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Fruit Development in Almond for Fresh Consumption

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Abstract

Commercialization of fresh almond [*Prunus dulcis* (Mill.) D.A. Webb] seed is a potential opportunity for diversification of the almond market. Characteristics required for the commercialization of this product include early market availability, suitable seed size and high seed/fruit weight ratio. In order to determine the effect of flowering and ripening dates on fresh market quality, fruit and seed development were studied in four almond cultivars: 'Ramillete' (early flowering and ripening), 'Desmayo Largueta' (early flowering and late ripening), 'Antoñeta' (late flowering and early ripening), and 'Wawona' (late flowering and ripening). Data were collected for time from flowering to ripening, fruit and seed length, seed fresh and dry weight, the seed/fruit weight ratio, and endocarp hardness. Results confirm a rapid growth of fruit in March and April. Accelerated cotyledon development was observed in April and May, while the hardening of the endocarp occurred gradually until ripening (mesocarp split). In general, the development of fruit and seed traits was similar for the four almond cultivars, regardless of their flowering and ripening date. However, the growth of cotyledons depended on both flowering and ripening dates, with early flowering and ripening cultivars appearing most suitable for the fresh almond market.

Almonds [*Prunus dulcis* (Mill.) D.A. Webb] are classified as a nut in which the edible seed (mainly composed of cotyledons) (Fig. 1) is the commercial product. Almond seeds are concentrated energy sources because of their high lipid content. The seed also contains considerable protein, minerals, and vitamins. Almond seeds are usually consumed mature either raw or roasted where they are used in the confectionery industry for various purposes (14). Commercialization of fresh immature seeds is a small but expanding market which offers diversification for the industry. Fresh seeds are mainly produced in May and June in Spain, Tunisia, and Morocco, and consumed in the South of France and countries such as Turkey and Lebanon. Fruit are harvested when the cotyledons are fully elongated. Commercially important characteristics for this use are early cotyledon development, large seed size and high seed/fruit ratio.

Breeding new traits requires a good understanding of the existing gene pool. In general, fruit and seed traits are quantitative (11, 13, 15). Flowering date has usually been described as under quantitative control (2, 20, 21) although some reports (8, 19) noted a late blooming major gene, which could be modi-

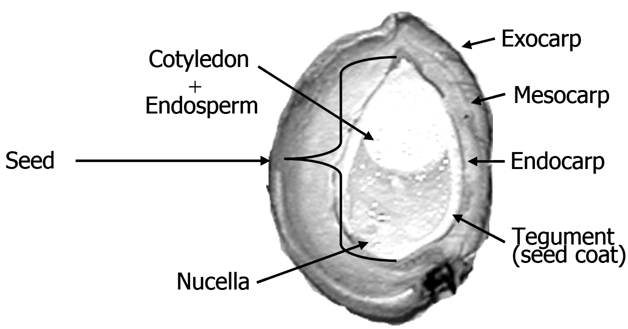

Figure 1. Parts of the almond fruit and seed.

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fied by minor genes. Ripening date is also a quantitative trait (14), although Dicenta et al. (2) suggested the presence of non-additive factors, which would allow breeders to accelerate the time of harvest.

The objective of this work was to determine the effect of cultivar flowering and ripening dates on cotyledon development.

Materials and Methods

Fifteen-year-old trees of four almond cultivars with different flowering and ripening dates were assayed: 'Ramillete' (early flowering and ripening), 'Desmayo Largueta' (early flowering and late ripening), 'Antoñeta' (late flowering and early ripening) and 'Wawona' (late flowering and ripening) were evaluated. Trees were grown in an experimental orchard in Santomera (Murcia, in southeast Spain). Flowering time was recorded as the time when 50% of flowers of each tree were open [stage F of Fleckinger, as described in almond by Felipe (3)] and ripening time was recorded as the time when 95% of mesocarps (hulls) were split.

