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THE EVOLUTION OF THE ALMOND CROP TECHNOLOGY - A REVIEW

Lucian CIOACĂ, Florin STĂNICĂ

Faculty of Horticulture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, 011464, Bucharest, Romania

Corresponding author email: cioaca_lucian@yahoo.com

Abstract

The almond (Amygdalus communis L.) is one of the first plants to be cultivated by man since prehistory. Often the almond is mentioned in the ancient religious texts, being appreciated for its tasty and healthy fruits, but also the plant as a whole is known as a symbol of hope. The Greeks and the Romans can be considered the first almond growers, spreading this species in their colonies. Nowadays, this crop evolved from solitary trees through the vineyards, to intensive orchards and more recently, to high and super high-density orchards. New resistant cultivars to specific climatic conditions, specific rootstocks, and technology contributed to the development of almond crop technology. In this review, we point out the evolution of the cultivation technologies for the almond crop with their specific characteristics like the planting density, the rootstock vigour, the cultivars specificity, the training, and the pruning systems, the irrigation, the soil management, the fertilizers, the plant protection, etc. This paper can be a useful tool for anybody interested in almond crop technology.

Key words*: Prunus dulcis, rootstock, cultivar, canopy, pruning system.*

INTRODUCTION

The almond (*Amygdalus communis* L.) is a deciduous tree native to South-West Asia. Almonds were collected into the wild, some 10,000 years ago, and were among the first plants to be domesticated by man, around the third millennium BC (Albala, 2009). The kernels are very nutritious and relatively non-perishable food, with many pharmaceutical uses, being among the medicinal plants to be prescribed and mentioned in the ancient books of medicine and religious texts.

This review is about the evolution of almond crop technology, from the beginning to present times.

Although not much written information succeeded until our days, about how the almond orchards were managed from the ancient times to the late modern period, there is clear evidence that in the Mediterranean basin and Asia, almonds were an important crop. Almond clonal propagation by grafting has been known since ancient Greek and Roman times, dating back to more than 2,000 years ago, from Columella (Batlle et al., 2017). Also, many important ancient medicinal texts from Hippocrates, to Charaka Samhita, Suśruta-saṃhitā, to the medieval period of Avicenna or Hu Sihui, or all the recipes mentioned in the ancient and medieval cookbooks like De re coquinaria, Kitab al-Tabikh, The forme of cury and others (Socias et al., 2017), indicates the importance of the almonds. It is important to state that the almonds are mentioned in Greek mythology, The Bible, The Torah, The Quran. In conclusion, almonds were and are an important part of human's life, in a socio-economic manner, spiritual, medicinal, culinary, art, etc. (Socias et al., 2017)

Little is known about how the almond orchards were managed in the past, that is why this paper will examine how the technology evolved in the last century.

The paper will try to examine the traditional, intensive, and super high density (SHD) almond orchard systems, with their particular-rities, and what differentiates them. What rootstocks and varieties are used for each orchard system, the planting distances, the type of training and pruning, how the pests and diseases, the soil and the row weeds are mana-ged, the irrigation system how the trees are fertilized and the fruits are harvested. Pointing out the different almond orchard systems, could offer a better understanding indicating how to choose this crop or another, a technology crop or the other, how a farmer can improve himself, etc.

At a worldwide level, in North America and Australia, this crop gained a lot of popularity among the farmers. In Europe, Africa, and Asia, the tendencies are recording a decrease of the cultivated surface, with several exceptions.

In Romania, the quantities produced and the land occupied by the almond crop also decreased in the last 30 years.

According to FAOSTAT (Figure 1), in the last twenty years, the almond production with shell doubled and the area harvested with almonds extended by 25%.

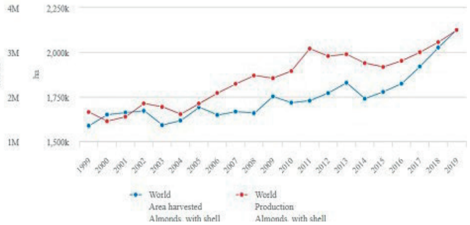

Figure 1. World production of almonds and the area harvested with almonds (1999-2019 period)

The most recent advances in the almond crop technology could represent an opportunity to disseminate information in the scientific world and farmers, that could lead to satisfying the Romanian market needs for almonds. Low vigor rootstocks, late and very late blooming cultivars, mechanical pruning, automatized irrigation systems, mechanical harvesting, and other advanced management practices could inspire the farmers to adopt this crop.

