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Almond breeding programme in CEBAS-CSIC, in Murcia (Spain)

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Abstract. The almond cross breeding program of CEBAS-CSIC began in 1985 with the objective of obtaining new self-compatible late flowering cultivars; since then more than 12,000 seedlings have been obtained. In 1995 the cultivars Antañeta and Marta, which fit the established objectives, were released. Afterwards we follow the breeding programme with the objective of delay more and more the flowering time, to obtain new extra-late flowering self-compatible almonds. These new cultivars could be grown in the colder areas where the culture of almond is being expanded, without risk of frost. A lot of hectares, nowadays cultured with less profitable cultures, could be replaced by almond. In 2007 we released Penta and Tardona. Both are self-compatible (S_2S_1 and S_5S_1 , respectively) with a high level of autogamy. They are extra-late flowering, between 10 and 15 days after Ferragnès, what reduce more than 80% the risk of damage by frost in comparison with traditional late-flowering cultivars. Both are very floriferous and productive. While Penta matures very early, Tardona matures with Ferragnès. Both are hard shelled with 27% and 25% of kernel percentage. The kernel weight is 1 g for Penta, and smaller (0.8 g) for Tardona. Due to their extra-late flowering, they are recommended for areas with a high risk of frost. Both have been registered in the Community Plant Variety Office of the European Union.

Keywords. Almond breeding – Self-compatibility – Extra-late flowering – New cultivars.

Le programme d'amélioration génétique de l'amandier du CEBAS-CSIC, à Murcie (Espagne)

Résumé. Le programme d'amélioration génétique de l'amandier du CEBAS-CSIC a commencé en 1985 avec l'objectif d'obtenir de nouvelles variétés auto-compatibles à floraison tardive ; depuis, plus de 12 000 plantes issues de croisements contrôlés ont été obtenues. En 1995, nous avons sélectionné les variétés Antañeta et Marta, qui correspondent aux objectifs pré-établis. Afin de retarder encore plus la période de floraison, nous avons poursuivi ce programme pour obtenir de nouvelles variétés d'amandier auto-compatibles à floraison ultra-tardive. Ce type de variétés pourrait être cultivé dans les zones plus froides où la culture de l'amandier est étendue, sans risque du gel. De nos jours, beaucoup d'hectares cultivés avec des cultures moins rentables pourraient être remplacés par l'amandier. En 2007, nous avons sélectionné Penta et Tardona. Toutes deux sont auto-compatibles (S_2S_1 and S_5S_1 , respectivement), avec un haut niveau d'autogamie et à floraison ultra-tardive (entre 10 et 15 jours après Ferragnès), ce qui réduit de plus de 80% le risque de dégâts par le gel en comparaison des variétés traditionnelles à floraison tardive. Toutes deux sont très florifères et productives. Penta mûrit très tôt en saison alors que Tardona arrive à l'époque de Ferragnès, avec un fort rendement au cassage respectivement de 27% et 25%. Le poids de l'amandon est 1 g pour Penta et de 0,8 g pour Tardona. Enregistrées à l'Office Communautaire des Variétés Végétales (Union Européenne), ces deux variétés sont recommandées en zones de production à fort risque de gel, en raison de leur floraison ultra-tardive.

Mots-clés. Amélioration génétique – Auto-compatibilité – Floraison ultra-tardive – Nouvelles variétés.

I – Introduction

The studies on almond breeding in the CEBAS-CSIC began in 1971. In 1981 we established a collection with 81 cultivars from Murcia, Spain and other countries, which were evaluated for 10 years. It was in 1985 when the first crosses were done. Progenitors and crosses were selected mainly considering two objectives: late flowering and self-compatibility (Dicenta *et al.*, 2002b).

Late flowering increases the possibilities of a cultivar to escape to the late frost, which is the main factor of the low productivity in Spain. On the other hand, self-compatibility allows the growers to cultivate only one cultivar in the orchard, with the numerous well known advantages (Dicenta *et al.*, 2000) and neither inconvenience (Dicenta *et al.*, 2002a; Ortega *et al.*, 2002, 2006) for almond production. Other evaluated traits were high productivity, good size of the seed, lack of double kernels and resistance to fungus diseases.

Since 1995, we focused the objectives to delay more and more the flowering time in order to avoid the late frosts and let the growers cultivate of almond in the traditional areas and in new colder areas, without any risk of lost of production by frosts.

II – Materials and methods

As pointed out above, progenitors used in our Breeding Programme have been very diverse, from autochthonous cultivars well adapted to arid conditions (but early flowering and self-incompatible) to foreign late-flowering and self-compatible cultivars. Nowadays most of progenitors we are using are ourselves selections.