At the beginning of each month, the lengths of fruit and cotyledons) were measured. Fresh and dry seed weights were recorded and seed/fruit weight ratio calculated. In addition, hardness was measured in the middle of the endocarp using a penetrometer with a diameter of 0.31 cm (HortPlus, Cambridge, New Zealand). Ten fruits of each cultivar were evaluated monthly. In order to compare the results obtained with the different cultivars, values for each trait were expressed as a percentage of the maximum value for each cultivar. Fruit were randomly collected except that fruits showing unusually fast or slow development were avoided.

Results and Discussion

'Desmayo Largueta' had the longest fruit and cotyledons at harvest time (Fig. 2). Fruit showed rapid elongation during March and April followed by the rapid expansion of the cotyledons during April and May, a month later. The delayed expansion of the cotyledons was more pronounced in the late flowering cultivar 'Wawona' (Fig. 3). These results support the two stages of development (single-sigmoidal model) described previously in almond by Grasselly and Crossa-Raynaud (9) and Kester et al. (16), and is similar to that described in peach by different authors (1, 10, 17).

In the first stage, rapid growth of the almond fruit and cotyledons was driven by a high cell multiplication rate. The beginning of rapid seed growth 1.5 months after flowering coincides with natural fruit drop (16). Competition for resources within the tree in this stage appears partly responsible for this young fruit drop. Consequently this stage is more sensitive to nutrient and water deficiencies (12) in almond and other *Prunus* species, such as peach (4, 6, 10). During the more stable second stage of fruit growth, water and nutrient supply greatly affect the final seed weight (6, 18).

In general, the development of the fruit and cotyledons was similar in all the cultivars and thus mostly independent of the flowering and ripening times. However, differences among cultivars in the rate of cotyledon development were observed in April and May, which appeared related to flowering and ripening dates (Fig. 2), supporting previous observations of Serafimov (19) and Kester et al. (16) with different almond cultivars. These differences were more important in early May, when the expansion of cotyledons of 'Ramillete' (early flowering – early ripening) was nearly complete, while that of 'Wawona' (late-late) was only beginning. Serafimov (18) found a different pattern of development for almond in Bulgaria (with colder weather than southeast Spain) depending on the flowering date. The cessation of the cotyledon enlargement occurred later, in the middle of June, with differing cotyledon growth rates depending on the flowering dates of the cultivar. The development of 'Wawona' shows some agreement with the Bulgarian results.

'Antoñeta' was the cultivar with the heaviest seed and the highest seed/fruit fresh weight ratio (Fig. 2 and 3). A rapid increase in fresh

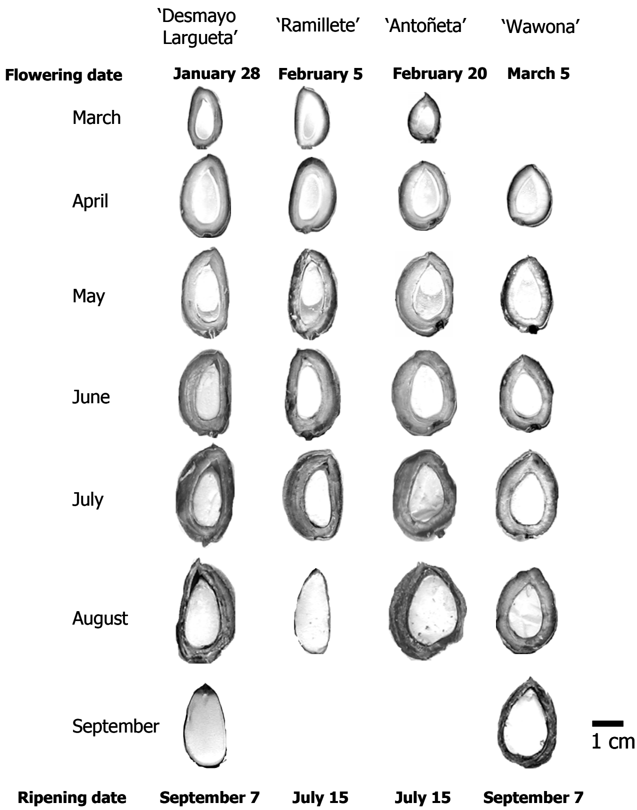

Figure 2. Development of the fruit and seed in the four almond cultivars. The flowering and ripening dates of the almond cultivars are also indicated.

weight occurred in March and April whereas a rapid increase in dry weight occurred from May to July. The progression of seed dry weight showed a similar delay as was observed in the length of the seeds in relation to fresh weight and fruit length, respectively (Fig. 3). At the beginning of growth, most of the seed is composed of the still-watery nucella and endosperm (19). However, later, the nucella and endosperm disappear, being replaced by the enlarging cotyledons, with a concurrent reduction in seed water content. This process is known as the 'fill-out' of the seed (11, 18) (Fig. 2).

