A Model for Predicting Diameter of 'Red Sensation' Pears

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Abstract

The pear cultivar 'Red Sensation' is showing popularity in the industry, because of its highly-colored, sweet and juicy fruit. Fruit size is critical for marketing pear; therefore, knowledge of growth dynamics becomes essential to program harvesting with minimum losses of size and flavor. The objective of this work was to develop a model to predict the seasonal growth for 'Red Sensation' pears, expressed in terms of fruit diameter as a function of time from full bloom. Fruit growth was followed at the Experimental Farm of the Universidad Nacional del Comahue, High Valley region, Río Negro, Argentina (38°56'S; 67°59'W), located in an arid region, with average annual rainfall of 250 mm, on a sandy loam soil, during the 2005-06, 2006-07, 2008-09, 2009-10 and 2010-11 growing seasons. The orchard was irrigated by surface flooding, and cultural practices were performed according to the local standard program. Trees were selected at random, and maximum fruit diameter (FD) measurements were carried out every two weeks with a Vernier caliper. The range of sampling dates was 19 and 117 days after full bloom (DFB). Equations were developed with SYSTAT procedure. The R^2 values and residual mean squares were used to evaluate the goodness-to-fit of the models. Results showed that the following logistic model provided the most satisfactory fit to the pooled data (*n*=695), as compared to the power and linear equations: FD (mm)= $81.49/(1 + e^{1.9865-0.0301\ DFB})$, R^2=0.92, *P*<0.001. Fruit maximal absolute growth rate, derived from the selected function, was 0.61 mm/day. A prediction chart was based on the development of the equation and showed 'Red Sensation' pear sizes, at various times after 112 DFB, with practical application to aid crop marketing. This model can also be used for planning orchard practices such as thinning and irrigation.

INTRODUCTION

The pear cultivar 'Red Sensation' (*Pyrus communis* L.) was first raised in Australia in 1940. It is showing popularity in the industry because of its highly-colored, sweet and juicy fruit. Fruit size is critical for marketing pear; therefore, knowledge of growth dynamics becomes essential to program harvesting with minimum losses of size and flavor in this climacteric fruit.

Methods for accurate prediction of fruit size and quality attributes are increasingly required as tools for achieving competitive advantages for fresh-marketing services. Winter (1987) reported that the fruit growth curve and the relationship between fruit weight and diameter of each particular cultivar, were essential components in the development of mathematical models. Forecasting methodology should provide estimates with known precision that can be calculated using the smallest sets of easily collected, simple measurements (De Silva et al., 1997).

The seasonal course of growth and development is a life process genetically determined, hormonally regulated and modified by location. This indicates that specific fruit growth curves are required according to particular cultivar, soil, climate and orchard management conditions (Ortega et al., 1998). Several factors affect final fruit size, such as cell number, cell size, intercellular spaces and rate of cell division, time and severity of thinning, temperature, irrigation and light stress (Garriz et al., 2009; Alvarez et al., 2010).

Different types of seasonal growth curves of pears were reported elsewhere

(Marsal et al., 2000; Arzani et al., 2008; Martins et al., 2008). While pear fruit ripening has been well studied, because of its importance in fruit harvest and storage (Garriz et al., 2008), there is still relatively little information on the growth pattern characteristic of each cultivar. In the High Valley region of Argentina, the fruit growth pattern of ‘Bartlett’ (Garriz et al., 1996), ‘Packham’s Triumph’ (Garriz et al., 1999) and ‘Abbé Fetel’ (Garriz et al., 2004) were determined under similar field conditions.

The objective of the present study was to develop a model to predict the seasonal growth for *P. communis* L., ‘Abbé Fetel’, expressed in terms of fruit diameter, as a function of time from full boom, under the orchard conditions of the Universidad Nacional del Comahue.

MATERIALS AND METHODS

A crop of ‘Red Sensation’ pear trees on *P. communis* L. rootstock, planted in 1993, at 4.00×2.80 m spacing, was studied at the Experimental Farm of the Universidad Nacional del Comahue, in the Rio Negro High Valley region of Argentina (38°56’S; 67°59’W), on a sandy loam soil. Trees were trained to palmette and row orientation was north-south. The orchard was kept weed-free, fertilized, thinned, pruned and sprayed for pest and disease control according to the local standard program for pears. Trees were surface irrigated at weekly intervals to match the crop evapotranspiration requirements throughout the season.

The experimental site was located in an arid region, with average annual rainfall of 250 mm. An automated meteorological station (Metos, Gottfried Pessl., Weis, Austria) situated close to the experimental orchard continuously monitored maximum, mean and minimum air temperature during the growth period. As shown in Table 1, the monthly temperature, in our study, varied little between seasons. The range of minimum and maximum temperatures was 1.7-4.1°C and 29.9-31.8°C, respectively.

