HISTORY OF OLIVE GROWING IN ARGENTINA

The origins of olive growing in Argentina can be traced to the Spanish colonisation when the first orchards were planted in Arauco (La Rioja). A 400-year-old specimen survives to this day as testimony to that period (Photo 1). However, it was not until the late 19th century that olive cultivation started to develop to cope with demand from the influx of Italian and Spanish immigrants which supplies from the existing Argentinean market were unable to meet. In 1953 there were estimated to be 7.5 million olive trees in the country, some of which were planted near urban areas (Photo 2). Olive growing started to decline in 1960 as it came up against competition from sunflower and corn oil (theoretically healthier and cheaper). Farm profitability decreased and olive orchards were abandoned or grafted to convert them to table olive or dual-purpose varieties. By 1984, only 3.72 million olive trees were cultivated, many in inadequate conditions.

The early 1990s signalled a radical about-turn in this state of affairs as olive acreage started to expand without interruption from the existing level of just under 30,000 ha. This expansion was due not only to enhanced profitability driven by olive oil prices and information campaigns about the health benefits of olive oil consumption, but also to support measures passed by the Argentinean government, notably the Tax Deferral Acts for industrial, agricultural, livestock and touristic undertakings (Act 22.021 in La Rioja, Act 22702 in Catamarca and Act 22973 in San Juan). This legislation was applied in agriculture from the start of the 1990s until 2008 and stimulated the development of new olive orchards in the Northwest provinces of San Juan, La Rioja and Catamarca (Fig. 1). Many of the new investors came from outside the agricultural/livestock in-

Photo 1. This 400-year-old olive tree (variety ‘Arauco’) is a National Historical Monument. A symbol of the identity of the Arauco people, it continues to stand erect after being saved in the 17th century from being felled as ordered by King Carlos III of Spain, who feared that the prosperity of olive growing in the area might eventually exceed olive production in Spain. Legend has it that this one plant is the source of the resurgence of olive growing not only in Argentina but also in Chile and Peru, where offshoots were taken.

OLIVÆ/No 114 - 2010
dustry because the legisla-
tion allowed Argentinean
companies to defer tax pay-
ments for 17 years in the
case of olive cultivation. The
defered payments were lat-
er settled in equal annual in-
stalments over a period of
five consecutive years, at no
interest.

The figures speak for
themselves. At the outset of
the 1990s Mendoza, San
Juan and Córdoba (Table 1)
were the main olive produc-
ing provinces, accounting
for 80% of the country’s
29,600 ha of olive trees,
concentrated primarily in the
departments of Pocito, Raw-
son, Rivadavia and Zonda in
San Juan, Junín, Maipú,
Lavalle and Luján de Cuyo
in Mendoza and Cruz del Eje
in Córdoba. The orchards
were traditional, 5–15 ha in
size on average and planted
on a 10 x 10 m layout. The
trees were pruned to several
scaffold branches and flood
irrigated. ‘Arauco’ was the
chief variety grown owing to
its high crop yield, large
fruit size and dual-purpose
characteristics (Photo 2).

Domestic production was
estimated to be 30,000 t of
table olives and 8,000 t of
olive oil (Fig. 2), which
went primarily to a market
led by product price as op-
posed to quality. In some
cases the oils had defects
(fusty and muddy sediment
defects) because of the
shortage of modern process-
ing facilities and the lack of
suitable storage. In 1998,
Argentina grew 71,000 ha of
olive trees, 70% of which
were varieties for oil pro-
TABLE 1
Expected olive growing area (ha) in Argentina
after the application of the Tax Deferral Acts

<table>
<thead>
<tr>
<th>Province</th>
<th>Prior area</th>
<th>Tax deferral area</th>
<th>Total area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mendoza</td>
<td>13700</td>
<td>300</td>
<td>14000</td>
</tr>
<tr>
<td>Córdoba</td>
<td>5000</td>
<td>470</td>
<td>5470</td>
</tr>
<tr>
<td>San Juan</td>
<td>4800</td>
<td>13800</td>
<td>18600</td>
</tr>
<tr>
<td>La Rioja</td>
<td>2900</td>
<td>27000</td>
<td>29900</td>
</tr>
<tr>
<td>Buenos Aires</td>
<td>1800</td>
<td>0</td>
<td>1800</td>
</tr>
<tr>
<td>Catamarca</td>
<td>1400</td>
<td>30000</td>
<td>31400</td>
</tr>
<tr>
<td>Total</td>
<td>29600</td>
<td>71570</td>
<td>101170</td>
</tr>
</tbody>
</table>

Source: Argentine Secretariat of Agriculture, Livestock, Fishing and Food (SAGPyA)
production and 30% for table production. By 2008, this area had expanded to 90,100 ha (more than 90% under irrigation), split roughly 60%/40% between oil-olives and table olives. This crop area has positioned Argentina in 13th place in the world olive acreage ranking, but many of the new orchards were planted in areas where little was known about the agricultural or processing performance of the olive varieties imported from Europe. As a result, some of the area planted with olives to qualify for the tax deferral measures did not bear crops due to frost damage or soil and plant health problems, and some varieties were switched to increase production.

The orchards planted since the enactment of the tax laws are between a minimum of 100 and 150 ha, although some are over 1,000 ha. Planting densities are higher, ranging from 250 to 330 olive trees/ha. The orchards were planted with stock from other producing countries and were often monovarietal, with one or two polliniser varieties. They also apply more advanced soil management practices such as localised irrigation and fertigation. This combination of factors has stimulated higher yields of 10–12 t/ha compared with 5–6 t/ha in traditional groves, which has resulted in higher domestic production. In 2007/08, Argentina produced 100,000 t of table olives and 27,000 t of olive oil (Fig. 2) and its commercial strategy placed growing priority on quality. Nowadays, Argentina is South America’s leading producer of table olives and olive oil. According to the average figures released by the International Olive Council (IOC) for the period 2002–07, it ranks ninth in the world table olive production league (4%) while remaining a minor player in world olive oil production (<1%).

