REVISTA
CIENCIAS NATURALES
Facultad de Ciencias Naturales · Universidad Nacional de Salta

e-ISSN 2953-5441
Vol. 4(1): 10-25

ARTÍCULO

Thermal Inversion and its Relationship with Jojoba Cultivation in the Ecotone between the Arid Chaco and the Mountain Chaco, Argentina

Inversión Térmica y su Relación con el Cultivo de Jojoba en el Ecotono entre el Chaco Árido y el Chaco Serrano, Argentina

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Abstract

Jojoba plants were tested for three years. They were planted in three plots in the western hillside of the Sierra de Pocho, Córdoba, Argentina. The EC-El Cerro, JI-Jardín de Introducción and LQ-La Quebrada plots were located at 360, 400 and 550 masl. respectively. Minimum extreme temperatures were -1, -3 and -6 °C for LQ, JI and EC, respectively. EC plants died in the first year due to low temperatures. Altitude and extreme minimum temperatures of May, June, July and August had a significantly high positive correlation (0.733; $P<0.05$). The production of LQ was significantly ($P<0.05$) higher than that of JI with 759 and 401 g/plant respectively. The seed weight of JI was significantly ($P<0.05$) higher than that of LQ with 0.85 and 0.76 g/seed respectively. Wax content was 51.4% (JI) and 51.1% (LQ). The wax content of LQ seeds varied significantly ($P<0.05$) between 40.6 and 55%. The presence of the atmospheric phenomenon of autumn-winter thermal inversion in the Sierra de Pocho foothills was determined as the factor of the persistence and production of jojoba.

Keywords: Seeds; *Simmondsia chinensis*; Temperature; Wax.

Resumen

Se testearon plantas de jojoba durante tres años. Fueron sembrados en tres parcelas en la ladera occidental de la Sierra de Pocho, Córdoba, Argentina. Las parcelas EC-El Cerro, JI-Jardín de Introducción y LQ-La Quebrada se ubicaron a 360, 400 y 550 msnm respectivamente. Las temperaturas mínimas extremas fueron -1, -3 y -6 °C para LQ, JI y EC, respectivamente. Las plantas de EC murieron el primer año debido a las bajas temperaturas. La altitud y las temperaturas mínimas extremas de mayo, junio, julio y agosto tuvieron una correlación positiva significativamente alta (0,733; $P<0,05$). La producción de LQ fue significativamente ($P<0,05$) mayor que la de JI con 759 y 401 g/planta respectivamente. El peso de la semilla de JI fue significativamente ($P<0,05$) mayor que el de LQ con 0,85 y 0,76 g/semilla respectivamente. El contenido de cera fue de 51,4% (JI) y 51,1% (LQ). El contenido de cera de las semillas LQ varió significativamente ($P<0,05$) entre 40,6 y 55%. Se determinó que la presencia del fenómeno atmosférico de inversión térmica otoñal-invernal en las estribaciones de la Sierra de Pocho era el factor de la persistencia y producción de jojoba.

Palabras clave: Cera; *Simmondsia chinensis*; Semillas; Temperaturas.

Ayerza R. (2026). Thermal Inversion and its Relationship with Jojoba Cultivation in the Ecotone Between the Arid Chaco and the Mountain Chaco, Argentina. Revista Ciencias Naturales 4(1), 10-25. https://id.caicyt.gov.ar/ark:/s29535441/zboroawcd

Recibido: 30/12/2025 Aceptado: 31/3/2026 Publicado: 31/7/2026 Editor: Olga Martínez

INTRODUCTION

Jojoba wax, produced from the *Simmondsia chinensis* (Link) C.K. Schneid. plant, is a raw material for the cosmetics and precision instruments industries. Its market has grown since the second half of the last century. This led to ambitious projects of planting that failed due to the lack of adaptation outside its area of origin, *viz*., Brazil, Costa Rica, Madagascar, Paraguay, Sudan, etc. The lack of information about regions suitable for production and the long time it takes to obtain yields have led to discouraging its cultivation, while demand continues to grow without being able to be satisfied. Today, the jojoba market is estimated at US$130.8 million per year mainly shared between the cosmetology, pharmacy and precision instruments industries (Grand View Research, 2023). In 2022, 18,211 tons of wax were sold and a growth of 6.6% is expected between 2023 and 2028 (IMARC Group, 2023).

The jojoba crop was introduced in Argentina in 1976 at El Desafío farm located in the Sierra de Pocho foothills, Córdoba. The place is an ecotone between the Mountain Chaco and the Arid Chaco (Ayerza, 1990a).

Today, Argentina has 2,455 commercial hectares, concentrated in the Arauco Department, La Rioja Province (Ayerza, 2020a; N. Vinelli, Aimogasta, La Rioja, personal communication 2025). However, it reached 13,000 hectares with commercial expectations, most of which they never produced due to the lack of adaptation of the species to the selected places (Coates & Ayerza, 2008). Planting sites included Capital Department (La Rioja), Valle de Catamarca (Catamarca) and Las Colmenas (Salta). Experimental plots were also established in Fuerte Esperanza (Chaco), Ing. Juárez (Formosa), San Martín (Mendoza) and Burruyacú (Tucumán).

This lack of adaptation was essentially due to thermal conditions. The minimum temperatures in areas such as San Martín, Mendoza (Monte Desert) and Department Capital, La Rioja (Arid Chaco) eliminated the flowers and even killed the young plants. In the Semiarid Chaco such as Tucumán, Salta and Formosa, the lack of enough winter cold did not allow the vernalization phenomenon thus inhibiting the beginning of the floral opening period (Ayerza, 1990a, 1992).

Between 2013 and 2017, Argentina was the main jojoba producer in the world. It was then displaced to third place by Israel and Peru due to increased yields and increased planted areas in both countries. The determination of new areas suitable for the crop, together with the availability of higher production clones could allow the country to retrieve positions in the market.

The Since 1990, the production area has remained constant (N. Vinelli, Aimogasta, La Rioja, personal communication, 2025). This area in the Arauco Department, La Rioja Province, could extend to the west, ascending on the foothill of the Sierra de Velazco, taking advantage of the winter thermal inversion phenomenon. There, the increased production of jojoba plants as altitude increases has been determined. In the center of the valley, the extreme minimum temperatures can reach -9°C (Ayerza, 1990a).

In these regions, the low rainfall (100 to 150 mm/year) on the slopes suitable for cultivation is an important limitation, so it is essential to resort to irrigation. The water tables are 200 m deep, with flows of 150 to 200 m^3/hour. To obtain higher flows and structural stability of the perforations it is necessary to reach 400 to 440 m deep. This implies very important infrastructure and pumping costs that put at risk the economic results of the plantations (Tálamo *et al*., 2013).

On the other hand, the decrease in water resources is forcing the world to pay attention to the use of water. The decrease in groundwater and its flows due to the overexploitation of aquifers, as well as the destruction of vegetation and tree cover that exacerbates soil erosion and reduces groundwater recharge, increases water scarcity and food insecurity (United Nations, 2019).

A basic factor for expanding jojoba cultivation in the country and ensuring sustainability is to find thermally suitable areas for cultivation with adequate rainfall regimes, using irrigation only as strategic support.

Based on the recent determination of the thermal inversion phenomenon in the Sierras de Pocho, Córdoba, Argentina (Ayerza, 2023), this paper is aimed to define its relationship with the productive jojoba behavior in the said ecosystem and under rainfed conditions. Even though the presented data were obtained between 1980 and 1986, the conclusions of the study were never published. Knowing the behavior of the species and the essential edaphoclimatic characteristics of the region, would allow adding an area to establish more sustainable commercial jojoba projects than the current ones, by not having to resort to irrigation.

MATERIALS AND METHODS

The work was carried out at El Desafío farm, located on the western slope of the Pocho Mountain, Pocho, Córdoba, Argentina. The place belongs to the so-called Eastern Pampa Mountains.

