



## IDENTIFICATION OF QUANTITATIVE TRAIT LOCI USING NEAR-ISOGENIC LINES OF MELON. A RESEARCH REVIEW COVERING POTENTIAL APPLICATIONS IN FRUIT QUALITY

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### INTRODUCTION

During the last seven years, the fruit quality differences based on a collection of near-isogenic lines (NILs) of melon (*Cucumis melo* L.) obtained from a cross between the Spanish cultivar “Piel de Sapo” (PS) (Figure 1) and the exotic Korean accession “Shongwan Charmi” [SC (PI 161375)] (Figure 2) have been studied to identify the quantitative trait loci (QTL) related to the most important fruit quality traits for the consumer.



Figure 1. Spanish cultivar “Piel de Sapo” (PS, Inodorus Group) used as parental of the near-isogenic lines of melon (*Cucumis melo* L.).



Figure 2. Exotic Korean accession “Shongwan Charmi” [SC (PI 161375)], Conomon Group.



### MAPPING QTLs OF MELON FRUIT QUALITY

The systematic fruit quality analysis of NILs allowed the differences to be detected in comparison to PS as for weight, fruit shape (Figure 3), commercial aspect, texture, taste (content of sugar, organic acid and aroma volatile compounds), nutritional quality (ascorbic acid content) and sensorial evaluation (sweetness, taste, sourness, bitterness, overall fruit quality) (Moreno *et al.*, 2008; Obando *et al.*, 2008; Tijskens *et al.*, 2009; Obando-Ulloa *et al.*, 2009a; 2009b; 2009c), which can be understood as a high response to selection, due to their high heredability values. In addition, it allowed 109 QTLs associated to the improvement of fruit quality traits at harvest and postharvest, while other 146 QTLs showed the opposite effect. Any previous study had allowed such number of QTLs associated to melon fruit quality to be identified and in most of the cases QTLs associated to quality traits were rarely mapped neither in melon, in fruit with commercial purposes nor at the senescent stage (Obando-Ulloa *et al.*, 2009c).



Figure 3A. Non-climacteric near-isogenic lines (NIL) of melon at harvest. External aspect of line SC SC 12-4hb.

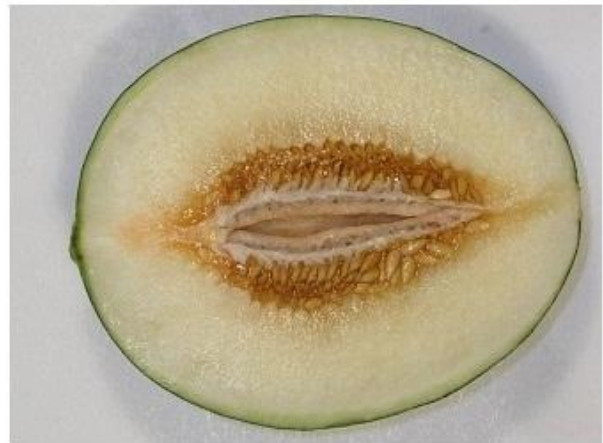


Figure 3B. Non-climacteric near-isogenic lines (NIL) of melon at harvest. Flesh of NIL SC8-1.

The study with the NIL's collection has also allowed multivariate statistical models to be performed (Obando-Ulloa *et al.*, 2009c) as well as new models of biologic variance applied to texture (Tijskens *et al.*, 2009).



Figure 4. Near-isogenic line SC8-3 at harvest containing a QTL in LGVIII that increase fruit length.

From the breeding and the commercialization point of view, the QTLs that showed an effect on the lightness of skin and flesh colour (Figure 4), the extractable juice, the whole fruit longitudinal section area and skin netting might contribute to develop new lines to satisfy the increasing demand of good quality and high nutritional value fruits by consumers (Obando *et al.*, 2008; Obando-Ulloa *et al.*, 2009a). On the other hand, from the point of view of either juice, drinks and spirit cannery or the flesh processing industry, including the fresh-cut processing, the QTLs related to extractable juice alone or in combination with the morphological traits mentioned above might be important according to the particular use. Although, the QTLs that improved the flesh area or diminished the fruit placental section might be useful to develop fruit oriented either to the mechanical



processing or to produce varieties for the purée industry and the fact to develop a variety with a higher flesh proportion might improve the fresh process or canning productivity. In addition, the QTLs related to fruit shape and weight are useful to improve the round shape of the commercial varieties of melon with the purpose to modify its aptitude for transportation, processing and consumer acceptance, etc (Obando *et al.*, 2008). Some of these QTLs have also shown a double interaction with environment, such as the ones planted in Cartagena which have certain internal quality traits (soluble solids) higher than the others cultivated in other places (Eduardo *et al.*, 2007).