Five trees were selected at random, and four fruits were sampled every two weeks until commercial harvest, during five consecutive growing seasons: 2005-06, 2006-07, 2008-09, 2009-10 and 2010-11. Full blossom was estimated to be at September 26, September 25, September 27, October 5, and September 29 (2005, 2006, 2008, 2009 and 2010, respectively) (Table 2). Maximum fruit diameter (FD) measurements were carried out with a Vernier caliper, to the nearest 0.01 cm (model 30-410-5, General Supply Corporation, Jackson, Miss., USA), and the range of sampling dates was 19 and 117 days after full bloom (DFB). A total of 695 fruits were measured. FD was regressed against DFB. Equations were developed with SYSTAT procedure. Model suitability was evaluated using goodness-to-fit measures.

RESULTS AND DISCUSSION

Several models were considered to determine the most consistent in being an adequate representation of the data. The R^2 values and residual mean squares were used to evaluate the goodness-to-fit of the equations. It was found that the following logistic regression provided the most satisfactory fit, with the highest coefficient of determination for the pooled data (0.92), compared to the power and linear models (0.91), and the residual mean square from fitting the logistic model was the smallest (Table 3):

$$Y=a/(1+e^{b-c\,X}) \quad (1)$$

(Y=FD; X=DFB; *a, b* and *c* are constants). Additionally, although agreements to power and linear equations were also significant, we have discarded those patterns, because no biological meaning can be sustained from models with no fruit growth limit.

In model (1), the constant *a* is the maximum size attained by the fruit (Milthorpe and Moorby, 1974). The rate at which the organ grows is controlled by the constants *b* and *c*, and they affect the slope of the growth curve. Based on the previously described criteria, we selected the following general predictive equation:

$$FD\ (mm)=81.49/(1+e^{1.9865-0.0301\ DFB}),\ R^2=0.92,\ P<0.001 \quad (2)$$

This model describes the fruit diameter obtainable in the specific orchard conditions for ‘Red Sensation’ pear growth. The logistic equation was also the most appropriate to describe fruit growth across seasons and no essential difference was found between them, suggesting that it may be possible to use a general predictive model for this specific orchard (Table 4). The graphic analysis of fit and the specific data for each year are indicated in Figure 1.

Fruit maximal absolute growth rate derived from function (2) was 0.61 mm/day. This point can be used to divide growth periods in physiological founded domains (growth phases). Three distinctive stages are evident in an S-shaped curve (Alvarez et al., 2010). An initial phase, when most cell division occurs, is followed by a rapid increase of size, mainly due to cell enlargement. Finally, during the last stage, fruit growth rate decreases as ripening approaches, and final fruit size tends to an asymptote.

Size prediction charts are important from a practical point of view, since they can provide growers with a tool to determine adequate fruit diameter at harvest, considering that unless a certain minimum size is obtained, the fruit will be given a lower grade and price. Table 5 shows ‘Red Sensation’ pear sizes at various times after 112 DFB, based on the development of Equation 2. However, determination of harvest time is a compromise between size and storage quality. The rate of the biochemical reactions, during pear ripening, may be modified by internal and environmental factors. Pear fruit is a typical climacteric fruit that undergoes increase in respiration, with a burst of ethylene production during ripening. In commercial practice, pear fruits are harvested at the preclimacteric stage, when the fruit is not ready for eating, due to firm flesh and incomplete conversion of starch to sugars (Kubo et al., 2003).

In conclusion, according to the results reported here, the logistic equation gave the best fit to describe growth of ‘Red Sensation’ pear in the specified orchard conditions. This model can be used as a tool for predicting the time at which fruits reach a given size, and as such, have practical application to aid crop marketing.

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Tables

Table 1. Maximum, mean and minimum temperatures in orchard, during the 2005-06, 2006-07, 2008-09, 2009-10 and 2010-11 growing seasons, in the Rio Negro High Valley region of Argentina.

	Months				
	Sep.	Oct.	Nov.	Dec.	Jan.
Maximum temperature (°C)					
2005-06	19.3	21.6	26.1	27.5	30.6
2006-07	19.4	21.9	26.1	28.8	30.5
2008-09	20.3	23.7	29.3	30.2	31.8
2009-10	18.0	22.5	22.7	28.1	31.3
2010-11	19.6	23.2	25.7	29.2	29.9
Mean temperature (°C)					
2005-06	11.9	14.8	19.3	20.5	22.6
2006-07	11.7	14.1	18.7	20.3	22.8
2008-09	13.2	17.2	23.0	23.7	25.4
2009-10	11.2	16.2	16.7	21.8	24.3
2010-11	12.9	16.6	20.0	21.6	23.5
Minimum temperature (°C)					
2005-06	3.80	7.30	11.4	12.6	13.1
2006-07	4.00	5.90	9.10	11.8	14.0
2008-09	3.90	6.30	10.2	13.6	13.1
2009-10	1.70	5.90	7.90	10.3	12.5
2010-11	4.10	7.30	10.8	12.6	13.8

Table 2. Full bloom date, first sampling date and commercial harvest date for 'Red Sensation' pears, during five growing seasons: 2005-06, 2006-07, 2008-09, 2009-10 and 2010-11, in the Rio Negro High Valley region of Argentina.

