

## Hazelnut Production and Prospects In Spain

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### Abstract

For many years, Spain was the fourth largest hazelnut producer worldwide, after Turkey, Italy and the USA. However, Spanish production currently occupies the tenth place with 10,500 t in 2017, due to the reduction of land used for cultivation, coupled with the growing importance of other producing countries: Azerbaijan, China, Georgia, Chile, Iran and France. In Europe, with 16% of world hazelnut production, in 2017, Italy is the main producer country (81%), followed by France and Spain, producing 6,7% and 6,5%, respectively. The hazelnut tree (*Corylus avellana* L.) grows wild in Spain. In 2017, the total cultivated area dedicated to this species was 12,806 ha, mainly (82%) concentrated in Tarragona, southern Catalonia. Finally, it is worth highlighting the sector's great investment in fruit processing technology. Currently, the main cooperatives offer semi-finished products to many European chocolate industries and have their own production of roasted products, in shell and flour, for direct sale.

**Key words:** Hazelnut Production, Prospects in Spain, Hazelnut

### 1. Current Situation

For many years, Spain was the fourth largest hazelnut producer worldwide, after Turkey, Italy and the USA (Tous et al. 2001). However, Spanish production currently occupies the tenth place with 10,500 t in 2017 (FAOSTAT 2019), due to the reduction of land used for cultivation, coupled with the growing importance of other producing countries: Azerbaijan, China, Georgia, Chile, Iran and France. In Europe, with 16% of world hazelnut production, in 2017, Italy is the main producer country (81%), followed by France and Spain, producing 6,7% and 6,5%, respectively.

The hazelnut tree (*Corylus avellana* L.) grows wild in Spain. In 2017, the total cultivated area dedicated to this species was 12,806 ha, mainly (82%) concentrated in Tarragona, southern Catalonia. (Ministry of Agriculture, Fisheries and Food 2019). In Tarragona province area, hazelnut cultivation expanded in the mid-nineteenth century, peaking at the end of the 1980s at about 35,000 ha, because of the grapevines death due to the phylloxera crisis (Baiges et al. 2012). In the last

twenty-five years, there has been a significant reduction in the crop surface, mainly due to the fluctuating price of hazelnut, the many plantations of low profitability, and the urban development, industry and infrastructure in Tarragona. Currently orchards are concentrated in flat areas with the best soils, under irrigation and, thus, with high productive potential. In 2017, Girona, Northern Catalonia, had nearly 1,000 ha (7.7% of the total cultivated area in Spain), and it is the main area of expansion due to the climatic (temperature and rainfall) and soil conditions are better suited to hazelnut cultivation (Figure 1), although the whole processing industry is concentrated in Tarragona. The hazelnut orchards in Catalonia are generally small, 0.5-2 ha (Table 1), the largest plantations being concentrated in the province of Girona, with an average of 6.7 ha.

Spain is traditionally an exporter country, but in recent years, it has also imported hazelnut, mainly from Turkey. This is due to the irregularity of national harvests, large transforming capacity, and the growth in sales of national operators.

Table 1. Distribution of hazelnut farms by orchards surface in Catalonia, Spain

Surface (ha)	Number of farms	% of total
< 1	1,463	35%
>=1 y <2	957	23%
>=2 y <3	583	14%
>=3 y <5	565	14%
>=5 y <10	414	10%
>=10 y <20	136	3%
>20	25	1%
Total farms	4,143	100%

Source: Baiges et al. (2012)

## 2. Propagation Systems

The hazelnut, as a shrub, prone to produce suckers. For many years, this characteristic, which is cultivar dependent and in many cases complicates the management of modern farms, helped the renewal of the stems in the orchards, which maintained a traditional cultivation system. The hazelnut suckers that the farmer kept at the time of pruning were used to plant new orchards (Tasias 1975). Some farmers still use this methodology and also nurseries are taking advantage of this ability to generate suckers, and have adopted the tie-off layering method from mother plants. This methodology also facilitates sanitary control and varietal trueness to type. The use of plant material with these characteristics improves orchard production, and thus its profitability (Aletà et al. 1997) (Figure 2).

