THE FRUITLET SIZE DISTRIBUTION (FSD) MODEL: A HOW-TO GUIDE

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I. BACKGROUND

Fruit set prediction models aim to produce timely estimates of fruitlet abscission after thinner applications to guide precision crop load management. The time to generate a prediction after an application is important to facilitate grower decisions to re-apply thinners while they are still efficacious, avoiding expensive hand thinning operations. The fruitlet growth rate (FGR) model, developed by Dr. Duane Greene, is a powerful tool that can accurately predict the percentage of fruitlets that will set in an orchard. Although a Excel data template and App are available to run the FGR model via computer and smartphone, respectively, adoption has been limited by the measurement-intensive procedure. A new approach, termed the 'Fruitlet Size Distribution (FSD) Model', described herein, was developed to produce predictions of apple fruit set comparable to the FGR model but achievable with less time investment. The principle underlying both models is the same: the relative growth rate or size of a fruitlet is compared to the most rapidly growing or largest fruitlet within the sample date to determine if it will abscise. Most predictions can be made within 8 days from thinner applications, though the duration of time depends on climatic, biological and horticultural factors. To optimize the FSD model we suggest beginning the model three days after the average fruitlet diameter of the orchard is 6 mm. Thus, the model partners well with thinning applications between bloom and 6 mm. For example, if, a prediction can be achieved by 8 days, assuming an average growth of ~0.8 mm per day, then fruitlets will be ~ 12 mm ***if*** another application is needed; 12 mm fruitlets are very sensitive to many thinning chemistries.

II. SUPPLIES

1. A laptop or desktop computer (with a USB port and Microsoft Excel software). Macros need to be enabled in order for the code to run automatically; see Section V, Troubleshooting.
2. A scale that can accurately measure to 0.1 gram and is capable of exporting data to Excel. The procedure below is based on a specific scale; manufacturer details are provided in Appendix 1.
3. A software program that can communicate between the scale and Excel (see Appendix 1).
4. The Excel file (FS Predict) downloaded from the Pacman website https://pacman.extension.org

III. THE EXCEL FILE

Open the Excel file FS Predict, then save and rename the file by clicking on the File tab, then Save As. Name your file (e.g., FS Predict Gala Block 3). This will retain the original file (FS Predict) on your computer in the unaltered condition. Repeat this file renaming procedure for all additional cultivars.

The FS Predict file contains three worksheets: 'Input data here', 'Sorting' and 'Results overview'. Essential information needs to be manually entered into the 'Results overview' sheet, as described below. All cells that require manual data entry are shaded yellow (Figure 1) and referenced below. Individual fruitlet weights will be imported from the scale into the 'Input data here' sheet (yellow-shaded columns), as described in Section IV (Figure 2). The 'Sorting' sheet imports data from the 'Input data here' sheet automatically via macros. Summary tables and a graphical display of the predicted fruit set will appear in the 'Results overview' sheet (Figure 3).

IV. SETTING UP THE SCALE

1. The OHAUS scale (Appendix 1) connects to your laptop via a USB interface / connection (Appendix 1). This USB interface must be inserted at the bottom of the scale, following the instructions in the instrument User manual.
2. The Software driver, available at no additional cost from the OHAUS website https://us.ohaus.com/en-US/Support/Software-and-Drivers will enable communication between the scale and laptop and automatically export weight data into Excel.
    a. Download the software driver for the 'Navigator' scale from the OHAUS website and install the software according to the download instructions displayed on your monitor.
    b. Connect the scale to your computer via the USB connection (see Section IV Troubleshooting regarding communication ports to correctly configure the port).
    c. Following the instructions in the instrument's User manual, set up the PRINT / Auto Print – Off function on your scale. This will ensure that data are sent to Excel when the PRINT button is clicked. You may also configure the scale to export data automatically to Excel once a stable value is reached (PRINT / Auto Print – On Stable).
    d. Open the 'Launch SPDC Data Collection' program.
        i. Under the Export File Type, select 'Excel'.
        ii. Under Export File Path press the 'Browse' button and select the FS Predict file.
        iii. Instrument Type should be 'Navigator Series'.
        iv. Press 'Run'.

