Using Growing Degree Hours Accumulated Thirty Days after Bloom to Help Growers Predict Difficult Fruit Sizing Years

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Abstract

The number of days between peach full bloom date (FBD) and harvest date have been previously related to accumulated growing degree hours during the first 30 days after full bloom (GDH 30). An analysis of historical data (1984–2004) from the California clingstone peach industry indicated that the same early spring temperature data could be used to predict the number of days from FBD to reference date (RD, a date that occurs ten days after pit hardening and is used by the industry to anticipate fruit sizing potential for a given year) and fruit size at reference date (RDFS). In the present study, these data were used to develop a critical value for the response of RD and RDFS to GDH 30. Fruit development rate was substantially increased in years when GDH 30 accumulation values were higher than 6000 compared to when GDH 30 was less than 6000. Under warm spring conditions the trees apparently did not supply resources rapidly enough to support potential fruit growth rates and consequently RDFS was negatively affected. The combination of the GDH 30 critical value and a web-based decision support tool which calculates GDH 30 values for different weather stations in California allows fruit growers to easily predict difficult fruit sizing years 30 days after FBD.

INTRODUCTION

Tree carbon models have been useful for identifying environmental factors limiting tree growth and yield in peach trees (Grossman and DeJong, 1994; Allen et al., 2005). Simpler models derived from the more detailed models can be used to assist in horticultural decisions after being calibrated to specific locations and years. For example, Ben Mimoun and DeJong (1999) used relationships between growing degree hour accumulation during the 30 days after full bloom (GDH 30) and the number of days between full bloom and harvest maturity to estimate harvest date for PEACH, a tree computer simulation model (Grossman and DeJong, 1994). The model predictions indicate that the number of days between full bloom and harvest decreases with increases in GDH 30. That fact appeared to explain the early harvests of California peaches in 2004, when record high temperatures were registered during full bloom (DeJong, 2005). During the same harvest season, peach growers experienced fruit growth limitations and therefore problems attaining the fruit sizes desired by the market (DeJong, 2005).

Fruit growth cannot be explained only by temperature patterns during early spring. However, when full bloom date (FBD), reference date (RD, a date that occurs ten days after pit hardening and is used by the industry to anticipate fruit sizing potential for a given year), and fruit size at reference date (RDFS) data collected from 1985 to 2004 at different locations in California were analyzed in conjunction with seasonal weather data, the dependence of peach fruit growth on GDH 30 became evident (Lopez and DeJong, 2007). Increased GDH 30 values were related to decreases in the number of days between FBD and RD. RDFS increased with increases in the number of days between FBD and RD and was negatively affected during years of high GDH 30.

These results provided practical information that could help peach fruit growers to understand that early fruit growth is more likely to be resource limited in years with warm spring temperatures. Since previous research has documented that fruit growth potential unfulfilled in early spring cannot be compensated for later in the season (Grossman and

DeJong, 1995), in years with warm spring temperatures early fruit thinning was recommended (Lopez and DeJong, 2007). However, in order to make general recommendations for optimizing the timing of fruit thinning in relation to GDH 30 data easy to implement, we believed it was necessary to establish a GDH 30 critical value that could be used by fruit growers as a reference to plan fruit thinning operations. To provide fruit growers with this GDH 30 critical value, we analyzed the twenty year historical data on FBD, RD, RDFS and GDH 30 for three different locations in California.

MATERIALS AND METHODS

Pooled data on FBD, RD and RDFS from all California clingstone peach cultivars were obtained from the California Canning Peach Association (CCPA) for three different locations in California; Fresno/Kings Counties (Kingsburg), Stanislaus County (Modesto) and Yuba/Sutter Counties (Yuba City). FBD was considered to be the time when 50% of the flowers in an orchard were estimated to be fully open. RD was considered as the date when 80% of sliced fruits have hardened pits near the distal end, plus 10 days. FBD and RD data were collected from 1984–2004. RDFS data were collected from 1994–2004.

GDH 30 was calculated using hourly temperature data based on the GDH equation presented by Anderson et al. (1986). Hourly climatic data were obtained from California Irrigation Management Information System (CIMIS) weather stations closest to locations where fruit data were collected; Parlier Station in Fresno County, Modesto Station in Stanislaus County and Nicolaus Station in Yuba County.