The review aims to highlight the new almond orchard systems and technologies.

MATERIALS AND METHODS

To achieve the goal there will be an extensive description of each crop technology taken into consideration, namely traditional, intensive, and super high-density almond orchards.

RESULTS AND DISCUSSIONS

Traditional almond orchards

The traditional almond orchards are to be found, in general, in Europe, Northern Africa, and Asia. The traditional almond orchards are included among "traditional agricultural landscapes", popular in the Mediterranean basin. The traditional agricultural landscapes are described by the use of land that has led to substantial changes to the original conditions, but has also maintained the functionality of the natural systems or has replaced it with other systems that are compatible with the local environmental conditions (Antrop, 2005).

Frattaroli et al. (2014), argues that in Italy, the traditional almond orchards were mixed, sometimes with olive trees, or were planted in a pure crop. The ones that were pure crop, are regular, with more than 50 trees per hectare, or irregular, with less than 50 trees per hectare. In Italy, it is still the most widespread almond crop technology (Sottile et al., 2014).

In Spain, some of the traditional almond orchards are also pastures for animals, as the Spanish call it "Dehesa de Almendros" (Font et al., 2010), or non-irrigated orchards with low-density planting distances like 8 m × 8 m or even wider, to make more efficient the use of the limited rainwater (Gradziel et al., 2017).

In the Middle East, generally, the almond grows under rain-fed conditions, water being hard to access resource.

In Romania, the almond growing zone is quite the same as the grapevine, that is why, traditionally, the almond trees are found through vineyards (Cociu, 2011).

In the traditional orchard system, the grafted almond trees were produced using seedlings as rootstocks (Cordeiro & Monteiro, 2002).

Most of the varieties used were local selections. The traditional almond orchards are characterrized by a low density, planting distances being 8 m x 8 m, or wider (Frattaroli et al., 2014).

The training and pruning are summary or not being done at all (Sottile et al., 2014). Pests and diseases control, soil management, inter or intra row weed management, in most of the cases, is not realized or is briefly done (Frattaroli et al., 2014). The trees are irrigated under rain-fed conditions and in most cases, are not fertilized. The harvest is done manually (Frattaroli et al., 2014).

The traditional almond growing system is less important for the profitability of this crop or the almond yields, but still, the almonds cultivated traditionally, are offering ecosystem services and producing fruits in deserted areas where not many fruit trees can live.

Intensive almond orchards

The intensive almond orchards are the most common ways this crop is cultivated worldwide. It is also the most widespread system for almond cultivation in Romania since all the recommendations are for wide-spacing planting (Cociu, 2011).

The development of the intensive almond orchards is correlated with the presence of the almond breeding programs, thus countries with important cultivated surfaces of intensive orchards had or have successful breeding programs. The recent almond breeding programs developed superior rootstocks and varieties, better adapted to local pedo-climatic conditions. In general, the breeding programs objectives varied from zone to zone. The main objectives of the almond breeding programs around the world were nut quality, late-blooming, self-compatibility, drought tolerance, resistance to different fungi, bacterial diseases, and insects, etc. (Segura et al., 2017).

Generally, the rootstocks used in the intensive almond orchards are GF-677, Garnem, Felinem, Nemaguard, seedlings, and others. In Romania, Felix and Tomis 1 are the rootstocks used (Şcheau, 2013).

A large number of varieties with commercial significance and different traits are being used, like Nonpareil, Texas, recently Butte and Monterey in the USA (Almond Board of California) and Nonpareil in Australia (Almond Board of Australia), Filipo Ceo, Tuono, and Cristomorto in Italy, Ferragnes and Ferraduel in France, Desmayo Largueta and Marcona, more recently Antoneta and Guara in Spain, Mărculeşti 3/51, Tohani 17, and more recently, Ana, April, Mirela and Veronica in Romania (Gavăt et al., 2015). Most of the varieties mentioned above are self-sterile, have an early or medium-late blooming, being frequently affected by the spring frosts, and need to be pollinated. Also, it is important to know the chilling and heat requirements of a variety, before choosing it for a new orchard (Gaeta et al., 2018).