V. THE PROCEDURE

1. Count the total number of flowering clusters on two to five representative trees of the cultivar of interest and enter each tree's data in cells B3 to F3 of TABLE 1 in the Excel template sheet entitled 'Results overview' (See Figure 1).
2. Flag 120 flowering spurs between pink and full bloom with brightly colored flagging so that they can easily be found for three subsequent sample collection dates (3, 6 and 9 days after thinner).
3. At full bloom, collect 25 clusters randomly from representative trees and count all flowers.
    a. Enter this number in cell B5 of TABLE 1 in the Excel template sheet entitled 'Results overview' (See Figure 1).
4. Enter your target fruit set in cell B8 of TABLE 1 in the Excel template sheet entitled 'Results overview' (i.e., the desired number of fruitlet you intend to set and harvest from the trees, Figure 1).
5. Enter the dates of your thinner applications in cells B14-B19 of TABLE 2 in the Excel template sheet entitled 'Results overview' (Figure 1). We have provided cells for additional details (thinning compound and rate, and the phenology stage at each application date) but these data are purely FYI. Be certain, however, to copy or enter the date of the most recent thinner application from cells B14-B19 into cell F14.
    a. The graphical display of predicted fruit set references and plots data from the most recent thinner application date (cell F14). This is to ensure that the prediction, made after ~8 days, reflects the most recent application.
6. We recommend conducting three measurement dates at 3-day intervals (day 3, 6 and 9 from the last thinner application) in order to generate a complete picture of the thinning activity. The first of these dates would ideally begin 3 days after the average fruitlet diameter is 6 mm (a 6-mm diameter apple fruitlet has a fresh weight of ~ 0.2 to 0.3 g, though we recommend measuring diameters directly via a digital caliper). Enter the first sample date in cell A14 of the 'Results overview' sheet. Successive sample dates are entered in (A15-19). For each sample (a.k.a., measurement date), collect 40 of the previously flagged 120 clusters and individually weigh each fruitlet (there is no linking of individual fruitlets with their respective clusters, simply weigh each and every fruitlet without regard to its cluster). Fruitlets may be weighed with or without their stems attached; however, all fruitlets on all sample dates should ideally be processed in a similar manner (i.e., with either stems present or absent). Prior to weighing the first fruitlet, refer to part a (directly below).
    a. For the first fruitlet weight, select cell L5 in the 'Input data here' sheet

i. ** if you are entering weight data manually you will also need to enter your data, starting with cell L5 of the 'Input data here' sheet. In this case, skip step "**b**" and proceed to step "**c**".

b. Place the first fruitlet on the scale and click the print button when the weight stabilizes
    i. The scale will automatically import the value into the selected cell. This value includes the unit (g). In the event a measure was taken prior to stabilization, a '?' will be reported; in this case, re-weigh the fruitlet, making sure to select the same cell.

c. Weigh every fruitlet
    i. Place each subsequent fruitlet on the scale and click the 'print' button, once a stable weight has been reached. The scale and program will automatically select the next cell in the column to input fruitlet weights.

d. When the last fruitlet of a sample date is weighed, save the data and then click the 'Input data' button in the Excel sheet. This will remove the unit associated with the weight data so that calculations in Excel can be performed.
    i. A window will appear asking if you would like to replace data. Select 'ok' (see Figure 4). This message occurs when more than one sample date has been entered and will repeat if multiple dates have been entered. Simply continue to select ok until the window no longer appears.
    ii. Another window will appear displaying a Debugging message. Clicking on the 'End' button on the screen will allow you to proceed to the next step (see Figure 5).
    iii. FYI: We have provided superfluous rows (500) for the individual fruitlet weights in columns L-V in the 'Input data here' sheet; any of these that remain blank after your last fruitlet weight will return a zero to columns A-G after the macros clean the data; have no fear, the macros ignore zeros (they do not factor into the means).

e. Click the 'Start calculations' button. After a few seconds, you can move to the 'Results overview' sheet in the Excel file and view the fruit set prediction graph (Figure 3).

f. For all other sampling dates, move the starting cell on the first sheet ('Input data here') to the next respective column titled 'Date 2', 'Date 3', etc. and repeat steps c through e.

