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**Francisco Gardiazabal**
**Francisco Mena**

Sociedad Gardiazabal y Mena Ltda.
Quillota, Chile

# The Avocado Industry in Chile and its Evolution

The avocado industry in Chile has grown over the past 30 years reaching approximately 40,000 hectares planted. Chile is now the second largest world producer and exporter of Hass avocados after Mexico. This strong growth is mainly due to exports to northern hemisphere markets that have experienced very rapid growth in demand and consumption.

In addition to market conditions, other factors influencing the growth of the industry are related to the positive growing and phytosanitary conditions of Chilean production areas. Chile's natural geographic isolation, with the Andes mountain range to the east, and desert to the north, helps limit pest problems to a level that requires at the most, spot treatments, and then only in some years. The low incidence of Phytophthora root rot has allowed the industry to be planted on seedling rootstocks, which in turn has facilitated and reduced the cost of planting of orchards. Other important favorable factors are the dry Mediterranean climate conditions in Chile, which implies better fruit quality and postharvest conditions, good technical and export infrastructure supporting the Chilean fruit industry, and until recently, the plentiful availability of soil and water for avocado production. (Fig. 1)

**Figure** 1: 6 year old 3x3 m 300 ha Grove

Official data on avocado plantings in Chile measured 7840 hectares in 1987, increasing to 17,047 hectares in 1997, and to 39,255 hectares in 2007 (FAOSTAT 2010). (1ha =2.47 acres) New development has been markedly reduced since 2009 due to severe drought conditions, which has been worse during the 2011/2012 season. Additional factors that have limited growth are frost problems (mainly in 2007, 2010 and 2011), availability of quality land, increasing costs (especially energy and labor) and the global economic crisis, which has provided a greater level of uncertainty for investment. However, market prices for avocados have remained attractive despite the increases in volume, where production has increased from near 55,000 metric tons in 1997 to 250,000 metric tons in 2007 (FAOSTAT 2010). Due to growth in consumption in traditional markets and the development of new ones, economic results for well-managed orchards are still very attractive. Similar to other avocado producing countries, domestic consumption has increased coupled with substantial increase in grower's returns.

## The development of Hillside Plantings

An important feature supporting the strong growth in the last 15 years has been the adaptation of planting of orchards on hillsides. The advantages associated with this type of site are the lower cost of land, the larger size of farm units, climatic conditions favorable for fruit set and reduced frost risk, and earlier maturity dates. This provides the possibility of planting in early inland areas where it is common to have frost in the piedmont and lower valley areas. The problems of these hillside plantations are: the high cost of energy related to water pumping (Chile has one of the highest energy costs in South America), the need for adequate labor, soil heterogeneity and reduced soil depth. We estimate that currently there are at least 18,000 hectares planted on slopes steeper than 30%, or 45% of the countries' total (Fig. 2)

**Figure** 2: Year one trees on steep hillside

## Competitive challenges

Today the Chilean avocado industry faces several challenges, both productive and economic. Increased production and international competition, in addition to changes in production conditions, require Chilean producers to focus on developing competitive advantages. These are expressed mainly as the production cost per kilogram, the quality and fruit condition, production reliability, and the efficient management of resources. In addition, another important but less tangible factor is the market-level image of the industry and also that of individual growers, in case the marketing system allows the grower to maintain his/her identity and image at the wholesale customer level.

The main factors affecting production costs are the level of productivity, and to a lesser extent, the production costs per hectare. The main factor affecting fruit value, mainly in export market conditions, is fruit size.

To address the above challenges, the use of pruning has become a common management practice in Chile and its aim has been to manage more compact trees, making management easier, allowing more consistent production and better fruit size (Fig. 3). In the case of new plantings, the use of high density systems has been the answer to obtain better productive and economic results.

**Figure** 3: Pruning in 6x6 m trees

## High Density

There are different designs of high-density orchards, but in this article we will refer to square planting systems, usually planting patterns of 3x3 m or 2.5x2.5 m, which means 1,111 to 1,600 trees per hectare (Fig. 4). This high density square layout system was originally developed in California (Hofshi, 2004) and its main initial objective was to

