‘H15’, an *Almagro*-type Pickling Eggplant with High Yield and Reduced Prickliness

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Pickling eggplants (*Solanum melongena* L.) are locally important in some areas of the Mediterranean region, Middle East, China, Korea, Japan, India, and southeastern Asia (Inden et al., 1999; Muñoz-Falcón et al., 2009). However, the breeding efforts devoted to the improvement of pickling eggplants have been limited, and these types of crops have been largely overlooked by the public and private breeding programs. This is mainly the consequence of the smaller acreage devoted to the production of pickling eggplants when compared with that of eggplants for the fresh vegetable markets or for the industrial preparation of frozen foods or dehydrated products. Also, the value of the harvest per individual plant is much lower than that of other varietal types of eggplants, like the hybrids for greenhouse production.

Consequently, the plant materials used for elaborating pickling eggplants usually consist of local landraces, which have been selected and conserved by the farmers (Muñoz-Falcón et al., 2009).

In Spain, pickling eggplants are produced in several areas in the center and south of the country. The most important area for the production of this type of eggplants is the region of the Campo de Calatrava, situated in the province of Ciudad Real, in the center of Spain. This region is home of the so-called *Almagro* (in reference to the city of Almagro, capital of the region of Campo de Calatrava) pickling eggplant, which is the only eggplant produce officially recognized in Europe with a Protected Geographical Indication (PGI) status, which was granted in 1994 (Castro, 2005). The acreage devoted to *Almagro* eggplant production is ≈60 ha and the total annual production oscillates between 1500 and 2000 tons. The final value of the *Almagro* eggplant produce in the market is ≈\$6 U.S. per 10⁶.

The *Almagro* pickling eggplant is grown in the open field during the summer growing season in fields that normally have been in fallow during the winter season after a previous winter or spring cereals crop. Because of the ample availability of land, farmers typically do not repeat the eggplant crop in the same land for 10 or 15 years, and most of the *Almagro* eggplant fields are isolated from other eggplant or vegetable crops fields, which results in a very low incidence of pests and diseases. *Almagro* eggplant fruits are harvested when very young, aged only ≈2 weeks after pollination, and are characterized by having fruits covered by a large and edible

acrescent calyx. After the pickling process, which involves fruit (including the berry, calyx, and part of the fruit pedicel) boiling, natural fermentation for several days, and canning in a brine solution (Ballesteros et al., 1999; Seseña and Palop, 2007), *Almagro* eggplant fruits have a green or golden color and a firm texture of the flesh, the latter being one of the most remarkable characteristic features of this variety (Seseña et al., 2001) and which differentiates it from other pickling varieties of Spain, like those of the neighboring region of Andalusia (*Andalusian* pickling eggplant), which have a softer internal texture after the pickling process.

One of the most important deficiencies of the *Almagro* eggplant landrace is the prickliness of the fruit calyx, which hampers the harvesting of the fruits, damages the fruits during the postharvest processing as a result of the pricks to the berries, and also makes the manual removal of the calyx prickles necessary before the pickling process. Prickliness of the calyx not only involves a greater demand of labor for removing the prickles, but, occasionally, some fruits for which the prickles have not been completely removed may go through the industrial process, which affects negatively the appearance of the final produce. Finally, prickliness increases the risk of injury by pricks of the workers during the harvesting and removal of prickles. Because of this, *Andalusian* pickling eggplants, which have a lower prickliness, although they give a lower quality of the pickles, have been introduced by some farmers in the *Almagro* region.

Farmers growing the *Almagro* eggplant usually produce their own seeds, which makes the *Almagro* eggplant a diverse landrace amenable to selection (Muñoz-Falcón et al., 2009). The goal of this research was to take advantage of this diversity to develop a selection of *Almagro* eggplant that, compared with the *Almagro* eggplant landrace, maintains the typical plant and fruit characteristics, has reduced prickliness, higher yield, and maintains the high-quality standards of the original landrace. The result of this selection program has been line ‘H15’.

