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J.M. Alonso Segura[1,*], R. Socias i Company[1], O. Kodad[1], J.L. Espada Carbó[2], J. Andreu Lahoz[2] and J. Escartín Santolaria[2]

[1]Centro de Investigación y Tecnología Agroalimentaria de Aragón,
Avda. Montañana 930, 50059-Zaragoza (Spain)
[2]Unidad de Tecnología Vegetal, Consejería de Agricultura, DGA
Avda. Montañana 930, 50059-Zaragoza (Spain)
*e-mail: jmalonsos@aragon.es

Abstract. Almond growing is lately increasing in Spain due to higher kernel prices and better orchard management techniques, making this crop more profitable and attractive. In addition, the release of more productive, extra-late blooming and fully autogamous cultivars, is allowing the shift of almond growing to inland areas with colder climates. The release of new cultivars must be based on their agronomic behavior under different climatic conditions. Consequently, the performance of the last commercial CITA almond cultivars ('Guara', 'Soleta', 'Isabelona', 'Diamar' and 'Vialfas') and some breeding selections ('G-3-3', 'G-3-4', 'G-5-25', 'G-2-22' and 'I-3-67') was studied in a trial at the "AFRUCCAS Experimental Fruit Farm" near Caspe (Zaragoza, Spain). The trial was established in 2005 at a distance of 6 x 7m on the peach x almond INRA GF-677 rootstock. Scions were grafted in 2006 and the trees were trained as free open vase and managed under usual commercial requirements and drip irrigation. Phenology, vigor, production, fruit and orchard parameters were controlled to ascertain the agronomical performance of each cultivar or selection. The success of any cultivar not only depends of the accuracy of the breeder's selection, but also its adaptability must be ascertained to be recommended in a specific region.

Keywords. *Prunus amygdalus* – Plant material – Production – Shelling percentage – Vigor – Adaptability.

Comportement des variétés d'amandier et de quelques sélections élite d'amélioration génétique du CITA

Résumé. *La production d'amandier ha récemment augmentée en Espagne. Les prix plus élevés de l'amande et l'amélioration des techniques de culture rendent cette production plus attractive et rentable. En plus, l'obtention de nouvelles variétés de fleuraison très tardive, complètement autogames et très productives ont permis l'introduction de cette culture aux zones d'intérieur de climat plus froid. L'enregistrement d'une nouvelle variété doit être basée sur son comportement agronomique dans différentes conditions climatiques. Par conséquent, le comportement agronomique des dernières variétés commerciales d'amandier du CITA ('Guara', 'Soleta', 'Isabelona', 'Diamar' and 'Vialfas') et de quelques sélections élite ('G-3-3', 'G-3-4', 'G-5-25', 'G-2-22' et 'I-3-67') a été étudié sur une parcelle expérimentale d'AFRUCCAS, près de Caspe (Saragosse, Espagne). La plantation des porte-greffe hybrides amandier x pêcher INRA GF-677 a été fate à une distance de 6 x 7 m en 2005. Les variétés ont été greffées en 2006, les arbres ont été formés comme vase libre ouvert et maintenus selon les pratiques commerciales normales à la région avec un système d'irrigation goutte-à-goutte. On a contrôlé la phénologie, le vigueur, la production, la productivité et les paramètres du fruit pour déterminer le comportement agronomique de chaque variété. Le succès d'une variété ne dépend pas seulement de la précision de la sélection de l'améliorateur, mais aussi son adaptabilité à une zone spécifique doit être évaluée pour déterminer sa convenance.*

Mots-clés. Prunus amygdalus *– Matériel végétal – Production – Rendement – Vigueur – Adaptabilité.*

I – Introduction

Since the beginning of almond research in Zaragoza in 1966, the most important problem detected in Spanish almond (*Prunus amygdalus* Batsch) growing was its low productivity attributable to the occurrence of frosts at blooming time or later, to deficient pollination, and to drought, because almond was mostly grown in rainfed conditions (Felipe, 2000). As a consequence, the main objective the CITA almond breeding program was the development of late-blooming and self-compatible cultivars. For more than 30 years, crosses between Spanish and foreign varieties were made with the aim of incorporating these and other interesting traits. 'Tuono' and 'Genco' were used as donors for self-compatibility, 'Titan' for late blooming, 'Desmayo Largueta', 'Marcona' and 'Belle d' Aurons' for fruit quality, 'Bertina' for fruit size and late blooming, 'Forastero' for disease resistance, etc. (Socias i Company *et al*., 2010). As a result, a series of successful cultivars have been released, including 'Guara', probably the plant cultivar of the highest success in Spanish agriculture, and, more recently, 'Belona', 'Soleta', 'Mardía', and 'Vialfas', now under evaluation for the Community Plant Variety Office.

