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Loquat fruit growth follows a single sigmoid pattern.

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Abstract

Loquat fruit growth measured by increases of equatorial diameter adjusts to a logistic curve. By means of sequential measurements of tagged fruits of cultivar 'Algerie', curves were obtained that fit significantly to a single sigmoid model in unthinned as well as in heavily thinned trees. Equations defining growth pattern of fruits from thinned and from unthinned trees showed different slopes that reflect greater growth rates under thinning. By the contrary, small and large fruits within the same tree showed minor variations in growth rates, and fruit size at harvest was largely due to fruit size at initial fruit set. Differences in size among fruitlets of the same tree at the time of hand fruit thinning never reversed and led to different commercial categories related with initial size; that allows us to recommend fruit thinning on a size basis. A strong significant correlation was also found at harvest between fresh fruit weight and equatorial diameter. Size and number of seeds were the major determinants of final fruit size in loquat whereas number of leaves and leaf area index of the bearing shoots showed a weak correlation with final size of formed fruits.

Keywords: Eriobotrya japonica; Loquat; Fruit growth model; Sigmoid curve, Fruit thinning; Fruit size

1. Introduction

Loquat (Eriobotrya japonica Lindl.) is a subtropical evergreen tree with delicate edible fruits. Considered indigenous to southeastern China, it has been cultivated in Japan for over 1,000 years (Morton, 1987). Unknown in the Western World until XVIII Century, its acclimation to the Mediterranean climate has permitted quick expansion in Mediterranean Basin countries. Land devoted to loquat, production and market is, therefore, concentrated mainly into native Asian areas and South Europe countries (Lin et al., 1999). Precocity and fruit size are critical for marketing loquat, making some kind of fruit thinning mandatory. In this context, knowledge of fruit growth dynamics becomes essential to program harvesting with minimum losses of size and flavor in this non-climacteric fruit (Blumenfeld, 1980).

Loquat belongs to Rosaceae family, subfamily Maloideae and its fruit is a pome. Pomes (apple, pear, quince...) follow a single S pattern of fruit growth. Three distinctive stages conform that model. An initial phase of slow growth (stage I) when most cell division occurs, is followed by a rapid increase of size (stage II), mainly due to cell enlargement, in which much of the final size is achieved. Finally, during stage III fruit growth rate decreases as ripening approaches and final fruit size tends to an asymptote (Dennis, 1988). This third stage may not be seen in pears usually harvested unripe (Westwood, 1993).

Loquat blooms in autumn forming terminal panicles on current year wood. Those and other differences with other pomes allowed Blumenfeld (1980) to inquire about the

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loquat fruit growth pattern. The author argues that since loquat fruit may present a few seeds as a pome, but of big size as in stone fruits, it is questionable if loquat fits better into a single or double S model. After studying evolution of fresh fruit weight in 'Akko 1' and 'Tanaka' he concluded that loquat fruit growth is exponential, and so it has been assumed in a recent review by Lin et al., (1999). Nowadays, the curves obtained by Blumenfeld (1980) seem incomplete, no including ripening, and no fit to any model was presented. With the explicit purpose of clarifying fruit pattern growth in loquat we compared dynamic of growth in small and large fruits from unthinned and flower-thinned 'Algerie' trees.

2. Materials and methods

Growth was followed on fruits of 'Algerie' cultivar trees grafted on 'Provence' quince at Las Palmerillas Experimental Station near El Ejido, Almería (Spain). Equatorial diameter growth measurements were carried out twice every week from set to harvest with a digital caliper to the nearest 0.01 cm, always on the same individual tagged fruitlets. For evaluation, we chose two fruits from of each of ten inflorescences located on four 20-years-old trees, where neither flowers nor fruits were detached. With the aim of checking thinning effects on the pattern of fruit growth, we followed on a second year, this time weekly, fruit growth of other 80 fruits on the same four trees that this year were flower-thinned at bloom by removing the two upper thirds of the inflorescence. Some fruitlets abscised during development in both seasons, so actual number of fruits measured changed slightly among dates. Data were expressed on the basis of accumulated degree-days from time of full bloom to harvest, calculated using single sin method (Zalom et al., 1983) with lower threshold temperatures of 4ºC (Hueso, unpublished results).