Due to the increasing interest in establishing orchards with grafted plants on non-suckering rootstocks (Rovira et al. 2015), some nurseries are propagating "in vitro" the non-suckering rootstock 'Dundee', obtained at the University of Corvallis (Oregon, USA) (Lagerstedt 1993). Around 100,000 plants/year of this rootstock are currently being produced in Spain, grafted by specialized nurseries that use different grafting methods: bench grafting in the greenhouse or chip-budding in the field (in spring or at the end of summer). Experience at IRTA has shown that the success rate for all these methods is more than 90%. On the other hand, some nurseries begin to produce varieties "in vitro".

## 3. Cultivars

The main cultivated variety is 'Negret' (65% of the surface), producing nuts very appreciated by the sector mainly for industrial use (Romero et al. 1997a) (Figure 3). There is also major

interest in the local variety 'Pauetet', similar to 'Negret', is more vigorous and productive, and orchards of the Italian cultivars 'Tonda di Giffoni' and 'San Giovanni' are currently being planted. These last two cultivars are well adapted to the growing conditions of Tarragona (Rovira et al. 2017). For some years now, growers in cold mountain areas have been planting varieties with larger hazelnuts intended for table consumption, such as the local cultivar 'Castanyera', the American 'Ennis' and the French 'Corabel'.

Spanish hazelnut production, mainly in Tarragona, is based on traditional cultivars with medium to small fruit for industrial uses. There is varietal diversity within orchards, with eight to ten local varieties being cultivated, including 'Gironell' (in irrigated flat areas), 'Culplà', 'Grifoll', 'Morell' and 'Ribet' (in mountainous areas, 300-800 m altitude), or 'Vermellet' which is scattered through almost all the growing areas of Tarragona.

Although hazelnut requires cross-pollination to produce fruits, monovarietal orchards still exist relying in the presence of other pollen sources. However, with the small surface of these farms (0.5-1 ha), the pollen is transferred from one farm to another, covering cross-pollination needs. However, as more and more growers are aware that it is necessary to use pollinizer cultivars in order to obtain good yields, new orchards are designed including the main cultivar and pollinizers (10-12%).

## 4. Orchard Site Selection And Plantation

The ecological conditions for hazelnut plantations in Tarragona are not the most suitable for this species to grow, with a warm climate and low rainfall, and some areas with limestone soils. Originally, hazelnut was cultivated in mountainous areas, with more suitable climatic conditions. In the mid-

nineteenth century, hazelnut was brought to flatter areas, where production is now based, following the uprooting of vineyards because of phylloxera. In these areas, the then existing network of wine cooperatives evolved and adapted to the change in cultivation and commercialization of this nut. This network survives today.

In Catalonia, three types of hazelnut plantations can be distinguished, according to their size, location and applied crop technology (Baiges et al. 2012). In the first place, there are still some rainfed orchards, marginal farms, on hilly terrain in mountainous areas characterized by low cultivation costs. They are aged orchards with average yields of 500-800 Kg/ha. These plantations still account for 20% of hazelnut production in Catalonia. Secondly, there are small irrigated orchards. These are located in industrial areas, with high urban and infrastructure development (roads, highways, motorways and railways) that makes it difficult to expand the crop surface area and compromises any modernization process. These farms account for 30% of Catalan production (Figure 4).

Finally, there are large irrigated orchards, between 5 and 10 ha, or more, that cultivate the hazelnut with irrigation in good growing conditions, which allow mechanization. They are in the coastal plain of Tarragona, and in the Girona province. The surface area allows continuous renovation of the farms with a view to competitiveness. These farms account for 50% of production in Catalonia (Figure 5).

