here represent a ground truthing effort of one of the new AI technologies, as compared to the previously validated hand measurement methods of fruit set predictions. The results and experiences from the 2022 season will be used to guide further evaluations of more technologies in the future.

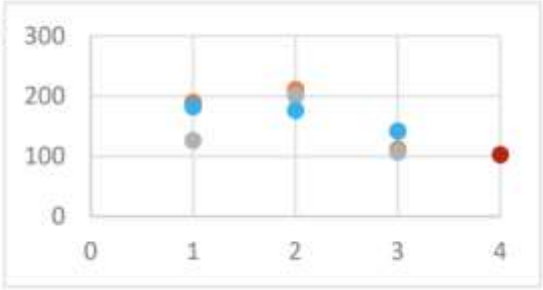
For the latest updates, please visit the PACMAN website: pacman.extension.org

Table 2 (A-J). Actual and predicted fruit set (per tree) using Malusim, Ferri, or Farm Vision technologies for orchard blocks in MA, MI, NY, and NC in 2022.

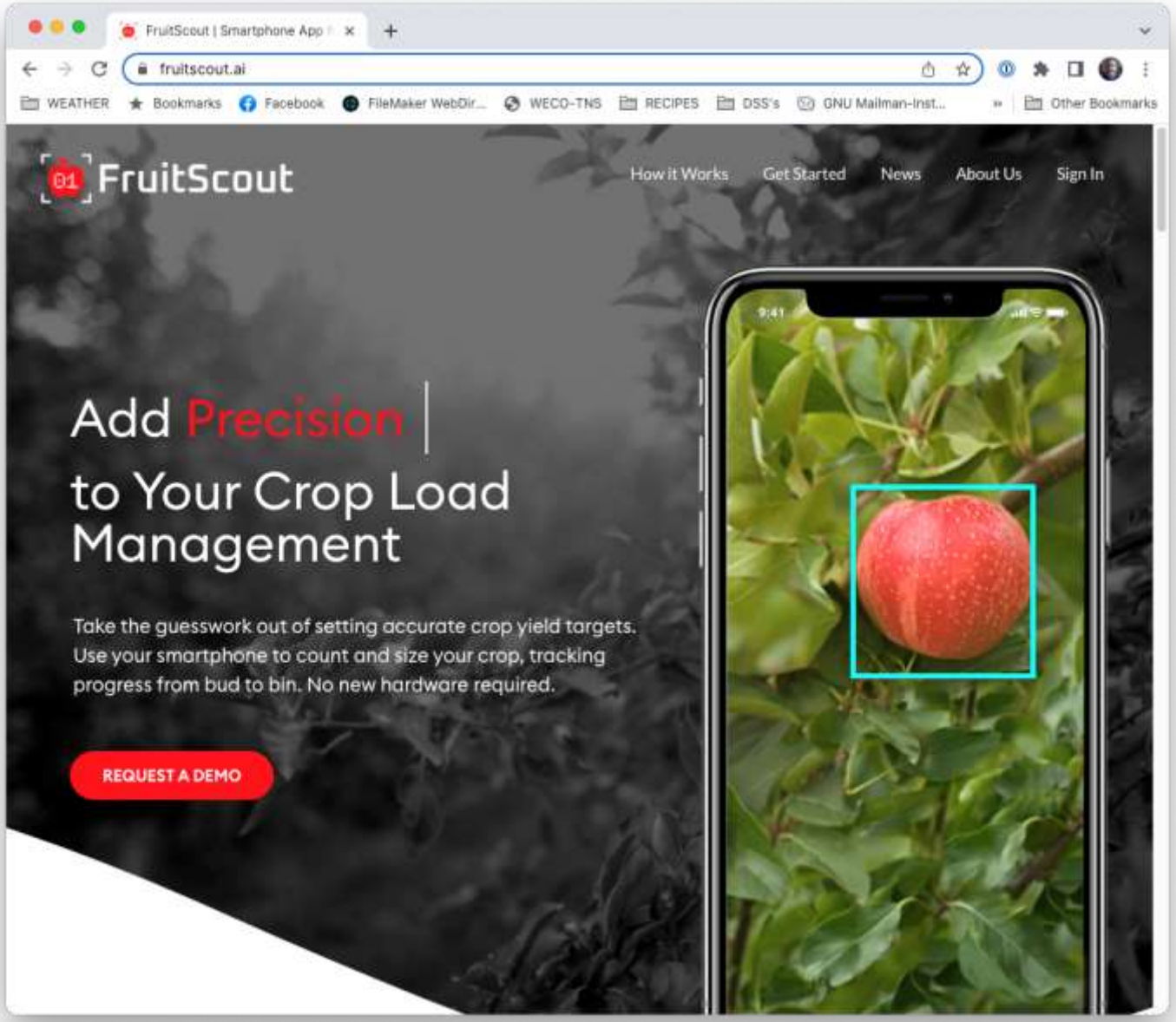
A. UMO Gala (MA)					
		1	2	3	4
Actual Count					103
Malusim	predicted[1] % of actual[2]	190 (184%)	211 (205%)	112 (109%)	
Ferri	predicted % of actual	126 122%	201 195%	107 104%	
Farm Vision	predicted % of actual	182 177%	176 171%	142 138%	