Currently, the olive growing map of Argentina mainly covers the provinces of Catamarca, La Rioja, San Juan and Mendoza (Fig. 3) where the most important olive growing areas are Valle Central, Pomán and Tinogasta in Catamarca; Chilécito, Aimogasta and La Rioja Capital in La Rioja; and Valle del Tulum, Jáchal and Ullum-Zonda in San Juan. Olives are also grown in the provinces of Córdoba and Buenos Aires, and new crop expansion projects have recently arisen in Río Negro, San Luis and Neuquén.
DESCRIPTION

OF VALLEYS

The topography of this region is characterised by a series of depressions or valleys running lengthwise parallel to the Andes, separated by a chain of mountains misleadingly called the Sierras Pampeanas or Pampean Ranges because they are not geographically related to the humid pampas region (Fig. 4). Moving from East to West, the first valley is the Valle Central de Catamarca, demarcated by the Sierra de Ancasti del Alto to the East (elevation of 1,573 m) and the Sierra del Ambato to the West (4,405 m) (Photo 3); the next valleys are the Bolsón del Pipanaco (where the Aimogasta and Pomán olive growing areas are located), with the Sierra del Ambato to the East and the Sierra de Velasco to the West (4,029 m), the valley of La Rioja Capital, lying at the foot of the Sierra de Velasco (Photo 4), the valley of Chilcito, lying between Sierra Velasco to the East and Sierra de Famatina to the West (6,097 m), and lastly the valley of Tulum in San Juan lying at the foot of the Sierra del Tontal in the Andean foothills. This includes the piedmont area of Cañada Onda–El Acequión where new orchard development is currently at its height.

Not all the valleys lie at the same altitude. The Valle Central de Catamarca and the valley of La Rioja Capital lie between 400 and 450 m whereas the valley of Tulum is at 650 m, the olive farms in Pomán and Aimogasta in Bolsón de Pipanaco lie at 800 m, the valley of Chilcito is at 950 m, and the Tinogasta area in Catamarca at 1,100 m. These differences in altitude cause major climatic differences despite the fact that the valleys are at the same latitude.

These valleys are depressions which gradually filled...
for livestock. Agriculture in the provinces of San Juan and Mendoza is centred on grapes for wine production. Although stone fruit, seed fruit and vegetable growing underwent heavy expansion in these two provinces, olive growing has now become the second agricultural activity in San Juan.

DETERMINANTS OF OLIVE CULTIVATION

Soil characteristics

The native vegetation is made up of species of xerophytes such as Cactaceae and thorn scrub. The region has long been used for goat grazing although some of the valleys were too arid for large-scale grazing and even now still have large tracts of virgin mountains. The construction of the railway led to deforestation in some areas.

Before the appearance of the large olive plantations prompted by the tax deferral laws, crops such as grape, olive, date (brought by Lebanese and Syrian immigrants in the early 20th century), pomegranate, aloe, other fruit trees such as peach, almond and quince and all kinds of vegetables were grown in oases in these valleys. Nowadays, the main agricultural activities are irrigated in the provinces of La Rioja and Catamarca where olive, grape, walnut and jojoba are cultivated, and to a lesser extent other fruit trees, vegetables and herbs. Dry farming is confined to the areas where rainfall is above 300 mm a year (La Rioja Capital and Valle Central de Catamarca) and is mainly associated with pastureland and cereal growing.
capacity owing to their low clay content. In some lower parts of San Juan olive growing encounters problems because of shallow groundwater levels and salt accumulation. Due to their coarse grain size and the absence of calcareous horizons, piedmont soils do not have problems of water logging.

Temperature and olive phenology

As can be seen from the map in Fig. 4, the region of Argentina where olive growing has basically developed lies between latitudes 28 and 32ºS; hence, it is closer to the equator than the traditional olive growing regions of the Mediterranean Basin (30–45ºN). However, the topography of Argentina’s mountain valleys is the clear determinant of their climate, which is of the arid basin-and-range type (http://www.ambiente.gov.ar/aplicaciones/mapoteca) as opposed to being subtropical, which might be expected. The Pampean Ranges and the Andes (3,000–6,900 m above sea level) are natural barriers that isolate the region from the influence of the humid winds from the Atlantic and Pacific, which release their moisture on the mountain crests and are dry by the time they reach the valleys.

Moreover, the NS orientation of the ranges allows the entry of masses of cold air from the South. Nevertheless, it is the snowfalls in the upper reaches of the Andes that lead to warm, dry winds like the Zonda, which affects all the valleys in the foothills to a varying extent. As already explained, climatic characteristics differ according to the altitude of the valleys.

Table 2 provides data on the chief climatic variables from four meteorological stations in Argentina, located in Catamarca, La Rioja Capital, Chilecito and San Juan, as well as three stations in major olive growing regions of Spain: Seville, the epicentre of table olive production (60,000 ha) where ‘Manzanilla de Sevilla’ variety is grown primarily; Úbeda, at the heart of the ‘Picual’ area (800,000 ha); and Toledo, the coldest region where the variety cultivated is ‘Cornicabra’ (200,000 ha). Figure 5 plots the changes through the year in mean temperature, ETo and precipitation at the Catamarca, San Juan, Seville and Toledo meteorological stations.

In general, the mean annual temperatures are milder in the mountain valleys of Argentina than in the olive growing regions of Spain. The combination of these temperature conditions and the low ambient humidity leads to high atmospheric demand, which reaches values above 1,500 mm at all the meteorological stations. The Valle Central de Catamarca is the warmest, followed by La Rioja Capital where absolute maximum temperatures in the vicinity of 45 ºC are recorded in summer.

The mild year-long temperatures modify the rate of vegetative growth of the trees relative to that of the Mediterranean Basin. In the valleys of La Rioja Capital and Central Catamarca where winters are shorter, the growth season runs from early spring to late autumn. This permits active vegetative growth to the extent where some shoots may reach 1 m in length when the olive trees receive abundant irrigation and fertilisation, which causes problems of excessive vigour (Photo 5).

