Using the Relation between Growing Degree Hours and Harvest Date to Estimate Run-times for *PEACH*: a Tree Growth and Yield Simulation Model.

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Abstract

The hypothesis that Growing Degree Hour (GDH) accumulation affects the length of the fruit growth period was tested on different stone-fruit cultivars. A strong correlation was found between the accumulation of the GDH during thirty days after bloom and the harvest date. This relation is introduced on PEACH, a computer simulation model of annual carbon supply and demand for reproductive and vegetative growth of peach trees. In previous versions, the PEACH model used the degree-day (DD) accumulation to predict the harvest date. The revised model uses the daily minimum and maximum temperatures to calculate the GDH accumulation during the first month of fruit growth and estimates the number of growing days for the specific year and cultivar. The GDH relation improves the model prediction of the harvest date and simultaneously improves the ability of the PEACH model to predict yield. Results are discussed for early and late peach cultivars and for different years and locations.

Additional Index Words: Growing Degree Hour, Harvest Day, Peach simulation model, yield.

1. Introduction

Carbon budget computer simulation models have been used to relate plant growth to environmental conditions for several years (Thornley, 1990). Few of them have been developed for deciduous fruit crops (Seem et al., 1986; Abdel-Razik, 1989; Buwalda, 1991; Wermelinger et al., 1991; Grossman and DeJong, 1994). Most of them use degree-days to estimate fruit growth run-times. Organ growths depend on the temperature accumulation from the bloom and fruit maturity is reached after having accomplished a fixed amount of degree-days. This solution allows to simulate and compare different years and locations.

One of these few whole tree basis models developed is *PEACH* (Grossman and DeJong, 1994). *PEACH* is a computer simulation model, on a daily basis, of the annual carbon supply and demand for reproductive and vegetative growth of peach trees. It is a state variable simulation model in which fruit, leaf, stem, branch, trunk and root weight are the state variables, and minimum and maximum air and soil temperatures, degree days, solar radiation and canopy light interception are the driving variables. *PEACH* uses the degree-days to estimate run-times.

Another tool to estimate the temperature accumulation is the growing degree hours (GDH) (Anderson et al, 1986). This concept was first developed to estimate the chilling and heat requirements of different deciduous tree (Anderson et al, 1986; Caruso et al, 1992). The GDH concept is based on a higher effect of the temperature at the optimum and a high decrease of this effect after that optimum.

The scope of this study was to find a relation between the GDH and fruit growth period and to integrate it in *PEACH* for the run-times estimation.

2. Materials and Methods

2.1. Temperature - GDH relation

To test the relation between the GDH and harvest date, data of full bloom and harvest date from different locations in California (Fresno, Stanislas and Yolo counties) and for different years (from 88 to 97 depending on the locations) were collected from growers. The data concerns different cultivars of prune, peach, cling peach and nectarine.
For each year, location and cultivar, the sum of GDH from the full bloom until 30 days after bloom was calculated using the hourly temperature based on the GDH equation presented by Anderson et al. (1986). The hourly temperatures were obtained from the California Irrigation Management Information System (CIMIS) weather stations closest to the data location.
For each cultivar, all relative data was used together to find the relationships between the sum of GDH one month after bloom and the number of day of growth (number of days between the full bloom and the harvest date).

2.2. Modifications to the *PEACH* model

The relation obtained between the sum of GDH one month after bloom and the number of days of fruit growth was integrated to *PEACH* for three cultivars: Spring Lady (early maturating peach), CalRed (late maturing peach) and Ross (cling peach).
The model computes the sum of GDH one-month after bloom and uses the relation GDH – number of days of growth to estimate the fruit harvest date. The GDH used only that estimation, all the model equations for growth in dry weight still running with the degree-days.

For each year and cultivar, *PEACH* was run using a first time the degree-days to estimate the harvest date (without modification) and the second time the GDH relation (with modification).

The harvest date estimated by the model in both cases was compared to the real harvest date. The fruit yield was also simulated in each case and compared to the simulation of the yield when *PEACH* stop running on the real harvest date observed on the orchard.