In the last decades, it became a necessity to realize intensive orchards with self-fertile and late-blooming varieties like Tuono, Antoneta, Guara, and other varieties.

Planting distances in Europe are ranging from 8 m x 8 m to 5 m x 4 m, from 156 trees to 500 trees per hectare (Cociu, 2011), while in California the common distance is 7.3 m x 7.3 m or even wider (Hendricks, 1996).

The fruit trees canopy is trained as an open vase and most of the pruning is done manually, with the possibility to apply the topping pruning, mechanically (Cociu, 2011).

Pests and diseases are managed manually or mechanically by spraying pesticides, using pheromone traps, and other cultural practices (Perju, 2002). Regular monitoring of the pest populations can predict potential problems. Keeping records of the monitoring results will help forecast pest outbreaks and schedule cultural practices. Table and graphs of pest counts can help identify population patterns (Flint, 2002).

Soil management is done mechanically. The space between rows is maintained tilled or with cover crops like leguminous and other species. Ramos et al. (2010) argue that cover crops in semi-arid conditions improve soil quality, compared to frequently tilled managed soil by increasing the organic matter content, improving the chemical and physical fertility of the soil, and enhancing the soil biology activity, in a wide-spaced 7m x 14 m rainfed almond orchard. Becerra et al. (2010) point out that soil compaction resulting from tractor traffic, increases soil cone index and soil bulk density, decreasing soil porosity, indicating that almond orchard soil is unable to limit subsoil compaction under moderate traffic intensity. Weed control is realized with herbicides or mechanically by tilling with inter-row rotary harrow or hoe or other devices through tillage, burning/flaming the weeds, or mowing. Intra row weed control it's done with herbicides (Ludwig et al., 2020). A study about mulching as an alternative technique for weed management draws attention to black geotextile and almond husks as organic mulch, which are successful alternatives to glyphosate applications for managing weeds (Verdu & Mas, 2007).

Most of the intensive almond orchards are not irrigated in Europe, Africa, and Asia. Some researchers have demonstrated that regular deficit irrigation and sustained deficit irrigation are financially feasible alternative methods to full irrigation, in semi-arid zones where water price is higher and hard to obtain. These irrigation treatments could help farmers to preserve production levels while ensuring the feasibility of the almond plantation investment

(Alcon et al., 2013). It is worth adding that Lipan et al. (2019) observed that in regular deficit irrigation and sustained deficit irrigation, there aren't significant differences in the lipid and minerals content, moreover in some regular deficit treatments there were discovered higher fat, potassium, and unsaturated fatty acids content. Another study observed that during the 3-year experimental period and two successive cycles of harvest-period irrigation deprivation resulted in yield reductions that were associated with reduced shoot growth in severely watered stressed trees. The water stress did not influence flowering and fruit set on established spurs, nor did it accentuate the spur mortality (Esparza et al., 2001). In California, nearly 80% of the almond orchards are using micro-irrigation (Schwankl et al., 2017). Some authors argue that in some parts of the world the production increases exponentially about the amount of irrigation water, being able to reach 3,000 kg of kernels/ha.

Fertilization is a base practice in managing an intensive orchard. Fertilization is done by incorporating manure 30 to 40 tons per hectare, once every three to five years, and complex NPK fertilizers, every winter (Cociu, 2011). For the young orchards, it is recommended that the annual dose of NPK be distributed as follows: in the autumn, after the leaves have fallen, the full P dose, half of the K dose, and of ¼ the annual N dose. The rest it's applied in the spring, when the shoots start to grow, half of the N annual dose, and half of K annual dose. The rest of ¼ N, it's applied at the beginning of June, when the buds start differentiating (Davidescu & Davidescu, 1992). It is important not to apply higher doses than necessary of N, after sampling the soil and leaf status, because the susceptibility of hull rot increases (Saa et al., 2016). It has been demonstrated that boron is an important micronutrient that increases fruit set if applied before the flowering period of a plant (Hanson et al., 1985), in some cases the increase can reach 100% like in the case of sour cherry, with post-harvest and pre-bloom foliar boron fertilization (Hanson, 1991). Nyomora (1997) observed that the fruit set was increased by 130% and the yield by 53% for the Butte cultivar, after applying B in the fall.