In springtime, the mild temperatures cause earlier flowering in olive and also move forward the other phenological stages (Fig. 6). As a result, fatty acid synthesis is concentrated in summer and early autumn, particularly in the Valley Central de Catamarca and La Rioja Capital where temperatures are high during this period (Table 2). In contrast, oil synthesis occurs in the autumn in Spain, when temperatures are lower. In all probability the high
temperatures are the reason for the reduction in oil synthesis that occurs in the majority of the varieties grown in Northwest Argentina because more moderate temperatures are typically needed to promote oil synthesis in olive (Salas et al., 2000; Bongi, 2004). For example, the ‘Arbequina’ variety in NW Argentina often does not give an oil yield of more than 12%. Furthermore, in some varieties the high temperatures also appear to be the cause of the low oleic acid content of the oils and conversely of their high linoleic acid content. In the specific case of the ‘Arbequina’ variety, and to a lesser extent of ‘Arauco’, the oil may not comply with IOC limits owing to its low oleic acid content (below 55%). Commercially, this is corrected by blending ‘Arbequina’ oil with oils from other high-oleic varieties (e.g. ‘Coratina’ and ‘Picual’). Preliminary trial results suggest that the temperatures reached during the months when oil synthesis is at a height (February–March) have the greatest impact on oil content while the temperatures reached near the stone hardening stage may best explain the variations in fatty acid composition (García-Inza, Castro and Rousseaux, unpublished data).

The temperature at harvest can also affect oil quali-
Mean temperatures of 25ºC and mean maximum temperatures of 31 ºC are reached in March (late summer, early autumn) when the first varieties are harvested in Catamarca. This means that the olives may start to ferment if they are not processed as soon as they are picked.

### Table 2

<table>
<thead>
<tr>
<th>Station</th>
<th>Variables</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catamarca</strong></td>
<td>Tmean (ºC)</td>
<td>23.1</td>
<td>27.3</td>
<td>20.8</td>
<td>13.8</td>
<td>21.3</td>
</tr>
<tr>
<td>28.36 S</td>
<td>Tmax (ºC)</td>
<td>30.2</td>
<td>33.7</td>
<td>27.2</td>
<td>21.4</td>
<td>28.1</td>
</tr>
<tr>
<td>65.46 W</td>
<td>Tmin (ºC)</td>
<td>16.0</td>
<td>20.9</td>
<td>14.5</td>
<td>6.1</td>
<td>14.4</td>
</tr>
<tr>
<td>454 m</td>
<td>Rainfall (mm)</td>
<td>79</td>
<td>211</td>
<td>94</td>
<td>13</td>
<td>397</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>480</td>
<td>544</td>
<td>343</td>
<td>252</td>
<td>1,619</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>287</td>
</tr>
<tr>
<td><strong>La Rioja Capital</strong></td>
<td>Tmean (ºC)</td>
<td>22.8</td>
<td>27.5</td>
<td>20.5</td>
<td>13.4</td>
<td>21.0</td>
</tr>
<tr>
<td>29.23 S</td>
<td>Tmax (ºC)</td>
<td>30.2</td>
<td>34.3</td>
<td>26.6</td>
<td>20.7</td>
<td>28.0</td>
</tr>
<tr>
<td>66.49 W</td>
<td>Tmin (ºC)</td>
<td>15.3</td>
<td>20.7</td>
<td>14.4</td>
<td>6.1</td>
<td>14.1</td>
</tr>
<tr>
<td>429 m</td>
<td>Rainfall (mm)</td>
<td>64</td>
<td>222</td>
<td>117</td>
<td>12</td>
<td>415</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>491</td>
<td>565</td>
<td>335</td>
<td>244</td>
<td>1,634</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>330</td>
</tr>
<tr>
<td><strong>Chilecito (La Rioja)</strong></td>
<td>Tmean (ºC)</td>
<td>19.8</td>
<td>25.3</td>
<td>18.4</td>
<td>10.5</td>
<td>18.5</td>
</tr>
<tr>
<td>29.14 S</td>
<td>Tmax (ºC)</td>
<td>27.9</td>
<td>32.6</td>
<td>25.4</td>
<td>18.7</td>
<td>26.2</td>
</tr>
<tr>
<td>67.26 W</td>
<td>Tmin (ºC)</td>
<td>11.6</td>
<td>18.0</td>
<td>11.5</td>
<td>2.2</td>
<td>10.8</td>
</tr>
<tr>
<td>945 m</td>
<td>Rainfall (mm)</td>
<td>18</td>
<td>110</td>
<td>29</td>
<td>7</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>474</td>
<td>556</td>
<td>337</td>
<td>234</td>
<td>1,602</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>641</td>
</tr>
<tr>
<td><strong>San Juan</strong></td>
<td>Tmean (ºC)</td>
<td>19.0</td>
<td>26.0</td>
<td>18.1</td>
<td>9.6</td>
<td>18.2</td>
</tr>
<tr>
<td>31.33 S</td>
<td>Tmax (ºC)</td>
<td>27.5</td>
<td>33.8</td>
<td>25.3</td>
<td>17.7</td>
<td>26.1</td>
</tr>
<tr>
<td>68.25 W</td>
<td>Tmin (ºC)</td>
<td>10.6</td>
<td>18.1</td>
<td>10.9</td>
<td>1.5</td>
<td>10.3</td>
</tr>
<tr>
<td>598 m</td>
<td>Rainfall (mm)</td>
<td>14</td>
<td>45</td>
<td>22</td>
<td>6</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>465</td>
<td>586</td>
<td>321</td>
<td>203</td>
<td>1,576</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>733</td>
</tr>
<tr>
<td><strong>Seville</strong></td>
<td>Tmean (ºC)</td>
<td>17.0</td>
<td>26.3</td>
<td>19.7</td>
<td>11.9</td>
<td>18.7</td>
</tr>
<tr>
<td>37.22 N</td>
<td>Tmax (ºC)</td>
<td>23.2</td>
<td>34.0</td>
<td>26.0</td>
<td>17.1</td>
<td>25.1</td>
</tr>
<tr>
<td>6.00 W</td>
<td>Tmin (ºC)</td>
<td>10.6</td>
<td>18.3</td>
<td>13.5</td>
<td>6.6</td>
<td>12.2</td>
</tr>
<tr>
<td>8 m</td>
<td>Rainfall (mm)</td>
<td>134</td>
<td>20</td>
<td>167</td>
<td>233</td>
<td>554</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>372</td>
<td>600</td>
<td>288</td>
<td>147</td>
<td>1,408</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>501</td>
</tr>
<tr>
<td><strong>Úbeda (Jaén)</strong></td>
<td>Tmean (ºC)</td>
<td>15.1</td>
<td>24.7</td>
<td>16.2</td>
<td>8.2</td>
<td>16.0</td>
</tr>
<tr>
<td>37.56 N</td>
<td>Tmax (ºC)</td>
<td>20.8</td>
<td>31.1</td>
<td>20.8</td>
<td>12.3</td>
<td>21.3</td>
</tr>
<tr>
<td>3.18 W</td>
<td>Tmin (ºC)</td>
<td>8.8</td>
<td>18.3</td>
<td>11.9</td>
<td>4.1</td>
<td>10.8</td>
</tr>
<tr>
<td>358 m</td>
<td>Rainfall (mm)</td>
<td>153</td>
<td>32</td>
<td>123</td>
<td>187</td>
<td>495</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>341</td>
<td>524</td>
<td>220</td>
<td>110</td>
<td>1,195</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>929</td>
</tr>
<tr>
<td><strong>Toledo</strong></td>
<td>Tmean (ºC)</td>
<td>13.6</td>
<td>24.6</td>
<td>15.8</td>
<td>7.3</td>
<td>15.3</td>
</tr>
<tr>
<td>39.53 N</td>
<td>Tmax (ºC)</td>
<td>19.7</td>
<td>31.9</td>
<td>21.7</td>
<td>12.1</td>
<td>21.3</td>
</tr>
<tr>
<td>4.03 W</td>
<td>Tmin (ºC)</td>
<td>7.5</td>
<td>17.3</td>
<td>10.0</td>
<td>2.5</td>
<td>9.3</td>
</tr>
<tr>
<td>516 m</td>
<td>Rainfall (mm)</td>
<td>110</td>
<td>49</td>
<td>100</td>
<td>100</td>
<td>359</td>
</tr>
<tr>
<td></td>
<td>ETo (mm)</td>
<td>324</td>
<td>556</td>
<td>238</td>
<td>107</td>
<td>1,225</td>
</tr>
<tr>
<td></td>
<td>Chilling hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,022</td>
</tr>
</tbody>
</table>
Mean winter temperatures are also higher than in Spain. For instance, while 501 chilling hours are recorded in Seville using the method of Mota, the warmest valleys of Argentina such as the Valle Central de Catamarca and La Rioja Capital record only 287 and 330 chilling hours, respectively. Given that the olive tree needs low winter temperatures to stimulate flower buds to emerge from winter rest, the lack of chilling in these valleys appears to be the reason why some high chill requirement varieties such as ‘Empeltre’, ‘Frantoio’ and ‘Leccino’ do not flower. However, flowering is not affected in varieties with lower chill requirements such as ‘Manzanilla’, ‘Coratina’, ‘Arbequina’ and ‘Coratina’ (De Melo-Abreu et al., 2004; Aybar, 2010). Mean minimum winter temperatures can be lower in the mountain valleys than in Spain, due to incoming cold fronts from the South which cause severe frost (Photo 6). Because it lies geographically furthest to the south Tulum valley is affected the most by the arrival of polar air masses. According to the agroclimatic

