VEGETATIVE AND REPRODUCTIVE GROWTH OF JOJOBA – Simmondsia chinensis (Link) Schneider – IN RELATION TO SOME ECOLOGICAL FACTORS

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RESUMO

CRESCIMENTO VEGETATIVO E REPRODUTIVO DA JOJOBA EM RELAÇÃO A ALGUNS FATORES ECOLÓGICOS

Jojoba – *Simmondsia chinensis* (Link) Schneider – foi estudada durante um ano de investigação intensiva em três diferentes áreas no estado do Arizona, U.S.A., levando-se em consideração o crescimento vegetativo e o desenvolvimento reprodutivo em relação a temperatura e a precipitação ocorridas na área durante a pesquisa.

As áreas 1 e 2 estão localizadas nas faces Este e Oeste, respectivamente, das montanhas de Tucson e a área 3 está ao Sudeste das montanhas de Santa Catalina.

Dez plantas femininas e cinco masculinas foram selecionadas ao acaso em cada área de estudo. Cinco ramos, em cada planta, foram marcados para o estudo do crescimento vegetativo quantitativo. Quatro destes ramos corresponderam aos pontos cardeais. O quinto foi escolhido no topo da planta.

Observações sistemáticas foram conduzidas a cada duas semanas para acompanhar o desenvolvimento reprodutivo de ambos os sexos.

Os valores de precipitação foram registrados semanalmente enquanto que as temperaturas do ar e do solo foram registradas continuamente.

Tanto o crescimento vegetativo das plantas femininas como o das plantas masculinas obedeceram a distribuição da precipitação durante o período de estudo. A influência do regime de temperatura foi melhor notada após a primeira metade do outono e no inverno. Quanto maior o crescimento vegetativo no outono, mais severa foi a ação do frio no inverno e as plantas foram menos produtivas em uma particular área.

PALAVRAS-CHAVE: Jojoba, Crescimento, Vegetativo, Reprodutivo, Precipitação, Temperatura.

ABSTRACT

The desert shrub jojoba – **Simmondsia chinensis** (Link) Schneider – was studied during an intensive one year investigation at three different sites in Arizona considering the vegetative and reproductive growth in relation to temperature and precipitation.

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Site 1 is located on the eastern slope of the Tucson Mountains, site 2 is on the west side of the Tucson Mountains, and site 3 is in the Southern foothills of the Santa Catalina Mountains.

Ten female and five male plants in each site of study, both randomly selected, were utilized for this research. Five branches on each selected plant were marked for quantitative study of vegetative growth. Four of the five branches corresponded to the cardinal compass points. The fifth was chosen from the top of the plant.

Systematic observations were conducted biweekly to follow the reproductive growth of both sexes.

The values of precipitation were recorded weekly and air and soil temperatures were recorded continously.

Vegetative growth of both male or female plants was related to the distribution of precipitation during the study period. The influence of the temperature regime was mostly found after middle of fall and winter. The greater the fall vegetative growth, the more severe was the frost damage and less productive plants at a particular site.

INTRODUCTION

Few studies have been conducted to measure the responses resulting from the relationships between the plant and its environment. One of the most intensive studies on jojoba ecology is natural history study of GENTRY[4]. He noted that in drier environments jojoba growth is usually short and die-back common. The wetter climates foster taller broomier shrubs with longer shoots and less lateral twigging. He adds that where long drought periods are interrupted by wet periods, growth is different with a distorted growth habit. Where light winter rains are regular, a rather uniform population with twiggy habit results. Jojoba, depending upon its environment, may grow to three meters or will mature at 0.2 to 0.5 meters.

GENTRY[4] indicated that drought inhibits flower bud development and vegetative growth of jojoba. ANI et alii[1] stated that this species may be found from temperature coastal to severe desert climates and at elevations from sea level to about 1300 meters. GENTRY[4] says that mature jojoba tolerates extreme annually and dayly fluctuations of temperature; annual fluctuations range from – 9.°C to 46.°C and dayly fluctuations commonly range through 17.°C to 22.°C during the morning.