Also, it is recommended to apply fertilizers along with the foliar spraying of pesticides.

The harvesting is done manually or mechanically. Mechanically is done by shakers, with at least two workers being used (Pascuzzi & Santoro, 2017). Shakers have the disadvantage of injuring the almond tree trunks during the harvest, which results in serious damage to tree vigour, health, and longevity. Injuries where the bark is crushed or torn from the trunk immediately attract a variety of insects, several of which are known vectors (Connell et al., 2005).

The intensive almond growing system is the most widespread and the first option when farmers choose to develop a new almond orchard. The initial investment, popularity, long-term certitude of the profitability, the evidence that others succeeded in realizing intensive orchards, etc., are important points of view when farmers choose not to risk applying newly developed technologies (Almond almanac, 2020). The intensive system's weaknesses are the necessity of specialized workers, trees training and pruning, harvesting, and so on. The need for irrigation in Europe, Asia, and Africa, on contrary, the excessive use of water in California for producing almonds became a state problem. The rootstocks and the varieties used, in many parts of the world, are pretty old and an advance towards renewing them would be a benefit for the production.

Super high-density almond orchards

The technology is advancing in horticulture and almond crop has known it recently, too.

Super high density (SHD) is said to be the future of the almond orchards. In the last decades, different researchers in Europe worked to develop a new almond crop technology (Iglesias, 2019a). More recently, the development of low vigor rootstocks had allowed testing higher trees densities per hectare. The novelty of SHD almond orchards consists of enabling to fully mechanize the orchard management operations (Iglesias, 2019b).

The mechanization reduces and solves the deficit of labor in horticulture, especially specialized workers. Also mechanizing the work results in lower costs saves time, improves workers' safety, reduces labor requirements

and production costs, and increases the quality of the products (Carbo et al., 2017).
The long-term effects are currently unknown, that is why at the moment, this new crop technology is still tested. Although California has the highest area harvested with almonds in the world and is the no.1 producer, the academics and the farmer's perspective over the SHD orchard system was conservatory over implementing it. In Spain, Portugal, and also Italy, the SHD model is developing more quickly (Maldera et al., 2021).
A study realized in 2018 and 2019, in an experimental almond orchard in Spain showed that the fruit set rates were similar in both SHD and open-center training systems. The average almond in shell weight was significantly higher in an intensive orchard where trees were trained in the open-center system, while the fruit yield was significantly higher in the SHD one. It follows, then, that the SHD training system would be more efficient, although less productive than the open-center training system (Gascón et al., 2019). In the same study, it is argued that the almond trees are prone to an alternate-bearing pattern (i.e., previous year fruit-bearing harms subsequent year flowering), which can be more or less pronounced depending on the specificity of the cultivar. That is said because two years were not enough to formulate appropriate conclusions.
It is believed that the SHD model offers advantages in the effectiveness of the phytosanitary treatments, in the management of water savings in irrigation, minimizing the soil maintenance, early yields, the possibility of harvesting with over-the-row machines or robotic harvester, the labour reduction, therefore results in an improvement of the profitability of the crop (Gascón et al., 2019).
The hedgerow is fully developed between the 3rd to the 5th year, this is the moment when the maximum production is attained while, in the intensive system, the maximum production is attained only after 10 to 12 years (Cociu, 2011). Thus, results that the initial investment is recovered more quickly, also higher profitability than in the intensive system.
The rootstocks recommended for SHD almond orchards are the low vigor ones, like Irta-1, Rootpac 20, Rootpac 40, Krymsk 86, Ishtara, or GF-677 (Duval, 2016). Low vigour rootstocks could be associated with a higher yield efficiency that is making it ideal for high-density orchards with the benefits of reducing labour costs, especially for pruning and harvest (Yahmed et al., 2016). Gascón et al. (2019), argues that the low vigour rootstocks are favouring smaller and more efficient canopies, and at the same time, reduce production costs due to better efficiency of water and fertilizers, better accessibility to the canopy, and easier mechanization. Since the market doesn't offer enough possibilities of low vigour rootstocks at the moment, a good alternative is GF-677. GF-677 is known as one of the best rootstocks for the almond crop and its medium-high vigour and excessive growth will be tempered by the high-density planting. The varieties used have high commercial significance. Independence, in the USA (Almond Board of California), Tuono and Supernova in Italy, Lauranne in France, Vayro, Marinada (Vargas et al., 2009), Penta (Dicenta et al., 2009), Belona (Dias et al., 2018), Soleta and Makako in Spain (Dicenta et al., 2018). Most of the varieties mentioned have good agronomic characteristics, are self-fertile, have medium or low vigor, have a late to very late blooming time, and are very productive (Socias et al., 2017).
Planting distances are ranging from 4 m x 2 m to 3 m x 1 m, from 1,250 trees/ha to 3,333 trees per hectare. The planting distances can differ from country to country and are based upon the latitude of the area of planting. For example, for 40° latitude North, 3.35 m between rows is an optimum distance. In Romania, for 45° latitude North, it is required 4.0 m between rows (Iglesias & Torrents, 2020).
The fruit trees canopy is trained as a single central axis. The pruning is done mechanically by limiting the height and the width of the fruit trees row, creating a hedgerow. Trees planted more densely are smaller being easier to fill the canopy space. They are less likely to have scaffold breakage problems regardless of how they are trained Gascón et al. (2019).
Pests and diseases are managed mechanically by spraying pesticides, using pheromone traps, and other cultural practices (Perju, 2002). Based on phenological observations, growers could easily monitor developmental stages and schedule timely various agronomic managements such as frost protection, pollination, fruit