Correlation and regression analyses were performed among final fruit size and number and size of the seeds included within the fruits (sink strength), and, only on thinned trees, with the number of leaves and total leaf area of the bearing shoots (source capacity). Results were processed and adjustments to different models checked using Statgraphics Plus v. 4.0 software.

3. Results

Equatorial diameter of fruits from heavily thinned and unthinned trees increased following a pattern that fitted significantly to a single sigmoid curve (Fig. 1). Coefficients of determination of 0.999 and 0.997 were obtained in unthinned and flower-thinned trees, respectively. Agreements to linear and exponential models were also significant ($p<0.01$), but data separated at the final stages of fruit growth (Fig. 1). Differences in equations among trees with different level of fruit load, caused by thinning, were mostly related to the slope of the curve, almost two times greater in the case of flower-thinned trees (Fig. 1).

Tagging individual fruitlets permitted us to follow their growth rates and group them according to their final fruit size. Fruit growth curves of average fruit is represented in Fig. 2 jointly with curves obtained from fruits included in the lower and the upper 10% classes. The pattern followed for any fruit population fitted again significantly to a sigmoid curve ($p<0.05$; coefficients of determination always over 0.98). In this case, differences among fruit populations were scarcely related to slope, slightly higher for larger fruits. By the contrary, size differences among fruits at harvest were mostly due to their size at initial fruit set. In this sense, small fruitlets when first measurement was done remained small at picking stage, whereas large fruitlets grew up to reach larger sizes (Fig. 2). Initial differences among fruit populations grouped by size were never reversed and led to different commercial categories related with initial size. Differences among classes increased initially but as ripening approached the ratio declined to initial values. Fruit size ratio between the lower and the upper 10% classes was 1.8 at two months from bloom and at first harvest date (140 days after bloom) for unthinned trees, and 1.5 and 1.6, respectively for thinned trees. However, maintaining same ratio between classes made it that initial differences of 2 mm in diameter between two fruits at 60 days after full bloom became more than 1 cm at harvest. Larger fruits also reached stage III, i.e. ripening, earlier than smaller fruits did (Fig. 2). Overripe fruits of loquat did not abscise, but shriveled and showed fresh weight losses (Fig. 3).

A strong significant correlation (r=0.97; for both thinned and unthinned trees) was found at harvesting between equatorial diameter (a non-destructive measure) and weight. Given the formerly described close relation between initial and final fruit diameter, such relationships allow us predict ultimate weight several weeks before harvest. A close and highly significant correlation was also found at harvesting between fruit diameter and diameter occupied by seeds in unthinned trees (r=0.80), as well as in heavily thinned trees (r=0.80). Association was less, although significant, between fruit diameter and number of seeds formed (r=0.66 and r=0.54, for unthinned and thinned trees, respectively). By the contrary, no relation at all was found between fruit diameter and number of leaves of the shoot or its total leaf area (r=0.15 and r=0.13, only measured on thinned trees).

4. Discussion

Blumenfeld (1980) described fruit growth pattern of loquat as neither single nor double sigmoid, but exponential. He justified such a model because loquat fruits may include several seeds, as other pomes with single sigmoid curve, but the seeds of loquat are of a big size as in one-seeded drupes that present a double sigmoid pattern. However, the curves Blumenfeld presented closely resemble a single sigmoid curve lacking Stage III, i.e. ripening. He did not present an equation sustaining his conclusion.

According to our data, fruits of cultivar ‘Algerie’ fit significantly to a single sigmoid model (Fig. 1). Large and small fruits proceeding from flower-thinned as well as from unthinned trees of cultivar ‘Algerie’ when harvested fully ripen conformed significantly to single S model (Fig. 2). This model is typical of pomes (Westwood, 1993). Our results fully coincide with figures presented by Rodríguez (1983) who extensively studied fruit growth of seventeen loquat cultivars. Rodríguez (1983) did not include ‘Algerie’ nor ‘Akko 1’ in his study, but curves characterizing growth of diameter of ‘Tanaka’ fruits seem to follow a single sigmoid pattern. Rodríguez (1983) did not present either equations describing fruit growth. Our data also coincide with Takase et al., (1988). These authors grew loquat cultivar ‘Mogi’ under greenhouses and followed evolution of the fruits under different temperature regimes. In all cases, figures presented there resemble single S curves, with a final period of negligible growth. Singh et al., (1960) represented evolution of fruit length and diameter of cultivars ‘Improved Golden Yellow’ and ‘Pale Yellow’ under different treatments with growth regulators, and also for non-treated, control, trees. In all treatments, growth curves resemble S-single models, although no model of fruit growth was proposed.

Disagreement with previous work by Blumenfeld (1980) seems to be related to harvest date. Premature harvest in loquat, often fueled by higher prices, can make stage III undetectable, leading to significant fitting to linear or exponential curves. Actually, until three weeks before harvest our data also fitted better to an exponential curve (Fig. 1). Early harvest has serious consequences in loquat commercialization because the non-climacteric nature of this crop implies selling of fruits too acid and unpalatable for the consumers. Harvest must be therefore programmed to maximize fruit size and procure plenty flavor. However, since loquat has no preharvest fruit abscission, and overripe fruits remain attached to the shoots, is possible that some fruit size losses (Fig.. 3) and unpleasant flavors appear with delayed picking. Although good and significant fittings to linear and exponential regression equations were found, we have also discarded those patterns because they do not incorporate Stage III and no biological meaning can be sustained from models with no fruit growth limit. A clear cut-off must be included in exponential models to take account of the limits of fruit growth.

Differences among fruits formed in flower-thinned trees and unthinned trees were mostly limited to the slope, which means a different rate of growth, more intense under heavy thinning. By the contrary, differences among small and large fruits within the same trees were more related to initial fruit size. Such results emphasize the importance of fruit size at the time hand-fruit thinning is performed to achieve better commercial grading. Fruit size differences, perhaps due to different cell numbers (Westwood, 1993), sustain thinning on a size base. Initial differences in growth rates, slight and later attenuated, among small and large fruits also led to an advanced ripening and harvesting for the latter. Finally, our results suggest that, under standard horticultural management, sink strength (number and size of seeds) more than the capacity of the source (number of leaves or total leaf area of the fruiting shoot) determines final fruit size in loquat. The importance of pollination in this alleged self-compatible species should not be, therefore, underestimated.

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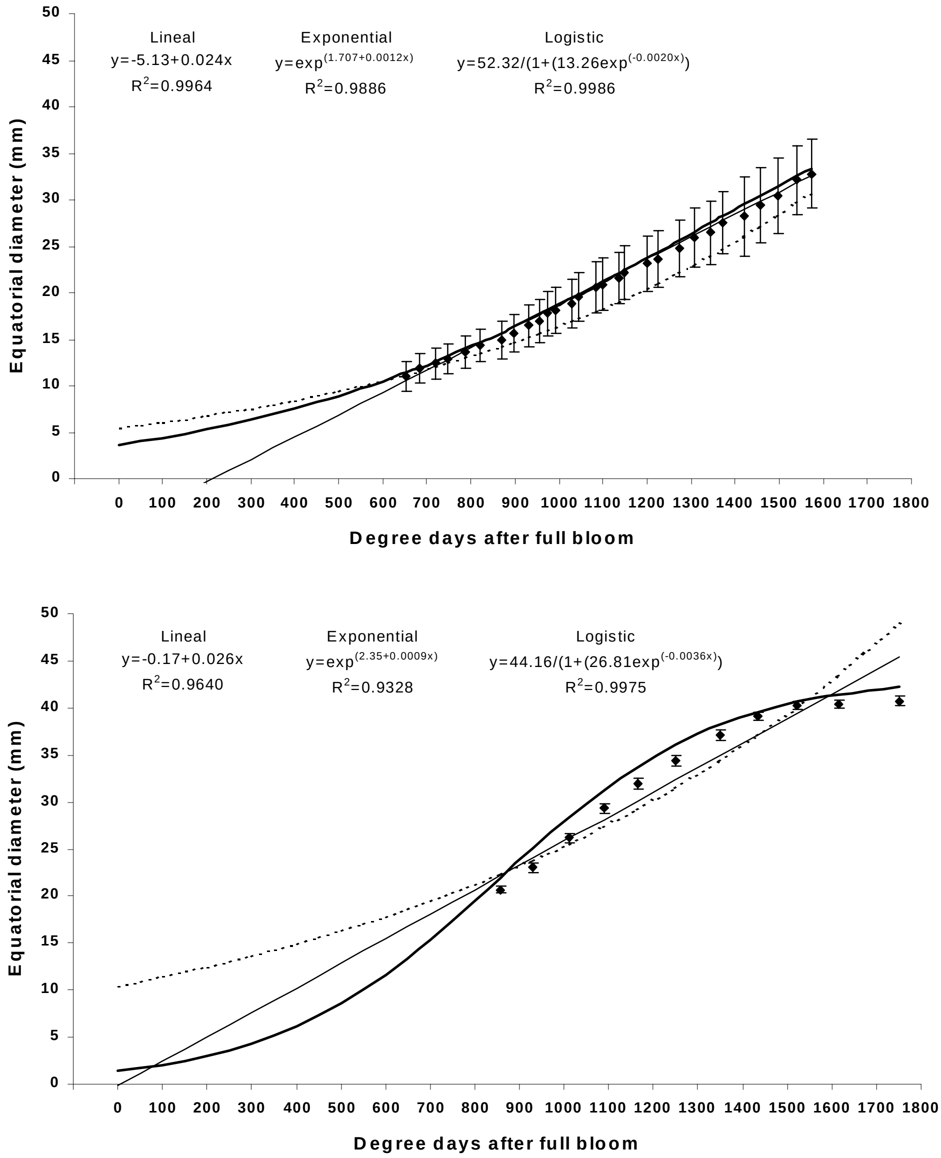

Fig. 1. Seasonal increase in fruit diameter of 'Algerie' loquat. Up: unthinned trees with an average of ten fruits per inflorescence. Low: trees thinned up to an average of three fruits per inflorescence. Lines correspond to lineal (dashed), exponential (dotted) and logistic (solid) fits. Symbols represent mean fruit and error bars 1 standard deviation.