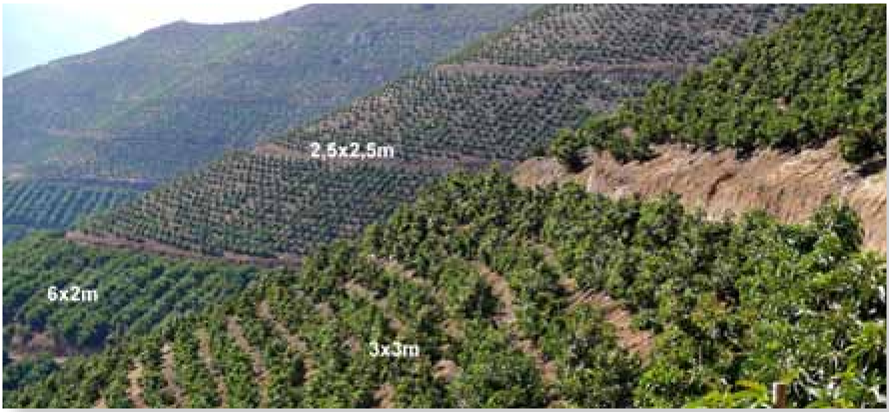


**Figure** 4: Multiple planting scenarios increase the efficiency and safety of workers, and to lower costs (Fig. 5). This system also proved to be more precocious and productive. The idea

**Figure** 5: Lamb Hass at 2.25 x 2.25 m in California 2002

is to work with individual trees with a central leader structure not taller than 2 m and a pyramid-shaped canopy, allowing for good illumination all around the tree, unlike rectangular standard plantings that eventually form a hedge with only two sides illuminated and productive (Fig. 6).

**Figure** 6: Five year old 3x3 m showing pyramidal shape

Square plantings at these densities do not allow for the use of machinery inside the orchard, but in Chile, machinery use is very limited in orchards planted on slopes. Nonetheless, hillside plantings require a very good road design to facilitate operations.

Another advantage of planting in square patterns is since it is meant to work with individual trees and not rows, it is not necessary to design the orchards with rows in a north-south orientation. This can be especially difficult on hills with slopes with multiple exposures and where ridges have to be built to increase soil depth and drainage (Fig. 7).

**Figure** 7: Seven year old 3x3 m with multiple aspect

A very important factor helping to control tree vigor and size is that, in general, trees planted at a 3 m spacing or less tend to encounter greater root competition, which reduces vegetative development and thus minimizes vigor (Stassen 1995). This concept is known in other crops where root growth restriction in pots or reducing the irrigated soil volume has the effect of reducing tree vigor and size and increasing production efficiency.

The first experiences in California were planted at 2.25x2.25 m using upright and semi-dwarf varieties such as Reed and Lamb Hass. The natural growth habit makes these varieties easier to adapt to high-density systems with minimal pruning compared with varieties with vigorous and extensive growth habits like Hass (Fig. 8).

**Figure** 8: Reed at 2.25x2.25 m in California

Newly planted Hass trees habitually tend to grow as a central leader. This structure is lost after a rest of growth which is followed by regrowth where lateral or basal shoots are vigorous and begin to compete with the initial central leader. This produces wide, big canopies with significant shading in the interior. Thorp and Sedgley (1992) studied the growth habit in avocados describing the occurrence of proleptic (vigorous) and sylleptic (weak) shoots. Semi dwarfing and upright varieties such as Reed and Edranol produce weak lateral growth, mainly based on sylleptic shoots, whereas varieties like Hass produce vigorous proleptic shoots that compete with the central leader. This habit in Hass forms large lateral structures causing the loss of the central shoot's dominance and resulting in a wider tree structure with great shading in the interior of the tree (Fig. 9). In the case of densely planted

**Figure** 9: 6x6 m overcrowding.

**Figure** 10: 3x3 m young tree pruning

Hass trees this growth tendency requires initial shaping during the first growing season, with pruning and branch selection. In later years, pruning consists of maintaining tree height and lateral growth to the trees' assigned space, and pruning weak branches to ensure light penetration by making small "holes" in the canopy (Fig. 10). In some years, selective pruning is needed to maintain the structure's initial shape and to correct any development of lateral vigorous branches and other problems related to light interception. The use of plant bio regulators (PBRs) after prunning in subsequent year to control vigorous regrowth could be of great help, because it greatly reduces the need for pruning.

## Conditions favoring high density in Chile

In general, growing conditions in Chile facilitate the management of high-density orchards. The Chilean growing areas experience a cool Mediterranean climate, with 900 to 1200 heat units over >12°C (54F) per year, far lower than subtropical humid regions, which reduces tree vigor and growth. (Editor Note- By comparison the two year average for San Luis Obispo, Camarillo, and Ramona, California airports were 1186, 1563, and 1661 heat units>12°C respectively for the period November 2009- October 2011).

