Aberrant Sex-Ratios in Jojoba Associated with Environmental Factors

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The present report is based on a three-month study of Jojoba, *Simmondsia chinensis* (Link) Schneider, growing under natural conditions at the Boyce Thompson Southwestern Arboretum during the late summer and fall of 1978. One purpose of the study was to obtain information of possible significance regarding differential natural selection in Jojoba with regard to sex of bushes on north-facing and south-facing slopes. I wish to thank Dr. Frank S. Crosswhite for suggesting this research and for providing much of the material in the introduction.

In a paper on the natural history of Jojoba and its cultural aspects, Gentry (1958) wrote that scientists at the Boyce Thompson Southwestern Arboretum (Fred Gibson and Bernard Benson) reported to him that the Jojoba population at Superior, Arizona, had about five males for every one female. This intrigued him and he reported that counts were subsequently made at seven locations; three in Arizona, three in Baja California and one in California. In Arizona 100 males to 23 females were found at Superior, 80 males to 40 females at Tucson and 3-4 males were estimated for each female at Camp Creek. In Baja California somewhat more normal ratios were found with 31 males to 20 females at Aguitos, 77 males to 62 females at the Meling Ranch and an even 50 males to 50 females in the San Telmo Valley. In California there were 30 males for 27 females at Aguanga. Gentry concluded that the ratio of male plants to female plants, at least in Arizona, was very unequal. Although he stated that the cause of the disparity in the sex-ratio was not known with certainty, he suggested that it might be due to environmental rather than genetic factors. He wrote that "apparently three to five males will survive the stresses of seedling establishment where as many females will fail." (Gentry, 1959. p. 278).

Aside from Gentry's hypothesis concerning differential selection in the seedling population, Crosswhite (1978) suggested that the rigors of producing five pounds of seed per female bush during the hot dry summer should theoretically place these bushes under greater water-stress than their male counterparts which become dormant during this period. A corollary to this might be a greater incidence of death in mature producing female bushes compared to the death rate in male or poorly bearing female bushes. Furthermore, such increased female mortality should be expected in populations where water-stress is a significant factor in the over-all survival of mature plants.

Such a water-stress situation might be expected to occur in populations where a large number of young

Table 1. Precipitation at the Boyce Thompson Southwestern Arboretum during alternately wet and dry years. Derived from data published by Crosswhite (1975).

Year	Precipitation (inches)
1933	18.22
1934	9.94
1941	27.58
1942	11.07
1952	19.16
1953	8.74
1959	22.42
1960	9.74
1965	26.15
1966	11.04

plants have matured and then, as larger plants, compete increasingly one with the other for available moisture. Such selection theoretically would be intensified under a climatic regime allowing rank plant growth during an extremely wet year followed by severe water stress in a succeeding drought year. Although rainfall is somewhat uniform in some regions outside Arizona where Jojoba grows, within the state and at the Boyce Thompson Southwestern Arboretum, a harsh climatic regime with quite nonuniform precipitation exists. The annual precipitation records at that location (Table 1) are taken from Crosswhite (1975).

In addition, at the Arboretum, tremendous fluctuations in precipitation from month to month occur. Four entire months without a trace of rain have occurred. On the other hand, over 19 inches of precipitation were received in another four-month period. Vegetative growth of Jojoba is correlated with the usually wet winter months of December through March, whereas seed-production occurs in the normally hot and dry pre-summer consisting of April, May and June. The seeds come to maturity in July, too late for the thunderstorms developing as a result of the Sonoran Monsoon to aid their development (Crosswhite, 1973).

The field study which follows was designed to test the hypothesis that there may be some correlation between the environment and the male-female ratio in populations of Jojoba. In particular, it was desired to record differences in the sex-ratio on south-facing slopes with extended exposure to solar radiation and on north-facing slopes with less such exposure.

Materials and Methods

Wild Jojoba plants growing on north-facing and south-facing slopes were examined and classified according to sex. Fourteen slopes, seven facing south, seven facing north, were chosen for this survey. In order that samples be relatively representative and that variables be limited, slopes having fairly uniform characteristics were used. The slopes were of moderate steepness (25° to 50° angles) and devoid of unique or outstanding features.