Worldwide almond demand has been increasing during the last years. Additionally, some works reported that a regular almond consumption may protect against risk of heart disease and diabetes (Spiller *et al*., 1992; Hyson *et al*., 2002). The rise of the almond kernel price, as well as the possibility of high crop mechanization, has turned almond growing into a very attractive activity. New plantings have caused the almond plant stock-out at the nurseries. A high percentage of the new Spanish plantings is made with the new releases from the Spanish almond breeding programs (Socias i Company *et al*., 2011). The introduction of these new varieties has probably influenced the increase of the Spanish almond yield. On the other hand, the significant advancement in the delay of the blooming date, in addition to the current high crop profitability, is allowing an important shift of almond culture towards inner cereal areas of Spain, of colder climate, where traditional almond cultivars are not productive due to continuous crop losses by the high incidence of spring frosts.

The perfect cultivar does not exist. As a consequence, the release of a new cultivar is a great responsibility due to the high investment required for a new orchard. Any breeding program stresses the objectives of autogamy and late blooming, but also includes fruit quality, kernel composition in nutritious and healthy compounds, as well as resistance to pests and diseases. However, the final selection has to be based on the results of agronomic trials under different climatic conditions to ascertain the adaptability and agronomic performance of the candidate selection.

Consequently, this work represents an advancement of the results of an evaluation trial with the last commercial CITA almond cultivars and elite selections. This trial was proposed by a farmer association, with the technical advice of the Aragon Government, in order to assess the performance of the new almond plant material in its specific region.

II – Materials and methods

A trial-collection of the CITA almond recent releases and new elite breeding selections was established at the AFRUCCAS (Association of fruit-tree farmers of Caspe) experimental farm in Caspe, NE Spain (41.16°N, 0.01°W). This area is characterized by cold winters with high chill accumulation, warm springs and very hot summers, resulting in early ripening for most fruit tree cultivars. The objective of this orchard was the assessment of the performance of the last commercial CITA almond cultivars ['Guara', 'Soleta', 'Isabelona' (syn. 'Belona'), 'Diamar' (syn. 'Mardía') and 'Vialfas'] and some breeding selections (G-2-22, G-3-3, G-3-4, G-5-25. and I-3-67) (Table 1) in order to obtain direct information about the adaptability of these genotypes to this growing area. The trial was established in 2005, planting the hybrid peach x almond INRA GF-677 rootstocks at a distance of 6 x 7m. In the spring of 2006 the rootstocks were randomly grafted with the almond scions having finally six trees by genotype. The trees were trained as free open vase and managed under drip irrigation. The soil of the plot has an average depth of 1.5 m and is of sandy-loam type, being classified as calcic haploxerept, fine loamy, mixed, thermic (Soil Survey Staff, 2006).

Table 1. Origin, blooming date and harvest date of the studied plant material

Genotype	Pedigree	Blooming date	Harvest date
'Guara'	Unknown	4 March ± 7days	24 August ± 8 days
'Soleta'	'Blanquerna' x 'Belle d'Aurons'	1 March ± 7days	13 September ± 6 days
'Isabelona'	'Blanquerna' x 'Belle d'Aurons'	28 February ± 8 days	28 August ± 6 days
'Diamar'	'Felisia' x 'Bertina'	18 March ± 9 days	4 September ± 5 days
'Vialfas'	'Felisia' x 'Bertina'	15 March ± 7 days	2 September ± 8 days
G-2-22	'Felisia' x 'Bertina'	10 March ± 13 days	30 August ± 10 days
G-3-3	'Felisia' x 'Bertina'	15 March ± 6 days	7 September ± 7 days
G-3-4	'Felisia' x 'Bertina'	14 March ± 7 days	3 September ± 4 days
G-5-25	'Felisia' x 'Bertina'	14 March ± 8 days	10 September ± 5 days
I-3-67	'Felisia' x 'Moncayo'	26 February ± 9 days	5 September ± 5 days

The orchard was managed according to the normal cultural practices of the region: Irrigation was applied daily with an automated drip system with two laterals per tree row, located at 0.5 m from the rows, with self compensating emitters of 4 L h^{-1} spaced at 1 m. Irrigation water was pumped directly from the Mequinenza reservoir of the Ebro River. Soluble fertilizers were applied with the irrigation system along the whole season. The fertilizer amount per year included 80 kg ha^{-1} of N, 30 kg ha^{-1} of P_2O_5 and 120 kg ha^{-1} of K_2O according to Espada (2009).