Relationships between FBD and RD were established independent of the locations. The variability observed in the relationship between FBD and RD was analyzed in conjunction with GDH 30 data. Similarly, RDFS was analyzed in conjunction with the variability observed in the relationship between FBD and RD. All the relationships were evaluated by regression analysis. An F-test was performed to determine whether the regression fits were statistically significant. Statistical significance was considered as $P<0.05$.

RESULTS

There were substantial differences in FBD's and RD's among locations and years over the 20 years for which data were analyzed (Fig. 1). FBD and RD tended to be earlier in Kingsburg than either Modesto or Yuba City but there were only small differences between the latter two locations (Fig. 1).

There was a significant positive correlation between FBD and RD but only 12% of the variance in RD could be predicted from FBD data (Fig. 2). The variability of the relationship between FDB and RD (residuals) was significantly correlated with GDH 30 data (Fig. 3). FBD data predicted RD in years in which GDH 30 was about 6150. The expected RD was earliest in years in which GDH 30 was higher than 6150 while it was delayed when GDH 30 was lower than 6150 (Fig. 3).

We also found a significant correlation between the residuals of the relationship between FDB and RD and RDFS (Fig. 4); a significant reduction in RDFS was observed in early RD years.

DISCUSSION

RD is used by the processing peach industry to determine the status of fruit sizing potential and to adjust subsequent thinning requirements but research by Grossman and DeJong (1995) indicates that RD is too late to make optimal thinning recommendations. An early estimation of RD and RDFS would be of great value to growers for making crop load management decisions earlier in the season. In spite of the significant positive correlation between FBD and RD only 12% of the variance in RD can be predicted from FBD data (Fig. 2). This result indicates that RD cannot be predicted by only taking into account FBD, and that variation in RD between years was caused by factors other than FBD. One of these factors was spring temperature variations during the first 30 days after full bloom expressed as growing degree hours; 63% of the variance in RD was explained by GDH 30 data (Fig. 3). Since much of the rest of the variability in the relationship between FBD and RD might be explained by the inherent variability in the source of fruit samples, we considered that GDH 30 played a major role in controlling peach fruit development (Ben Mimoun and DeJong, 1999; DeJong, 2005; Lopez and DeJong, 2007).

It is noteworthy that as the GDH 30 increased substantially beyond 6000, there was a clear advance in RD, i.e., in 2004, when record high temperatures were registered during full bloom, RD was 15 days earlier than in a year with 6000 GDH 30 (Fig. 3). We also know that fruit harvests were relatively early in that year and that peach growers experienced fruit size problems (DeJong, 2005). In our study, in years with high, early spring temperature conditions the realized RDFS was also less than occurred in years when accumulated GDH 30 was below 6000 (Fig. 4). This may be because trees were not capable of supplying resources rapidly enough to support fruit development rates that apparently accompanied the high temperatures (Grossman and DeJong, 1994; DeJong and Grossman, 1995, Lopez and DeJong, 2007).

Our results indicate that high temperatures following bloom are a major factor affecting realized fruit development and ultimately RD. This study also indicates that early fruit growth is likely to be more resource limited in warm springs. It is well known that with normal peach fruit sets, fruit thinning any time before harvest will reduce fruit to fruit competition for carbohydrates, but fruit thinning early in the season will result in the greatest size increase (DeJong et al., 1990; Grossman and DeJong, 1995; Costa and Vizzoto, 2000). Hence, growers may particularly improve production results by early thinning in years with warm, early spring temperatures. We believe that recognition of a critical value of 6000 GDH 30 will be of value to fruit growers in predicting difficult fruit sizing years. When GDH 30 is higher than 6000, it is recommended that growers thin as early as is economically feasible (DeJong 2005). Following this recommendation, fruit growers near Kingsburg should thin early the most of the years (see GDH values in Fig. 3). Traditionally, fruit growers from the Kingsburg area have had to make special effort in optimizing their commercial practices to obtain similar results as in other locations in California. Now we know that this is because Kingsburg generally has higher temperatures during bloom time than other areas from California such as Modesto or Yuba City (Lopez and DeJong, 2007).

With knowledge that high early spring temperatures tend to decrease peach fruit size, we recommend that growers keep track of bloom dates and use local weather information (in California that can be done by visiting the Fruit and Nut Research and Information Center website, http://fruitsandnuts.ucdavis.edu) to determine GDH 30 values and then get a general idea of the fruit sizing potential for the coming season by comparing the current year GDH 30 value to the critical value of 6000 GDH and adjust management practices accordingly. The higher the GDH 30 value, the more important it is to thin early.