On the other hand, the QTL mapping allowed one QTL to be identified in the III linking group, which could be related to the climacteric behaviour with pleiotropic effects on the aroma volatile compounds (Obando-Ulloa *et al.*, 2008) and the sensitivity to chilling injury (Fernández-Trujillo *et al.*, 2007 and 2008; Figure 5), which is useful for the postharvest physiologists to understand either the climacteric pattern or the cold storage behavior, the synthesis of aroma and the relationship between aroma and ethylene production. A climacteric line developed from non-climacteric parental was never identified before, but it together with the NILs and sub-NILs with these characteristics were studied by Obando-Ulloa *et al.* (2008; 2010). In addition, this finding will help to develop non-climacteric cultivars with similar behavior, but aromatic, which could be used in the fresh cut industry in a more efficient way instead of mixing cultivars with different climacteric behavior, as it has always done up to now in the industry.



Figure 5. Chilling injury in near-isogenic line SC9-3 after 35 d at 8°C.

It was possible to map QTLs related to the physiological alterations in preharvest, harvest and postharvest stage (cold storage) for the first time. It also allowed the identification of new alterations such as internal necrosis of the placental tissue of melon as well as the QTLs related. It was also possible to identify QTLs related to the vitreous texture (vitrescence, water-soaking) of melon, one of the main problems of internal quality, as well as the susceptibility to certain moulds and physiological alteration of commercial concern (Fernández-Trujillo *et al.*, 2007; 2008; Martínez *et al.*, 2009). In this way, the QTL related to the climacteric behavior might also induce a high susceptibility to scalding, a common kind of chilling injury in cold stored melon.

These works have established the first aroma profile of “Piel de Sapo” melons, as well as their links with other commercial cultivars and some hybrid of this kind and its relationship with fruit senescence (Obando-Ulloa *et al.*, 2008; 2009b; 2010). In this study, it was the first time some QTLs related to some aroma volatile compounds of this kind of melon have been mapped.

### POTENTIAL APPLICATIONS AND PERSPECTIVES

The usefulness of this model system of NILs for physiology and postharvest studies and for the gene mapping in the future have been proved. For example, it has been shown very valuable to demonstrate the presence of ethylene dependent and independent compounds during the ripening of melon.

In general, the identified QTLs are more flexible for the breeding companies, in cooperation with the industry, to develop new cultivars for specific purposes based on the consumer’s interest or to distinguish products in a specific niche market. In addition, the NILs can be considered as a potential tool and a model system for studies on horticulture, postharvest, etc. (Eduardo *et al.*, 2007, Obando *et al.*, 2008; Fernández-Trujillo *et al.*, 2008).

The team is under continuous renewal and with two new projects is in the process of new research



and publications covering other melon quality traits and different aspects of melon postharvest physiology (climacteric behavior, texture, nutrients, aroma volatiles, etc.) and modelling postharvest ripening. Some of the results will be disseminated concerning traits with interest for climacteric behavior and nutritional quality, fresh-cut processing and modelling of different QTLs associated with quality traits.