3. Results

3.1 GDH- Day of Growth relationship

An important correlation was found between the sum of GDH one month after bloom and the number of day of fruit growth for 10 cultivars of cling peaches (Fig. 1). The number of days of fruit growth decreases with increase of GDH sum one month after bloom. The same results were found for five peach cultivars (Fig. 2), four nectarine cultivars (Fig. 3) and six plum cultivars (Fig. 4). The slopes of the different equations are on the same order for each species.

3.2 Model simulation

3.2.1 CalRed

In all fives years of simulation, using the GDH – day of growth relationship, the estimation of the day of harvest is closer to the real date of harvest than using the degree-days (Table 1). This difference affects the estimated yield per tree. The difference between the estimated yield using the real date of harvest and GDH is less than 5%.

3.2.2 Spring Lady

In three years (out of four) of simulations, *PEACH* using the GDH estimates the real date of harvest (Table 2). The model running with the degree–days, makes a mistake of 3-4 days with the real date of harvest, which induces a difference on the estimated yield per tree superior to 20%.

3.2.3 Ross

In all four years of simulation, a better estimation of the day of harvest is found using the GDH relationship (Table 3). The difference on estimated yield is less than 7% with GDH while it is more than 17% when the model runs using the degree-days.

4. Discussion

The relation observed between the sum of GDH one month after bloom and the date of harvest confirmed the importance of temperature during the early time of fruit growth found by Weinberger (1948) on peach or Bergh (1990) for apple. It seems interesting that the slope of the different equations is in the same order. Further investigation need to be made to verify this result which could indicate a specific species answer to temperature increase during the period following bloom on the decrease of number of day of fruit growth.

Using the relation between the GDH and the harvest date, *PEACH* makes a better estimation of the number of day of fruit growth and the simulated yield per tree. This effect is greater for early cultivars (Spring Lady). In that case, the number of day of growth is low (85 days) and two or three days of growth could have an important effect on the yield. The fruit growth rate is high during that period.
For Ross cultivar, the real data used to be compared with the simulation were from other locations than the location used to fit the model fruit growth equations. The differences in environmental conditions (temperature) could explain the results obtained.

In both Spring Lady and Ross cultivars, the difference in simulated fruit yield per tree is higher than 20% compared to the simulated real data. This result indicates the high sensitivity of *PEACH* to the date of harvest, especially for early cultivars and when *PEACH* is running for others environmental conditions than the ones fits for.

The effect on fruit harvest date affects also all the carbohydrate balance of the tree. The fruit being the most important sink, its absence (stop of growth) or presence (still growing) affects the partitioning of carbohydrate to the other sinks.

In conclusion this works shows the problem of a good estimation of the harvest date for modeling and the sensitivity of PEACH to that factors. Using GDH improve that estimation in all the cases. Further works are needed to improve this study and to confront the simulation for the yield per tree with real data.

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Figures:

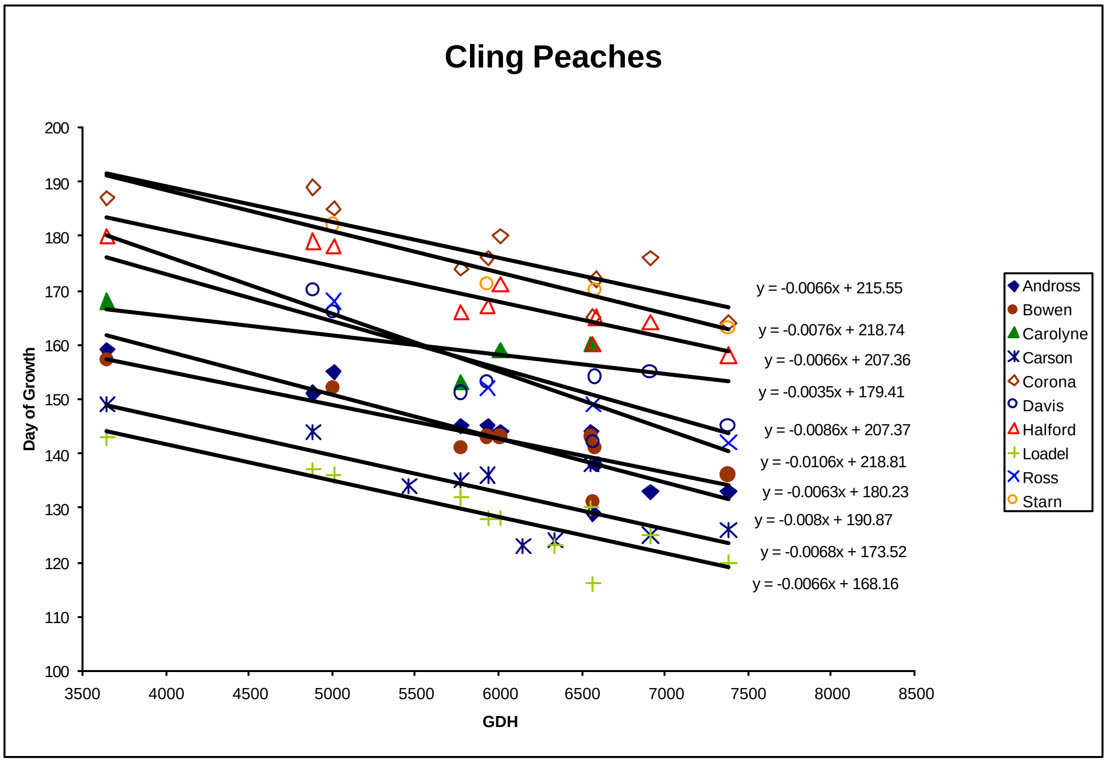

Figure 1: Effect of sum of GDH one month after bloom on number of days of fruit growth on ten cling peach cultivars.

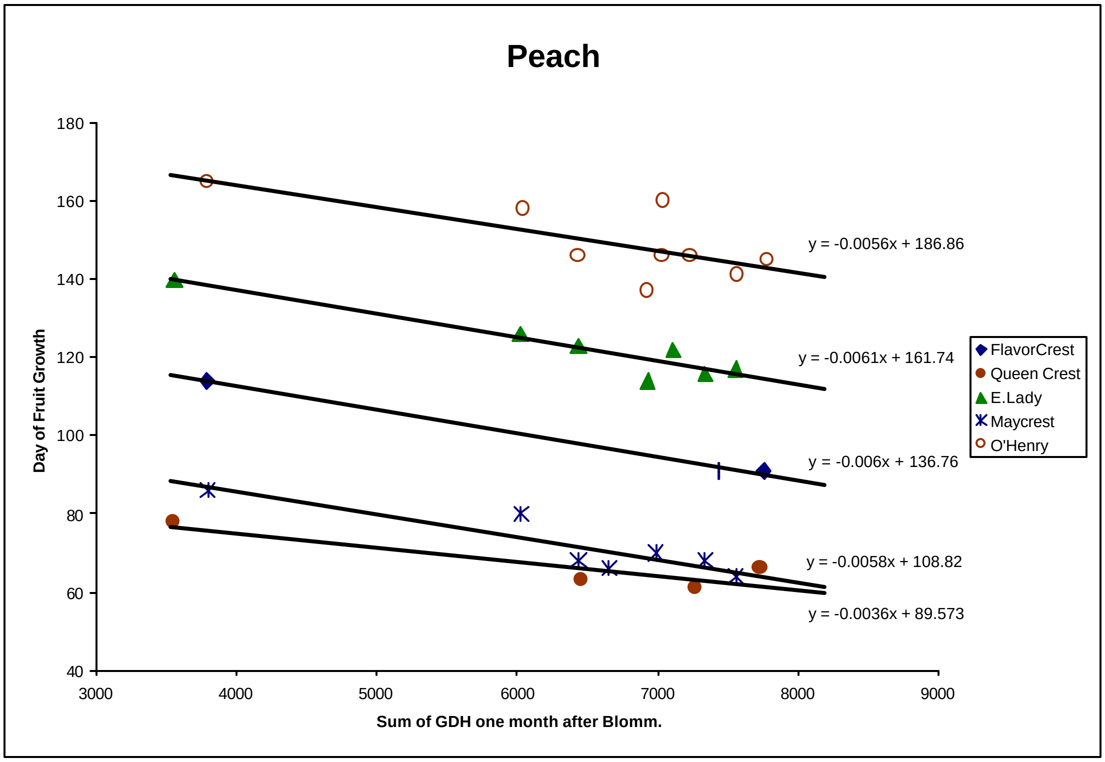

Figure 2: Effect of sum of GDH one month after bloom on number of days of fruit growth on five peach cultivars.