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Literature Cited

Allen, M.T., Prusinkiewicz, P. and DeJong, T.M. 2005. Using L-systems for modeling source-sink interactions, architecture and physiology of growing trees: The L-peach model. New Phytol. 166:869–880.

Anderson, J.L, Richardson, E.A. and Kesner, C.D. 1986. Validation of chill unit and flower bud phenology models for "Montmorency" sour cherry. Acta Hort. 184:71–78.

Ben Mimoun, M. and DeJong, T.M. 1999. Using the relation between growing degree hours and harvest date to estimate run-times for peach: a tree growth and yield simulation model. Acta Hort. 499:107–114.

Costa, G. and Vizzotto, G. 2000. Fruit thinning of peaches. Plant Growth Regulation. 31:113–119.
DeJong, T.M. 2005. Using physiological concepts to understand early spring temperature effects on fruit growth and anticipating fruit size problems at harvest. Summerfruit 7:10–13.
DeJong, T.M. and Grossman, Y.L. 1995. Quantifying sink and source limitations on dry matter partitioning to fruit in peach trees. Physiol. Plant. 95:437–443.
DeJong, T.M., Day, K., Doyle, J.F. and Johnson, R.S. 1990. Evaluation of physiological efficiency of peach nectarine, and plum trees in different orchards systems. California tree fruit agreement annual research report, p.7.
Fruit and Nut Research and Information Center (FNRIC), University of Davis California. http://fruitsandnuts.ucdavis.edu.
Grossman, Y.L. and DeJong, T.M. 1994. PEACH: a simulation model of reproductive and vegetative growth in peach trees. Tree Physiol. 14:329–345.
Grossman, Y.L. and DeJong, T.M. 1995. Maximum fruit growth potential following resource limitation during peach growth. Ann. Bot. 75:561–567.
Lopez, G. and DeJong, T.M. 2007. Spring temperatures have a major effect on early stages of peach fruit growth. J. Hort. Sci. Biotech. 82:507–512.

Figures

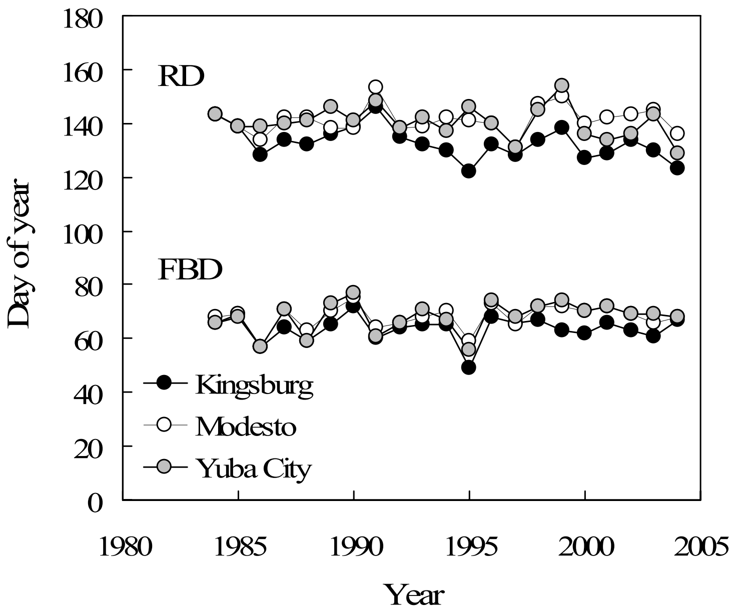

Fig. 1. Full bloom date (FBD) and reference date (RD) for three locations in California from 1984–2004.