HAASE[5], reporting on the phenological aspects of jojoba in southern Arizona, noted that in November of 1974 a site located West of the Tucson Mountains, vegetative growth was recorded in 62% of the jojoba plants on a south facing slope and in 35% on a north facing slope. In November of 1975, after no significant rainfall for more than two months, no new growth was observed. The flowering peak for most male and female plants was in April. Fruit production was observed in more than 40% of the pistillate plants. At this site located west of the Tucson Mountains, vegetative growth was recorded in 62% of the jojoba plants on a south facing slope and in 35% on a north facing slope, most vegetative growth occurred in July and August.

ANI et alii[1] noted that in Tucson, where most precipitation occurs in the summer, most vegetative growth of jojoba occured during the winter and the bud flowers were formed during the summer (july). In San Diego, where precipitation occurs mostly in the winter, jojoba flowered in the winter and the fruits matured in the summer. Clavijero (1789) quoted in LAKE & GRAY[6], reported that in California jojoba does not produce fruit each year but only when at least one heavy rain has fallen during the winter. This was restated later by GENTRY[4]. He observed that jojoba growth is almost entirely in response to winter and spring rains. Because the drought of summer and cold of winter, jojoba to concentrate its flowering in the spring months. The rains of summer, according to him, appear to have little influence on its annual growth and reproductive cycle. He does suggest, however, that summer rains may fill out the maturing seeds prolonging their ripening. HAASE[5] stated that summer rains play an important role in the growth and survival of the Arizona jojoba populations.

Although the NATIONAL ACADEMY OF SCIENCES[7] reported that jojoba occurs where soils are usually infertile and where rainfall varies from 100 to 500 millimeters annually, GENTRY[4] noted that jojoba can occur where annual rainfall is less than 10 millimeters if runoff from higher slopes increases the moisture available to jojoba.

The main objective of this study was to investigate the behavior of the desert shrub jojoba in three different sites in Arizona considering its vegetative and reproductive growth in relation to temperature and precipitation.

MATERIALS AND METHODS

During an intensive one year (March 23, 1978 to March 26/1979) investigation of jojoba, several approaches were followed to better understand its ecological relationships at three study sites. Criteria for the selection of the sites were: (1) areas with abundance of jojoba, (2) areas with slopes not exceeding 15 percent (3) areas topographically suitable for machine operation, (4) areas with elevations above 730 meters more conducive to growth, in Arizona, (BURDEN[2]), and (5) areas with ease of accessibility.

Site 1, on the eastern slope of the Tucson Mountains is located on Speedway Blvd. close to the Painted Hills Road, 10 km west of the University of Arizona Campus. The elevation of the site is 790 m and its topography is undulating.

Site 2, on the westside of the Tucson Mountains, is located at an elevation of 820 m in Tucson Mountain Park, west of Tucson, 24 km from the University of Arizona Campus. Its topography is almost level with 1 to 3 percent slope.

Site 3, in the southern foothills of the Santa Catalina Mountains, north of Tucson, is located 14 km from the University of Arizona Campus. The elevation of this site is 850m and its topography is almost level with a slope of 1 to 3 percent.

The sites were 40 m long and 25 m wide.

Ten female and five male plants both randomly selected, in each site, were utilized for this study. Plants with excessive dieback and those very close to associated shrub species were avoided. Five branches on each selected plant were marked for quantitative study of vegetative growth. Four of the five branches corresponded to the cardinal compass points. The fifth was chosen from the top of the plant. Three twigs, numbered from the base to the apex on the selected branches were measured biweekly. The average growth of the plant was obtained by summing these measurements and dividing the total by the number of twigs. The average gain in growth for both males and females at each site was determined by averaging the growth for all selected plants and determining the difference between consecutive measurements. Systematic observations were conducted biweekly to follow the reproductive growth of both sexes. Among these observations were flowering and fruit set, anthesis, fruit maturation and fruit dehiscence.