thinning, irrigation, fertilization, pruning, pests and diseases management, and harvesting (Sakar et al., 2019).

The soil is managed mechanically. The space between rows can be maintained by no-till, tilled, or covered with green crops like leguminous and other species, soil work being reduced to a minimum. On the row, weed control is realized with herbicides or mechanically by tilling with intra row rotary harrow or hoe (Socias et al., 2017).

It is a necessity to irrigate the SHD almond orchards, even with a deficit of water, the most recommended being drip irrigation.

Fertilization is a necessity in a SHD almond orchard. Fertilizers application is preferred to be done when the plant has the most need of them. If the soil is not tilled, fertilization is required to be done by fertigation also by applying fertilizers with foliar spraying of the pesticides. (Muhammad et al., 2017)

The harvesting is done mechanically by machines, such as the over-the-row harvesters of olive hedgerows and grapevine's trellis. This innovation offers a better fruit quality. The fruit does not touch the ground, thus contamination risks by aflatoxins and salmonella are avoided (Carbo et al., 2017).

The SHD system is the last almond crop technology improvement, and to summarise its advantages, less human labour is needed, rapidly entry into full production, higher effectiveness, on the long term could be more profitable by paying less on human labour, on water, and pesticides, also new and more qualitative and efficient rootstocks and varieties are being used, fully mechanized pruning and harvesting, and better harvesting machines. As for disadvantages, for the moment, it is an orchard technology still in test, in the long term all the good and bad effects can't be anticipated. It is unknown exactly how a SHD orchard will behave 20, or 30 years after being planted. What would be the yields, how the yields evolve in relation with the almond predisposition to alternate-bearing, long-term management, and evolution of the pests and diseases in an SHD orchard. Another disadvantage is the higher cost of orchard establishment, plus not enough nurseries and rootstocks diversity (Socias et al., 2017).

To better view and understand the differences between each crop technology, Table 1, is presented, the summarized characteristics of the main almond orchard systems, like what rootstocks are being used, the varieties characteristics, the planting distances, the trees training, the pruning, the pests, diseases and weeds management, the irrigation, the fertilization, and the harvesting.

Like a quick insight into the strengths and weaknesses of each crop technology, traditional, intensive, and SHD.