Another factor affecting vigor are the predominant soil types in the producing areas, especially on hills, where soil depth generally ranges between 30 and 100cm (12-40 in.) deep . It is common in the case of shallow or heterogeneous soils to plant on ridges, increasing depth and

**Figure** 11: Closeup of 2.5x1.25 m on ridges.

promoting drainage (Fig. 11). This implies a restriction on soil available volume for root growth additionally affecting tree vigor. Another factor that facilitates the control of tree growth is the concentration of rainfall only in only the winter months, when plant activity is slower. This provides further root growth restriction, especially when this is also managed by controlled irrigation practices. In high density plantings, most trees are irrigated by Microjets (when using ridges) or short range Microsprinklers (without ridges). Drippers are used to a lesser degree, and when used they are normally spaced at 50 cm from each other.

## Current Results

The first high-density Hass avocado orchards in Chile, planted at 3x3 m (~10x10 ft), were planted in 2004 (Figs. 12, 13). We estimate currently more than 3500 hectares are planted in this high density system. Although these orchards were planted and managed with the idea of not removing trees, one of the reasons why this system was initially adopted so fast was that these distances allow for a good escape route through tree removal, ending up with 6x3 m distances in case that tree size control proves to be impossible. This reduced the risk of possible long term crowding problems while growers clearly understood the advantages of orchard precocity and reduced tree size. However, the different experiences so far have proven that through smart management, trees planted in these densities are maintainable in the long term.

The following table shows production of one of the first orchards

**Figure** 12: First year showing road system

**Figure** 13: Five year old 3x3 m

planted with a spacing of 3x3 m in Chile, DASA in Llay Llay, Aconcagua Valley.

**Table** 1. Annual production (average Of 20.7 hectares) of an orchard planted in August 2004 at 3X3 m (DASA in Llay Llay, Chile)

| Year | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012* |
|---|---|---|---|---|---|---|---|
| Kg/ha | 9,288 | 17,711 | 4,425 | 39,526 | 19,138 | 31,480 | 20,000 |

* Estimated

These results show the precocity of orchards planted in high density systems. If an orchard is planted early in the season (like in this orchards case that was planted in August at the end of winter in the southern hemisphere), it is possible to form the structure (2 m high central leader with lateral shoots) in the first season, then induce the tree to flower the following spring (October), and harvest the next spring 24 months after planting (Fig. 14).

**Figure** 14: Second year flower

Another interesting aspect that reflects this first high density experience is that the first production can be very high due to the large number of trees per hectare.

In this orchard's case, training pruning was done only during the first year to form the central leader, but no special selection of lateral shoots was done, nor were vigorous shoots removed later. Because of this lapse in training, the orchard quickly became overcrowded and shaded.

In 2008 a heavy pruning was done to correct shaping problems and permit light interception in all areas of the tree.

This experience showed the importance of maintaining the initial structure for the long term, preventing excess of vigor and shading. Alternate bearing could be reduced with tree management, requiring especially judicious production reduction in "on" years. This is not necessarily better from the economic point of view nor something growers do easily, but is a practice we are currently working on, with the aim of reducing alternate bearing.


**Figure** 15: Llayquen

In a comparable orchard, Llayquen, (Fig. 15) planted in January (mid summer) of 2006, stricter training pruning was done during the first year, taking care to select only sylleptic lateral shoots. Production data are shown in Table 2.

**Table** 2. Annual production (average of 28.7 Hectares) of an orchard planted in January 2006 with a spacing of 3x3 m (Llayquén in Chagres, Chile)

| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012* |
|---|---|---|---|---|---|---|
| Kg/ha | 453 | 18,263 | 20,581 | 23,911 | 23,532 | 19,000 |

* Estimated

Under this early managed pruning/training scenario, production was more stable and there were no shading problems that required heavy pruning as in the previous orchard's case. On the other hand, the maximum production of this orchard has been lower, but more stable from season to season. This is partly because the selection of shoots in the first year that made trees grow in a more balanced way and do they not use the total available space as fast. At Llayquen, trees are more compact, and 6 years after planting, the trees are just covering the available space. Based on this experience, new trials with planting distances of 2.5x2.5 m (8.2x8.2 ft) have been planted. This implies a 45% increase in the number of trees per hectare (1,600 trees/ha), which will of course have an important effect on orchard precocity (Fig. 16).

**Figure** 16: Ten month old 2.5x2.5 m

Another interesting point to consider is fruit size (ideally fruit between 210 and 300 g) (7.4-10.6 oz), which is one of the most important factors determining fruit prices. In high density orchards, with 2 m high trees, size picking without the use of ladders is very efficient, improving not only size distribution but also total production by allowing the remaining smaller fruit to grow (Fig. 17).

Table 3 presents fruit size distribution data from a high density orchard (3x3 m) harvested three times (during the first 2 passes fruit heavier than app. 220 g was harvested, and the 3rd pass was stripping the remaining fruit) compared with a traditional orchard (6x6 m) harvested in a single pass (DASA in Llay llay, Chile).