A weather station consisting of a tru-check rain gauge made by Edwards Mfg. Co. and a two point thermograph made by Weather Measure Corporation was used at each study site. The thermograph measured air temperatures and soil temperatures at a depth of 30 centimeters where the roots of jojoba are presumably most active. Standard procedures were used to eliminate evaporation of water caught by the rain gauge (DAUBENMIRE[3]). The values of precipitation were recorded weekly and air and soil temperatures were recorded continuosly. All instruments were read and serviced weekly. Temperature data were compiled into thirty-day, season, and yearly periods. The amount of precipitation was compiled biweekly and by season. Also, the total amount of rainfall registered during the period of study was totalled. The biweekly precipitation was compiled to show the distribution of rainfall during the period of study and to try to relate it to the biweekly vegetative growth. Seasonal and yearly precipitation were related to plant yield variables.

RESULTS AND DISCUSSIONS

Vegetative growth patterns at all study sites were approximately similar. Vegetative growth of both male or female plants was related to the distribution of precipitation during the study period. The influence of the temperature regime was mostly found after the middle of fall and winter (see Figures 1 and 2 and Table 1). Jojoba is greatly responsive to precipitation as shown in Figures 1 and 2. At sites 1 and 3 growth was fairly active on 14 August after a heavy rain on 31 July. This kind of relationship was greatly emphasized when site 2 plants showed a corresponding peak of growth only on 11 September, also responding to a rain that occurred two weeks earlier. This rain was exactly two weeks after rains at sites 1 and 3. The percentage of male and female plants growing at each site is shown in Tables 7, 8, and 9. Although the winter precipitation was higher at site 1 than site 2 winter precipitation, their vegetative growth, during the first of the spring, were similar. With the exception of spring, site 2 plants showed growth at all other times. At the second half of the fall, this growth was highly influenced by air temperature. At sites 1 and 3, jojoba growth was less than at site 2 because the minimum air temperatures exerted a negative effect on plants at sites 1 and 3 (see Table 1). Because of this higher growth, the plants at site 2 affected most when the air tempe-

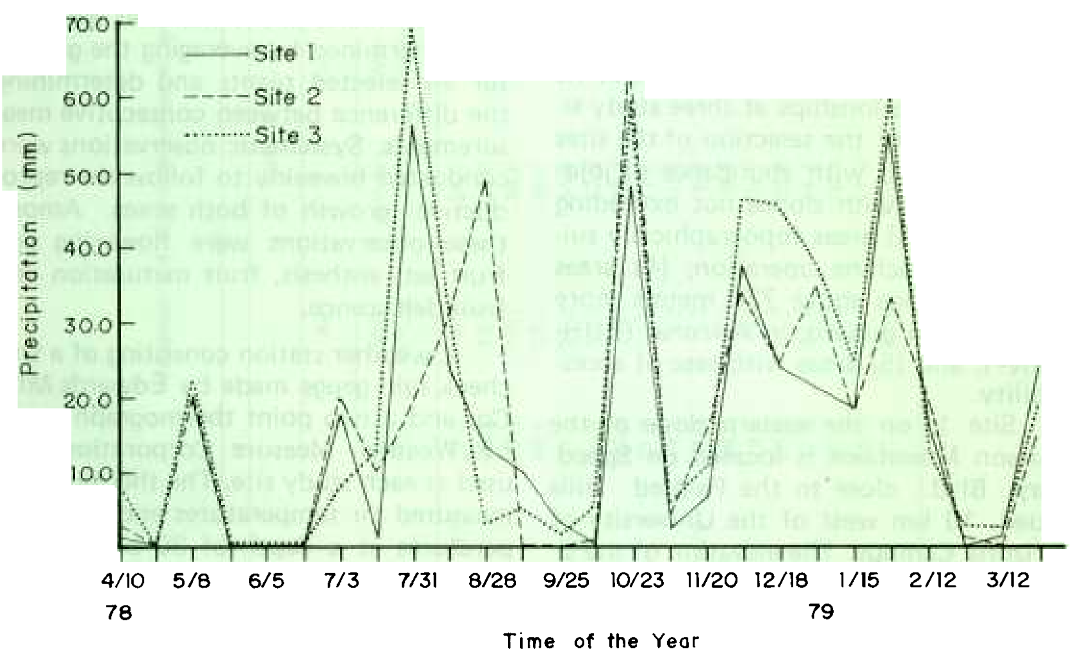

Figura 1 — Biweekly distribuition of precipitation at the three sites of study from March 27, 1978 to March 26, 1979.