Growing season	Full bloom date	First sampling		Commercial harvest	
		Date	DFB	Date	DFB
2005-06	Sep. 26, 2005	Oct. 24, 2005	30	Jan. 16, 2006	113
2006-07	Sep. 25, 2006	Nov. 8, 2006	44	Jan. 18, 2007	115
2008-09	Sep. 27, 2008	Oct. 20, 2008	19	Jan. 26, 2009	117
2009-10	Oct. 5, 2009	Oct. 28, 2009	23	Jan. 15, 2010	102
2010-11	Sep. 29, 2010	Oct. 25, 2010	26	Jan. 18, 2011	111

Table 3. Regression models of fruit diameter in mm (Y) and days after full bloom (X) for 'Red Sensation' pears growing in the Rio Negro High Valley region of Argentina.

Model	Residual mean square	Degrees of freedom	Coefficient of determination (R^2)
$Y=81.49/(1+ e^{1.9865-0.0301X})$	23.4	692	0.92
$Y=0.99\ X^{0.8885}$	23.6	693	0.91
$Y=0.55\ X+ 4.1968$	23.6	693	0.91

Table 4. Regression models of fruit diameter in mm (Y) and days after full bloom (X) for 'Red Sensation' pears, during five growing seasons in the Rio Negro High Valley region of Argentina.

Growing season	Model	Residual mean square	Degrees of freedom	Coefficient of determination (R^2)
2005-06	$Y=81.16/(1+e^{2.0201-0.0301X})$	15.0	137	0.94
2006-07	$Y=84.82/(1+e^{1.9699-0.0257X})$	7.49	117	0.95
2008-09	$Y=81.45/(1+e^{1.9257-0.0306X})$	15.9	157	0.95
2009-10	$Y=70.76/(1+e^{2.1436-0.0358X})$	13.5	137	0.94
2010-11	$Y=86.34/(1+e^{1.9689-0.0314X})$	18.1	137	0.94
Combined data	$Y=81.49/(1+e^{1.9865-0.0301X})$	23.4	692	0.92

Table 5. Rate of increase in fruit diameter of 'Red Sensation' pears during harvest time, at various days after full bloom, in the Rio Negro High Valley region of Argentina.

Days after full bloom	Fruit diameter (mm)	Increase in diameter (mm) every 2 days	Increase in relation to fruit diameter at 110 DFB (%)
110	64.43	-	0.00
112	65.23	0.80	1.24
114	66.00	0.77	2.44
116	66.75	0.74	3.59
118	67.46	0.71	4.70
120	68.15	0.69	5.76
122	68.81	0.66	6.78

Figures

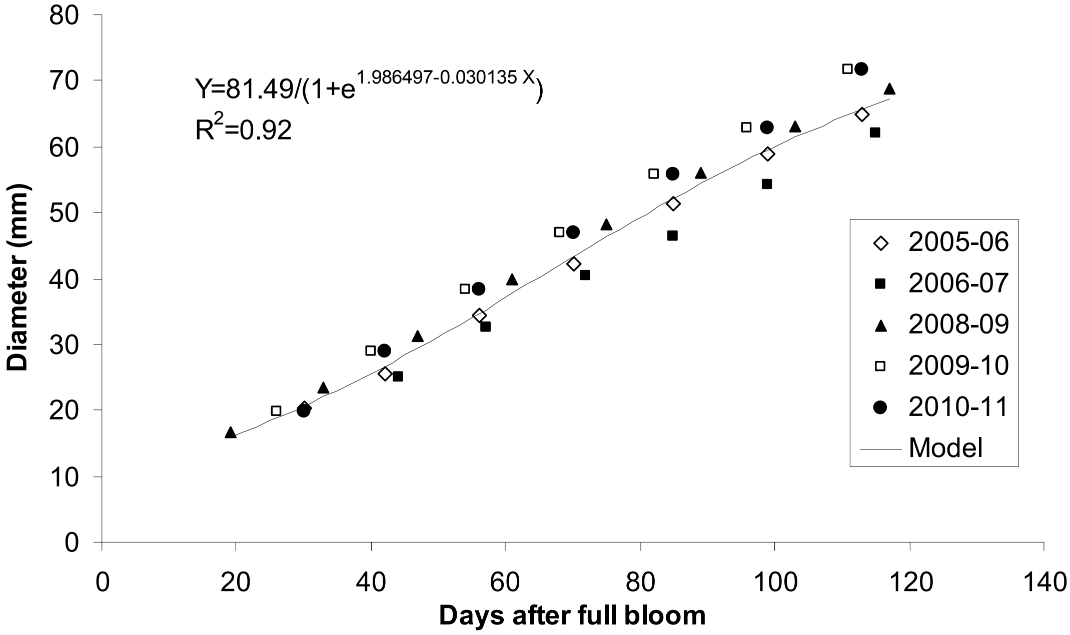

Fig. 1. Changes in 'Red Sensation' pear fruit diameter plotted on a time-from-bloom basis. The line is the fitted model to the data.