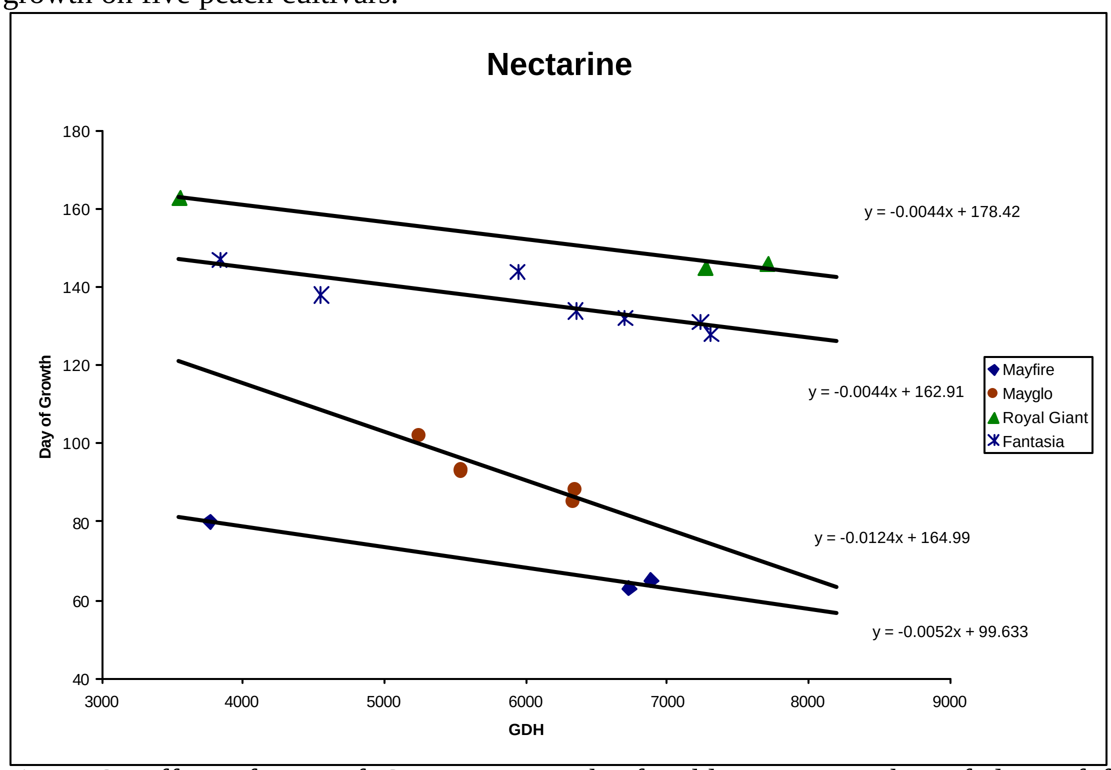

Figure 3: Effect of sum of GDH one month after bloom on number of days of fruit growth on four nectarine cultivars.