Origin

The participatory selection program that led to the development of ‘H15’ began in 2004. A team formed by breeders, farmers, local industrialists, and staff from the *Almagro* eggplant PGI Council visually screened for prickliness and fruit characteristics thousands of individual plants growing in the fields of different farmers in the Campo de Calatrava region. Twenty-seven selected individual plants displaying low prickliness were pruned, uprooted, and carried to Valencia, where each of them was transplanted into a 25-L pot and grown in a greenhouse. Self-pollinated offspring of the selected plants were grown during the following season in farmers’ fields in the Campo de Calatrava region. Most offsprings were homogeneous, and the few heterogeneous offsprings were discarded. In this respect, although the

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eggplant is mostly autogamous, a variable rate of cross-pollination occurs, especially under open-field conditions (Daunay, 2008; Pessarakli and Dris, 2004). A participatory selection among homogeneous offspring originating from different individual plants was performed for low prickliness, high yield, and plant and fruit characteristics typical of the *Almagro* landrace. This led to the selection of several promising lines that were subsequently characterized, tested for agronomic performance in more extensive plots in farmers' fields, and evaluated for pickling quality. Seed increase of the lines was always performed by self-pollination under greenhouse conditions in Valencia. 'H15' is the final selection of this process and originates from the selfing of an individual plant selected in 2005 in one of the *Almagro* eggplant farmers' fields.

Description

The plant of 'H15' has a semierect habit with purple stems and a strong anthocyanin intensity in the shoot tip (Fig. 1). The stem and leaves are not prickly and have purple veins. The inflorescences have from one to five flowers with a mean number of 2.7 flowers per inflorescence. Flowers have a white and pale blue corolla, and all flowers are functionally hermaphroditic. Contrarily to what occurs with many large-fruited eggplants, fruit setting of the basal flower of the inflorescence does not inhibit the setting of the distal brevistyled flowers from the inflorescence, which behave as functionally

hermaphroditic, and infrutescences with multiple fruits are common (Fig. 1).

The berry of 'H15' is oblong with a length/width ratio of ≈ 1.5 (Table 1), and although it can grow to more than 25 cm long when left on the plant until reaching its full size, to be used for pickling, it should be harvested when it has a length of 4 to 9 cm and a fruit weight of 40 to 60 g (Fig. 2). At this stage, the pedicel length varies between 9.5 and 12 cm long and it is slender and smooth in the proximal part (Table 1; Fig. 3). This trait clearly distinguishes the 'H15' eggplant from other morphologically similar pickling eggplants native to other regions of Spain, like those of Andalusia, which display a wider and rougher proximal part of the fruit pedicel. At the stage of harvesting, the acresent calyx covers all or most of the berry (Table 1), a trait required for the elaboration of *Almagro* pickling eggplant. The calyx is purple and green in color and presents reduced prickliness when compared with the original *Almagro* landrace (Table 1; Fig. 4). The berry is green in color in the area covered by the calyx and purple in the area exposed to the sun, indicating that, like the *Almagro* landrace, 'H15' is homozygous for the dominant alleles of the *A* (fruit anthocyanin presence) and *G* (fruit chlorophylls presence) genes as well as for the recessive alleles of the *Gv* (reticulated pattern of chlorophyll) and *Puc* (purple under calyx) genes (Daunay et al., 2004; Tigchelaar et al., 1968).

Characterization data using primary descriptors from EGGNET (Eggplant Genetic Resources Network; EGGNET, 2005; Prohens et al., 2005; van der Weerden and Barendse, 2007) shows that 'H15' is morphologically very similar to the *Almagro* landrace used by the farmers, except for a lower prickliness of both the leaves and fruit calyx (Table 1). Morphologically, 'H15' can also be distinguished from other Spanish pickling eggplants from the neighboring region of Andalusia for having smaller leaves (shorter leaf petiole, leaf blade length, and width) and smaller corolla, and also for some fruit traits, it has lower calyx anthocyanin pigmentation, shorter fruit pedicel length, smaller fruit pedicel width at the proximal end, and with a higher length/width ratio (Table 1).