Seeds to be planted were harvested in July 1980, from a hillside exposed to the north of the Tucson Mountains, Tucson, Arizona (32°14’13” N and 111°02’55” W) between 778 and 810 masl, with a slope of 25.6%. Plants density was 0.21 plants/m^2 with a male-to-female ratio of 46.55% of male plants and 51.72% of female plants, which suggests a significant variability in the seed’s genetic composition (Ayerza, 2025).

Seeds from 10 plants selected at random two years earlier were harvested (Tables 3 and 4). These plants had been identified and monitored and their annual fruiting was observed (Ayerza, 1984). Later on, between 1981 and 1984, the floral biology of this jojoba stand was studied confirming a significant variability among individuals (Buchmann, 1987).

Winter thermal inversion phenomenon was determined in the Tucson Mountains hillsides where the native jojoba plants grow (Shreve, 1912; U.S. Army Corps of Engineers, 1997). This explains this species’ presence on the hillside as well as their absence in the center of the valleys (Ayerza, 1990a).

The seeds were brought to Argentina where three random samples were taken after mixing them. In October 1980, three plots were planted in a western hillside of the Sierra de Pocho, in an ecotone between the Arid Chaco and the Mountain Chaco, at 31°64’ south latitude. The EC (El Cerro) plot was located at 360, the JI (Jardín de Introducción) plot was located at 400 masl and LQ (La Quebrada) plot was located at 550 masl.

The distance between LQ and JI was 2,404 m and between JI and EC, 1,649 m. The slope percentage was 4.16 and 2.43 for LQ and JI respectively. The description of the measurement instruments placed in each site for the collection of temperature and rainfall data for the period 1983-1986 were described by Ayerza (2023).

To determine possible differences between the soils of the plots, a chemical analysis of composite samples from each plot, taken in the first 40 cm of depth, was carried out. The method used was Mehlich 3 (Mehlich, 1984) for calcium, magnesium, potassium and sodium; that of Bray & Kurtz (1945) for phosphorus; that of Kjeldahl for nitrogen (Chapman & Pratt, 1961) and that of Walkley-Black for organic matter and carbon (Walkley & Black, 1934). The pH was determined by electrometric method (Bates, 1973).

The planting framework was one seed per meter in the row, and four meters apart between them. The seeds were soaked for 48 hours before planting and only those that were swollen were planted. The plots were irrigated by furrow only during the first month and no fertilizer were applied during the analyzed years. When the plants were three years old, 43 female plants were randomly selected in LQ and 22 in JI, being 50% of the total female plants of each plot. The selected plants were within the rows, discarding the edges with a male-to-female ratio being 1:1 in each plot. In the EC plots no plants were chosen since they disappeared before they were three years old due to the extremely low temperatures.

Every year, between November and January, the seeds were manually collected. The following April, they were cleaned, dried in the shade and weighed. In all cases, the weight had 4% moisture, using for its determination a Delver HD-1021 meter (Delver S.A., La Plata, Buenos Aires, Argentina).

The seeds were stored at room temperature until 1988, when the liquid wax content was determined. Seeds from seven plants were taken at random from the QL site and since after the physical determinations the JI seeds were mixed, two composite samples (JI_1 and JI_2) were taken for analysis. The determination was done through the AOCS Ac-3-44 (AOCS, 1984) method at the laboratory of Jojoba Growers and Processors Inc., Apache Junction, Arizona, US.

The information collected in this experiment was analyzed in 2022. The statistical determinations (Standard Deviation, Multiple Comparison of Means and Correlations) were carried out using the CoStat software (CoHort Stat, 2006).

AI was not used in the preparation of this paper.

RESULTS AND DISCUSSION

Table 1 shows the soils chemical composition of the EC, JI and LQ plots and Tucson hillside where the plants from which the original seeds were collected.

The soils of the three trial plots were chemically very similar to each other, being typical of the region (Hang *et al*., 1995; Bocco *et al*., 2007; Karlin, 2013). Therefore, an influence of this factor between the implanted sites was ruled out. All the values obtained were within the limits of the Sonora Desert and Californian Mediterranean soils, where the native jojoba stands are located (Ayerza, 2025). However, the Tucson soil presented a lower pH, a lower organic matter content, a lower calcium content and more phosphorus than the soils of the trial. The data of the soils in which the jojoba crop is successfully developed show that the differences between the Tucson soils and those of the trial are not sufficient to interfere in their development (Gentry, 1958; Brooks, 1978; Ayerza, 1990a).

Table 2 shows the extreme temperatures recorded during the studied years. The plants from the EC plot were strongly affected by low temperatures, most of them dying at temperatures of -6°C. The remaining plants died between 1984 and 1985 with temperatures of up to -5 and -6°C without any producing, so the EC plot had to be left aside. Although adult jojoba plants can survive extreme minimum temperatures of -9.5°C, young plants die with

Site	pH	C	MO	N	Ca	Mg	K	Na	P	C/N
			%			mg/100 g of soil				ratio
LQ	7.6	1.05	2.10	0.099	370	30	89	3	0.8	10.6
JI	7.6	1.10	2.20	0.093	380	60	87	3	1.08	11.8
EC	7.8	1.25	2.50	0.096	290	36	89	3	0.96	13.1
Mean	7.7	1.1	2.3	0.1	346.7	42.0	88.3	3	0.9	11.8
SD[1]	0.12	0.10	0.21	0.00	49.33	15.87	1.15	0.00	0.14	1.25
Tucson[2]	6.6	0.45	0.90	0.051	160	48	16	3	5.76	8.8

[1] Standard Deviation; [2] hillsides where the original seeds were collected.

Table 1. Soils chemical composition of the EC, JI, LQ plots in the Sierra de Pocho foot hills, Córdoba, Argentina

Month	J	F	M	A	M	J	J	A	S	O	N	D	SD	Mean
						Absolute minimum temperature(°C)								
LQ-83	12.70	15	12	13	-1	-1	1	4	3	7	12	16	6.36	7.81
LQ-84	18	13	12	7	1	1	1	1	4	6	10	7	5.59	6.75
LQ-85	10	14	8	6	5	1	-1	-1	4	6	10	10	4.71	6.00
SD[1]	4.07	1	2.31	3.79	3.06	1.15	1.15	2.52	0.58	0.58	1.15	4.58	-	-
Mean	13.60	14	10.70	8.70	1.70	0.30	0.30	1.30	3.70	6.30	10.70	11	5.60	6.90
JI-83	19	17	12	13	-3	-3	0	3	0	6	12	16	8.09	7.67
JI-84	13	17	10	5	-1	2	3	-3	4	9	7	11	5.87	6.42
JI-85	8	10	7	0	3	-2	-2	0	3	6	11	12	5.03	4.67
SD	5.51	4.04	2.52	6.56	3.06	2.65	2.52	3.00	2.08	1.73	2.65	2.65	-	-
Mean	13.33	14.67	9.67	6	-0.33	-1	0.33	0.00	2.33	7	10	13	6.33	6.25
EC-83	16	16	12	2	-4	-6	0	2	0	4	14	18	8.50	6.17
EC-84	19	18	10	4	-5	-3	-4	-5	4	7	7	9	8.32	5.08
EC-85	10	9	7	-3	-3	-6	-5	-4.5	0	7	10	11	6.82	2.71
SD	4.58	4.73	2.52	3.61	1	1.73	2.65	3.91	2.31	1.73	3.51	4.73	-	-
Mean	15	14.30	9.70	1	-4	-5	-3	-2.50	1.30	6	10.30	12.70	7.90	4.70

[1] Standard Deviation

Table 2. Absolute minimum temperature by site and year.

extreme minimum temperatures between -4 and -5°C (Gentry,1958; Yermanos, 1982; Nelson & Palzkill, 1993). In addition to the differences in the extreme minimum temperatures of the studied period, there were also differences in the number of months with frosts, being 11, 6 and 4 for EC, JI and LQ, respectively (Table 2).