[1]predicted fruit set per tree | [2]percent accuracy = predicted fruit set / actual fruit set

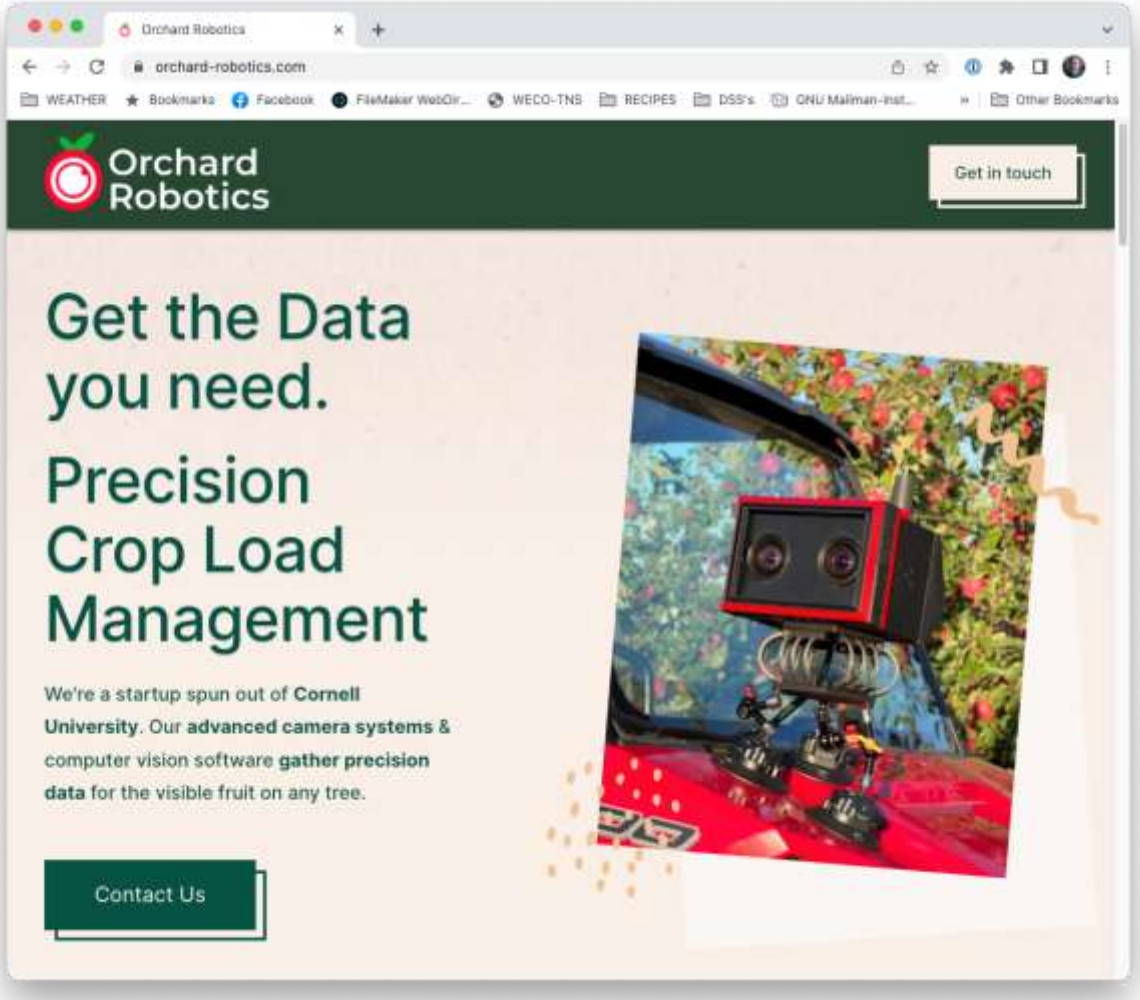
Figure 2A



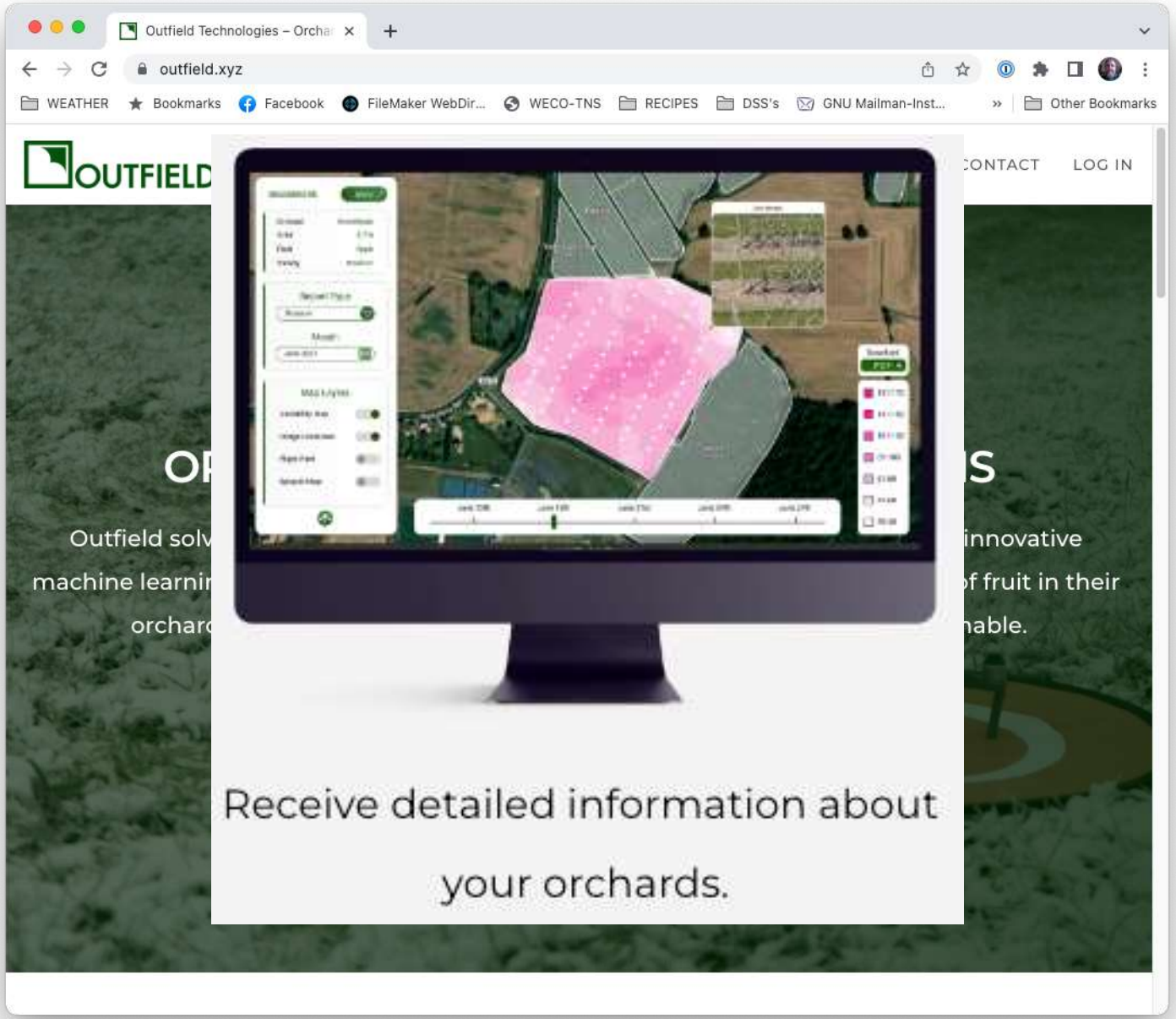
fruitscout.ai



orchard-robotics.com