7. Repeat the above procedure for the remaining 2 measurement dates (+6 and +9 days from the most recent thinner application; harvesting 40 of the flagged spurs each date) to generate the percent fruit set prediction of the orchard.

VI. TROUBLESHOOTING

1. Error message when launching the SPDC program: “COM4 connection not available”. Your laptop needs to be able to communicate with the scale via the COM4 port. To set this up for Windows, open the Windows device manager and select the multi-port serial adapter tab. Right click to open the menu and click on the Properties tab. Open the ports configuration tab. Click on the port setting button and select COM4, then click ok to apply the changes. You may also have to install the free 'Serial Port Data Collection Software', available on the OHaus website and under this link:https://dmx.ohaus.com/WorkArea/downloadasset.aspx?id=4294968885
2. Summary data and fruit set prediction graph do not update after a sample date of fruitlet weights has been exported to Excel from the scale. Enable macros in Excel.
    a. Click on the File tab and go to Options. A new window opens. Click Trust Center and then click the Trust Center Settings. In the Trust Center, click the Macro Settings. Select the ‘Disable VBA macros with notification’ option (Figure 6). This is the recommended setting for Excel. Hence, opening an Excel file that contains macros (like the FS Predict) will prompt a notification at the top of the file to click on ‘Enable content’ to enable the automatic functions within the file.

VII. FIGURES

TABLE 1. Information on Tree spur counts

	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5
number of clusters	500	467	387	598	
number of flowers	average number of flowers on 25 clusters				
	131	5.24			
number of clusters harvested	number of clusters harvested on first sample day				
	40				
target fruit number	250				

TABLE 2. Information on thinner application

Sample Date	Date of thinner application	Thinner (compound) and rate	Phenology stage		Date of last thinner application
05/23/22	05/23/22				05/30/22
05/25/22	05/30/22				
05/31/22					
06/02/22					
06/04/22					

Figure 1. The ‘Results overview’ sheet of the FS Predict Excel file. Results will appear next to this yellow area after all calculations have been done. You have the option to override the number of spurs harvested (if you choose a number other than 40) or enter additional information regarding your thinning program (i.e., number of applications, dates, formulation, rate, and phenology stage at the time of applications).

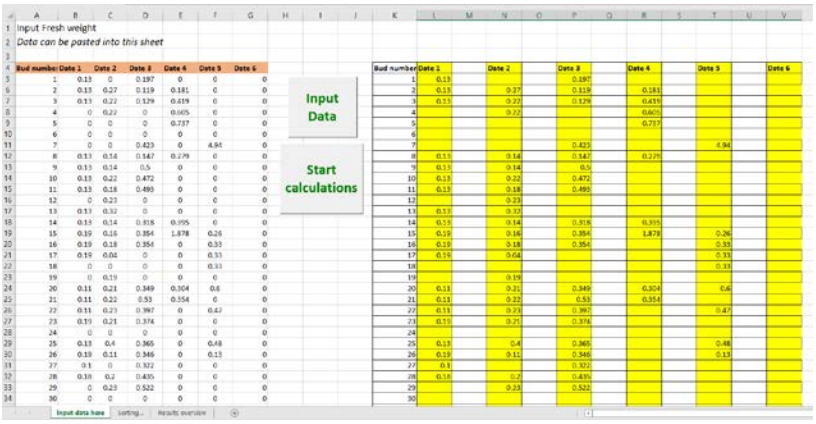

Figure 2. The 'Input data here' sheet of the FS Predict Excel file. Data will be entered into the yellow highlighted areas only.