The most commercially attractive sizes are # 50's and # 40's (210 to 300 g/fruit) and in the case of the high density orchard size picked three times, these sizes represented almost 80% of the crop, compared with 55% in the traditional density orchard harvested once per season.

**Figure** 17: Picking in 3x3 m

## Future projections

**Table** 3. Fruit size distribution of a high density orchard (1,100 trees/ha) harvested by size picking in 3 passes compared with a single harvested orchard of normal density (277 trees/ha) in the DASA farm, Llay Llay, Chile. (28.35 g=1 oz)

| # Sizes (**11.2** kg box) | **High** Density Block (**3x3** m) | | **Traditional** Density Block (**6x6** m) | |
|---|---|---|---|---|
| | % | % **(accumulated)** | % | % **(accumulated)** |
| **28** (400 g) | **0.39** | | **0.00** | |
| **32** (350 g) | **6.19** | **6.58** | **0.46** | **0.46** |
| **36** (311 g) | **2.71** | **9.29** | **0.82** | **1.28** |
| **40** (280 g) | **38.84** | **48.13** | **18.20** | **19.48** |
| **50** (224 g) | **39.70** | **87.83** | **37.62** | **57.10** |
| **60** (187 g) | **7.30** | **95.13** | **26.93** | **84.03** |
| **70** (160 g) | **3.27** | **98.40** | **13.03** | **97.06** |
| **84** (133 g) | **1.60** | **100.00** | **2.94** | **100.00** |

Experiences with high density have proven very successful until now and in building on these experiences, we currently have investigations and trials that are being carried out in order to improve results and provide stability to this highly intensive cropping system. Currently we are testing even higher densities, with spacing such as 1x1 m, 1.25x1.25 m, 2.5x1.25 m among others (Fig. 18).

**Figure** 18: 1.25x1.25 m

One of the main challenges to guide efforts in the design of a production system is to know what the maximum productive potential of avocados is, both in general, and of each particular avocado orchard, given their individual characteristics and conditions. We don´t expect to reach a perfect answer to this question, especially because both environmental and orchard conditions change in time. However, it is important to have an idea based on this potential, of what the critical points are that limit reaching the maximum sustainable production potential of each orchard. An important factor is to understand that with the maximum productive potential comes also the need to produce high quality avocados, suitable for market and consumption conditions while maintain in the long-term stable and sustainable production.

Sustainable production is related to the above mentioned points in all the complexity that it implies; it is very relevant in production systems that tend to be more intensive and are dependent on external inputs. Factors such as efficient use of resources like water and energy, the quality – stability and health of the soil, the evaluation and management of environmental impacts, and the development of positive and safe working conditions are very important and must be considered in long term economic businesses such as ours.

Based on those principles, management of high density production systems is more dependent on external inputs, but on the other hand, the use of these systems has shown to have a direct positive impact on quality and safety for labor, uses less nitrogen and water, and offers better economic results (Fig. 19). The more efficient use of resources is even better expressed if it is considered by the kilogram and not by the hectare.

**Figure** 19: Picking 3x3 m

In relation to orchard design, there are ongoing research efforts to evaluate alternative tree structures with the goal being to achieve efficient canopy lighting and develop foliage renewal forms that are more balanced and less invasive. Also, new pruning systems have to be easy to understand and perform at a practical level, something that is easier when it's not done severely (Fig. 20). In relation to the spacing issue, we think that distances of 2.5x2.5 m could be well adapted to trees formed on a central leader. New trials are beginning that will test even higher densities to further increase orchard precocity, increase root competition to reduce vigor and pruning interventions, and have a simpler tree structure.

**Figure** 20: Pruning in DASA 3x3 m

In the long run it is believed that finding new varieties with

Hass-like fruit and with semi-dwarf growth habits, similar to Reed or Edranol, such as Carmen® or Gem® would help solve many of the complications and input requirements.

## Conclusions

In Chile, high density production systems, planted in square pattern, have been very effective in terms of increasing orchard precocity, productivity, fruit sizes, and the easing of harvest, and improving worker safety. Since the first High Density orchards were planted eight years ago more than 3500 hectares have adopted the system and have been planted with tree densities higher than 1100 trees/ha.

A very important factor for the success of such orchards is to restrict extensive root development, which is achieved by competition between trees planted at a distance of 3 m or less, with restricted localized irrigation and soil volumes.

Pruning and shoot selection during the first year and the maintenance of tree structure and shape in the following years is very important, especially in vigorous varieties like Hass.

Alternate bearing is an important problem in high density systems since tree size and vigor is very difficult to control in OFF years.

After eight years of experience there are many aspects of production systems that are being changed and adjusted, but new experiences with even higher densities than 1100 trees/ha are being attempted.

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