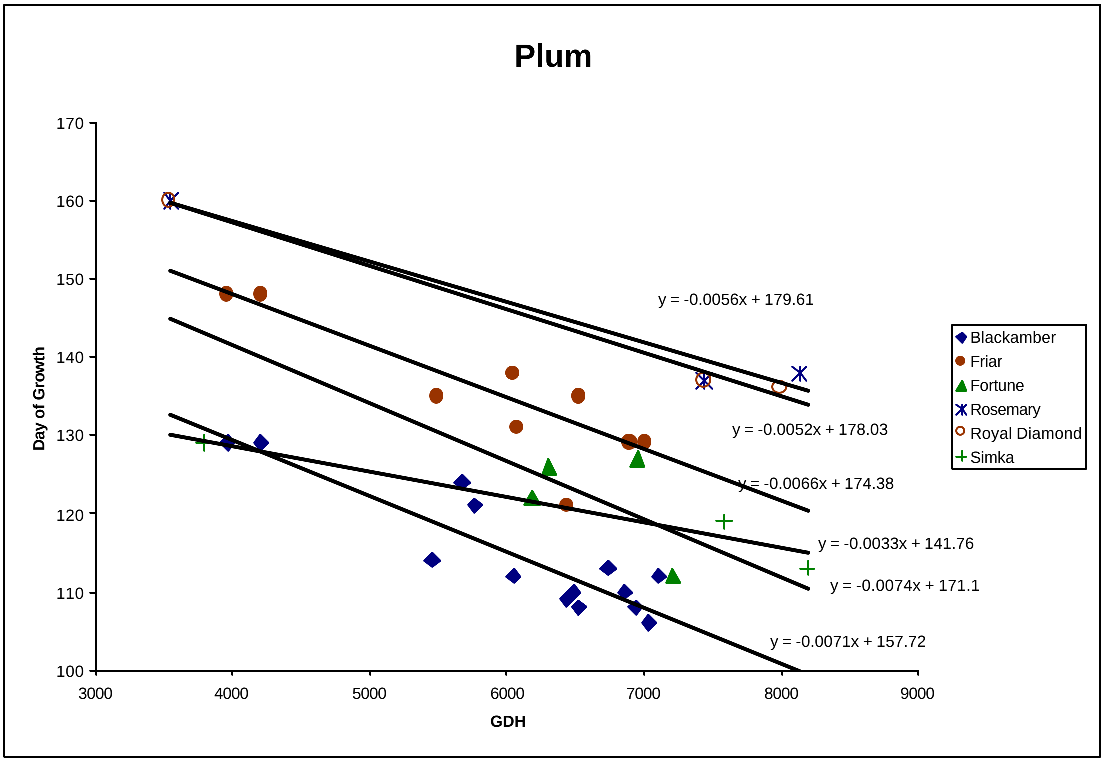

Figure 4: Effect of sum of GDH one month after bloom on number of days of fruit growth on six plum cultivars.

Table 1: *PEACH* simulation results using Degree-days (DD) and GDH and real data (RD) for CalRed for date of harvest and simulated yield.

	Day of Harvest			Estimated yield /tree (g DW)				
Year	RD	DD	GDH	RD	DD	%	GDG	%
1989	18 Aug	8 Aug	14 Aug	9866	8455	14	9339	5
1990	17 Aug	10 Aug	22 Aug	9462	8398	11	10163	7
1991	23 Aug	20 Aug	23 Aug	10512	10122	4	10512	0
1993	5 Aug	12 Aug	10 Aug	9033	10017	11	9717	8
1994	11 Aug	9 Aug	13 Aug	10041	9770	3	10300	3

Table 2: *PEACH* simulation results using Degree-days (DD) and GDH and real data (RD) for Spring Lady for date of harvest and simulated yield.

	Day of Harvest			Estimated yield /tree (g DW)				
Year	RD	DD	GDH	RD	DD	%	GDG	%
1991	1 Jun	4 Jun	1 Jun	1796	2155	20	1796	0
1992	20 May	16 May	20 May	2370	1885	20	2370	0
1993	20 May	23 May	18 May	1721	2068	20	1511	12
1994	21 May	25 May	21 May	1728	2185	26	1728	0

Table 3: *PEACH* simulation results using Degree-days (DD) and GDH and real data (RD) for Ross for date of harvest and simulated yield.

	Day of Harvest			Estimated yield /tree (g DW)				
Year	RD	DD	GDH	RD	DD	%	GDG	%
1994	12 Aug	30 Aug	18 Aug	9454	11797	25	10217	8
1995	16 Aug	29 Aug	14 Aug	9634	11292	17	9359	3
1996	15 Aug	21 Aug	20 Aug	9734	10428	7	10324	6
1997	30 Jul	13 Aug	5 Aug	9400	11384	21	10292	9