The fruit of 'H15' had a soluble solids content of 5.5% to 6.3%, a pH of 5.4 to 5.8, and an ascorbic acid content of 15 to 23 mg·kg⁻¹. Values for these traits do not differ

significantly from those of the *Almagro* and *Andalusian* landraces. As is general with the *Almagro* eggplant landrace, 'H15' presents a high content in antioxidant phenolic compounds (0.7 to 0.9 g·kg⁻¹ of fresh weight), and because of this, it represents a source of variation for breeding programs aimed at increasing the phenolic acid content of eggplant (Prohens et al., 2007; Stommel and Whitaker, 2003).

Molecular characterization with 36 simple sequence repeats has shown that 'H15' clusters with other *Almagro* eggplant materials and also that it is genetically differentiated from the *Andalusian* pickling eggplant landrace. 'H15' is homozygous for the allele 206 for the EM127 marker and the allele 360 for the EM145 marker. These alleles are specific to the *Almagro* eggplant landrace and are used as diagnostic markers to distinguish *Almagro* eggplants from other Spanish pickling eggplants (Muñoz-Falcón et al., 2009).

Performance

Fruit production of 'H15' was compared with those of the local *Almagro* landrace materials used by the farmers and with high yield and low prickliness (but low quality) *Andalusian* pickling eggplant landrace materials for 3 years (2006 to 2008) in multi-location replicated trials in fields of farmers associated with the PGI *Almagro* eggplant. Results consistently have shown that 'H15' had a high yield with an average yield across the 3 years of trials of one-third higher than the original *Almagro* landrace and almost 20% higher than the *Andalusian* landrace (Table 2).

Regarding prickliness, 'H15' shows much lower fruit calyx prickliness than the materials of the local *Almagro* landrace used by the farmers (Table 2; Fig. 4). In all the trials done, the average degree of prickliness of 'H15' ranged between 1.2 and 1.4, whereas for the *Almagro* eggplant it ranged between 1.8 and 2.0. This represents an important advance, although the *Andalusian* landrace, with a degree of prickliness ranging between 0.4 and 0.6, is less prickly than 'H15' (Table 2).

Fruit quality of the pickled fruits of 'H15' was compared with those of the *Almagro* landrace used by the farmers as well as with the *Andalusian* pickling landrace. Samples of each of the materials were boiled, naturally fermented, and pickled using the traditional

Fig. 1. Young plant (A) and older plants showing inflorescences of 'H15' (B) with abundant flowering and fruit setting. The rectangular plate of the T-label plate stake measures 9.4 × 5.4 cm.

Table 1. Mean and range for fruit morphological traits of 'H15' and of the *Almagro* and *Andalusian* landraces obtained from five characterization trials performed in 3 years (2006 to 2008).

	H15	<i>Almagro</i> landrace	<i>Andalusian</i> landrace
Fruit pedicel length (cm)	10.3 (9.5–11.8)	9.6 (8.5–10.8)	9.2 (8.0–10.5)
Fruit pedicel diameter at the proximal end (mm)	7.2 (6.9–7.6)	7.5 (7.0–8.0)	10.8 (10.3–11.3)
Fruit pedicel diameter at the distal end (mm)	18.9 (18.4–19.4)	19.1 (18.4–19.9)	18.4 (17.7–18.8)
Calyx color ^a	4.1 (3.8–4.5)	4.4 (4.0–4.7)	5.7 (5.4–5.8)
Fruit area covered by the calyx (%)	75.3 (70.9–81.1)	73.4 (68.8–79.7)	89.1 (82.2–90.7)
Fruit length (mm)	63.7 (62.4–65.1)	62.1 (57.6–64.5)	60.8 (56.4–62.7)
Fruit width (mm)	41.8 (41.1–42.8)	41.3 (40.0–42.3)	44.6 (43.2–45.1)
Fruit length/width ratio	1.53 (1.48–1.56)	1.50 (1.44–1.53)	1.36 (1.31–1.40)

^aMeasured on a 1 to 7 scale (1 = green; 7 = purple).