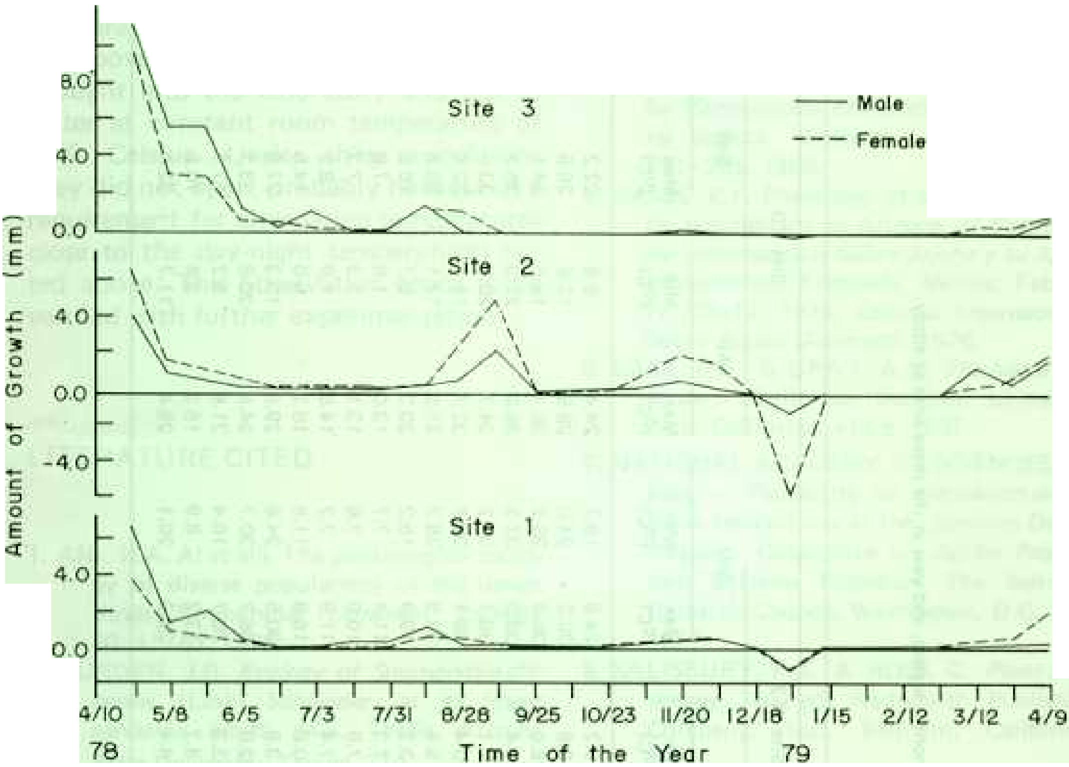

Figura 2 — Biweekly amount of growth of male and female jojoba plants at the three sites of study from April 10, 1978 to April 9, 1979.

ratures decreased below the freezing point (Table 2). The warmer the fall the more freeze damage is found on jojoba. Mild temperatures favor higher growth, exposing the plants no greater damage by the frost (see Figure 2). For cultivated plants it is important to avoid stimulating fall vegetative grouth. It was observed that site 2 plants tended to be more vegetative which reduced reproductive growth. Site 2 was the least productive site. Female plants were more vegetative than male plants but were less productive. SALISBURY & ROSS[8] observed that reproductive processes can interfere with vegetative growth and that if reproduction is prevented, the remaining organs of the plant grow faster. He says that there is evidence that the factors that stimulate shoot growth retard flower and fruit development.

On late March, 1978, when this research was started, 100% of the mature plants at all sites of study set new flowers. Flowers of male plants, presumed to have been set the previous year, were at anthesis and female plants were in active process of fructification. It seemed that part of the fertilized flowers were set the previous fall and withstood the low temperatures of the winter. The fruits were at the beginning stage of development in all sites but less advanced at the third site.