Table 1. The summary of the almond orchard systems characteristics

Orchard system	**Traditional**	**Intensive**	**Super high density**
Rootstocks used	Seedlings	Medium to high vigour	Low to medium vigour
Varieties characteristics	Local selections	Self-sterile; Early to medium-late blooming	Medium-late to very late blooming
Planting distances (m)	8 x 8 or higher	8 x 8 to 5 x 4	4 x 2 to 3 x 1
Training	Rarely done	Open vase	Central axis
Pruning	Rarely done	Manual to semi mechanized	Mechanical
Pests & Diseases	Rarely done	Mechanically	Mechanically
Soil Management	Rarely done	Mechanically	Mechanically
Weed management	Rarely done	Mechanically	Mechanically
Irrigation	Rain fed	Rain fed to drip irrigation	Drip irrigation
Fertilization	Rarely done	Mechanically	Mechanically
Harvesting	Manual	Done with shakers	Done with over-row harvesters

CONCLUSIONS

The traditional almond orchards are less and less an option for today's farmers. The traditional orchards offer important ecosystem services but are not concentrated on almond production. It is believed that traditional almond orchards are one of the last options when a farmer is interested in developing a new orchard.

At present, most of the producing almond orchards are managed in an intensive system. This crop technology is the farmer's first option when choosing to develop a new almond orchard. Along the time the possibility of mechanizing increased, resulting in higher profits and larger yields. Until clear evidence of the SHD system's superiority and profitability, it will remain the farmer's first option for the almond orchards.

SHD is a new almond crop technology, developed in the last decades. The SHD model attracts more and more interest in the academic world. Until now the science confirmed that this crop technology offers the possibility to fully mechanize the work, rapidly enter into full production, higher effectiveness than the intensive orchards, lower water and pesticide use, less human labour needed. More studies are needed to confirm its higher profitability over the intensive crop system. The orchard establishment costs, the prediction in time over the stability of the orchard in terms of pests and diseases management, prediction on the long term of yields and profitability, are serious questions that somehow are still unanswered in comparison with the intensive crop system.

The SHD crop system is necessary to be studied more. This model could represent an important option, in the future, for farmers around the world and from Romania, also.

Scientific progress is necessary to evolve, for horticulture, in general, and for the almond crop, particularly.

REFERENCES

Albala, K. (2009). Almonds Along the Silk Road: The Exchange and Adaptation of Ideas from West to East. *Petits Propos Culinaires*, 88, 19-34.

Alcon, F., Egea, G. & Nortes A.P. (2013). Financial feasibility of implementing regulated and sustained deficit irrigation in almond orchards. *Irrigation Science*, 31, 931–941.

Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban Planning*, 70, 21–34.

Batlle, I., Dicenta, F., Socias, R., Gradziel, T.M., Wirthensohn, M., Duval, H. & Vargas, F.J. (2017). Classical Genetics and Breeding. In Socias R., Gradziel T.M., *Almonds. Botany, Production and Uses*, Boston, MA: CABI, 111-148.

Becerra, A.T., Botta, G.F., Bravo, X.L., Tourn, M., Melcon, F.B., Vazquez, J., Rivero, D., Linares, P. & Nardon, G. (2010). Soil compaction distribution under tractor traffic in almond (*Prunus amigdalus* L.) orchard in Almeria Espana, *Soil & Tillage Research*, 107, 49–56.

Carbó, J.L.E., Joseph H., & Connel, J.H. (2017). Almond Harvesting. In Socias R. I Company, Gradziel T. M., *Almonds. Botany, Production and Uses*, Boston, MA: CABI, 406-427.

Cociu, V. (2011). *Nucul, alunul, migdalul*. Bucuresti, RO: M.A.S.T. Publishing house.

Connell, J.H., van Steenwyk, R.A. & Gubler, W.D., (2005). Almond trunk injury treatment following bark damage during shaker harvest. *XIII GREMPA Meeting on Almonds and Pistachios CIHEAM*, 199-202.

Cordeiro. V. & Monteiro, A. (2002). Almond growing in Trás-Os-Montes region (Portugal). *Acta Horticulturae*, 591, 161-165.

Davidescu, D. & Davidescu, V. (1992). Agrochimie Horticola. Bucuresti, Ro: Editura Academiei Romane.

Dias, A.B., Caeiro, L., Félix, G. & Falcão, J.M., (2018). Evaluation of biometric parameters of 'Belona', 'Guara' and 'Lauranne' cultivars in a superhigh density orchard. *Acta Hortic*, 1219, 73-78.

Dicenta, F., Egea, J., Cremades, T., Martínez-Gómez, P., Ortega, E., Rubio, M., Sánchez-Pérez, R. & Martínez-García, P.J. (2018). 'Makako': a new extra-late flowering self-compatible cultivar from CEBAS-CSIC, *Acta Horticulture,* 1219, 9-12.

Dicenta, F., Ortega, E., Martínez-Gómez, P., Sánchez-Pérez, R., Gambin, M. & Egea, J. (2009). Penta and Tardona: Two New Extra-Late Flowering Self-Compatible Almond Cultivars. *Acta Horticulture* 814, 189-192.

Duval, H. (2016). Genetic diversity of almond rootstocks. The INRA Prunus rootstock breeding program. *Options Méditerranéennes: Série A. Séminaires Méditerranéens,* 119, 163-165.

Esparza G., Dejong M.T., Weinbaum A.S. & Klein I. (2001). Effects of irrigation deprivation during the harvest period on yield determinants in mature almond trees. *Tree Physiology*, 21(14), 1073-1079.

Flint M.L. (2002). *Integrated Pest Management for Almonds, 2nd Edition*. Davis, Ca: Division of Agriculture and Natural Resources Publication.

Font, R.M.E., Cruz, R.A.B. & Rebollar, G.J.L. (2010). Efectos del manejo del suelo en la production y composicion botanica de los pastos de una "dehesa de almendros" en el sudeste Iberico. *Pastos,* 40(2), 157 - 173.

Frattaroli, A.R., Ciabò, S., Pirone, G., Spera, D.M., Marucci, A., & Romano, B. (2014). The disappearance of traditional agricultural landscapes in the Mediterranean basin. The case of almond orchards in Central Italy, *Plant Sociology,* 51(2), 3-15.

Gaeta, L., Stellacci, A.M., & Losciale, P. (2018). Evaluation of three modelling approaches for almond blooming in Mediterranean climate conditions. *European Journal of Agronomy*, 97, 1–10.

Gascón, J.C., Panillo, M.F, Castellarnau, I.I., & Ramos, P.M. (2019). Comparison of SHD and Open-Center

Training Systems in Almond Tree Orchards cv. 'Soleta'. *Agronomy,* 9(12), 874.

Gavăt, C., Militaru, M., Dumitru, L.M., Opriță, A. & Miron, L. (2015). Productivity of some almond varieties in Dobrogrea, *Fruit Growing Research,* XXXI.

Gradziel, T. M. (2017). History of Cultivation. In Socias, R. I Company, Gradziel T. M., *Almonds. Botany, Production and Uses*, Boston, MA: CABI, 43-69.

Hendricks C. L. (1996). Orchards Planning, Design and Development. In Micke W., *Almonds Production Manual*, Davis, CA: UCANR Publications, 47-51.

Hanson, E.J., Chaplin M.H., & Breen P.J. (1985). Movement of foliar applied boron out of leaves and accumulation in flower buds and flower parts of 'Italian' prune. *HortScience*, 20, 747–748.

Hanson, E.J. (1991). Movement of boron out of tree fruit leaves. *HortScience*, 26, 271–273.

Hanson, E.J. (1991). Boron requirement and mobility in tree fruit species. *Current Topics in Plant Biochem. Physiol*, 10, 240–246.

Iglesias, I. (2019a) Sistemas de plantación 2D: Una novedad en almendro, una realidad en frutales. Hacia una alta eficiencia*. Rev. Fruticult.*, 67, 22–44.

Iglesias, I. (2019b). Costes de producción, sistemas de formación y mecanización en frutales, con especial referencia al melocotonero. *Rev. Fruticult.*, 69, 50–59.

Iglesias, I. & Torrents, J. (2020). Diseño de nuevas plantaciones adaptadas a la mecanización en frutales. *Horticulture*, 346, 60–67.