Figure 6. Mean date of flowering (F), stone hardening (SH) and harvesting (H) of the ‘Arbequina’ and ‘Manzanilla de Sevilla’ varieties at locations in Argentina (Chilecito, Catamarca and San Juan), shown in red, and Spain (Toledo, Úbeda and Seville), shown in green.

Mean winter temperatures are also higher than in Spain. For instance, while 501 chilling hours are recorded in Seville using the method of Mota, the warmest valleys of Argentina such as the Valle Central de Catamarca and La Rioja Capital record only 287 and 330 chilling hours, respectively. Given that the olive tree needs low winter temperatures to stimulate flower buds to emerge from winter rest, the lack of chilling in these valleys appears to be the reason why some high chill requirement varieties such as ‘Empeltre’, ‘Frantoio’ and ‘Leccino’ do not flower. However, flowering is not affected in varieties with lower chill requirements such as ‘Manzanilla’, ‘Coratina’, ‘Arbequina’ and ‘Arbequina’ (De Melo-Abreu et al., 2004; Aybar, 2010). Mean minimum winter temperatures can be lower in the mountain valleys than in Spain, due to incoming cold fronts from the South which cause severe frost (Photo 6). Because it lies geographically furthest to the south Tulum valley is affected the most by the arrival of polar air masses. According to the agroclimatic

Figure 6. Mean date of flowering (F), stone hardening (SH) and harvesting (H) of the ‘Arbequina’ and ‘Manzanilla de Sevilla’ varieties at locations in Argentina (Chilecito, Catamarca and San Juan), shown in red, and Spain (Toledo, Úbeda and Seville), shown in green.

Mean winter temperatures are also higher than in Spain. For instance, while 501 chilling hours are recorded in Seville using the method of Mota, the warmest valleys of Argentina such as the Valle Central de Catamarca and La Rioja Capital record only 287 and 330 chilling hours, respectively. Given that the olive tree needs low winter temperatures to stimulate flower buds to emerge from winter rest, the lack of chilling in these valleys appears to be the reason why some high chill requirement varieties such as ‘Empeltre’, ‘Frantoio’ and ‘Leccino’ do not flower. However, flowering is not affected in varieties with lower chill requirements such as ‘Manzanilla’, ‘Coratina’, ‘Arbequina’ and ‘Arbequina’ (De Melo-Abreu et al., 2004; Aybar, 2010). Mean minimum winter temperatures can be lower in the mountain valleys than in Spain, due to incoming cold fronts from the South which cause severe frost (Photo 6). Because it lies geographically furthest to the south Tulum valley is affected the most by the arrival of polar air masses. According to the agroclimatic

Photo 5. Mild temperatures coupled with high irrigation rates (>1,200 mm) and fertilisation lead to greater tree growth than in the Mediterranean Basin. The olives shown are 11-year old ‘Arbequina’ trees in the Valle Central de Catamarca, planted on an 8 x 4 m layout (left) and 10-year-old ‘Barnea’ trees in Chilecito (La Rioja) planted on a 6 x 4 m layout (right). Shoots grew to a length of more than 1 m per year.
data for the locality of Meda Agua over the last 25 years, mean absolute temperatures below -7ºC were recorded in 45% of the winters. This has a heavy impact on olive orchard yields, as is borne out by the low crop production of 2007/08 and 2009/10 when temperatures reached -10 ºC and -10.5 ºC, respectively.