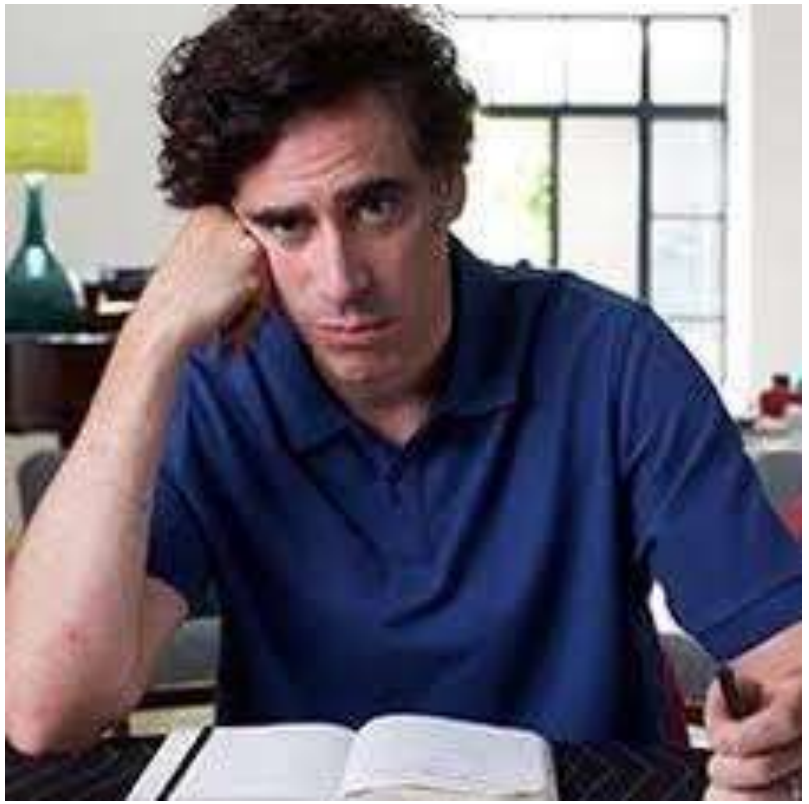


outfield.xyz

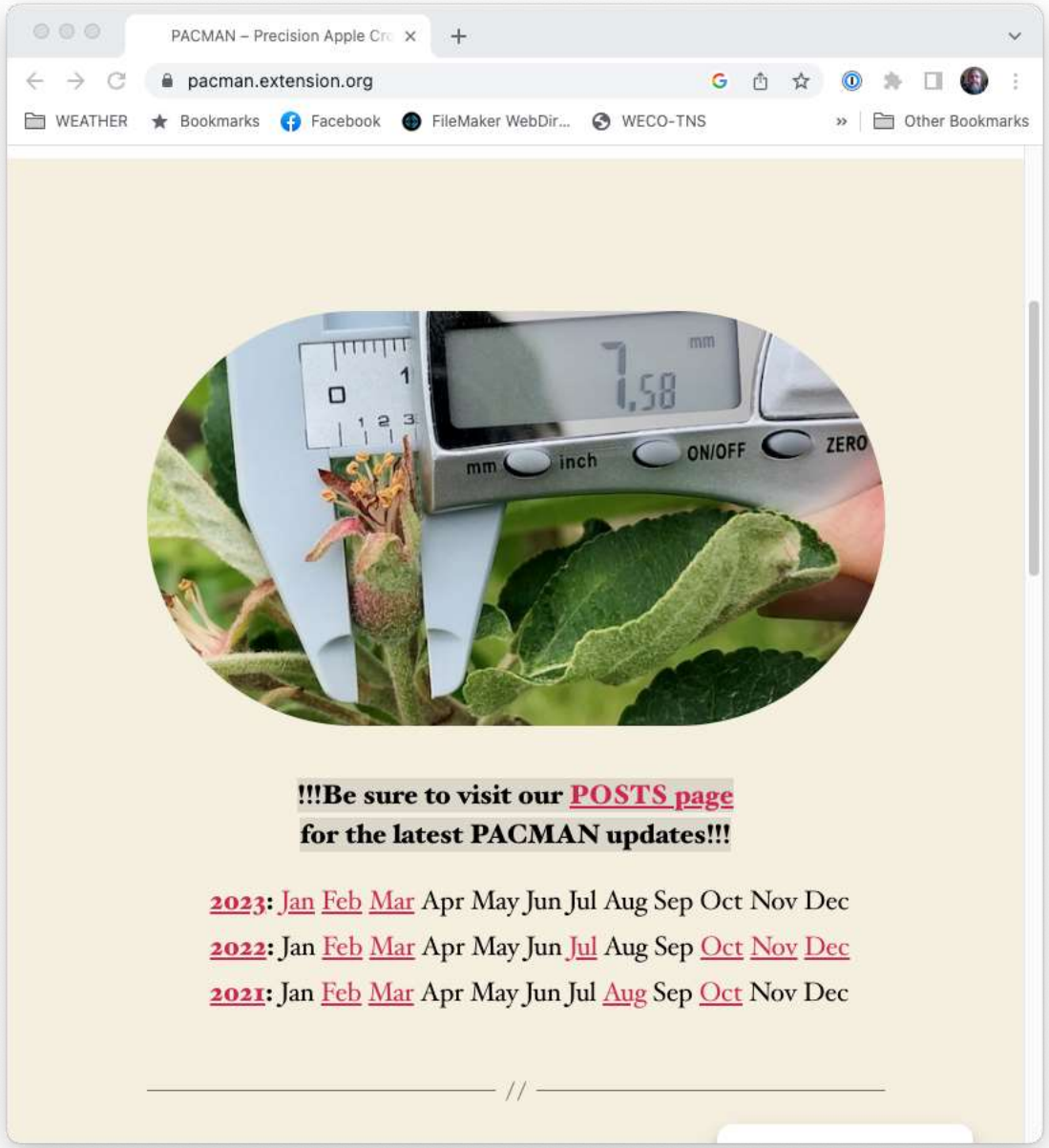


What are the hang-ups?

- Yield estimation and size distribution at harvest
- You can’t image what you can’t see
  - Occlusion
  - Fruitlets
  - 2-D canopies
- Cost???
- Actionable???




STAY
TUNED
COMING SOON


PACMAN – Precision Apple Cr
pacman.extension.org
WEATHER
Bookmarks
Facebook
FileMaker WebDir...
WECO-TNS
Other Bookmarks
7.58
mm
mm
inch
ON/OFF
ZERO
!!!Be sure to visit our POSTS page
for the latest PACMAN updates!!!
2023: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2022: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2021: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec