2016 - Proceedings of the International Workshop on Olive and Jojoba. State Institute of Agriculture Management, Government of Rajasthan, Jaipur, India, pp. 1-14.

Case Studies - Jojoba, New Industrial Crop Development and Commercialization in Argentina: 1976 -2015

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ABSTRACT

The history of the jojoba crop in Argentina started in 1976. Thirty-five years after this first attempt, Argentina has become the first jojoba oil producer and exporter of the world. Key domestication trials in jojoba included plant selection and the development of agronomic practices (e.g., a site selection, seed and oil yield improvement, chilled requirements, cloning, rooting capacity, frost tolerance, pruning, land preparation for seed harvest, fertilization, artificial pollination, oil extraction and refined). Country yield average was approximately 800 kg/hectare over the last years (2003-2015). However, the crop showed the potential of yielding 3,000-3,500 kg/ hectare using the combination of improved agronomic practices and selected clones. The characteristics considered among the tops when it comes to selecting a clone have been seed yields, late flowering, plant architecture, shattering, rooting capacity, seed size and oil content. The success of the introduction of jojoba is clearly demonstrated, being one of the few new industrial crops that reach the stage of commercialization. The establishment of a new agricultural industry in the arid region encouraged productive diversification.

Keywords: jojoba, Argentina, supplemental pollination, yields, arid climate, *Simmondsia chinensis* L.

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INTRODUCTION

The history of the jojoba crop in Argentina started in 1976. Mr. P. Qüerio, G. Triest and R. Fasciolo, owners of a petrol company, encouraged the author to begin a research and development project. The first plantation was carried out in Las Oscuras, Cordoba Province, in the Arid Chaco Ecosystem. The University of Arizona provided the seeds. Some plants still survive, even today, the beef cattle's predator action. Thirty-five years after this first attempt, Argentina has become the first jojoba oil producer and exporter of the world (IJEC, 2010).

The uses of this shrub liquid wax were original intended to be a basic compound for the pharmacy industry at first, and energy industry later. However, almost all the jojoba produced today is used in the cosmetic industry to make high quality products.

The first pharmacology work to show the early potential of the jojoba wax was developed in 1949 in Argentina. Dr. José W. Tobías, Dr. Aimar F. Mazzuco and Dr. Raúl J. Latorre realized the investigations in the Medical Model Institute Luis Agote, in Buenos Aires, demonstrating that the jojoba liquid wax, extracted from the USA collected seeds, could control the development of the tuberculosis bacillus (Tobias et al., 1949).

Yacimientos Petrolíferos Fiscales (YPF), an Argentine government petrol company, later determined the convenience of including jojoba wax in the formulation of maximum strength lubricant's formula. They first used wax extracted from the University of Arizona seeds in 1978, and then from the first harvested seeds in Cordoba in 1985. Nowadays, jojoba attires the attention of petrol industry as clean and renewable alternative of energy capturing the world attention to replace the finite and contaminant fossil's resources.

Jojoba is one of the few new crops that reach commercialization stage, Argentina is the major producer, and exporter of Jojoba seeds and oils worldwide (IJEC, 2010). By providing a review of the history and most relevant issues of the process, it can help new crops' development and serve as model for them.

RESEARCH AND DEVELOPMENT

The introduction period of jojoba in Argentina dates from 1976 until the beginning of the

90's. It is known for the development of investigation projects spread in the northwest of the country. The model of information exchange was a triangle between researchers, those transferring information, and private enterprises. Big part of these plantations where established in research centers and farmer fields located in arid and semiarid zones in the Dry Chaco (Arid and Semiarid Chaco) and the Northern Monte Desert ecosystems (Fig. 1).

The second period goes from the ending of the introduction period and the beginning of the 2000's. Jojoba plantation development increased because taxation. Jojoba and olive crops were benefit by taxes' money that was invested in the plantations, causing a rapid implementation of research and development projects. The period is known for the plantation of large areas, specially bought for the projects. Big companies from outside the agricultural sector developed these projects.

This period is also characterized for a close collaboration between both private and government organizations in the United States and Argentina. These countries have been working together since the ending of the 90's decade. Equipment to mechanize jojoba production and the implementation of new agricultural techniques, have been very important to establish a successful agro-industry.

A third period can be considered from the late 90's. The first plantations with selected clones with high seed production were made. This period still goes on in time. Almost 50% of jojoba surfaces are planted with this kind of selected clones. This selected clones come from the first plantations in the country grown with seeds brought from the wild Sonoran Desert populations.

Key domestication traits in jojoba included plant selection and the development of agronomic practices (e.g., a site selection, seed and oil yield improvement, chilled requirements, cloning, rooting capacity, frost tolerance, pruning, land preparation for seed harvest, fertilization, artificial pollination, oil extraction and refined).

Site selection

The initial trial was followed by nine experimental plantations developed by government organizations and private companies (Ayerza, 1990a). They were established in two ecosystems: Northern Monte Desert and the Dry Chaco (Arid Chaco and Semiarid Chaco). Commercial

plantations begun due to the pressure exerted by the private sector (in counting high quantities of commercial seeds) in the first three years, even before there was basic information about jojoba behavior in different environments. The process grew when jojoba qualified to receive government financial help, deferring national taxes in jojoba commercial plantations in La Rioja and Catamarca provinces and in other tax incentive places like Salta Province. This help worked more like subsidies and this financial mechanism allowed the government to approve the installation of 10,000 hectares in three provinces (Ayerza, 1995).

The arid zone typical plant characteristics, low water requirements, salty soils, dry long-lasting seasons' tolerance, and high temperature resistance, made jojoba an attractive species choice for arid lands in Catamarca and La Rioja provinces.

On the other hand, the lack of productive information so typical in new crops development makes it risky for commercial investment.

The main reason of plantation abandoning in Argentina, as well as in other countries, was bad site selection. Only 8,175 hectares planted around the world with commercial porpoises, are left from the 37,000 original ones: 29.8% in Argentina, 14.7% in India, 14.1% in USA, 8.3% in Israel, 6.9% in Peru and 4.1 in Australia. The rest of the hectares are divided between Mexico, Chile, China, and Egypt. The 93% of seed production is concentrated in four countries, Argentina, Israel, Peru, and USA, with 34%, 28%, 17%, and 14%, of the total seed produced yearly, respectively (IJEC, 2010).

Nowadays, commercial jojoba plantations in Argentina are located in La Rioja Province, in the Northern Monte Desert Ecosystem. The similarities between the Northern Monte Desert and Sonoran Desert have been already pointed out (Orians and Solbrig, 1977; Ayerza, 1990a). Apart from being the original jojoba ecosystem, the Sonora Desert is where the totalities of the USA commercial plantations are located.

The cold temperatures in the Semiarid Chaco region not enough to fulfill the chilling requirement process (Ayerza, 1992) and the extreme minimum temperatures in Arid Chaco (Coates and Ayerza, 2008), were the main causes of low production in the Gran Chaco Ecosystem. More than 4,000 hectares intended commercially were abandoned, half in the Semiarid Chaco in Salta province and half in the Arid Chaco in La Rioja and Catamarca provinces.

From the total plantations, 34% achieved to set like a commercial crop. Argentina, with

2,424 hectares, is positioned as the main producer and exporter of jojoba seeds and oil worldwide (Table 1).

Planting and production

Seed yields

Country yield average was approximately 800 kg/hectare over the last years (2003-2015). However, the crop showed the potential of yielding 3,000-3,500 kg/hectare using the combination of improved agronomic practices and selected clones.

Although the technology for rooting jojoba cuttings has been available since the early 80´s, and the availability of superior selected clones in the country has been available since late 80´s, only a small percentage of the planted surfaces were planted with the clones. Even the first plantations made out of rooted cuttings were made by cloned plant mixtures where the only information they hardly had, is that they were female plants. They had no production data however.

This risky way of working was adopted, mainly because the high costs of producing seed or selected clone plantation could not be easily understood and accepted by investors that could not see the future benefit of this, in future yields. It is important to highlight that hardly any commercial planted plantations in Argentina where made by farmers. They were made by investors gathered in the principal cities of the country, who had access to taxing benefits, but low access to jojoba technology and management knowledge of the fragile arid and semiarid ecosystems.

The great genetic variety plus the lack of agronomic knowledge, made investors disappoint as the price of average yields in commercial plantations, was far behind from what they had expected.

Clone selection

The productive variability between the jojoba plants could be seen in the first plantations of the country, since the early 80's (Ayerza and Zeaser, 1987). A collection of germ plasm, from

all around the Sonora Desert, Arizona and California, was carried out in 1986 (Ayerza, 1990b), and planted in Cordoba Province that year. In La Rioja Province, seeds coming from three origins (the collection of germ plasm, the plot established in Cordoba Province in 1976, and a commercial plantation in La Rioja established with seeds from the University of California-Riverside) were planted in 1987. They were planted according to their origin, forming the large genetic base from where the majority of actual high producing clones come from
. The characteristics considered among the tops when it comes to selecting a clone have been seed yields, late flowering, plant architecture, shattering, rooting capacity, seed size and oil content (Ayerza, 1990c, 1992, 1995, 2001; Kolodziejczyk et al., 2000; Tobares et al., 2004).

Selection of clones with long chilling requirements

Since the open flowers die at temperatures of 0ºC, while the closed buds can withstand several degrees below zero, clones with sufficiently long vernalization requirements in order to avoid the opening of the buds until the threat of frost has passed (Dunstone, 1996) were selected.

Agronomic practices

Frost is the main constraint for obtaining annual cash crops. This climate phenomenon has been responsible for the abandonment of the vast majority of plantations in Argentina. Thus, the search for solutions to this problem became an activity around which all else revolved. The research focused on the selection and agricultural practices.

Decrease in the plant's metabolic activity

By progressively diminishing the frequency of watering in late summer and early fall until irrigation levels reach zero at the beginning of winter, the metabolic activity of the plant decreases until the growing of new biomass stop, thus being significantly more resistant to the frost that during periods of active growth (Nelson, 1996). This technique has proven effective to reduce or even prevent frost damage.

Supplemental pollination

One of the recurring themes addressed during the process of domestication of jojoba, are the inconsistent or poor performance levels. Studies have identified as major causes the small number of male plants and /or the distance between male and female plants. In other cases, these problems relate to concentrated flowering in very short periods dominated by climatic events such as very high temperatures and strong winds or rains during the pollination stage (Niklas, 1985; Benzioni and Ventura, 2003), affecting the pollination process.

Based on this information and experience, a program in order to develop and implement the mechanical application of supplemental pollen was created. The program was launched in 2002 run by the University of Arizona and funded by Fincas de Ambato and the State of Arizona.

The program developed the machinery required to collect pollen and apply management techniques and preservation thereof, dosages, etc. Due to the possibility of working in both Arizona and Catamarca, a six-month reduction has been achieved in the period between harvest and application of pollen (Coates et al., 2006).

Supplementary pollination may increase quickly and dramatically the yields in commercial plantations of jojoba around the world, whose low yields are mainly due to its high ratio of female/male plants. Another option would be to plant a greater number of males; however, it would require a period of 3-6 years to produce enough pollen to be effective. Although increasing the number of male plants would increase yields, it also reduces the number of female plants in a given field, decreasing the production per hectare (Coates and Ayerza, 2008).

While assisted pollination proved to be a solution to these problems, it had not yet been incorporated as part of a package of technological culture.

Harvesting

The equipment for transplanting cuttings, pruning plants and prepare the soil for harvest, inclusive the design and construction of a new type of harvester specially adapted to the

conditions of Argentina are already developed.

The current harvesting techniques allow the seeds to ripen on the plant and fall naturally to the ground, getting ready to be collected. Today, more than 70% of the seed is mechanically harvested with vacuum systems.

COMMERCIALIZATION

The commercialization of jojoba in Argentina began in the late 80´s, when the first production reaches levels that justify their export quantities (Table 1). There was a very low consumption, locally. Companies in the USA, located almost exclusively in Arizona, bought all of these exports. In the mid-90´s, the first extractor facility of jojoba oil was installed.

Nevertheless, seed exports remained important until 2002, when export a tax of 21% for seed and 5% for oil was established. Two more extraction plants were installed. Currently there are three extraction plants in operation, two of which belong to farmers. No seeds are almost exported. The oil is marketed as a simple product of the extraction called gold, or deodorized and bleached, called light. The main destination is the European Union, and secondly, the USA. Jojoba seed's production from 1989 to 2015 showed in Table1 is the result of the surveys made by the author, visiting each plantation annually during that period.

CONCLUSIONS

The study of a successful new crop shows a variety of introduced and established trails. Normally, new crops require different forms of government support, especially funding for research and development of plant lines, production, product development and marketing. Several organizations must engage to solve problems that cross disciplinary boundaries and benefit from the efforts over time. The introduction of a new crop demands leadership and coordination between different economic sectors, including research, production, processing and marketing.

The success of the introduction of jojoba is clearly demonstrated, since it is one of the few new industrial crops that reaches the stage of commercialization, making Argentina the largest producer and exporter of jojoba seeds and oil, worldwide (IJEC, 2010). The

establishment of a new agricultural industry in the arid region of the Northern Monte Desert Ecosystem encouraged productive diversification in an area where olive was the only tree grew commercially. The industry also carried a number of benefits to the community because of an improved economy in an underdeveloped area suffering problems of rural emigration.

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TABLES

Table1. Annual Argentina Jojoba Seed production: 1989 - 2015

Year	Area Has.	Farms quantity	Total produced ton	Yield (kg/ha)
1989	400	18	9	----[1]
1990	525	18	20	----[1]
1991	659	15	120	----[1]
1992	2,000	11	100	----[1]
1993	3,100	11	100	----[1]
1994	4,000	11	200	----[1]
1995	4,000	11	300	----[1]
1996	n/a	n/a	n/a	n/a
1997	n/a	n/a	n/a	n/a
1998	n/a	n/a	n/a	n/a
1999	2,580	12	367	142
2000	2,695	13	898	333
2001	3,441	15	935	272
2002	3,611	19	875	242
2003	3,191	18	2,351	737
2004	3,296	17	1,780	540
2005	3,296	17	2,298	697
2006	2,776	16	2,452	883
2007	2,828	15	2,748	972
2008	2,828	15	1,171	414
2009	2,678	12	3,188	1,190
2010	2,678	10	2,310	862
2011	2,439	11	658	285
2012	2,308	10	1,625	704
2013	2,379	10	3,000	1,261
2014	2,424	10	1,506	621
2015	2,424	10	3,375	1,392

[1] most of the plantations were to young to bearing; n/a: not available

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FIGURES

Fig.1 Arid Chaco, Semiarid Chaco and Northern Monte Desert ecosystems (Karlin and Bronstein, 1986).