The Fig. 1 shows the curves of the mean extreme minimum, mean extreme maximum and mean annual temperatures for the period 1983-1985 at the three surveyed sites. This graph allows us to observe the presence of the atmospheric phenomenon of thermal inversion during autumn-winter (May, June, July and August), responsible for the increase in extreme minimum temperatures as altitude increases, as reported for the 1983-1986 period (Ayerza, 2023).

This same behavior regarding altitude and minimum winter temperatures was determined in the northern Sonoran Desert, on a slope with native jojoba in Cave Creek, Arizona, USA, between the base 610 masl and 730 masl (Burden, 1970).

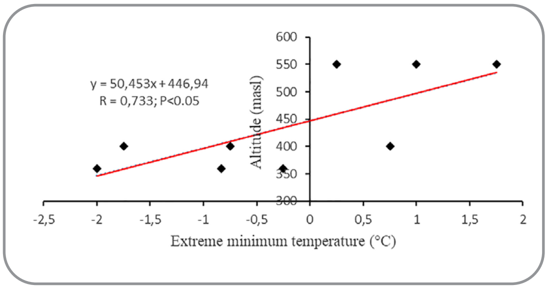

Figure 1. Correlation of the extreme minimum temperature of May, June, July and August versus altitude.

The extreme minimum temperatures of May, June, July and August (Fig. 2) and the altitude between 360 and 550 masl, presented a significantly high positive correlation (0.733; P<0.05).

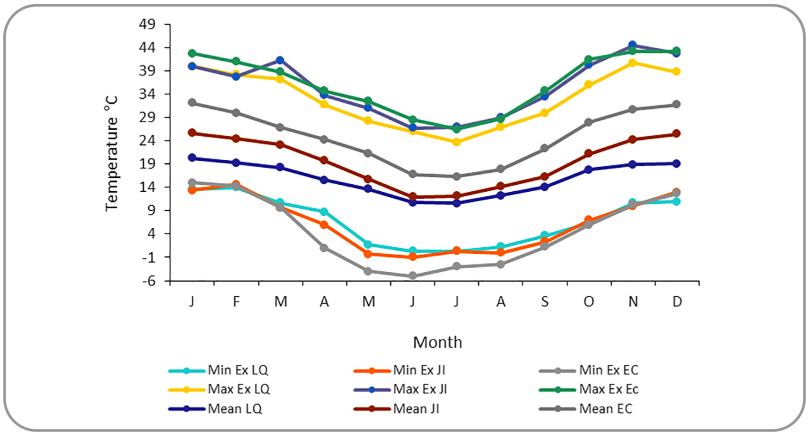

Figure 2. Extreme minimum, extreme maximum and annual mean temperatures for the period 1983-1985 at the three surveyed sites.

According to Ayerza (2004), the jojoba flowering period in the ecotone between the Mountain Chaco and the Arid Chaco forms a Gaussian curve that begins in mid-June and lasts until mid-September, coinciding this extension of the floral period with that of the original population (Buchmann, 1987). This long flowering period is made up of two essential aspects: variability of the flowering beginning of the different genotypes and extended opening period in the same plant. It has been shown that the beginning of flowering depends on the vernalization requirement of each genotype (Ferriere *et al*., 1989; Benzioni et *al*., 1992; Dunstone, 1995; Milthorpe, 2006), as well as the length of the opening period (Dunstone, 1980; Nerd & Benzioni, 1988), and in both cases of their interactions with climatic conditions.

In the foothills of the Sierra de Ancasti, Catamarca, Argentina, an ecotone between the Mountain Chaco and the Arid Chaco, the individual flowering period has been determined between 20 and 46 days to reach 90% of floral opening, depending on the genotype and weather conditions (Ayerza, 2004). Although the same clone controlled in this foothill for two consecutive years, presented a similar flowering period of 27 days, between August 20 and September 17, and 24 days, between September 8 and October 2, the following year, the start date presented a difference of 19 days (Coates & Ayerza, 2008). The variation between years in the beginning and length of flowering has been determined in other jojoba populations with similar values (Nahla *et al*., 2018; Perry *et al.,* 2021).

Since freezing in plants is a progressive process, the duration of freezing temperatures is a decisive factor (Díaz-Queralto, 1971; Livingston, 2018; Bravo *et al*., 2020). The frequency variability of wild jojoba plants is influenced by changes in slope angle (Burden, 1970); the steeper the slope, the shorter the duration of the frost (Snyder & Melo-Abreu, 2005).

In the northern Sonoran Desert, in the mountains of Cave Creek, Arizona, a highly significant positive correlation ($R = 0.524$; $P<0.01$) was demonstrated between the presence of this plant and the slope angle. Its degree is closely linked, not only with the circulation of the air, but also with its speed and, therefore, with the duration of the low temperatures (Burden, 1970).

The slope in LQ was 4.16% while in JI it was 2.43%, so the duration of the low temperatures must necessarily have been shorter in LQ than in JI, which must also have influenced the differences between the plant yields of both sites. Tables 4 and 5 show the individual weights of the seeds and the yields per plant of the LQ and JI sites during the three years studied.

Plant	Weight (g/seed)				Yield (g/plant)			
	1983	1984	1985	Media	1983	1984	1985	Total
Q_7P_{11}	0.79	0.92	0.73	0.81	4.0	272.0	115.4	391.3
Q_7P_{12}	0.77	0.88	0.71	0.79	4.6	268.4	206.6	479.6
Q_4P_4	0.89	0.83	0.71	0.81	7.1	243.2	117.9	368.3
Q_6P_9	0.48	0.75	0.76	0.66	6.8	290.0	241.5	538.3
Q_4P_8	0.79	0.89	0.62	0.77	346.0	644.5	814.7	1,805.2
Q_4P_3	0.63	0.85	0.68	0.72	23.4	349.3	1,087.1	1,459.8
Q_7P_2	0.89	0.87	0.69	0.82	8.0	226.8	198.7	433.5
Q_9P_9	0.93	0.90	1.01	0.95	10.2	266.0	307.9	584.1
Q_6P_{10}	0.58	0.88	0.78	0.75	27.8	442.0	1,088.3	1,558.1
Q_5P_{15}	0.22	0.88	0.67	0.59	35.7	464.3	1,140.3	1,640.3
Q_4P_1	0.63	0.78	0.70	0.70	6.9	170.0	150.4	327.3
Q_3P_2	0.59	0.88	0.74	0.74	31.7	208.0	1,284.2	1,523.9
Q_4P_{16}	0.72	0.68	0.53	0.64	22.9	324.6	518.7	866.3
$Q_{11}P_{12}$	0.63	0.86	0.72	0.74	24.5	212.6	834.9	1,072.0
Q_4P_2	0.60	0.83	0.65	0.69	22.1	359.2	283.4	664.8
Q_5P_{17}	1.12	0.88	0.88	0.96	17.9	390.6	223.5	632.1
Q_9P_7	0.56	0.91	0.67	0.71	15.7	234.0	371.0	620.6
Q_8P_3	0.59	0.85	0.73	0.72	8.3	155.3	142.7	306.2
Q_4P_{10}	0.96	0.74	0.60	0.77	67.1	534.0	560.7	1,161.8
Q_6P_{13}	0.68	0.88	0.66	0.74	56.1	492.8	570.3	1,119.3
Q_5P_8	0.62	1.01	0.67	0.77	99.2	290.0	1029.7	1,418.9
Q_3P_{10}	0.46	0.82	0.56	0.61	41.8	315.5	525.2	882.5
Q_3P_{14}	0.77	0.84	0.82	0.81	81.6	319.6	186.7	587.9
Q_3P_8	0.64	0.84	0.66	0.71	44.1	351.9	469.4	865.4
$Q_{11}P_9$	0.86	0.86	0.70	0.81	18.9	184.0	477.8	680.7
Q_5P_5	0.58	0.88	0.66	0.71	23.2	242.2	415.3	680.7
Q_3P_{13}	0.61	0.80	0.84	0.75	7.9	138.9	274.8	421.6
Q_3P_3	0.77	0.77	0.70	0.75	17.0	221.9	372.8	611.7
Q_3P_7	0.59	0.78	0.67	0.68	300.2	559.6	556.7	1,416.5
Q_5P_{18}	0.82	0.87	0.86	0.85	58.9	299.1	656.0	1,014.0
Q_5P_{16}	0.77	0.85	0.64	0.75	11.5	176.9	292.9	481.3
Q_3P_5	0.77	0.87	0.70	0.78	138.0	288.6	776.4	1,203.0
Q_3P_6	0.60	0.79	0.73	0.71	15.1	163.6	390.9	569.6
Q_1	0.52	0.67	0.75	0.65	25.4	76.0	420.5	521.9
Q_3P_{20}	0.74	0.89	0.70	0.78	24.5	247.5	166.9	438.9
Q_5P_{12}	0.79	0.87	0.84	0.83	25.4	214.4	224.0	463.8
Q_1P_6	0.85	0.93	0.96	0.91	27.2	187.7	299.3	514.2
Q_3P_{17}	0.78	0.85	0.74	0.79	28.9	242.0	182.0	452.9
Q_4P_{17}	0.63	0.64	0.62	0.63	19.6	163.1	142.2	324.8
Q_2P_5	0.90	0.80	0.71	0.80	55.5	177.2	183.4	416.1
Q_2P_{10}	0.71	0.87	0.90	0.83	32.8	163.6	326.9	523.3
Q_3	0.57	0.67	0.68	0.64	18.3	91.5	220.6	330.5
Q_1P_2	0.77	0.94	0.97	0.89	13.1	76.1	156.9	246.2
Mean	0.70	0.84	0.73	0.76	43.60	272.99	441.99	758.59
SD[1]	0.16	0.08	0.10	0.084	68.10	127.88	314.65	426.18

[1] Standard Deviation

Table 3. Seeds weight and yield of plants from LQ site.

Table 3 shows that 30.1% of the LQ plants reduced their production between 1984 and 1985, compared to only one (5%) in the JI (Table 4). In this last site, the J_4P_7 plant was the only one between both sites that reduced its production between 1983 and 1984. Works have been reported in which many jojoba genotypes present the characteristic called alternation, which implies productive alternation, which in many cases becomes very pronounced both in commercial plantations and in native plants (Yermanos & Duncan, 1976; Yermanos, 1982; Perry et *al*., 2021). This phenomenon is common in other crops such as olive (*Olea europaea* L.), juniper (*Juniperus thurifera* L.), pecan (*Carya illinoensis* [Wangenh] K. Koch) and various fruit trees. (Medina-Morales *et al*., 2000; Ramírez-Santa Paul, 2001; Montesinos-Torres, 2007).

The alternating or biennial production is a widely distributed phenomenon that is repeated in the different production areas and the metabolic processes and their induction are still only partially known. (Lavee, 2007; Kour *et al*., 2018; Wünsche, 2021). It has recently been shown in jojoba that, depending on the genotype and the type of pruning applied, the alternation phenomenon can be significantly reduced (Lazare *et al*., 2021).

However, Table 3 shows that 69.8% of the LQ plants did not present alternation, and Table 4 shows that 96% of JI plants

Plant	Weight (g/seed)				Yield (g/plant)			
	1983	1984	1985	Media	1983	1984	1985	Total
J_3P_{22}	---	0.90	1	0.95	---	1125.1	261.2	1386.3
J_4P_5	0.74	0.86	0.99	0.86	182.3	235.8	340.8	759.0
J_4P_{14}	0.81	0.97	0.98	0.92	81.5	110.1	225.4	416.9
J_3P_{20}	0.67	0.74	0.90	0.77	15.5	140.6	263.3	419.4
J_3P_{11}	0.64	0.82	0.99	0.82	5.8	47.5	155.7	209.0
J_3P_1	0.83	0.86	0.70	0.80	59.7	197.3	273.7	530.7
J_3P_8	0.77	0.94	1.01	0.91	50.8	111.8	258.5	421.1
J_2P_9	0.88	0.93	0.99	0.93	49.3	69.0	161.6	279.9
J_3P_5	0.65	0.74	0.77	0.72	21.5	117.7	239.7	378.9
J_2P_8	0.85	0.95	0.92	0.91	113.3	206.8	320.7	640.8
J_4P_2	0.69	0.77	1.01	0.82	22.0	75.5	145.0	242.5
J_4P_{21}	0.58	0.92	0.97	0.82	12.2	96.9	183.9	293.0
J_4P_6	0.78	0.94	0.91	0.88	110.8	211.7	297.6	620.1
J_4P_{14}	0.81	0.82	1.00	0.88	10.5	59.1	137.0	206.7
J_3P_{16}	0.93	0.75	1.00	0.89	14.8	67.7	150.4	232.9
J_2P_{10}	0.88	0.82	0.85	0.85	33.5	69.2	143.0	245.7
J_4P_7	1.05	0.54	0.98	0.86	45.3	40.6	184.3	270.3
J_4P_{20}	0.86	0.93	0.79	0.86	30.1	80.8	173.9	284.8
J_3P_{19}	0.88	0.70	0.95	0.84	29.0	41.9	131.2	202.1
J_3P_{13}	0.82	0.81	0.97	0.87	27.2	75.5	155.6	258.2
J_2P_{12}	0.85	0.82	0.94	0.87	35.7	61.8	161.2	258.7
J_4P_3	0.54	0.62	0.93	0.70	30.3	68.0	120.4	218.6
Mean	0.79	0.83	0.93	0.85	46.72	150.47	203.82	398.89
SD	0.12	0.11	0.09	0.06	43.17	225.42	67.01	271.26

[1] Standard Deviation

Table 4. Seed weight and yield of plants from the JI site

did not present this characteristic either. The presence of plants with and without alternation was identified in plantations carried out in Riverside, California, both within plots with wild seeds originating from the coast and the inland of the Californian Mediterranean ecosystem (Yermanos, 1982), in Mesa, Arizona, with seeds from wild plants originating in Arizona, California and Baja California, and in cultivated plants from Israel; 90% of plants showed productive alternation (Palzkill & Hogan, 1982). In Hermosillo, Sonora, Mexico, 210 plants were studied for four years, determining 49.7% of plants with alternate production (Durazo, 1982). The alternate production regarding the number of inflorescences has also been reported in male jojoba plants (Tel-Zur *et al.*, 2020).

With the information available here, it is not possible to determine the reasons for the differences in the percentages of alternation between the LQ and JI plants, but it could be related to the interactions between genetics and the environment, especially with the differences in extreme minimum temperatures between both sites (Table 2). From the genetic point of view, it should be kept in mind that the 10 plants from which the original seeds were collected had annual production determined, but since these were not measured, we do not know if they were productions with or without annual ups and downs. It should be added that jojoba has separate sexes and in the same plant the different seeds can have different male parents, making up a high genetic variability between the used seeds.

The values of the standard deviation of the total produced in the tested period (Tables 3 and 4) show a greater dispersion of the yields among the LQ plants than among the JI ones. The extreme minimum temperatures when damaging flowers, both closed at -3°C and open at -1°C, prevent expressing the productive potential of many genotypes (eg. the occurrence of -1°C in early flower openings), standardizing mean production from the JI site. The standard deviation values show that for the LQ site a clonal selection process would be much more efficient than in the JI. Likewise, the reduced magnitude of the standard deviation of the plants from the JI site could indicate that these genotypes are at the limit of their adaptation zone as suggested by Ayerza & Zeaser (1986).

Table 5 shows that despite the high percentage of biennial plants in the LQ plot, the production per area unit increased every year. This characteristic of a high number of alternations, but with an annual increase in total production per area unit, was previously reported in experimental and commercial plantations in Mesa, Arizona, US, and in Bakersfield, California, US (Palzkill & Hogan, 1982). The annual increase in the production of the non-alternation plants compensated the decrease of the alternation plants, in the yields per area unit.

Table 5 shows that the mean production of both sites increased significantly ($P<0.05$) with age, except for the JI site between 1984 and 1985 which, although numerically increased, the difference was not statistically significant ($P<0.05$). These annual yields increase is the usual result for numerous species and within them among genotypes that do not present the phenomenon of alternation; in developing

Site	1983	1984	1985	LSD[2]	Total
		g/plant			g/plant
LQ	43.6$^{a.C.1}$	272.2$^{a.B}$	441.9$^{a.A}$	85.40	758.6^{a}
JI	46.7$^{a.B}$	150.5$^{b.A}$	203.3$^{b.A}$	85.78	400.5^{b}

[1]differentlowercase letters in the same column (t Student test) and uppercase letter in the same row (Student-Newman-Keuls test), are significantly ($P<0.05$) different;[2] least significant difference according to Student-Newman-Keulstest..

Table 5. Mean jojoba productions from the LQ and JI sites at 3, 4 and 5 years of age.

plants it is related to the increase of biomass volume (Jiménez-Méndez *et al*., 2019; Fan *et al*., 2020).

Undoubtedly, the LQ site was significantly (P<0.05) more productive than the JI (Table 5). Taking the yield of the LQ site to one hectare after five years means production of 995 kg/ha (2,500 plants – 10% of male plants = 2,250 female plants/ha), which is within the yields achieved at that age in commercial plantations originating from seeds in Mexico, the US and the current area of commercial production in Argentina, in the Province of La Rioja (Ayerza, 2016, 2020b).

The mean yields reached in the fifth year were higher than the mean attained in Riverside, California, USA, in plantations originating from seed and with irrigation (Ayerza, 1989). But in the third year they were lower than the media obtained from three-year-old plants from seeds in Hermosillo, Sonora, Mexico, under irrigation conditions (Ramonet & Morales, 1985).

The mean of the eight three-year-old clones implanted under irrigation conditions in the foothills of the Sierra de Ancasti, Catamarca, Argentina, was higher than the mean of the LQ plants. However, of except one of these clones, the mean yields of the four-year-old LQ plants exceeded those of the other seven clones.

It has been shown that in the yields of the first years, the jojoba plants from seed are 2 to 3 years behind the clones (Ramonet, 1988).

At the same age, three years old, the J_3P_{22} genotype (1,125 gr/plant) was superior to the highest producer (777 gr/plant) of the clones selected by the National Institute of Agricultural Research (INIAP), tested in Hermosillo, Sonora, Mexico (Sonora Desert) under irrigated conditions, while the Q_4P_8 genotype (645 gr/plant) was higher than 30% of the selected clones and practically equal to the mean (667 gr/plant) of the 10 clones which were selected by INIAP (Ramonet & Morales, 1985).

Table 5 shows that the comparative production between sites determined productions without significant difference (P<0.05) in 1983, while in 1984 and 1985 the production of the LQ plants was significantly (P<0.5) higher than those of JI. The lack of statistical significance (P<0.05) between the productions of 1983 in both sites, may be due to the presence of frosts in June and July (Table 2). Although they were lower in LQ, one degree Celsius below zero is enough to kill open flowers (Ayerza, 1990a). In 1984 and 1985, frost occurred early in JI but not in LQ, thus justifying the productive differences between sites.

Milthorpe and Dunstone (1989) found that genotypes that broke dormancy late were more likely to survive frost events. The variability in the floral opening date of the different genotypes has been demonstrated on the slope where the original seeds were collected (Buchmann, 1987).

The potential, resorting to the cloning and use of the superior genotype, in the fifth year represents productions of 2,900 kg/ha for the LQ site (Q_3P_2) and 767 kg/ha for the JI (J_4P_5). The projection of the LQ production is higher than the mean of 954 kg/ha, mean 2010-2019, and even the 1,363 kg/ha of the year 2015, which was the one with the highest mean production, of the adult Argentine commercial plantations maintained under irrigation in La Rioja (Ayerza, 2020b). However, it is far from the maximum yields achieved in Israel (7,070 kg/ha) (Perry *et al*., 2021) or Aimogasta (5,000 kg/ha) (Norberto Vinelli, personal communication, Aimogasta, La Rioja, Argentina, 2023) in adult plantations of clones with drip irrigation and fertilization.

Q_4P_8 and J_3P_{22}were the plants with the highest accumulated production of the analyzed three years with 1,805 g and 1,386 g/plant respectively (Tables 3 and 4). The productive difference determined between the LQ and JI sites, considering only the production of the most productive plant in the fifth year, significantly decreased in favor of

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total	SD
	Rainfall (mm)													
LQ-83	398	0	17	26	0	0	0	31	29	65	76	85	727	115.63
LQ-84	197	106	63	6	0	0	0	0	48	2	20	212	654	62.45
LQ-85	100	0	62	11	0	0	110	36	0	7	82	96	504	43.59
SD	151.9	61.20	26.27	10.41	0.00	0.00	63.51	19.50	24.17	35.02	34.20	70.36		37.36
Mean	231.7	35.3	47.3	14.3	0.0	0.0	36.7	22.3	25.7	24.7	59.3	131.0	628.3	73.9
JI-83	322	51	6	16	0	0	13	26	26	54	62	88	664	88.35
JI-84	189	104	59	6	0	0	0	0	44	2	25	218	647	77.02
JI-85	104	72	54	8	0	0	107	27	0	10	85	62	529	41.57
SD	109.8	26.69	29.26	5.29	0.00	0.00	58.39	15.31	22.12	28.00	30.27	83.58		24.40
Mean	205.0	75.7	39.7	10.0	0.0	0.0	40.0	17.7	23.3	22.0	57.3	122.7	613.3	69.0
EC-83	369	46	11	19	0	14	14	29	28	57	65	82	734	100.04
EC-84	190	112	52	5	0	0	0	0	44	2	21	216	642	77.50
EC-85	105	68	46	10	0	0	107	0	0	12	102	64	514	44.66
SD	134.7	33.61	22.14	7.09	0.00	8.08	58.16	16.74	22.27	29.30	40.55	83.05		27.85
Mean	221.3	75.3	36.3	11.3	0.0	4.7	40.3	9.7	24.0	23.7	62.7	120.7	630.0	74.1

Table 6. Rainfall by site and year.

LQ. Thus, production of JI went from 26% to 77% concerning LQ.

These productions were obtained without irrigation, with the annual rainfall shown in Table 6. The data show that the maximum difference in rainfall between sites occurred in 1983 with 10% in favor of the LQ site. The distribution of rainfall was typical of the Chaco region, with a hot and rainy season and a temperate and dry season. The rainfalls of June and August 1984 must be considered an anomaly in the Arid Chaco (NCEI, 2022).

The rainfalls of the three studied years agree with the mean values of the period 1970-2011 (673 mm) in Villa Dolores, Córdoba, 30 km south of El Desafío, on the foothills of the Sierras de los Comechingones. Thus, they also agree with the mean for the period 1973-2003 (512 mm) measured in the Chancani Forest Reserve, on the foothills of the Sierra de Pocho, 24 km north of El Desafío (Iglesias *et al*., 2010; Karlin, 2012).

Rainfalls measured in this work were 45% above the mean of 433 mm obtained in Superior, Arizona, in the northern limit of the Sonoran Desert, considered one of the most productive areas of native jojoba (Ayerza, 1990a).

Except the LQ weights for 1983 and 1985, the individual seed weights obtained for both sites (Table 7) were higher than those determined as the mean of the germplasm collection of the native stands of the species in their areas of origin: Sonoran Desert,

Site	1983 (g/seed)	1984	1985	LSD[2]	Total (g/seed)
LQ	$0.70^{b.B.1}$	$0.83^{a.A}$	$0.73^{b.B}$	0.05	0.76^{b}
JI	$0.79^{a.B}$	$0.82^{a.B}$	$0.93^{a.A}$	0.07	0.85^{a}

[1]differentlowercase letters in the same column (t Student test) and uppercase letter in the same row (Student-Newman-Keuls test), are significantly (P<0.05) different; [2] least significant difference according to Student-Newman-Keuls test.

Table 7. Mean weight of the seeds produced in LQ and JI at 3, 4 and 5 years of age.

Year	1983	1984	1985	Media	SD	LSD[4]
Plant	(% of wax[2])					
Q_3P_2	52.9	53.2	51.2	52.4[ab3]	1.08	---
Q_3P_6	49.8	52.4	50.6	50.9[ab]	1.33	---
Q_3P_8	40.6	51.9	49.7	47.4[b]	5.99	---
Q_3P_{10}	49.7	52.8	49.7	50.7[ab]	1.79	---
Q_4P_8	55	53.5	50.8	53.1[a]	2.13	---
Q_4P_{10}	49.7	52.8	49.7	50.7[ab]	1.79	---
Q_6P_{10}	50.9	53.4	52.3	52.2[ab]	1.25	---
Mean	49.8[b.3]	52.9[a]	50.7[ab]	51.1	---	3.61
SD[1]	4.52	0.57	0.98	1.87	---	---
LSD[4]	---	---	---	4.74	---	---
JI_1[5]	---	---	---	51.7	---	---
JI_2[5]	---	---	---	51.1	---	---
Mean	---	---	---	51.4	---	---
SD[1]	---	---	---	0.42	---	---

[1]Standard deviation;[2] percentage on the dry weight of the seed; [3] different letters in the same column or row are significantly (P<0.05) different according to Student-Newman-Keuls test; [4] least significant difference; [5]years and plants sample; LQ n = 3.

Table 8. Variability of wax content between years and between genotypes.

Californian Mediterranean and Los Cabos Tropical Region. This was 0.56 g (0.36 – 0.75g/plant) measured at 4% seed moisture (Ayerza,1990b). The variability of the individual seeds' weight between years is affected by climatic conditions (Goytia-Jiménez *et al*., 2011), which may be the explanation for the indicated variations. The significant difference (P<0.05) between the individual weights of LQ and JI cannot be explained with the available information.

The wax content of seven plants chosen at random from the LQ site (Table 8) showed yields between 40.6% and 55%, depending on the genotype and the year. Through the analyzed three years, the Q_4P_8 genotype had the highest mean percentage of liquid wax; however, it was only significantly (P<0.05) different from the Q_3P_8 genotype, which in turn was not significantly (P<0.05) different from the other five genotypes. Although with this information it is not possible to explain the variations in the analyzed period, it has been shown that these occur between years, influenced by the climate, the genotype and their interactions, both in jojoba and in other species, *viz.*, moringa and olive (Dunstone *et al*., 1985; Ayerza, 2011, 2020b; Nissim et *al.,* 2020), which could justify the differences measured in this work.

Open pollination and the availability of pollen from different male plants in jojoba plots also influence the variability of the wax content of the seeds from different plants of the same clone, in the same site and year. This was demonstrated in the foothills of the Sierra de Ancasti, Catamarca, Argentina (Ayerza, 2020b) and Ramat Negev, Israel (Benzioni & Vaknin, 2002).

The standard deviation magnitude of the wax percentage of the three measured years (Table 8) shows a great dispersion between genotypes for 1983 and within each genotype through the years. The standard deviation of the Q_3P_8 genotype showed the highest comparative variability.

The mean annual wax production of the LQ plant seeds (Table 8) was significantly (P<0.05) higher in 1984, compared to that of

1983, and also 1985, although in the latter case the difference was not significant (P<0.05). It has been shown that the percentage of jojoba wax increases when the fruiting process starts early (Perry *et al*., 2021). The year with the highest wax content was 1984, with no frost interfering with the beginning and development of the fruiting period (Table 2).

On the other hand, the JI_1 and JI_2 composite samples (Table 8), with liquid wax yields of 51.70% and 51.10% were within the limits obtained from the LQ plants.

The wax percentages obtained here agree with those reported by other authors in seeds collected from wild plants in different regions of the Sonoran Desert and the Californian Mediterranean ecosystem. Araiza-Lizarde *et al*. (2017) reported for seeds collected in three locations in Mexico, Sonoyta, Todos Santos and La Huerta, (49 ± 2.80), (44 ± 1.35) and (43 ± 1.00) %, respectively. Miwa (1971) determined 48.4%and 40.5% for two sites in Arizona, and for the Californian Mediterranean ecosystem, 52,5% in inland stands and 49.4% in plants located on the coast; Ayerza (1990b) in wild jojoba plants located in 8 sites in Arizona, 3 in Baja California, 4 in Baja California Sur, 3 in California and 2 in Sonora, obtained a mean of 48.9% and extremes of 45% and 53%.

Regarding their comparison with the wax content of selected clones of the Q_3P_8 genotype in 1983, they agree with the values of 49.2% and 57.5% obtained in 14 selected clones in Aimogasta, La Rioja (Tobares *et al*., 2004), with 49.4% and 56.2% of 13 clones selected in Zancas, Catamarca (Ayerza, 2020b), and with 54.9% and 58.8% of five clones, located in the Pampa de Villacurí, Ica, Peru (Ayerza, 2001); the three locations under irrigation.

CONCLUSIONS

These results contribute to understanding the ecosystem conditions where jojoba was planted in Argentina, explaining its persistence 40 years later. The work surveyed the climatic conditions that allowed its planting and development in the ecotone between the Arid Chaco and the Mountain Chaco, between 550 and 400 meters above sea level, in the foothills of the Sierra de Pocho, Córdoba, whose slope allows a suitable strip 2.4 km wide.

The presence of the atmospheric phenomenon of autumn-winter thermal inversion in the Sierra de Pocho foothills was determined as the factor of the persistence and production of jojoba. This phenomenon decreases the extreme minimum temperatures when ascending the slope. The intensity of this effect decreased as the altitude descended, making the autumn-winter thermal regime inadequate for jojoba below 400 masl.

ACKNOWLEDGMENTS

The author acknowledges support for this project from Quitral-co SAIC, Buenos Aires, Argentina and International Flora Technologies, Chandler, Arizona, U.S.A

REFERENCES

AOCS. (1984). *Official methods of AOCS. Official Methods and Recommended Practices of the American Oil Chemists Society*. First Edition, American Oil Chemists´ Society, Champaign, Illinois, U.S.A.

Araiza-Lizarde, N., Alcaraz-Meléndez, L., Angulo-Escalante, M. A., Reynoso-Granados, T., Cruz-Hernández, P., & Calderón-Vázquez, C. L. (2017). Physicochemical Composition of Seed Oil of Wild Jojoba Populations in Northwestern Mexico. *Journalof Food and Nutrition Research,* 5(6), 443-450.

Ayerza, R. (1990a). *La Jojoba: ecología, manejo y utilización*. Orientación Gráfica Editora. Buenos Aires, Argentina.

Ayerza, R. (1990b). Variabilityof oil content in jojoba *(Simondsia chinenesis* L.[Schneider]) seeds harvested in the Sonoran desert. In *Proceedings of the 8th International Conference on Jojoba and Its Uses, and 1st International Conference on Promising Crops for Arid and Semi Arid Lands* (pp. 200-205). Latin America Jojoba Association and Jojoba Growers Association. Asunción, Paraguay.

Ayerza, R. (1992). Deficiente vernalización de la jojoba en el Chaco Paraguayo.*Gaceta Agronómica*, 12(68), 264-268.

Ayerza, R. (2001). Seed wax ester composition of ten jojoba clones growing in two arid ecosystems of South America. *Tropical Science,* 41, 1-4.

Ayerza, R. (2004). *Polinización de la jojoba en Catamarca: comparación de los años 2002 y 2003*. Fincas de Ambato S.A. Catamarca, Argentina.

Ayerza, R. (2011). Seed's yield components, oil content, and fatty acid composition of two populations of Moringa (*Moringa oleifera* Lam.) growing in the Arid Chaco of Argentina. *Industrial Crops and Products*, 33, 389-394.

Ayerza, R. (2016). Case studies - Jojoba, new industrial crop development and commercialization in Argentina. In *Proceedings of the International Workshop on Olive and Jojoba* (pp. 1-14). State Institute of Agriculture Management, Government of Rajasthan, Jaipur, India,

Ayerza, R. (2020a). Producción anual de semilla de jojoba en Argentina: Período 1999-2020. In *20ava, Reunión Argentina de Productores de Jojoba* (pp. 1-2). Aimogasta, La Rioja, Argentina.

Ayerza, R. (2020b). Variability in oil content in Argentine jojoba. *Revista Mexicana de Ciencias Agrícolas,* 11(4), 841-852.

Ayerza, R. (2023). Variation of Temperatures, Rains and Winds, Related to the Altitude in an Eco-tone between the Mountain Chaco and the Arid Chaco. *Revista Industrial y Agrícola de Tucumán,* 100(1), 37-45.

Ayerza, R. (2025). *Jojoba: ecology and development in the Sonoran Desert: 50 years of history*. Editorial Hecho a Ojo LLC. La Rinconada, Santa Elena, Ecuador.

Ayerza, R., & Zeaser, D. (1987). Evaluation of two origins of jojoba from production. In *Proceedings of the II Australian Jojoba Association Seminar* (pp. 5-7). Australian Jojoba Booklet. Perth, Australia.

Bates R. G. (1973). *Determination of pH. Theory and practice.* 2nd. Ed. Wiley. New York, U.S.A.

Benzioni, A., Palzkill, D. A., & Nelson, J. M. (1992). Flower Bud Dormancy, ABA Concentration, and Survival during Frost of Jojoba Genotypes under Water Stress. *Journal of the American Society for Horticultural Science,* 117(6), 976-980.

Benzioni, A., & Vaknin, Y. (2002). Effect of Female and Male Genotypes and Environment on Wax Composition in Jojoba. *Industrial Crops and Products,*10(2), 85-95.

Bocco, M., Coirini, R., Karlin, U., & von Müller, A. (2007). Evaluación Socioeconómica de Sistemas Productivos Sustentables en el Chaco Árido, Argentina. *Zonas Áridas* 11(1), 70-84.

Bravo, R., Muñoz, M., & Quintana, J. (2020). *Heladas. Factores atmosféricos, tendencias y efectos en frutales y vides.* Instituto de Investigaciones Agropecuarias (INIA). Boletín N° 417. Osorno, Chile.

Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic and available forms of phosphate in soils. *Soil Science,* 59, 39-45.

Brooks, W. H. (1978). Jojoba a North American desert shrub; its ecology, possible commercialization, and potential as an introductory species into other arid regions. *Journal of Arid Environnment,* 1, 227-236.

Buchmann, S. L. (1987). Floral Biology of Jojoba (*Simmondsia chinensis*), an Anemophilous Plant. *Desert Plants,* 8(31), 111-124.

Burden, J. D. (1970). *Ecology of Simmondsia chinensis (Link) Schneider at its lower evational limits.* Thesis Master of Science. Arizona State University, Tempe, Arizona, U.S.A.

Chapman H. D.& Pratt, P. F. (1961). *Methods of Analysis for Soils, Plants, and Waters*. University of California. Riverside, California, U.S.A.

Coates, W., & Ayerza, R. (2008). Supplemental pollination-increasing jojoba (*Simmondsia chinensis* L. [Schneider]) seed yields in the Arid Chaco environment. *Industrial Crops and Products*, 27(3), 364-370.

Cohort Stat (2006). Cohort Stat 6.311. Cohort Software Inc. Monterey, California, U.S.A.

Díaz Queralto, F. (1971). *Práctica de la defensa contra heladas*. Dilagro, Lérida, España.

Dunstone, R. L. (1980). The reproductive cycle in jojoba. In A. R. Baldwin (Ed.). *Proceedings of the Seventh International Conference on Jojoba and Its Uses.* American Oil Chemists' Society (pp. 50-59). Champaign, Illinois, U.S.A.

Dunstone, R. L. (1995). Predicting flowering time in different genotypes of jojoba. Effect of Temperature on the Synthesis of Jojoba Wax. *Australian Journal of Plant Physiology*, 12*,* 355-362.

Durazo, U. (1982). Estabilidad y Media de Producción en Plantas de Jojoba, *Simmondsia chinensis* (Link) Schneider, Bajo Cultivo en la Costa de Hermosillo. In A. E. Cesnik (Ed.), *Proceedings of the Fifth International Conference on Jojoba and Its Uses* (pp. 237-244). Office of Arid Lands Studies, University of Arizona. Tucson, Arizona, U.S.A.

Fan, Z., Xiong, H., Luo, Y., Wang, Y., Zhao, H., Li, W., He, X., Wang, J., Shi, X., & Zhang, Y. (2020). Fruit Yields Depend on Biomass and Nutrient Accumulations in New Shoots of Citrus Trees. *Agronomy,*10*,* 1988. https://doi.org/10.3390/agronomy10121988

Ferriere, J., Milthorpe, P. L., & Dunstone, R. L. (1989). Variability in chilling requirements for the breaking of flower bud dormancy in jojoba (*Simmondsia chinensis* [Link] Schneider). *Journal of Horticultural Science,* 64(3), 379-387.

Gentry, H. S. (1958). The natural history of jojoba (*Simmondsia chinensis*) and its cultural aspects. *Economic Botany,* 12*,* 261-295.

Goytia-Jiménez, M. A., Gallegos-Goytia, C. A., & Núñez-Colín, C. A. (2011). Relación entre variables climáticas con la morfología y contenido de cera de semillas de higuerilla (*Ricinus communis* L.) de Chiapas. *Revista Chapingo Serie Ciencias Forestales y del Ambiente,* 17(1), 41-48.

Grand View Research.2023. *Jojoba Oil Market Size, Share & Trends Analysis Report By Type, By Application (Cosmetics & Personal Care, Pharmaceutical), By Sales Channel (B2B, B2C*), b*y Region, and Segment Forecasts, 2023 – 2030.* Dowload on May 30, 2023. https://www.grandviewresearch.com/industry-analysis/jojoba-oil-market [accessed: May 2023].

Hang, S., Mazzarino, M. J., Núñez, G., & Oliva, L. (1995). Influencia del desmonte selectivo sobre la disponibilidad de nitrógeno en años húmedos y secos en sistemas silvopastoriles en el Chaco Árido Argentino. *Agroforestería de las Américas,* 2(6), 9-14.

Iglesias, M. R., Barchuk, A., & Grilli, M. (2010), Dinámica estacional e interanual del NDVI en bosques nativos de zonas áridas argentinas. *Revista de Teledetección,* 34, 1-11.

IMARC Group. (2023). Jojoba Oil Market: Global Industry Trends, Share, Size, Growth, Opportunity and Forecast 2023-2028. Download on May 20, 2023 from https://www.imarcgroup.com/prefeasibility-report-jojoba-oil-processing-plant

Jiménez-Méndez, A., Guerrero-Peña, A., García-López, E., & Carrillo-Ávila, E. (2019). Producción de biomasa total, rendimiento y composición de la semilla de *Jatropha curcas* L. con diferentes dosis de fertilización. *Interciencia,* 44(9), 529-534.

Karlin, M. S. (2012). Cambios temporales del clima en la subregión del Chaco Árido. *Multequina,* 21*,* 3-16.

Karlin, M. S. (2013). Suelos. In R. O. Coirini, M. S. Karlin, U. O. Karlin, G. J. Reati and R. M. Zapata (Eds.). *El Chaco Árido* (pp. 51-77). Universidad Nacional de Córdoba. Córdoba, Argentina.

Kour, D., Bakshi, P., Wali, V. K., Sharma, N., Sharma, A., & Iqbal, M. (2018). Alternate Bearing in Olive - A Review *International Journal of Current Microbiology and Applied Sciences,*7(9), 2281-2297. https://doi.org/10.20546/ijcmas.2018.709.283

Lavee, S. (2007). Biennial bearing in olive (*Olea europaea*). *Annales. Series Historia Naturalis,* 17(1), 101-112.

Lazare, S. Zipori, I., Cohen, Y., Haberman, A., Goldshtein, E., Ron, Y., Rotschild, R., & Dag, A. (2021). Jojoba pruning: New practices to rejuvenate the plant, improve yield and reduce alternate bearing. *Scientia Horticulturae,* 277*,* 109793. https://doi.org/10.1016/j.scienta.2020.109793

Livingston, D. P. (2018). Investigating Freezing Patterns in Plants Using Infrared Thermography. In M. Iwaya-Inoue, M, Sakurai & M. Uemura (Eds.). *Advances in Experimental Medicine and Biology, Survival Strategies in Extreme Cold and Desiccation*, Advances in Experimental Medicine and Biology (pp. 117-127). Springer Nature Singapore Pte Ltd.

Mehlich, A. (1984). Mehlich-3 soil test extractant: a modification of Mehlich-2 extractant. *Communications in Soil Science and Plant,* 15*,* 1409-1416.

Medina Morales, M. C., Samaniego-Gaxiola, J. A., Santamaría-César, J., Faz-Contreras, R., Herrera-Pérez, T., Ramírez-Delgado, M., & González- Cervantes, G. (2000). Alternancia en la producción del nogal pecanero, en la comarca lagunera de México. *ITEA,* 96(2), 132-138.

Milthorpe, P. L. (2006). *Evaluation of jojoba germplasm in different environments*. A report for the Rural Industries Research and Development Corporation, RIRDC Publication No 05/184. Australian Government, Condobolin, New South Wales, Australia.

Milthorpe, P. L., & Dunstone, R. L. (1989). The potential of jojoba (*Simmondsia chinensis*) in New South Wales 2. Some factors affecting yield. *Australian Journal of Experimental Agriculture,* 29*,* 389-395.

Miwa, T. (1971). Jojoba Oil Wax Esters and Derived Fatty Acids and Alcohols: Gas Chromatographic Analyses*. Journal of the American Oil Chemists' Society,* 48(13), 259-264.

Montesinos-Torres, D. (2007). *Juniperus thurifera*: una especie dioica, vecera y relíctica. *Ecosistemas,*16(3), 172-185.

Nahla, A., Adawy, S., Eliraq, M., Abo-El-Khasab, A., Abd-El-Aziz, Y., El-Bassel, E., Esmail, A. S., Attaia, M., Darwish, S. H., El-Ashry, H., & Gawish, M. S. (2018). Selection and Agronomical Evaluation for Some Elite Genotypes of Jojoba. *Journal of Applied Life Sciences International,* 18(1), 1-12.

Nelson, J. M., & Palzkill, D. A. (1993). Irrigation effects on growth, cold tolerance of flower buds, and seed yield of jojoba. In J. Janick and J. E. Simon (Eds.), *New crops* (pp. 360-362), Wiley, New York, U.S.A.

NCEI- National Centers for Enviromental Information. 2022. *Global Summary of the Month (GSOM), Version 1*. https://www.ncei.noaa.gov/access/search/data-search/global-summary-of-the-month?dataTypes=PRCP&bbox=-28.663,-67.606,-30.163,-66.106&startDate=1968-12-13T00:00:00&endDate=1968-12-13T23:59:59

Nerd, A., & Benzioni, A. (1988). Effect of water status, genetic background gender and fertilizer on flowering in jojoba. *Advances in Horticultural Science,* 2*,* 48-51.

Nissim, Y., Shloberg, M., Biton, I., Many, Y., Doron-Faigenboim, A., Zemach, H., Hovav, R., Kerem, Z., Avidan, B., & Ben-Ari, G. (2020). High temperature environment reduces olive oil yield and quality. *PLoS One,*23*,* 15(4), e0231956. https://doi.org/10.1371/journal.pone.0231956

Palzkill, D. A., & Hogan, L. (1982). Jojoba seed yield from a seedling planting at Mesa, Arizona, and from a cutting-grown planting near Bakersfield, California. In *Proceedings of the Fifth International Conference on Jojoba and Its Uses*, (pp. 231-236). Office of Arid Lands Studies, University of Arizona. Tucson, Arizona.

Perry, A., Tel-Zur, N., & Dag, A. (2021). Vegetative and Reproductive Response to Fruit Load in Two Jojoba (*Simmondsia chinensis*) Cultivars. *Agronomy*11(5)*,* 889. https://doi.org/10.3390/agronomy11050889

Ramírez-Santa-Pau, M. M. (2001). *Variabilidad de la producción en olivo* (*Olea europaea* L.)*. relación entre alternancia, floración, vigor y productividad*. Tesis Doctoral, Universidad de Córdoba, Córdoba, España.

Ramonet, R., & Morales, A. M. (1985). Seed yield variability and selection criterion of jojoba clones in Mexico. In *Proceedings of the Sixth International Conference on Jojoba and Its Uses*. (pp. 279-286). University of The Negev. Beer-Sheva, Israel.

Ramonet, R. (1988): Selection criteria and evaluation procedures for jojoba plant improvement. In *Proceedings of The Seventh International Conference on jojoba and its Uses*. (pp. 60-68.). American Oil Chemists Society, Phoenix, Arizona, U.S.A.

Shreve, F. (1912). Cold air drenaje. *Plant World,* 15*,* 110-115.

Snyder, R. L., & de Melo-Abreu, J. P. (2005). *Frost Protection: fundamentals, practice, and economics*. Food and Agriculture Organization of the United Nations. Rome, Italy.

Tálamo, E., Moya-Ruíz, F., García, R., Rocha-Fasola,V., & López, F. R. (2013). El Complejo Acuífero Profundo de Arauco, provincia de La Rioja. In N. González, E. E. Kruse, M. M. Trovatto, & P. Laurencena (Eds.). *Agua subterránea recurso estratégico*. (pp. 140-147). Editorial de la Universidad de La Plata. La Plata, Buenos Aires, Argentina.

Tel-Zur, N., Rothschild, R., Zurgil, U., & Vaknin, Y. (2020). Characterization of Flowering Time and Pollen Production in Jojoba (*Simmondsia chinensis*) towards a Strategy for the Selection of Elite Male Genotypes. *Agronomy,*10, 592. https://doi.org/10.3390/agronomy10040592

Tobares, L., Frati, M., Guzmán, C., & Maestri, D. (2004). Agronomical and chemical traits as descriptors for discrimination and selection of jojoba (*Simmondsia chinensis*) clones. *Industrial Crops and Products,* 8*,* 145-149.

United Nations. (2019). *Informe de políticas de ONU-AGUA sobre el Cambio Climático y el Agua*. UN Water-United Nations. Geneve, Suisse.

U.S. Army Corps of Engineers. (1997). Agronomical and chemical traits as descriptors for discrimination and selection of jojoba (*Simmondsia chinensis*) clones. *Tucson area drainage study, AZ (Tucson Arroyo) Feasibility study phase feasibility report and environmental impact statement*. U.S. Army Corps of Engineers. Los Angeles, California, U.S.A.

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Science,* 63*,* 251-263.

Wünsche, J. (2021). *Physiological, metabolic and molecular basis of biennial bearing n apple*. Horticulture Innovation Australia. Sydney, New South Wales, Australia.

Yermanos, D. M. (1982). *Jojoba out of the Ivory Tower and into the real world of agriculture.* University of California. Riverside, California, U.S.A.

Yermanos, D. M. & Duncan, C. C. (1976). Quantitative and qualitative characteristics of jojoba seed. *Journal of the American Oil Chemists' Society,* 53*,* 80-82.