Each tree was individually harvested when the genotype had more than the 70% of open mesocarps. For the seasons 2009-2014, fresh yield was weighted in the orchard, and a sample of 200 whole fresh fruits per tree was collected for further analysis. Once in the laboratory, mesocarps (hulls), endocarps (shells) and seeds (kernels) were separated and keep in a heater at 45ºC till constant weight. Fresh and dry weights of whole and shelled nuts and kernels were obtained for every year of study. Percentages of kernel from whole and from shelled nuts were calculated from these weights (Table 2).

Vigor was determined as the trunk cross sectional area (TCSA, cm^2). TCSA was calculated after harvest from the perimeter value measured at 30 cm above the soil surface. TCSA was calculated assuming a circular cross sectional area of the trunk. Tree productivity was expressed as the accumulated weight of the kernel yield (g of dry matter) divided by TCSA (g cm^{-2}) at harvest time.

Statistical analysis was performed using Analysis of Variance (ANOVA) and General Linear Model (GLM) procedure of the SAS 9.1 software (SAS Institute, 2004). Comparisons among genotypes were performed using Duncan test at $P = 0.05$.

III – Results and discussion

All almond genotypes studied showed kernel percentages (in relation to the whole fruit weight) from 19 to 28%, and shelling percentages from 25 to 35% (Table 2). 'Guara' showed the highest percentages for both cases. A high kernel percentage contributes to improve the crop input transformation, such as water and fertilizers (Alonso *et al*., 2012).

Vigor measured has ranged between 326 and 166 cm^2. 'Soleta' was the most vigorous genotype whereas 'Vialfas' was the less vigorous, with half of the 'Soleta' TCSA. Presumably, vigorous and productive genotypes are more suitable for wide planting distances in high potentially growing conditions, whereas less vigorous and productive genotypes show better adaptation to reduced planting distances, even in high density plantings, or in more limiting growing conditions.

'Guara' and selection I-3-67 showed the highest accumulated yields and, with 'Vialfas', the highest productivities. These data corroborate that selection I-3-67 could be a firm candidate to be registered as suitable for growing areas with low risk of spring frosts, and that 'Vialfas', the new ultra late blooming cultivar, showed an excellent adaptability not only for high late frost risk areas, but also for very low frost risk areas as is the case of this trial.

The success of any cultivar not only depends on the accuracy of the breeder's selection, but also its adaptability must be ascertained to be recommended with success in a specific region, as shown with the results obtained in this trial.

Table 2. Vigor, kernel percentage, accumulated yield and productivity showed by the different CITA releases and elite selections

Genotype	Vigor TCSA (cm^2)	Kernel percentage: Whole nut	Kernel percentage: Shell almond	Accumulated yield (2009-2014) Unshelled nut: kg/tree	Unshelled nut: kg/ha	Kernel: kg/tree	Kernel: kg/ha	Productivity (g/cm^2)
'Vialfas'	166.2 e	20.4 b	25.3 c	56.6	13,479 bc	14.3	3,397 b	85.9 a
G-3-4	199.4 de	19.4 b	24.9 c	26.9	6,407 g	6.7	1,594 e	33.6 d
G-3-3	203.1 de	20.9 b	26.5 bc	35.5	8,444 efg	9.4	2,243 de	46.4 c
'Mardía'	215.9 cde	21.0 b	24.9 c	40.2	9,575 def	10.0	2,376 cd	46.2 c
G-5-25	219.6 cde	20.4 b	25.0 c	59.2	14,098 bc	14.8	3,517 b	67.3 b
G-2-22	255.9 bcd	19.6 b	24.9 c	33.7	8,030 gf	8.4	2,001 de	32.9 d
I-3-67	258.7 bce	23.2 b	29.3 bc	76.7	18,249 a	22.5	5,350 a	86.9 a
'Guara'	275.8 abc	28.4 a	35.8 a	66.4	15,792 b	23.8	5,654 a	86.1 a
'Belona'	303.0 ab	22.4 b	28.4 bc	45.4	10,810 de	12.9	3,060 bc	42.4 cd
'Soleta'	326.3 a	22.5 b	30.0 b	54.3	12,919 cd	16.3	3,877 b	49.9 cd

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