In general, there is a high level of mechanization in hazelnut orchards in Catalonia. Integrated Pest Management, soil management, weed control and harvesting are carried out using own machinery or by contracting service companies. Only pruning of suckers is carried out manually, or often using herbicides.

## 5. Orchard Management

In the hazelnut groves of Tarragona it can be observed how different production systems, cultivars, orchard design and age, coexist today. Most of the traditional orchards are several stems plantations. In the 1970s, in the irrigated areas of Tarragona, a few orchards used a single stem in an intensive spacing of 6-7 m between rows and 1-2 m between trees, with a density of

800-1000 trees/ha. During the first seven to eight years of life, more production was obtained per hectare than in those of medium spacing, 6 x 4m (400 trees/ha), but this was reversed when crop limitations arose afterwards due to lack of light towards the base of the trees (Gil 1997). The current planting scheme is designed to facilitate the passage of machinery and range from 6 x 3 m to 7 x 4 m, leaving wide spacing for fertile land and vigorous varieties such as 'Gironell' or 'Pauetet'. However, since 2010 there has been a technological evolution due to the low profitability of traditional orchards. Many of the modern plantations use single trunks, placing the cross of the trunk at 20-40 cm (some 60 cm) from the ground and trained as a vase with 3-4 main branches, which facilitates mechanization. These new orchards use self-rooted or grafted plants. In the latter case, the hazelnut is grafted on a vigorous and non-suckering rootstock, which allows integral mechanization, facilitating mechanized harvesting as there is no need to eliminate suckers (5-10% of the total cost), either manually or using herbicides (two applications per year), also reducing the use of chemicals and, thus preserving the environment. In most cases, in this type of orchards the ground cover is maintained using a rotary mower instead of the traditionally used cultivator, milling machine and roller. In grafted orchards, the cultivar 'Negret' and its pollinizers are planted, grafted on the non-suckering rootstock 'Dundee' which confers high vigor, less sensitivity to iron chlorosis and lengthens the vegetative cycle of the conal selection 'Negret-IRTA-N-9' virus free (Rovira et al. 2014) (Figure 6). Nurseries are extending the varietal grafted range by grafting other cultivars like the Italian 'Tonda di Giffoni', which adapts very well to the Tarragona area, and the local variety 'Pauetet', which is also very much appreciated by the sector, although there are some technological drawbacks during shelling operation. Finally, in Catalonia there are nearly 2,500 ha of hazelnut orchards under the Integrated Production (IP) certification. Some growers also use the system of Ecological Agricultural Production (PAE) aimed at covering the ever-increasing demand organically produced hazelnuts, currently highly valued by consumers. In 2017, 260 ha of ecological hazelnut trees were registered.

### **5.1. Fertilization**

Hazelnut nutrition is a determining factor for growth, vigour, balance and production. In traditional irrigated orchards with average harvests of 2,000 kg in shell/ha, the usual doses were of approximately 90 kg /ha of N, 40 kg/ha of P<sub>2</sub>O<sub>5</sub> and 80 kg/ha of K<sub>2</sub>O. However, the quantities used in plantations varies, depending on the cultivar and type of soil. It is recommended to fertilize according to the leaf analyses carried out each year in mid-July. Hazelnut adapts badly to limestone soils, frequently found in Tarragona area, where the application of iron chelates is necessary but expensive. In irrigated farms with a high level of crop technification, fertigation is used, a technique by which hazelnut nutrition is provided through the irrigation water, in a multifractionated form, during the spring-summer period (Gispert et al. 1997). The use of mowers in orchards, with the incorporation of the crushed leaf into the soil, also favors the return of organic matter to the soil. Occasionally, farmers may provide micronutrients by leaf spraying (amino acids, biostimulants, etc.).