Lipan, L., Martín-Palomo, J.M., Sánchez-Rodríguez, L., Cano-Lamadrid, M., Sendraa, E., Hernándezd, F., Burló, F., Vázquez-Araújo, L., Andreu, L. & Carbonell-Barrachina, A.A. (2019). Almond fruit quality can be improved by means of deficit irrigation strategies. *Agricultural Water Management*, 216, 236-242.

Ludwig, G., Wolter, D. & Hanson, B. (2020). Effective Weed Management Considetaions, *Almond Board of California*.

Maldera, F., Vivaldi, A.G., Iglesias-Castellarnau, I. & Camposeo, S. (2021). Row Orientation and Canopy Position Affect Bud Differentiation, Leaf Area Index and Some Agronomical Traits of a Super High-Density Almond Orchard. *Agronomy*, 11(2), 251

Muhammad, S., Saa, S., Khalsa, S.D.S., Weinbaum, S. & Brown, P. (2017). Almond tree nutrition. In Socias, R. I Company, Gradziel T. M., *Almonds. Botany, Production and Uses*, Boston, MA: CABI, 291-320.

Nyomora, A.M.S., Brown P.H. & Freeman M. (1997). Fall foliar-applied boron increases tissue boron concentration and nut set of almond*. J. Amer. Soc. Hort. Sci.* 122, 405–410.

Pascuzzi, S, Santoro, F. Analysis of the Almond Harvesting and Hulling Mechanization Process: A Case Study. *Agriculture*. 2017; 7(12):100.

Perju T. (2002). Dăunatorii Organelor de Fructificare şi Măsurile de Combatere Integrată *Plantele Lemnoase, Vol II*. Cluj-Napoca, RO: Editura Academic Pres.

Ramos, E.M., Benitez, E., Garcia, A.P. & Robles, B.A. (2010). Cover crops under different managements vs. frequent tillage in almond orchards in semiarid conditions: Effects on soil quality, *Applied Soil Ecology*, 44(1), 6-14

Saa, S., Peach-Fine, E., Brown, P., Michailides, T., Castro, S., Bostockm, R. & Laca, E. (2016). Nitrogen increases hull rot and interferes with the hull split phenology in almond (*Prunus dulcis*). *Scientia Horticulturae*, 199, 41-48

El Sakar, H., El Yamani, M., Boussakouran, A. & Rharrabti, Y. (2019). Codification and description of almond (*Prunus dulcis*) vegetative and reproductive phenology according to the extended BBCH scale. *Scientia Horticulturae*, 247, 224-234.

Schwankl, L., Prichard T. & Fulton, A. (2017). Almond irrigation improvement continuum. *Almond board of California*.

Segura, J. M. A., Socias, I.R. & Kodad, O. (2017). Late-blooming in almond: A controversial objective. *Scientia Horticulturae,* 224, 61–67.

Socias, R.I Company & Gradziel T.M., Almonds. Botany, Production and Uses, Boston, MA: CABI.

Sottile, F., Barone, E., Barbera, G. & Palasciano, M. (2014). The Italian Almond Industry: New Perspectives and Ancient Tradition. *Acta Horticulture,* 1028, 401-407.

Şcheau, V. (2013). Selection of rootstocks, creation of new cultivars and significant changes in the almond assortment, *Natural Resources and Sustainable development,* 3.

Vargas, F., Romero, M., Clave, J., Verge, J., Santos, J. & Batlle, I. (2008). 'Vayro', 'Marinada', 'Constanti', and 'Tarraco' Almonds. *HortScience,* 43(2), 535–537.

Verdu, M.A. & Mas, T.M. (2007). Mulching as an alternative technique for weed management in mandarin orchard tree rows. *Agronomy for Sustainable Development*, 27, 367–375.

Yahmed, B.J., Ghrab M. & Mimous B.M. (2016). Eco-physiological evaluation of different scion-rootstock combinations of almond grown in Mediterranean conditions. *Fruits*, 71 (3), 185-193.

Almond board of California (2020). Almond Almanac.

Almond board of Australia (2020). 2019/2020 Almond Insights.

http://www.fao.org/faostat/en/#data/QC/visualize