

Model Comparisons of Pistachio Nut Growth and the Development of Web Applications

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INTRODUCTION

Knowing a plant's seasonal growth and development as a function of temperature accumulation can facilitate production. The ability to predict the three nut growth stages, or biomarkers, rely on: 1) hull and shell (pericarp) expansion; 2) endocarp (shell) hardening; 3) embryo development—can aid in irrigation, pest management, and harvest timing.

Nut growth is a function of heat, or physiological time. Plants require a specific amount of heat to develop through their seasonal growth and crop development. We plotted the correlations between degree-days and calendar days in multiple pistachio cultivars, in multiple locations, for three years. The final results demonstrated that at different locations the growth stages can differ by almost a month within a season. Accurately predicting when a specific growth stage might occur requires developing a model; a prediction equation that a grower can use by inputting local factors to generate predicted growth.

We compared several models: Asymptotic Regression; Michaelis – Menten; 3-parameter Logistic and Gompertz models, to select the one that provides the most accurate prediction for pistachio nut growth.

The predictions from the best model were then converted to mathematical formulas to build a web application—a website where growers can input their location, cultivar and local temperature accumulation to date. The website can then calculate when a growth stage, by heat unit accumulation and date, will be achieved for that location and cultivar. The final output will give also information on nut size, shell firmness, kernel size, nut-split rate and optimal harvest date.

METHOD

The nut growth of five cultivars, i.e., Kerman, Lost Hills, Golden Hills, Kaleghouchi and Pete 1, from six locations, was monitored through the 2014, 2016 and 2017 growing seasons. Bloom date, endocarp and embryo growth, shell hardness, nut split, fresh and dry weight and yield, and CPC grade were measured and recorded. Hourly temperatures were collected by dataloggers (Onset HOBO® U23-001 Pro v2 Temperature/ RH Data Loggers) installed at each location. The thermal units were determined by taking daily average and removing the base temperature of 7 °C.

Model Comparisons: The full theoretical model for the year and site sources of variation was: Total deviation $e = e_{\text{year}} + e_{\text{site}} + e_{\text{yr-st}}$, where the combination of site and year as a random effect that combines the variation. The comparisons among the Asymptotic Regression,

Michaelis – Menten, 3-parameter Logistic and Gompertz models were coded in the R Statistics program.

Web Application: The interface was powered by Spring Framework running on an AWS Server.

RESULTS

Four growth models fit the three stages of pistachio nut growth well. For all the models, the coefficient of determination values, (R^2), were more than 0.86. R^2 shows how much of the variance is explained by the model. Akaike's Information Criterion (AIC) demonstrated that the four models better fit embryo length than the other two growth stages. AIC is based on maximum likelihood and reflects the penalty for each parameters of models. The Gompertz model did not require random effects and had a high R^2 of 0.95. Both the R^2 and AIC indicated that the Gompertz model was the best model for all the variables.

CONCLUSION AND APPLICATIONS

The most consistent model was the Gompertz. Compared to the other three models, it best predicted pistachio nut growth at both low and high heat-unit accumulation. Now, using local historical and current temperatures in the Gompertz model, the pistachio nut-growth stages, including split, can be predicted. Fig 1 shows a screenshot of the web interface of "Report and Summary," where pistachio growers can input the local temperature data and receive a prediction of current nut growth and the optimum harvest date for their orchard.

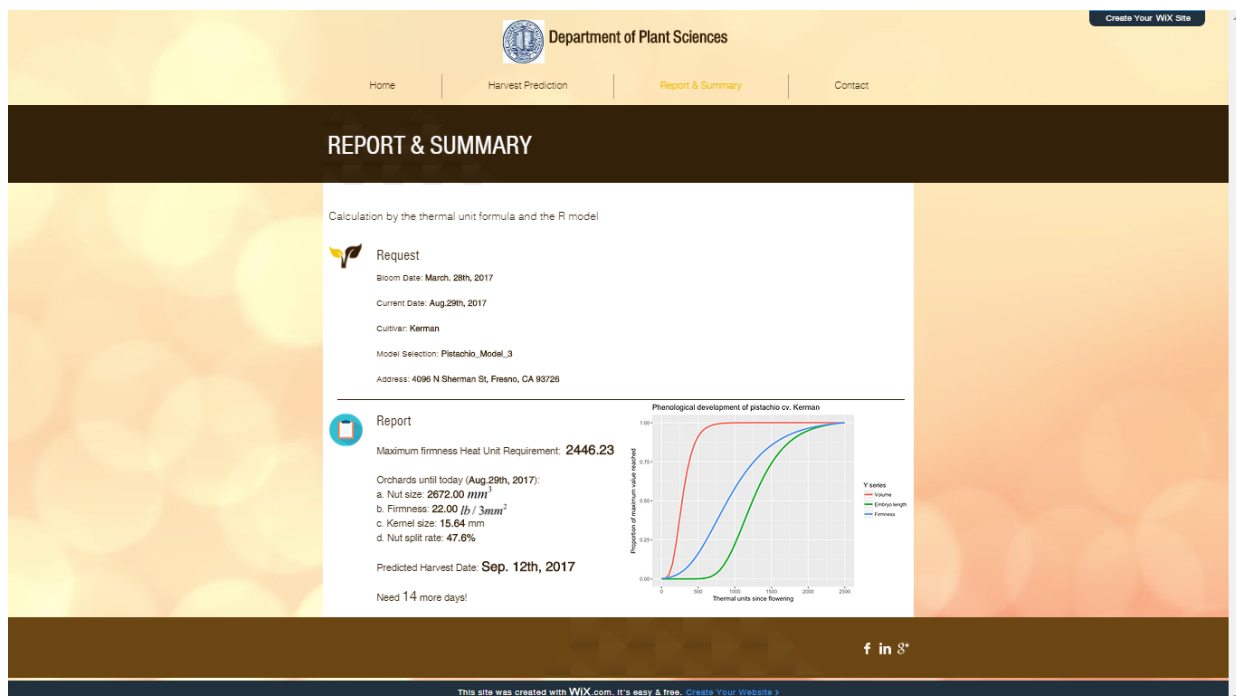


Fig 1. This website screenshot demonstrates predicted pistachio nut growth and harvest date. Growers enter bloom date, current date, cultivar and orchard location. The report predicts nut size, shell hardness, kernel size, nut-split rate and optimum harvest date. The graph in the lower right corner is the prediction of the nut growth (red color: nut volume; green color: embryo

length; blue color:shell firmness); the Y-axis is the Proportion of Maximum Value Reached, the X-axis is the Thermal Unit accumulation with a lower threshold of 45°F since bloom.