### **5.2. Irrigation**

In the groves of Tarragona, as there is a total rainfall of 400-450 mm/year, and largely ineffective, 70% of the orchards have an irrigation system (Baiges et al. 2012). Near rivers and streams, some orchards are still irrigated by controlled flooding, a usual practice in the original hazelnut plantations in Tarragona. For this type of irrigation, labour and a sufficient water are needed. The socioeconomic changes in the 1970s meant the grower no longer had sufficient labour, and at the same time, there was over-exploitation of water from local aquifers, decreasing the amount and quality available for irrigation (Girona et al. 1997). As a result, localized irrigation systems were quickly and massively introduced, being considered a more efficient use of applied water (Gispert et al. 2015). Currently, the most widespread system is localized self-compensating drip or microtube irrigation. In some orchards, underground irrigation is beginning to be fitted, which easier field work. Annual water doses are usually 3,000 m<sup>3</sup>/ha, depending on the availability in

each zone, distributed between April and September, as recommended by Gispert et al. (2005). The orchards in the plains of Tarragona are irrigated mainly from a reservoir in the village of Riudecanyes and its distribution network, or through private wells, with a high cost of energy and equipment maintenance.

### **5.3. Pruning**

Hazel pruning only became a regular practice a few years ago. Previously, it was limited to eliminating suckers in winter, and those branches which were dead, deteriorated or excessively arched towards the ground. In some orchards, pruning was carried out on adult trees by cutting, more or less intensively, to induce new shoots the following year, and to allow light and air penetration in the tree (Santos and Plana 1997). Currently, in some of these adult plantations, pruning rejuvenation is carried out, eliminating the old branches and allowing growth of the new shoots that will be the future branches of the trees. In single-trunk orchards, the tree is trimmed, leaving three to four main branches (for the first three years). In successive years, the inner branches are eliminated to facilitate light inside de canopy. In some adult orchards in Girona, where the trees shade the rows, mechanical pruning with discs is used between the rows, to allow light to enter. The growth of new shoots in response to this pruning is adequate. When hazelnut pruning, it is important to make clean cuts in the branches and protect them from external agents that can cause wood diseases such as *Cytospora corylicola* Sacc. Sealing products and closure films (mastic type) are commonly applied to wounds caused by pruning.

### **5.4. Plant protection: pests and diseases**

The hazelnut has a rich auxiliary fauna, with numerous species of insects thriving in the trees and surrounding. The most important pests are the hazelnut weevil (*Curculio nucum* L.), which affects the fruit, and the bud mite (*Phytoptus avellanae* Nal.), which affects the buds. Recently, white spot in kernel, caused by the green shield bug (*Palomena prasina* L., mainly), has become a problem that worries the sector, since it affects the quality of the nut and depreciates its value (Batlle et al. 2017). These pests are increasing in importance, and this

produces an imbalance in the crop caused by the chemical products used (Barrios et al. 2014). Other pests that attack hazelnuts are aphids (*Myzocallis coryli* Goeze and *Corylobium avellanae* Schrank), which cause damage during the months of May and June, when populations are higher. Aphids draw the sap from the tree, causing a decline in vigour and stored reserves. Hazelnut leaf roller (“cigarrer”) (*Archips rosana* L.), so called because of the characteristic rolling of the leaves caused by the larvae, can cause very serious damage because it destroys the new sprouts and the formation of the buds which are responsible for the sprouting the following year. The woodborer (*Zeuzera pyrina* L.) is a polyphagous pest that can attack a large number of plant species. The control against it is decisive: the mechanical elimination of the caterpillars inside the galleries through the use of wires. Sexual confusion is also used for this plague, by placing diffusers on the trees at the end of April-early May, before the adults begin to fly, at the rate of 300 diffusers/ha, in the upper third of the vegetation. Currently there is the threat of *Halyomorpha halys* (BMSB) arriving to the hazelnut orchards as it is happening in many other European countries.

Regarding diseases several fungi attack hazelnuts, including dry bud (*Cryptosporiopsis* spp.), which causes drying and subsequent fall of the hazelnut buds, and hazelnut canker (*Cytospora corylicola* Sacc.), a fungus which attacks old plantations or those weakened by adverse agronomic or environmental conditions, such as water deficiency and irrational cultural techniques. It is recommended to protect wounds with mastic and to use copper treatments at the time of leaf bud break and leaf fall.