Figure 6 shows the average dates for flowering, stone hardening and harvesting of ‘Arbequina’ and ‘Manzanilla de Sevilla’, the two most widespread varieties in the mountain valleys. The corresponding dates for locations in Spain are also given. The phenological stages of ‘Manzanilla de Sevilla’ are only specified for Seville, because neither Úbeda nor Toledo is a major growing area of this variety.

Although there is normally a difference of six months between the northern and southern hemispheres, flowering is a month earlier in the mountain valleys owing to the high spring temperatures. Stone hardening takes around two months, as in Spain; a further two–three months are needed before harvesting ‘Manzanilla de Sevilla’, or four months in the case of ‘Arbequina’. The fact that ‘Arbequina’ is harvested so early in Toledo (before 15 November) is not due to earlier ripening but to the risk of autumn frosts detrimental to oil quality. Harvesting of ‘Arbequina’ begins in late March in the Valle Central de Catamarca, followed by La Rioja and ends in May in San Juan and Chilecito. In Spain harvest does not start until November. Harvesting of ‘Manzanilla de Sevilla’ begins in mid-February in Argentina, and seven months later (September) in Spain.

**Rainfall and irrigation water**

Two aspects of rainfall in the mountain valleys should be highlighted: the low level of rainfall and the difference in distribution compared with the Mediterranean Basin (Table 2 and Fig. 5). Mean annual rainfall is below 500 mm; the valleys receiving the least rainfall are the Bolsón de Pipanaco (where Aimogasta and Pomán are located) and the Tulúm valley, with less than 100 mm. More than half of the rainfall occurs in summer and in many cases is torrential. This rainfall does not usually heighten the risk of disease owing to the low relative ambient humidity and the rapid percolation into the soil profile. This contrasts with the Mediterranean Basin where summer is the driest season.

The low rainfall and high atmospheric demand in these valleys therefore make it necessary to irrigate intensive olive orchards. The irrigation water used in commercial orchards in the

---

Photo 6. ‘Picual’ olive trees in the valley of Chilecito (La Rioja) damaged by frosts in May 2008 (-6ºC for 8 h).
provinces of Catamarca and La Rioja comes mainly from the aquifers. The water is pumped from a depth of 80–300 m and recharge comes from the Pampean Ranges where rainfall is higher. However, there are signs that annual recharge is often less than orchard water consumption (>1,000 mm/ha). Well water has an electrical conductivity (EC) ranging between approximately 0.5 and 2.0 dS/m and a high carbonate content as well in some cases. However, the level of salinity does not tend to lower crop yields provided that the soil humidity of the wet-bulb is maintained. In the province of San Juan, surface water is more important and both the foothills and Andes feed the waters of the rivers San Juan in the South and Jáchalan in the North, which are of high quality with a low EC.

**Frost and wind**

Another characteristic feature of the mountain valleys is the damage they suffer from two types of wind: the cold South wind, and the warm Northwest wind known as the Zonda wind. The south wind blows from the SE; in some valleys in autumn and winter it moves masses of cold Antarctic air which can reach temperatures between -8 and -14°C, with the lowest temperatures being recorded in the highest valleys like Jáchalan or Chilecito. When this wind occurs in autumn, it not only damages the vegetative structures of the trees but may also jeopardise the quality of the oil owing to severe oxidation of frost-damaged fruit cells if the olives have not yet been harvested. Lowering irrigation and fertilisation rates in the autumn can reduce vegetative damage by promoting lignification. Additionally, windbreaks (Photo 7) of the evergreen species *Casuarina equisetifolia* from Australia (Photo 8) are used to protect crops from these winds. Other species such as the deciduous *Populus nigra* lose their leaves and do not provide protection for the orchards in winter. *Casuarina* is quite a hardy species and poses few health risks (i.e. diseases or insects) to olive trees. Windbreaks are usually oriented EW to stop the passage of the South wind, but this is never done when the orchards lie on slopes, because this prevents air drainage. Despite the incoming polar air, many frosts are radiation frosts and a slope of more than 1% permits air drainage to the lowest lying areas. Furthermore, late frosts are quite common at the beginning of spring and cause significant damage to flowering, leading to lower crop production.

The Zonda wind occurs mainly in winter and spring and affects the valleys closest to the Andes; consequently, the Tulúm valley in San Juan is the most heavily affected. It occurs when a
mass of damp air from the Pacific ascends the Andes, losing its moisture and growing colder along the way. On its descent it grows warmer, eventually reaching the valleys in hot, dry gusts, generally from the northwest. When it occurs in the spring, it can jeopardise flowering because it is usually accompanied by a rise in temperatures and very low ambient humidity which can cause the flowers to dehydrate. In short, it is a dry, warm wind that reaches temperatures of about 35 °C and which is characterised by strong gusts (40–100 km/hour).

**ORCHARD DESIGN**

**Plant material**

The plant stock for the traditional orchards in the mountain valleys was often obtained from seed or from vegetative propagation of specific specimens, mainly ‘Arauco’ for table olive production, while ‘Arbequina’, ‘Frantoio’ and ‘Picual’ were planted on a smaller scale for oil production. The olive fruits of the ‘Arauco’ variety are characterised by their high resistance to detachment from the tree, large size (similar to ‘Gordal de Sevilla’), high flesh-to-stone ratio and a flesh firmness suited to several methods of table olive preparations. However, owing to its asymmetric shape, the stone of this variety is difficult to remove (Barranco et al., 2000). This description coincides with that of the ‘Azapa’ variety of Chile and the ‘Sevillana’ variety of Peru. Some genetic differences are also found between ‘Arauco’ of different regions; for instance, the ‘Arauco riojano’ differs from the variety found elsewhere in the country.

The varietal makeup changed when it became necessary to import large amounts of plant material to plant the orchards covered by the tax deferral legislation. In 1997 alone, 12 million olive trees belonging to over 30 varieties were imported. Later, a preference developed for varieties internationally renowned for the quality of their olives or oils, specifically ‘Manzanilla de Sevilla’ for table production and ‘Arbequina’, ‘Frantoio’, ‘Leccino’ and ‘Picual’ for oil production. In some cases, there was little control of the plants imported from Mediterranean nurseries; the upshot was that some orchards were planted with mixed varieties. Moreover, some of the varieties planted had not been evaluated beforehand in the region and over the years it has been found that they do not adapt well to specific climatic conditions. The most striking examples are the orchards planted with ‘Frantoio’, ‘Empeltre’ and ‘Leccino’ in the valleys of Catamarca, La Rioja Capital and San Juan where these varieties do not flower, or do so...
occasionally but without setting any fruit. Orchards planted with the ‘Picual’ variety also have some flowering problems owing to the lack of winter chilling. As already mentioned, there is evidence that these varieties do not receive sufficient hours of chilling to emerge from winter rest and continue with the process of flower structure differentiation. These varieties are currently grafted or replaced outright by ‘Arbequina’, ‘Arauco’ or ‘Hojiblanca’ (Photo 9).

The design of the new olive orchards incorporated polliniser varieties, chiefly in the Valle Central de Catamarca and La Rioja Capital. Some olive varieties are partially self-incompatible, i.e. they have difficulty in fertilising the flower ovules with their own pollen and need the help of other varieties to do so. Given this physiological aspect of the olive, in some olive growing countries such as Italy it is frequent for more than one variety to be grown in the same plot. However, this is not taken into account in the design of olive orchards in Spain because in traditional orchards it was common for a mix of varieties to be planted. Nevertheless, there is no consensus on the optimum design to ensure adequate pollination in Argentina’s olive orchards. To give some examples, table olive orchards usually include rows of trees belonging to the ‘Arbequina’, which is used as a polliniser variety, while ‘Arbequina’ orchards are usually also planted with ‘Hojiblanca’ or ‘Picual’ as polliniser varieties, which are grown on a small portion of the orchard, often located solely along the edges of the plots.

The varieties that are cultivated vary from province to province. Taking the province of Catamarca as an example, the bulk of production is from oil varieties, mainly ‘Arbequina’ because it starts to bear crops early and its oil is highly rated on international markets. In both the Valle Central de Catamarca and La Rioja Capital, a high percentage of production is from oil varieties but these give low oil processing yields (10–14%) due to the high temperatures during oil synthesis. For reasons of profitability, ‘Picual’ is considered nowadays to be a dual–purpose variety, with a large part of production going for table olives. In the province of La Rioja as a whole, 60% of the olive orchards grow olives for table production and the main varieties are ‘Manzanilla’ and ‘Arauco’; ‘Aloreña’ is also grown on a small area. The ‘Manzanilla’ variety passed ‘Arauco’ in terms of crop area due to the expansion triggered by the orchards which took advantage of the tax deferral legislation. ‘Manzanilla’ has gained prominence in these new orchards because of its international reputation. Nevertheless, ‘Arauco’ continues to be important because of the strong demand from the Ar-

Photo 9. Graft union of a ‘Frantoio’ olive tree in the Valle Central de Catamarca onto which ‘Hojiblanca’ had to be grafted (left) and close-up of the graft (right). The chilling requirements of ‘Frantoio’ are not met in the warmer valleys and so the trees do not flower.
gentine and Brazilian markets. Within the ‘Manzani-
lla’ designation there are several types which are proba-
bly different varieties, such as ‘Manzanilla de Sevilla’,
‘Manzanilla Criolla’, ‘Man-
zanilla Fina’, ‘Manzanilla Reina’,
‘Manzanilla Común’, ‘Manzanilla Aceit-
era’, ‘Manzanilla Denté’,
‘Manzanilla Californiana’,
and ‘Manzanilla israeli’.
‘Arbequina’ is the main oil
variety in La Rioja although
‘Picual’, ‘Coratina’ and
‘Barnea’ are also grown. To
the south in San Juan where
the climate is not as warm,
70% of the olive growing
area is for the production of
oil-olives. ‘Arbequina’ is the
chief variety (60% of the
area), followed by ‘Man-
zanilla de Sevilla’ (10%).
‘Changlot Real’ (table
olives), ‘Picual’, ‘Hojiblan-
ca’ and ‘Arauco’ are minor
varieties, while ‘Coratina’,
‘Arbequina’ and ‘Hojiblan-
ca’ are clearly expanding.

Orchard layout and
training systems

Planting densities in the
olive farms set up under the
tax deferral legislation are
generally between 250 and
330 trees/ha. The usual lay-
out is 7–8 m between rows
and 4–5 m between trees in
the same row. In recent
years, especially in San
Juan, the tendency has been
to increase planting density
by using layouts of up to 6 x
2 m (approximately 800
trees/ha), and even 4–3.5 x
1.5 m (between 1,600 and
1,900 trees/ha). This in-
crease in planting density
has been prompted in part by
the mounting cost of hand
harvesting and the financial
necessity of mechanising
harvesting by using shakers,
over-the-row harvesters or
other machinery like the
Colossus harvester or the
Jacto coffee harvester.

The orchards were de-
signed without foreseeing
that vegetative growth
would be greater than in the
Mediterranean Basin. The
trees were trained to a vase
shape (Photo 10), but in
some cases the excessive
vigour of the trees caused
the canopies to touch and
form hedgerows 5.5 m high
and 4.0 m wide (Photo 5).
The large size of the trees
adds considerably to the
cost of cultural practices
such as harvesting and prun-
ing. Moreover, it does not
generally result in higher
crop production because of
the lack of light penetration
to the leaves and fruit and
the competition between
fruit development and vege-
tative growth. Consequent-
ly, the hedgerows are
topped to lower them to
around 3.5 m so that light
can penetrate through to the
side walls and harvesting is
made cheaper (Photo 11). Even
so, in some cases the upper
parts of the canopy close over
and it is neces-
sary to pull out whole rows
(Photo 12).
natural or sown plant cover within the row interspace all year round (Photo 13). Mowing or the application of contact herbicides is used to keep the cover crops to a specific height to stop them from flowering and seeding. In areas where rainfall is minimal (<100 mm/year), the plant cover barely develops within the row interspace (Photo 14).

Irrigation

So far there is enough water – chiefly belowground water of medium quality – in the mountain valleys for irrigation purposes. The biggest constraint on water use for irrigation is the cost of pumping. In some cases, farms and urban areas compete for electricity in summertime, which limits electricity consumption and hence farm irrigation at this time of year.

The majority of the farms calculate irrigation rates according to FAO recommendations for the crop coefficient method (0.70-0.75), which means applying 1,000–1,200 mm of water throughout the year. The irrigation strategy for which these coefficients were calculated aims to satisfy the water requirements of the olive; hence, the crop has access to water which can be readily used throughout the year.

CULTURAL PRACTICES

Soil management

Because the olive farms are generally very large and the orchards are irrigated, farmers tend to pay little attention to soil management and weed control. Nevertheless, the most widespread technique is a combined system of herbicide application along the orchard rows and...
cycle. Because the temperatures are so mild (Table 2), this year-long water availability leads to excessive vegetative growth and makes it difficult for the olive trees to enter winter dormancy. Several experiments with olive have shown that the application of deficit irrigation at specific times causes moderate water stress. This reduces vegetative growth without affecting crop production and may even increase it. Vegetative growth can be controlled by decreasing water applications at times when this does not interfere with fruit growth and oil synthesis, such as from the end of fruit set until peak oil synthesis. In addition, post-harvest water stress forces the tree into winter dormancy and permits subsequent flower differentiation, which would not be achieved otherwise due to the mild autumn and winter temperatures.

**Fertilisation**

Fertilisation tends to be applied empirically as is still the case in many orchards of traditional producing countries, and often it depends on the financial resources available. Nitrogen, phosphorus and potassium are applied frequently. Overfertilisation, particular-
deficient, which often causes deficiencies.

**Main pests and diseases**

So far, olive orchards do not have any major health problems that cannot be controlled by chemical means. The main pests are the ash whitefly (*Siphoninus phillyreae*), mites (*Aceria oleae* and *Oxycenus maxwellii*) and black scale (*Saissetia oleae*). A few orchards are affected by nematodes or fungi such as *Verticillium dahliae* and *Phytophthora* spp. The appearance of the latter two problems is usually connected with poor health control in the source nurseries from which the plant material is obtained.

**Harvesting**

Harvesting occurs over five months in the mountain valleys, beginning in February in table olive orchards and running through to June or July in oil orchards. The first table olive variety to be harvested is the ‘Aloreña’ in early February, followed by ‘Manzanilla de Sevilla’ and one month later by ‘Arauco’ and ‘Picual’ when they are intended for Spanish-style green olives, and two months later when they are for black olives in brine. Harvesting of oil-olives begins with ‘Arbequina’ in April and May (depending on the area and mill capacity). The varieties ‘Changlot Real’, ‘Frantoio’, ‘Leccino’ and ‘Farga’ are all harvested at the same time. One month later, it is the turn of the ‘Barnea’, ‘Coratina’ and ‘Arbosana’ varieties to be harvested, while ‘Picual’ harvesting for oil production gets underway in June.

Although the orchard lay-outs chosen for many oil-olive orchards (7–8 x 4–5 m) permit harvest mechanisation, the olives are picked by hand with the aid of large stepladders because of the large size of the trees (Photo 15); poles are not used. Olive farmers are starting to view harvest mechanisation as a must due to the amount of labour required for harvest – more and more manpower comes from other northern provinces such as Salta, Jujuy and Tucumán, as well as from Bolivia – and the mounting costs of hiring harvest workers (at present, harvest labour can account for 60% of total production costs). Some farms are equipped with trunk shakers (Photo 16) or Jacto coffee harvesters, which can harvest less vigorous trees although harvesting is sometimes difficult because the trees are not properly trained. Currently, large ‘Colossus’ harvesters are
being developed (Photo 17). In the case of table olives, mechanised harvesting detracts from their quality. As a result, harvesting will be a big problem in a few years’ time if costs continue to climb. The province of La Rioja in particular will be heavily dependent on labour owing to the large expanse of orchards dedicated to table olive growing.

**CROP PRODUCTION AND QUALITY**

As a rule, well managed farms produce around 10,000 kg olives/ha on average, which can rise to 20,000 kg/ha in bumper years. When viewed in terms of oil production, ‘Arbequina’ stands out because although higher in San Juan (16%) than in La Rioja and Catamarca (12%), it gives quite poor oil yields compared
with rates in several olive growing areas of Spain where it can easily reach 18% and even 22%. The high temperatures, which hinder oil synthesis, appear to be the most likely cause although other factors such as high irrigation rates also have to be taken into account. This last factor is due to the fact that generally growers sell their olives by weight and do not stop irrigating prior to harvest; as a result the olives arrive at the mill with a high moisture content, which lowers oil extraction efficiency. As far as the effect of temperature is concerned, a zoning study carried out in several agro- ecological areas of the Tulum valley (San Juan) revealed that oil synthesis levels were higher in the ‘Arbequina’ variety in the southern part of the valley where the temperatures are lower.