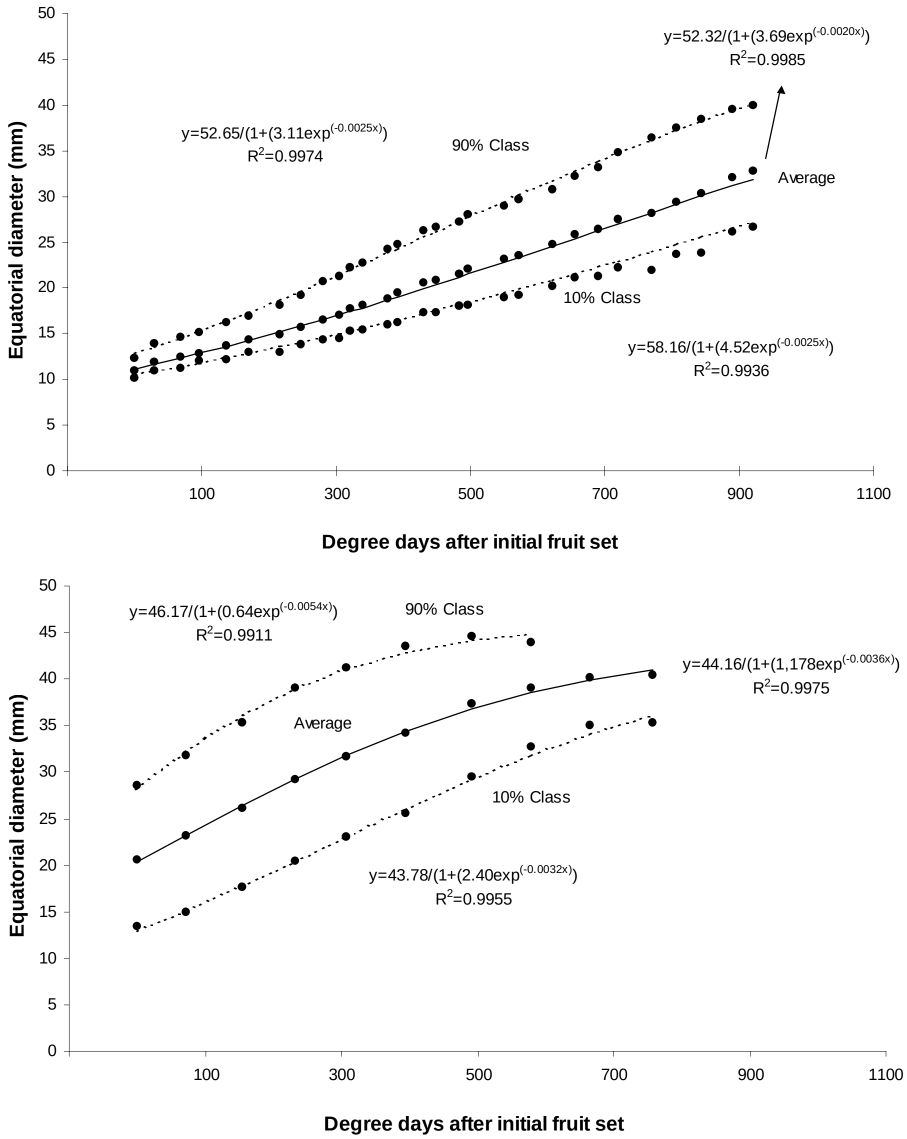

Fig. 2. Seasonal pattern of fruit growth in diameter of mean fruits of average (solid) and upper and lower 10% classes (dotted) growing on ‘Algerie’ loquat trees. Up: unthinned trees with an average of ten fruits per inflorescence. Low: thinned trees up to an average of three fruits per. Symbols represent mean fruit for each class.

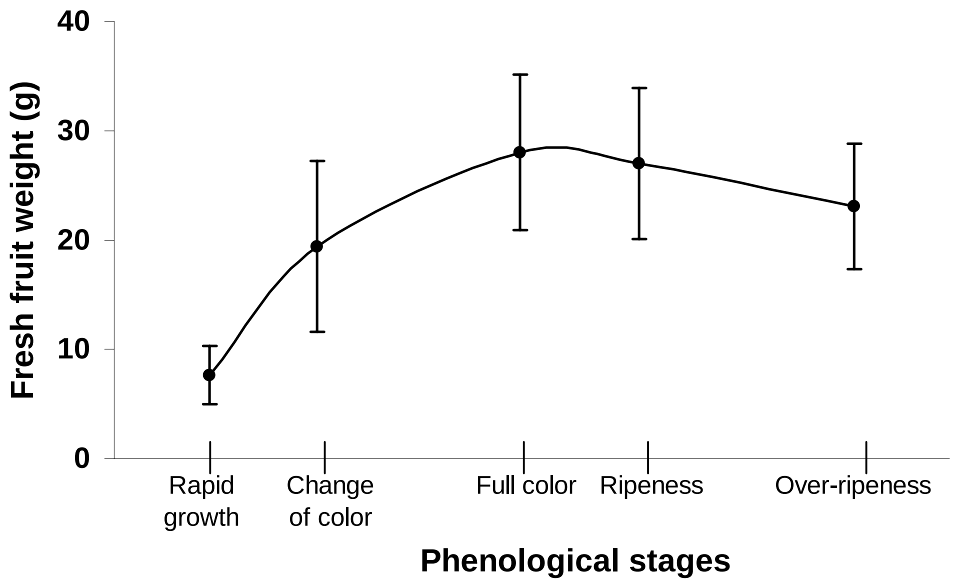

Fig. 3. Evolution of fresh fruit weight at distinctive stages of fruit development in unthinned trees of ‘Algerie’ loquat. Symbols represent mean fruit and error bars 1 standard deviation. N varied between 22 at full color, and 77 at over-ripeness.