It should be noted that in Catalonia there are Plant Protection Associations (ADV), which offer technical assistance for monitoring and recommending treatments for pests and diseases. These associations are co-funded by the sector and the Catalan administration (Santiveri et al. 2004).

## 6. Harvest, Post-Harvest and Main Uses of Hazelnut

Until the 1960s, hazelnuts were collected by hand from the ground as the fruits drop from the tree, usually in two labourious passes.

However, for years now farmers in the area have been using different types of machinery for hazelnut harvesting, depending on the orography of the land. Before the fruit ripens, the farmer cleans and prepares the ground to make it smooth and firm for harvesting. Once the fruit is ripe and falls from the tree (late August - mid-September, depending on the varieties), it is collected from the ground with different machinery. The simplest machines are vacuum hoses, handled by one or two operators. Driven by tractor, the hazelnuts are vacuum from the ground, previously grouped with a blower in rows or mounds. The hazelnuts are suctioned into a cleaning machine connected to the tractor, for an initial cleaning, where empty hazelnuts (which have little weight) are separated together with the leaves and also the stones (heavier than the hazelnuts) (Figure 7). The fruits are collected either in bags or in the hopper of the tractor, which is then unloaded in the warehouse. In some orchards, vacuum hoses are used, and one or two people collect the hazelnuts from the prepared piles, put them in baskets, and empty these into the cleaning machine attached to the tractor. More and more self-propelled machines are being used, with the need for a single operator. These machines also separate the nut from empty shells and leaves and load the crop into the hopper of the same machine. They are suitable for flat orchards and large planting schemes, but are not for stony soils (Figure 8).

It is important to harvest the nuts as soon as possible once they have fallen to the ground, in order to avoid possible humectation and preserve their quality. It is advisable to stop watering during the harvesting season so that fallen fruit does not get wet, which would cause excess humidity in the hazelnut, the development of molds, the generation of mycotoxins, increased acidity and loss of stability. Some growers harvest two or three times when fruits fall from the tree, depending on the variety, to avoid these problems. Only a few farmers have a hazelnut cleaning and drying plant on their own farms. Most producers take the harvest directly to cooperatives, where good conservation of the fruits is guaranteed. These keep the hazelnut at less than 6% humidity in-shell and in silos that are normally ventilated and protected from significant temperature fluctuations. The cooperatives process the hazelnut according to

the demand of their customers. Cooperatives currently separate hazelnuts according to commercial type. In Catalonia, two main categories are distinguished: 'Negret' (which in some cases also includes the 'Pauetet' cultivar) and "common" (a mixture of all the other varieties). Recently, due to the large production of Italian cultivars, some years and in some cooperatives the Italian varieties 'Tonda di Giffioni' and 'San Giovanni', are also separated, having different prices.

Modern hazelnut processing facilities include classifiers for image analysis, which allow the elimination of rotten grains, shell pieces and other contamination. There is also a great capacity for calibrating the grains, which allows for homogenization of the batches. Once the hazelnut has been shelled and classified in the corresponding batch (by cultivar, size, quality, etc.), they are stored in controlled environment chambers (temperature and relative humidity) until they are marketed or processed.

In Spain, as with the world hazelnut market, 90% of the product is destined for the industry, and only 10% is sold for table consumption, although this market has grown in the last ten years. The hazelnut is mainly used as human food: fresh, roasted, fried, salted or as an element of different processed products, associated with cocoa in chocolates, or in the manufacture of nougats, marzipan, ice cream, cakes, beverages, spreads, etc. (Romero et al. 1997b). The potential markets for this nut are the processing industry, the food industry and fresh consumption. The hazelnut is considered, like other nuts in general, a typical food of the Mediterranean diet, and its acceptance is growing in the international market (Batlle et al. 2018).