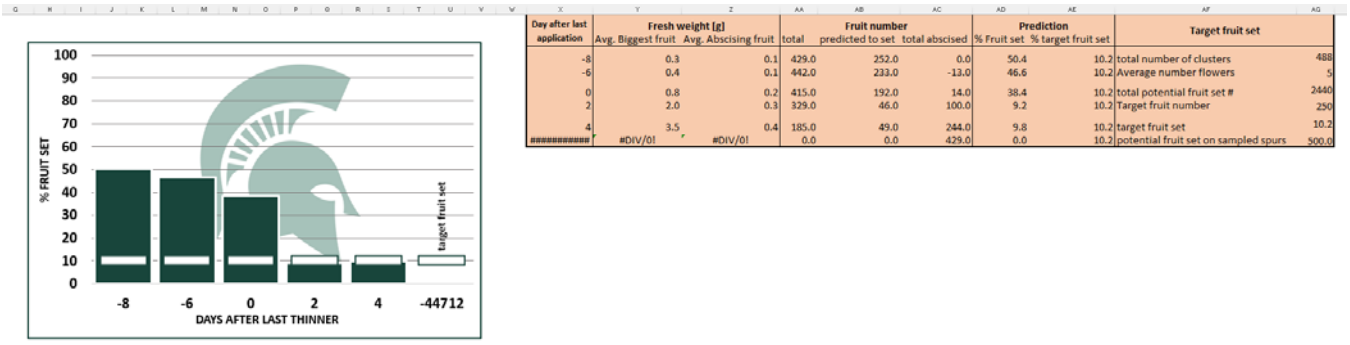

Figure 3. The percent fruit set prediction will be displayed in the form of a bar graph with summary data in table format in the 'Results overview' sheet of the FS Predict Excel file.

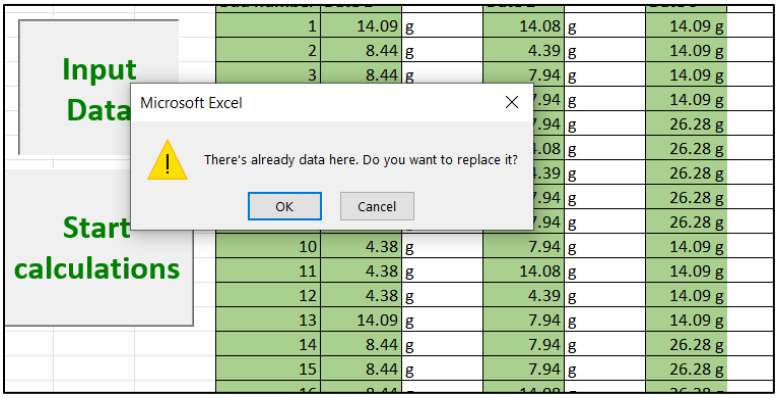

Figure 4. This message will appear when you enter data into the Input data here sheet and click the 'Input Data' button. Clicking the 'ok' button will continue the automatic macros.