At maturity, 'Desmayo Largueta' had the lowest seed/fruit weight ratio (Fig. 3). Observed values were higher than those obtained by Godini (5). In addition, the early flowering cultivars 'Desmayo Largueta' and 'Ramillete' had the highest values in May, whereas 'Antoñeta and 'Wawona', the late flowering cultivars, achieved the highest values in June (Fig. 3). Differences in the seed-fill were also described by Serafimov (19), although Hawer and Buttrose (12) described a similar seed-fill in all the almond cultivars they assayed.

'Desmayo Largueta' was the cultivar with the hardest endocarp, achieving the highest penetrometer values in July (Fig. 3). Results show a gradual hardening of the endocarp until ripening, as described by Gradziel and Martínez-Gómez (7) when the desiccation and splitting of the mesocarp occurs, except for 'Desmayo Largueta'. 'Desmayo Largueta' showed significant hardening during May. Grasselly and Crossa-Raynaud (9) and Kester et al. (16) reported a similar phenomenon in the very hard-shelled almond cultivars they assayed. A correlation between the speed of shell hardening and the flowering date was also observed during May and June with later-flowering cultivars showing a delayed hardening of the shell. Serafimov (18) had previously reported a close association between endocarp hardening and seed growth rate.

Results indicate that cultivar development projects targeting the commercialization of fresh almonds should utilize both early flowering and early ripening germplasm. In areas where the risk of spring frost is great, the selection of cultivars such as 'Antoñeta', with its later flowering and early ripening times and seed of good size and quality, would be recommended.

Acknowledgments

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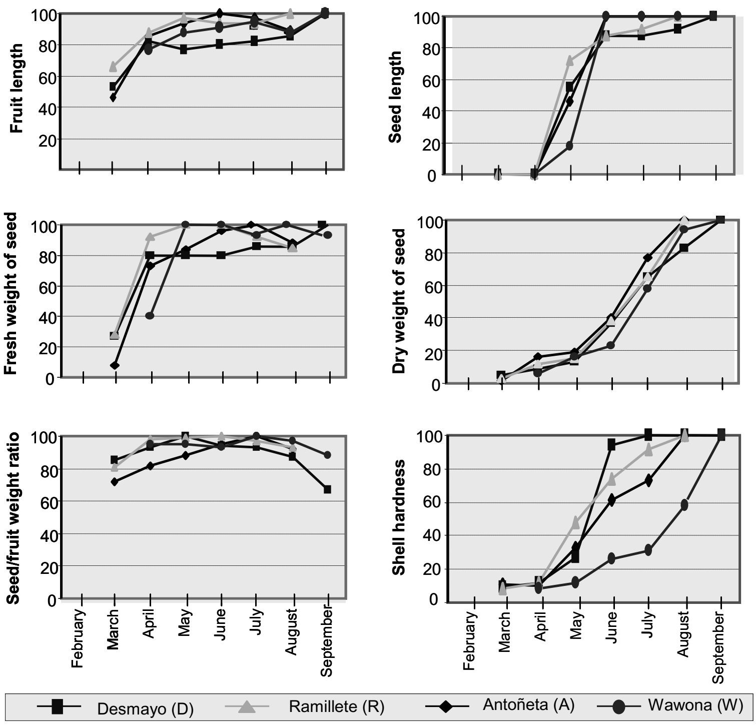

Figure 3. Relative growth of fruit and seed, relative fresh and dry weight of seed, seed/fruit weight ratio, and relative endocarp hardness expressed as a percent of maximum for each of the four almond cultivars assayed during the period of development of the fruit.

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