The hazelnut producing and marketing sector in Spain is located in Tarragona and is basically grouped into six growers' associations (OPAs), of which three are cooperatives, which market 65% of the Spanish production.

In 1991, to promote domestic consumption and guarantee a high quality product, the Protected Designation of Origin "Avellana de Reus" was launched, for hazelnut, both for table use and for processed products. Likewise, recently (2018), the "Associació Avellana de Brunyola i Comarques Gironines" was created to promote the hazelnut produced in Girona.

## **7. Overview and prospects**

From the 1980s, there was a decline in the Spanish hazelnut productive surface, although this now seems to be stabilizing and even increasing. The fluctuating prices of this nut, as well as the small size and age of many of the orchards, were the main factors responsible for this decline. Hazelnut production in Tarragona is currently limited to the most suitable areas and is now expanding into better adapted areas such as Girona. Although the surface dedicated to this crop has not or hardly increased recently, the sector is evolving favourably. Old orchards are pulled out and replaced by new ones, using selected varieties and better cultivation techniques: Spain is undergoing an innovation process and major technological changes.

The evolution of the design and improvements in the cultivation system of the new orchards has been remarkable. Three essential changes can be highlighted. Firstly, the maintenance of the orchard floor and the adventitious flora through the introduction of rotary - mowers to replace cultivator operations, milling machines and rollers for soil conditioning before harvesting. Secondly, the evolution of pest and disease control with the rationalization of pest and fungal treatments from the introduction of improvements developed in integrated production, with the technical support of plant defense groups (ADV) and specialists from the Tarragona Plant Health Service (DARP, Generalitat de Catalunya). And finally, the incorporation of self-propelled machinery for integral harvesting. These improvements have transformed the hazelnut crop of the late 1980s, from labour-intensive and with high production costs, into intensive production systems.

Additionally, the recent establishment of an Association of Technicians "Corylus Technicae" in the Catalan sector, aimed at providing technical advice to hazelnut producers, undoubtedly contributes to implementing the necessary technological changes in the crop and improving its competitiveness. This evolution should be continued. The modification of the production systems together with the demands of the consumer who increasingly demands products as natural as possible, has led to hazelnut orchards cultivated under the guidelines of organic farming.

The use of non-suckering rootstocks in the Tarragona area, for the low vigorous 'Negret' cultivar, could reduce orchards management problems, saving time and costs in the elimination of suckers from the trees, and facilitating mechanized harvesting of the crop. Currently, the demand for grafted hazelnut plants by farmers is high, so in the coming years these orchards will increase. Some other Spanish growing regions are also interested in new plantations with grafted hazelnuts. The nurseries have different cultivars, so growers can ask for one or another to be grafted according to their preferences, always considering the climatic conditions to choose the right varieties to be planted.

Finally, it is worth highlighting the sector's great investment in fruit processing technology. Currently, the main cooperatives offer semi-finished products to many European chocolate industries and have their own production of roasted products, in shell and flour, for direct sale.

### Acknowledgements

This work is based in the results of the ERASMUS Project (2016-1-TR01-KA202-034979) (2016-2018). We thank CERCA Programme of the Generalitat de Catalunya.

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Figure 1. Distribution of hazelnut orchards in Catalonia. (The percentage is with reference to the whole of Spain)



Figure 2. Hazelnut seedlings obtained from suckers of mother plants after ringing. (Photo IRTA)



Figure 3. Fruits of 'Negret' cultivar. (Photo IRTA)





Figure 4. Traditional small surface irrigated orchard in Tarragona. (Photo IRTA)



Figure 5. Hazelnut plantation in Girona. Trees in a single-trunk and natural vegetation on the orchard floor (Photo IRTA)



Figure 6. Plantation of 'Negret' grafted onto 'Dundee' rootstock. (Photo IRTA)



Figure 7. Hazelnut vacuum harvester. (Photo IRTA)



Figure 8. Automatic hazelnut harvesting machine. (Photo IRTA)