Some of the male flowers which were set at the end of winter and at the beginning of the spring reach a stage of development very close to anthesis in May. It seems that these flowers do not open because both the daily minimum and maximum temperatures are too high. Most of these flowers prepared for anthesis apparently resist the high temperatures of the summer and thus survive until fall. When maximum temperatures average about 27.^{o} Celsius and minimum temperatures averages about 16.^{o}C, some of these flowers showed anthesis, at

TABLE 1

Maximum and minimum average air and soil temperatures by month, season, and year at the three sites of study.

	Site #1				Site #2				Site #3			
	Air		Soil		Air		Soil		Air		Soil	
Date	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)
Mar 24/Apr 23, 1978	29.0	9.7	24.2	21.3	26.4	9.2	24.9	19.7	24.4	8.8	22.2	16.0
Apr 24/May 23	33.3	12.3	29.0	25.0	30.5	13.6	30.2	24.0	28.8	12.6	26.5	19.8
May 24/Jun 23	39.5	16.1	35.6	30.6	37.6	18.6	36.3	30.2	36.1	18.5	34.1	27.9
Jun 24/Jul 23	40.1	23.1	36.7	32.4	37.8	23.4	38.3	32.2	36.9	22.3	35.2	29.2
Jul 24/Aug 23	37.5	21.8	34.3	30.4	34.5	22.1	36.7	30.2	34.7	20.5	33.4	26.9
Aug 24/Sep 23	35.8	19.9	32.3	29.1	34.5	20.4	35.1	29.7	32.7	19.7	32.4	27.1
Sep 24/Oct 23	33.6	17.6	28.3	25.8	33.0	19.4	30.9	26.2	31.6	17.1	28.8	23.9
Oct 24/Nov 23	21.7	8.6	17.7	16.3	22.5	13.2	19.9	15.2	20.3	8.7	16.6	13.2
Nov 24/Dec 23	14.1	1.2	10.0	8.9	15.9	7.3	11.4	7.7	13.0	1.8	7.6	4.8
Dec 24/Jan 23, 1979	14.2	2.3	9.3	8.3	15.6	7.9	10.9	7.6	13.1	3.3	7.3	4.7
Jan 24/Feb 23	16.0	0.2	9.9	8.1	16.6	7.4	11.9	7.2	14.6	1.9	9.2	5.0
Feb 24/Mar 23	19.9	3.8	15.2	12.6	20.2	10.8	16.9	11.8	18.2	5.0	14.9	10.0
Spring 78	33.9	12.7	29.6	25.6	31.5	13.8	30.5	24.6	29.8	13.3	27.6	21.2
Summer	37.8	21.6	34.4	30.6	35.6	22.0	36.7	30.7	34.8	20.8	33.7	27.
Fall	23.1	9.1	18.7	17.0	23.8	13.3	20.7	16.4	21.6	9.2	17.7	15.7
Winter 78/79	16.7	2.1	11.5	9.7	17.5	8.7	13.2	8.9	15.3	3.4	10.5	6.6
Annual Mean	27.9	11.4	23.5	20.7	27.1	14.4	25.3	20.1	25.4	11.7	22.4	17.4

TABLE 2

Air and soil temperature extremes observed at the three sites of study; values expressed in degree Celsius (°C).