Fig. 2. Fruits of 'H15' at the harvesting stage, in which the acrescent calyx must cover all or a major part of the berry. The rectangular plate of the T-label plate stake measures 9.4 × 5.4 cm.

Fig. 3. Fruit pedicel of *Andalusian* pickling eggplant landrace (above) and of 'H15' (below). The pedicel of 'H15' is slender and smooth at the proximal end, whereas the *Andalusian* landrace is wider and rougher. Scale in centimeters.

Fig. 4. Differences in fruit calyx prickliness between 'H15' (left) and the *Almagro* landrace (right) grown under the same conditions.

method (Castro, 2005). They were scored for five traits by a trained panel for sensorial quality using a standard score tasting card for the *Almagro* eggplant, in which higher scores are better. Traits scored were: 1) color (0 to 20 points); 2) fruit conformation (1 to 5 points); 3) harmonious appearance (1 to 10 points); 4) firmness (1 to 10 points); and 5) texture (1 to 10 points). The organoleptic

Table 2. Performance of 'H15' and of the *Almagro* and *Andalusian* landraces at multilocation trials for yield (kg·m⁻²) and fruit calyx prickliness [measured on a 0 to 9 scale: 0 = no prickles; 1 = very few (less than 3); 3 = few (≈5); 5 = intermediate (≈10); 7 = many (≈20); 9 = very many (greater than 30)].

	2006		2007		2008	
	Yield	Prickliness	Yield	Prickliness	Yield	Prickliness
H15	9.4 a ^z	1.2 b	6.3 a	1.4 b	5.7 a	1.3 b
<i>Almagro</i> landrace	6.0 b	2.0 a	5.8 ab	1.9 a	4.2 b	1.8 a
<i>Andalusian</i> landrace	7.9 ab	0.5 c	4.9 b	0.4 c	5.3 a	0.6 c

^zMeans within columns with different letters are significantly different ($P < 0.05$) according to the Student-Newman-Keuls test.

Table 3. Scores obtained by 'H15' and by the *Almagro* and *Andalusian* landraces in sensory quality tests performed in 2006 using a hedonic scale (lowest values = dislike; highest values = like) after being subjected to the traditional procedures of boiling, fermentation, and pickling according to color (0 to 20 points), fruit conformation (1 to 5 points), harmonious appearance (1 to 10 points), firmness (1 to 10 points), texture (1 to 10 points), and total score (4 to 55 points).

	Color	Fruit conformation	Harmonious appearance	Firmness	Texture	Total
H15	15.0 ab ^z	3.0 a	6.0 a	8.0 a	8.0 a	40.0 a
<i>Almagro</i> landrace	16.7 a	3.3 a	6.0 a	8.0 a	8.0 a	42.0 a
<i>Andalusian</i> landrace	13.8 b	3.3 a	7.0 a	5.3 b	4.0 b	33.3 b

^zMeans within columns with different letters are significantly different ($P < 0.05$) according to the Student-Newman-Keuls test.

tests showed that 'H15' does not differ significantly in quality traits from the *Almagro* landrace materials used by the farmers for any of the quality traits studied (Table 3). However, 'H15' had significantly better scores for firmness and texture than the *Andalusian* landrace materials.

In summary, 'H15' had a higher yield and lower prickliness than the *Almagro* landrace and maintains the same levels of quality for the processed pickled produce. Furthermore, 'H15' had a higher yield and better quality than the *Andalusian* pickling eggplant landrace. Consequently, 'H15' represents substantial improvement over the currently used plant materials.

Availability

Seeds of 'H15' for commercial use can be obtained through a concession agreement from the Asociación para la Promoción de la IGP Berenjena de Almagro, C/ Toledillo 59, 13260 Bolaños de Calatrava, Spain; e-mail: berenjenas@castillalamancha.es. Small samples of 'H15' seeds for research purposes are available from Jaime Prohens, COMAV, UPV, Camino de Vera 14, 46022 Valencia, Spain; e-mail: jprohens@btc.upv.es.

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