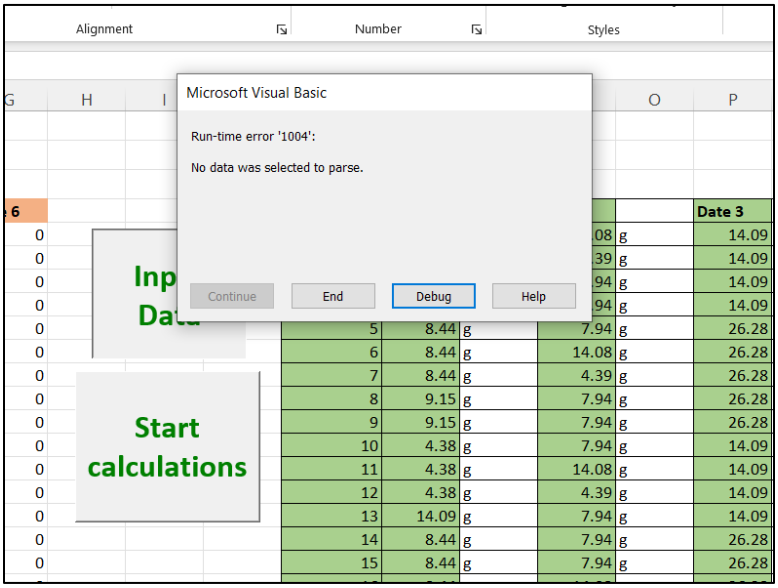

Figure 5. Debugging message in the Input data here sheet. This message will appear for the first few sample dates. The macros set up on this sheet transform data in all yellow cells. When some of those columns are empty, this error message appears as a 'warning'. Clicking the "End" button will allow the continuation of the calculations while ignoring the empty cells.

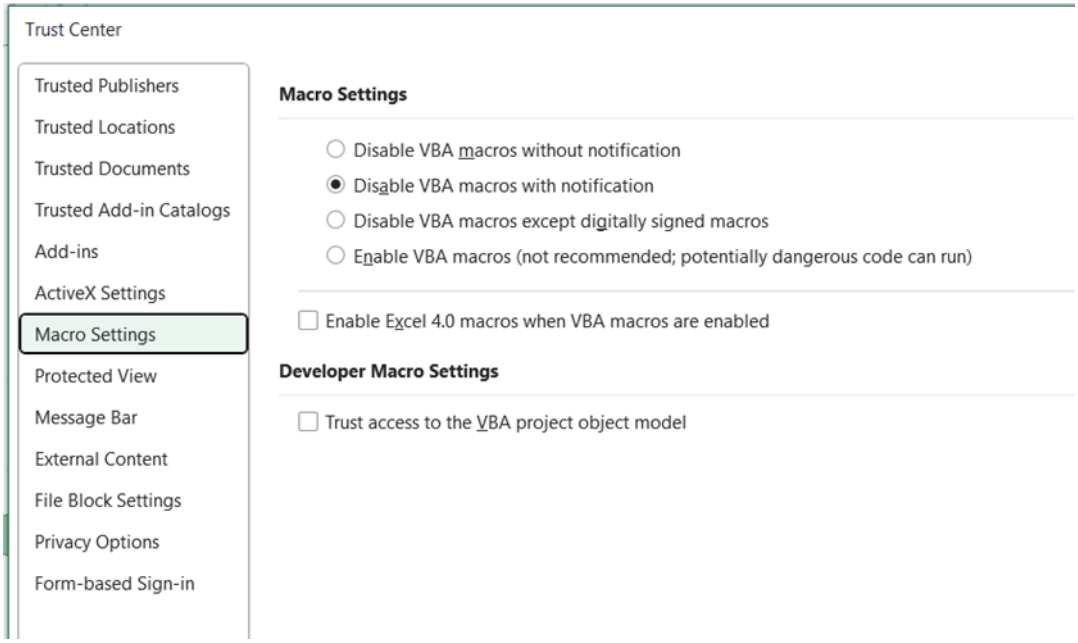

Figure 6. Macro Settings window within the Excel Trust Center. In order to use macros in Excel, the VBA macros have to be enabled. Selecting the 'Disable VBA macros with notification' option will allow you to choose whether to enable macros from a trusted source. A notification will appear at the top of the screen when opening any Excel files containing macros.

Appendix 1

There are few affordable and accurate scales that measure in the required range ***and*** communicate with Excel. We have no affiliation with the manufacturer of the example described herein, nor do we promote this brand over any other; we simply provide instructions because we use this particular instrument in our lab and have found it reliable. The intention, therefore, is to expedite adoption.

Scale: OHAUS NV1202 Navigator portable balance, 1200 g x 0.01 g. Price: $400-$500*

USB interface: OHAUS USB Kit TA NV NVT. Price: ~$200*

**prices as of 2022; these will vary depending on supplier*.

***About the Authors*:**

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