The methodology to obtain the descendants is the classical in cross breeding programs:

- (i) Selection of the male and female progenitors.
- (ii) Extraction of pollen of the male progenitor.
- (iii) Emasculation and pollination of the female progenitor.
- (iv) Harvest of mature fruits obtained.
- (v) Germination of seeds by stratification.
- (vi) Establishment of the nursery.
- (vii) Planting the young trees in the experimental orchard.

From several years ago, we apply the early selection using molecular markers (MAS) for self-compatible genotypes by PCR of S-RNase alleles in the nursery (Ortega and Dicenta, 2003, 2004), so only the self-compatible genotypes are taken to the experimental orchard.

Three years later, trees come into bearing and they are evaluated for different traits:

- (i) Blooming date (Julian days when 50% of flowers were opened).
- (ii) Blooming density (scored between 0 = null and 5 = maximum).
- (iii) Productivity (scored between 0 = null and 5 = maximum).
- (iv) Ripening date (Julian days when 95% of fruits had their mesocarp opened).

The fruit and kernel traits usually studied are:

- (i) In-shell weight (g).
- (ii) Shell hardness (scored between 1= very soft and 5= very hard, by cracking with a hammer).
- (iii) Kernel weight (g).
- (iv) In-shell/kernel ratio (%).
- (v) Empty nuts (%) (nuts without kernels).
- (vi) Double kernels (%) (two deformed kernels in the same nut).
- (vii) Kernel thickness (scored: 1.flat, 2.intermediate, 3.globose).

(viii) Kernel shrivelling (scored: 1.smooth, 2.intermediate, 3.wrinkle).

(ix) Pellicle colour intensity (scored between 1= very light brown and 5= very dark brown).

(x) Kernel bitterness (by tasting some almonds by two people, classifying each genotype as sweet, slightly bitter or bitter).

(xi) Susceptibility to fungus diseases (scored between 1= very resistant 5= very susceptible).

Since the beginning of the Almond Programme, more than 12,000 seedlings have been obtained and evaluated.

III – Results and discussion

In 1995, we released the cultivars Antoñeta and Marta almonds, which fit most of the objectives established.

- *Antoñeta* is self-compatible and late-flowering (close to Ferragnès) with a great vigour and productivity (Egea *et al.*, 2000). The ramification is abundant and its habit a little drooping. The kernel is very big and attractive, with a very clear tegument.

- *Marta* is also self-compatible and late-flowering (a little earlier than Ferragnès). It has a greater vigour than Antoñeta and is very productive (Egea *et al.*, 2000). The ramification and the habit are intermediate. The kernel is also very attractive.

In 2007 we released the cultivars Penta and Tardona (Table 1).

Table 1. Main traits of Penta and Tardona almonds

Characteristic	Penta	Tardona
Pedigree	S5133 [†] × Lauranne	S5133 [†] × R1000 ^{††}
Self-compatibility	Yes	Yes
S-genotype	S ₂ S _f	S ₅ S _f
Flowering time	Ferragnès + (10 to 20 days)	Ferragnès + (20 to 30 days)
Ripening time	Early	Intermediate
Kernel weight (g)	1.0	0.8
Percentage of kernel	27	25
Shell hardness	Hard	Hard
Double kernels	0%	0%
Empty nuts	0%	0%
Ramification	Intermediate	Dense
Growth habit	Intermediate	Intermediate
Resistance to diseases	Intermediate	Intermediate

[†]S5133 is a late-flowering self-incompatible selection of CEBAS-CSIC.

^{††}R1000 is a late-flowering self-compatible French selection coming from Tardy Nonpareil × Tuono.

- *Penta* is self-compatible. It flowers between 10 and 20 days after Ferragnès (depending on years and areas). It has a percentage of kernel of 27% and a kernel weight of 1 gram. It has not double kernels and it matures very early (Fig. 1).

- *Tardona* is also self-compatible. It flowers between 20 and 30 days after Ferragnès. It has a percentage of kernel of 25% and a kernel weight of 0.8 gram. It has not double kernels and it matures intermediate (Figs 1 and 2). As far as we know, is the latest flowering almond cultivar in the world.

Penta



Tardona



Fig. 1. Nuts and fruits of Penta and Tardona.



Fig. 2. Fruits of Ferragnès and flowers of Tardona in Santomera. This year Tardona flowered 41 days after Ferragnès.

The four cultivars were bagged before flowering to check their ability to produce almonds in absence of bees, and the fruit sets were very high. However, we recommend putting beehives in the orchard (not only for our cultivars but for all the self-compatible or incompatible cultivars).

We think that these self-compatible extra-late almond cultivars will allow the culture of almond in solid orchards, in areas where nowadays production is usually lost because of late frost, and also in new inland colder areas where the almond culture was unthinkable because of frosts.

The four cultivars are protected and numerous nurseries under license of CSIC are propagating these cultivars.

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