The oil made from some varieties does not always meet the parameters required by the IOC for extra virgin olive oil. For instance, ‘Arbequina’ tends to give oils with low concentrations of oleic acid (<55%) in La Rioja Capital and the Valle Central de Catamarca whereas in colder areas such as San Juan the concentrations are generally above the limit. This low oleic acid content is related to compositional changes during oil accumulation. The oil obtained from ‘Arbequina’ and ‘Arauco’ olives picked from the tree contains 70% oleic acid one month after stone hardening, but this level gradually decreases through fruit ripening until it reaches values of close to 55% when oil synthesis is completed. Other varieties like ‘Coratina’ and ‘Picual’ have a high oleic acid content (around 70%) which remains constant throughout fruit ripening (Deborah Rondanini, personal communication). Campesterol and waxes are two other sets of compounds whose levels are frequently not accepted under IOC standards because they are above the permitted limits. Total polyphenols content is lower than in olive growing areas of Spain owing to the high temperatures and abundant irrigation during fruit ripening. Experimental trials applying deficit irrigation during fruit ripening have managed to achieve an increase of up to 30% in total polyphenol content.

In some cases, the long distance (100–500 km) the olives have to travel from the farm to the mill where they

Photo 17. Over-the-row harvester (Colossus) for harvesting oil-varieties, which can harvest trees up to 4 m high and 4m wide.
are eventually processed also affects the quality of the oils, which sometimes have free fatty acid values above the limit set for extra virgin olive oil (0.8%). However, these levels are not related to the date of harvest or maturity index (Rondanini et al., 2007). Other quality parameters such as the K232 and K270 specific extinction coefficients, the peroxide value and oxidative stability generally lie inside the parameters proposed by the IOC (Ceci et al., 2004; Ceci and Carelli, 2007).

Where table olives are concerned, the traditional local variety (‘Arauco’) stands out in terms of quality. This variety is in great demand because of its large fruit, which is prepared as Spanish-style green olives or natural black olives, although the market is limited due to the difficulty in removing the stone. The introduction of ‘Manzanilla de Sevilla’ in newly established farms has recently facilitated exports to new markets such as the United States and Canada where until now there had been no tradition of importing olives from Argentina.

**PROCESSING AND MARKETING**

In the 2007/08 crop year Argentina produced 27,000 t of oil (Fig. 2). Rising production in recent years has gone hand in hand with rising processing capacity. The majority of oil mills are modern and use the two-phase system. Most of the oil (69% in 2007/08) is exported to other countries because of its high cost compared with seed oils since it is five to six times more expensive than domestically produced soybean and sunflower oil. As a result, per capita consumption in Argentina is no more than 0.1 kg compared with 24.2 kg in Greece and 12.3 kg in Italy and Spain. Most of the oil exported is sold in bulk, chiefly to the United States (40%), followed by Brazil (25%).

In the early 1990s Argentina produced some 30,000 t of table olives, mainly belonging to the ‘Arauco’ variety. These were chiefly processed as green olives and to a lesser extent as natural black olives. By 2007/08 production had reached 100,000 t, principally of the ‘Manzanilla de Sevilla’ variety. This has forced the industry to change its processing techniques because the skin of this fruit variety needs more delicate handling and lye treatment. Modern processing facilities (Photo 18) enable the industry to turn out a top-quality, internationally renowned product. Processing is very highly concentrated in that although there are more than 90 registered processing companies, only four process 70% of production. Ninety per cent of the table olives produced go for export, chiefly to Brazil (80%), and then the United States.

**STRENGTHS AND WEAKNESSES OF THE SECTOR**

The mountain valleys contain a large land area that is practically flat or only moderately sloping. This land has not been cultivated previously and is therefore pathogen-free. The coarse textured soils are highly suited to olive growing, provided irrigation water is available. The fact that the information gleaned from existing orchards is available to establish new orchards means that the right varieties can now be selected. In addition, the nursery industry has developed in recent years and produces quality plants to meet the needs of new orchards.

The climatic conditions in the highest valleys of the provinces of Catamarca, La Rioja and San Juan are ideal for olive production and are therefore well suited for growing top quality oil vari-
and will thus be able to participate in decision-making on olive oil policies, benefit from international technical cooperation, and take part in promotional activities. Furthermore, several national scientific research and technical teams are working in Northwest Argentina in partnership with the private sector (e.g. Provincial Chambers of Commerce and other producer groups such as the Regional Consortium of Experimental Agriculture and Livestock, CREA) to improve crop management.

Generally speaking, olive management in the climatic conditions of the arid valleys in Northwest Argentina faces two challenges: control of vegetative vigour and resistance to the cold South winds. Excessive vigour means that the trees grow to a huge size...
and makes harvesting very costly. A combination of irrigation and nitrogen fertilisation control and adequate pruning will help to obtain canopies suited to mechanical harvesting or at least to lower harvesting costs if done by hand. The winds from the South Pole in winter cause severe damage to plants which are not hardened off or to trees whose crop has not yet been harvested. Moving forward the winter rest period by lowering irrigation and fertilisation will help to trigger the process of lignification. Earlier harvesting will also be necessary. New orchards established in the coldest valleys should not be located in the valley floor but on the hill sides.

The last aspect that should be highlighted is the availability of irrigation water. The water level is becoming lower in the aquifers of many mountain valleys where groundwater is the primary water source. Hence, the sustainability of the crop may be threatened in the coming decades unless water use is better controlled.

ACKNOWLEDGEMENTS

This article has been written thanks to the support of various organisations. The Polytechnical University of Madrid financed the collaboration of its faculty members with CRILAR (Supplementary activity AL09-PAC-10 and Seed-Project AL10-PID-20). The Department of Innovation, Science and Business of the regional government of Andalusia financed collaboration through the programme of incentives for scientific and technical activities (call for proposals 1/2009). The stay of professors Gómez-del-Campo and Morales-Sillero in La Rioja and Catamarca was financed by the Argentinian Scientific and Technological Advancement Agency (PICT 2005 No 32218). The stay in San Juan was funded by the firm Agromillora Andina.

REFERENCES

Aybar V. 2010. Floración en olivo (Olea europaea l.): evaluación del ajuste de un modelo predictivo para las condiciones del chaco árido argentino y utilización de hormonas exógenas. Tesis de Maestría, Escuela para Graduados, Facultad de Agronomía, Universidad de Buenos Aires