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### LITERATURE CITED

- EDUARDO, I., ARÚS, P., MONFORTE, A.J., FERNÁNDEZ-TRUJILLO, J.P., OBANDO, J., MARTÍNEZ, J.A., ALARCÓN, A., ÁLVAREZ, J.M. and VAN DER KNAAP, E. (2007). Estimating the genetic architecture of fruit quality traits in melon (*Cucumis melo* L.) using a genomic library of near-isogenic lines. *Journal of the American Society for Horticultural Science*, 132: 80-89.  
<http://journal.ashspublications.org/cgi/reprint/132/1/80?maxtoshow=&hits=10&RESULTFORMAT=&author1=obando&andorexactfulltext=and&searchid=1&FIRSTINDEX=0&sortspec=relevance&resourcetype=HWCIT>
- FERNÁNDEZ-TRUJILLO, J.P., OBANDO, J., MARTÍNEZ, J.A., ALARCÓN, A.L., EDUARDO, I., ARÚS, P. and MONFORTE, A.J. (2007). Mapping fruit susceptibility to postharvest physiological disorders and decay using a collection of near-isogenic lines of melon. *Journal of the American Society for Horticultural Science*, 132: 739-748. <http://journal.ashspublications.org/cgi/reprint/132/5/739?maxtoshow=&hits=10&RESULTFORMAT=&author1=obando&andorexactfulltext=and&searchid=1&FIRSTINDEX=0&sortspec=relevance&resourcetype=HWCIT>
- FERNÁNDEZ-TRUJILLO, J.P., OBANDO-ULLOA, J.M., MARTÍNEZ, J.A., MORENO, E., GARCÍA-MAS, J. and MONFORTE, A.J. (2008). Climacteric or non-climacteric behavior in melon fruit 2. Linking climacteric pattern and main postharvest disorders and decay in a set of near-isogenic lines. *Postharvest Biology and Technology*, 50: 125-134. <http://dx.doi.org/10.1016/j.postharvbio.2008.04.007>
- MARTÍNEZ, J.A., JOWKAR, M.M., OBANDO-ULLOA, J.M., MORENO, E., VARÓ, P., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2009). Uncommon disorders and decay in near-isogenic lines of melon and reference cultivars. *Horticultura Brasileira* (Brasilia), 27(4): 506-515. <http://dx.doi.org/10.1590/S0102-05362009000400017>
- MORENO, E., OBANDO, J., DOS-SANTOS, N., FERNÁNDEZ-TRUJILLO, J.P., MONFORTE, A.J. and GARCÍA-MAS, J. (2008). Candidate genes and QTLs for fruit ripening and softening in melon. *Theoretical and Applied Genetics*, 116: 589-602. <http://dx.doi.org/10.1007/s00122-007-0694-y>



OBANDO, J., FERNÁNDEZ-TRUJILLO, J.P., MARTÍNEZ, J.A., ALARCÓN, A.L., EDUARDO, I., ARÚS, P. and MONFORTE, A.J. (2008). Identification of melon fruit quality quantitative trait loci using near-isogenic lines. *Journal of the American Society for Horticultural Science*, 133: 139-151.

<http://journal.ashspublications.org/cgi/reprint/133/1/139?maxtoshow=&hits=10&RESULTFORMAT=&author1=obando&andorexactfulltext=and&searchid=1&FIRSTINDEX=0&sortspec=relevance&resourcetype=HWCIT>

OBANDO-ULLOA, J.M., MORENO, E., GARCÍA-MAS, J., NICOLAI, B., LAMMERTYN, J., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2008). Climacteric or non-climacteric behavior in melon fruit 1. Aroma volatiles. *Postharvest Biology and Technology*, 49: 27-37.

<http://dx.doi.org/10.1016/j.postharvbio.2007.11.004>

OBANDO-ULLOA, J.M., EDUARDO, I., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2009a). Identification of QTLs related to sugar and organic acid composition in melon using near-isogenic lines. *Scientia Horticulturae*, 121: 425-433. <http://dx.doi.org/10.1016/j.scienta.2009.02.023>

OBANDO-ULLOA, J.M., NICOLAI, B., LAMMERTYN, J., BUESO, M.C., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2009b). Aroma volatiles associated with the senescence of climacteric or non-climacteric melon fruit. *Postharvest Biology and Technology*, 52: 146-155.

<http://dx.doi.org/10.1016/j.postharvbio.2008.11.007>

OBANDO-ULLOA, J.M., JOWKAR, M.M., MORENO, E., SOURI, M.K., MARTÍNEZ, J.A., BUESO, M.C., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2009c). Discrimination of senescent fruit of climacteric and non-climacteric near-isogenic lines of melon by quality traits. *Journal of the Science of Food and Agriculture*, 89: 1743-1753. <http://dx.doi.org/10.1002/jsfa.3651>

OBANDO-ULLOA, J.M., RUIZ, J., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2010). Aroma profile of a collection of near-isogenic lines of melon. *Food Chemistry* 118: 815-822. <http://dx.doi.org/10.1016/j.foodchem.2009.05.068>

TIJSKENS, L.M.M., DOS-SANTOS, N., JOWKAR, M.M., OBANDO, J., MORENO, E., SCHOUTEN, R.E., MONFORTE, A.J. and FERNÁNDEZ-TRUJILLO, J.P. (2009). Postharvest fruit firmness behaviour of near-isogenic lines of melon. *Postharvest Biology and Technology*, 51: 320-326.

<http://dx.doi.org/10.1016/j.postharvbio.2008.06.001>

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