	Site #1				Site #2				Site #3			
	Air		Soil		Air		Soil		Air		Soil	
Date	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Mar 24/Apr 23, 1978	2.0	34.0	18.0	27.0	3.0	32.0	15.0	28.0	1.0	29.0	10.0	25.0
Apr 24/May 23	8.0	43.0	21.0	36.0	8.0	41.0	16.0	35.0	4.0	38.0	8.0	31.0
May 24/Jun 23	10.0	44.0	27.0	38.0	12.0	41.0	27.0	39.0	11.0	41.0	23.0	37.0
Jun 24/Jul 23	17.0	44.0	27.0	39.0	18.0	42.0	26.0	41.0	17.0	41.0	24.0	38.0
Jul 24/Aug 23	17.0	41.0	27.0	37.0	19.0	38.0	27.0	39.0	17.0	37.0	25.0	36.0
Aug 24/Sep 23	11.0	39.0	24.0	36.0	12.0	37.0	26.0	37.0	12.0	37.0	24.0	36.0
Sep 24/Oct 23	11.0	38.0	20.0	31.0	12.0	37.0	20.0	34.0	12.0	36.0	15.0	32.0
Oct 24/ Nov 23	–1.0	29.0	11.0	22.0	2.0	29.0	7.0	25.0	1.0	27.0	7.0	22.0
Nov 24/Dec 23	–11.0	23.0	3.0	14.0	–2.0	24.0	–1.0	13.0	–8.0	22.0	–1.0	11.0
Dec 24/Jan 23, 1979	–4.0	22.0	6.0	11.0	–3.0	22.0	4.0	13.0	–4.0	21.0	2.0	9.0
Jan 24/Feb 23	–8.0	28.0	4.0	14.0	–5.0	27.0	2.0	16.0	–7.0	27.0	0.0	15.0
Feb 24/Mar 23	–3.0	27.0	9.0	19.0	1.0	28.0	8.0	21.0	0.0	26.0	6.0	19.0
Year Range	–8.0	44.0	3.0	39.0	–5.0	42.0	–1.0	41.0	–8.0	41.0	–1.0	38.0

TABLE 3.

Phenological events observed from March 1978 to March 1979 at site 1, east of Tucson Mountains.

Stage of Development	Month												
	M	A	M	J	J	A	S	O	N	D	J		M
Male Plants (%)													
Vegetative growth	100	100	90	40	40	50	20	0	40	40	0[1]	0	60
Initiation of new flowers	100						20						
Plants with flowers	100	100	100	100	100	100	100	100	100	100	20	20	20
Anthesis	100	100											
Female Plants (%)													
Vegetative growth	100	100	90	60	20	90	40	0	70	60	0[1]	0	40
Initiation of new flowers	100						50	10					
Plants with flowers	100	100	100	100	100	100	80	90	90	70	20	20	20
Anthesis													
Fruit set	100												
Initiation of fruit maturation			100										
Beginning of dehiscence				100									

[1] Moderate frost damage occurred.

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TABLE 4

Phenological events observed from March 1978 to March 1979 at site 2, west of Tucson Mountains

Stage of Development	Month												
	M	A	M	J	J	A	S	O	N	D	J		M
Male Plants (%)													
Vegetative growth	100	100	80	10	20	80	50	0	60	60	0[1]	0	90
Initiation of new flowers	100					20			60				
Plants with flowers	100	100	100	100	100	100	100	100	100	100	100	100	100
Anthesis	100	100							20				
Female Plants (%)													
Vegetative growth	100	100	100	10	50	70	80	0	100	100	0[1]	0	70
Initiation of new flowers	100					40		20	40				
Plants with flowers	100	100	100	100	90	90	100	100	100	90	80	60	60
Anthesis									30				
Fruit set	100												
Initiation of fruit maturation			100										
Beginning of dehiscence				100									

[1] Severe frost damage occurred.

TABLE 5.

henological events observed from March 1978 to March 1979 at site 3, south foothills of the Catalina Mountains.

Stage of Development	M	A	M	J	J	A	S	O	N	D	J	F	M
						Month							
Male Plants (%)													
Vegetative growth	100	100	100	60	90	70	0	0	20	20	0[1]	0	80
Initiation of new flowers	100						80		20				
Plants with flowers	100	100	100	100	100	100	100	100	100	100	100	60	60
Anthesis	100	100								20			
Female Plants (%)													
Vegetative growth	100	100	100	70	40	70	0	0	0	20	0[1]	0	90
Initiation of new flowers	100					50	50		90				
Plants with flowers	100	100	100	100	100	100	100	100	100	100	100	80	80
Anthesis													
Fruit set	100												
Initiation of fruit maturation			100										
Beginning of dehiscence				100									

1 Moderate frost damage occurred.

(see Tables 3, 4 and 5). When
ture extremes were higher than
ve cited range, male flowers were
into the laboratory and put in
: constant room temperature of
elsius. Under these conditions
not open, probably because of a
ient for alternating temperatures
the day-night temperatures no-
ve. This observation needs to be
with further experimentation.

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