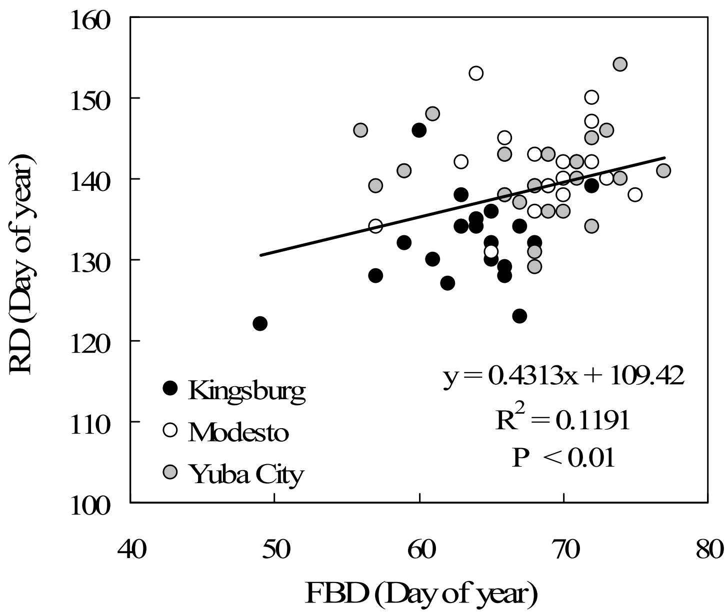

Fig. 2. Relationship between full bloom date (FBD) and reference date (RD) for three locations in California from 1984–2004.

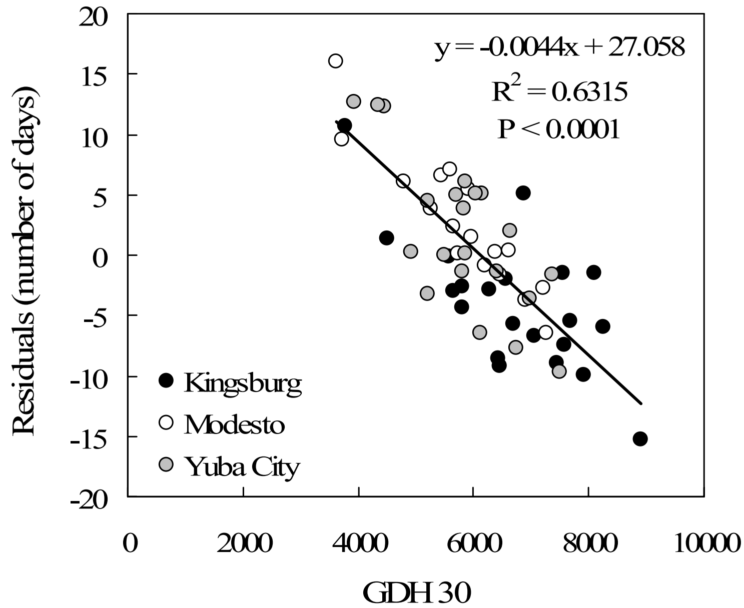

Fig. 3. Relationship between GDH 30 and the residuals observed in the relationship between full bloom date (FBD) and reference date (RD) in Figure 2.

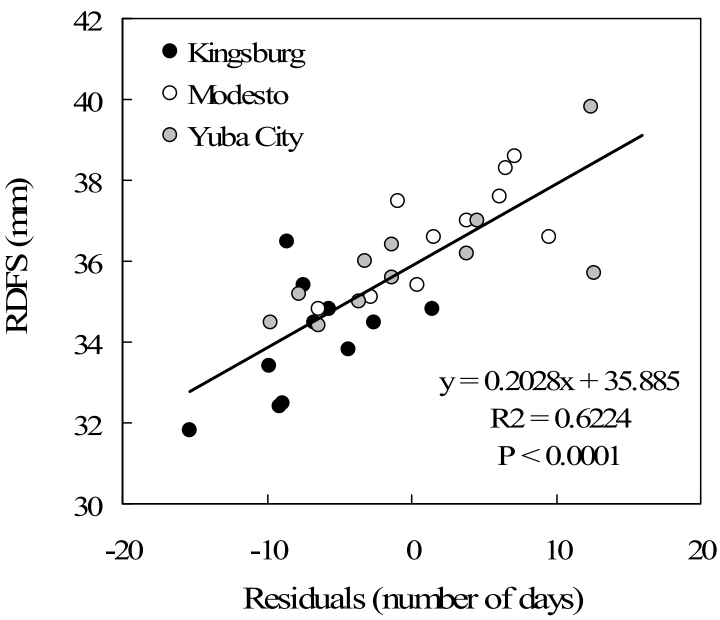

Fig. 4. Relationship between the residuals observed in the relationship between full bloom date (FBD) and reference date (RD) in Figure 2 and fruit size at reference date (RDFS).