Note was taken of angle of slope, soil characteristics, plant communities and other noteworthy information (e.g. presence of numerous rodent burrows or nearby roads) concerning each slope. A line transect was chosen randomly about midway up each slope along a horizontal plane. Plants falling along this transect were recorded by sex. For uniformity and because the sex of individual bushes is not readily apparent at all times of the year, counts of male and female plants were restricted to September. At that time of year mature female plants bear ripe seeds and the males retain desiccated flowers.

A few plants too young to bear any indication of sex were not included in the data. A total number of male and female plants along each transect was tabulated. The samples for each slope ranged in size from n=23 to n=141, depending upon the area of the slope and upon population density. Sample size averaged n=71.5 plants and a total of 1,003 plants was recorded.

The entire population observed in this study was included in the area comprising the Boyce Thompson Southwestern Arboretum, west of Superior in Pinal County, Arizona. The Arboretum property is considered to be in the Arizona Upland Division of the Sonoran Desert, within the Lower Sonoran Life Zone, as designated by C. Hart Merriam (1898). Elevation of the area is 2400 feet, at a latitude of 33°17′ North and longitude of 111°8′30″ West. Annual precipitation at the Arboretum is 16.30 inches, averaged over the past 50 years.

Results and Discussion

Female Jojoba plants represented 51 percent of the population on north-facing slopes but only 45 percent of the population on south-facing slopes (Tables 2, 3). Percentages of male and female plants occuring on each of the seven north-facing slopes are presented in Table 2. These percentages, being derived from line transect counts, make an unbiased generalization concerning the populations which were surveyed. Sample size for each slope is also presented in the table. A similar treatment of transect data is used

Table 2. Percentages of male and female plants on north-facing slopes at the Boyce Thompson Southwestern Arboretum.

Slope No.	Percent female	Percent male	Sample size
1	60.9	39.1	23
2	46.1	53.9	39
3	50.7	49.3	138
4	58.9	41.1	73
5	36.7	63.3	60
6	41.5	58.5	65
7	62.2	37.8	39
Mean	51	49	62.1
Range	36.7-62.2	37.8-63.3	
Standard Deviation		24.6	

Table 3. Percentages of male and female plants on south-facing slopes at the Boyce Thompson Southwestern Arboretum.

Slope No.	Percent female	Percent male	Sample size
1	35.8	64.2	53
2	48.2	51.8	27
3	51.6	48.4	93
4	35.5	64.5	141
5	46.4	53.6	69
6	48.4	51.6	62
7	49.6	50.4	123
Mean	45.1	54.9	81
Range	35.5-51.6	48.4-64.5	
Standard Deviation	16.3		

for counts taken on south-facing slopes and these percentages are presented in Table 3.

Information concerning variable characteristics such as soil type, steepness of slope, other plant species present, geological peculiarities and other notable features have not been presented as correlations were not found in relation to Jojoba growth or sex-ratio. A Student's t-test comparing the means of the two populations (those of Table 2 vs. Table 3) rate the differences between the means as significant for α 0.1 with a critical value of 1.712, d.f. 12.

It is apparent from the results of this survey that there is some correlation between orientation of slope and the male-female ratio. Although standard deviations are fairly large, the data indicate a distinct trend and are, therefore, of value. Populations occuring on north-facing slopes are composed of nearly equal proportions of male and female plants. Indeed, some populations are predominantly female, a situation quite at odds with the literature so often quoted that in Arizona the males outnumber the females anywhere from a ratio of two to one to a ratio of five to one. However, on south-facing slopes, the male plants are indeed apparently more successful.

The aberrant sex-ratios may be attributed to one of several possible causes, some of which seem difficult to examine. In the Arboretum region the south-facing slopes are much hotter and drier than the north-facing slopes, a condition prevalent in the northern hemisphere where the sun tends on the average to be to the south. The two physical factors, heat and dryness of soil, must be looked at independently even though the latter is a consequence of the former.

The effects of high temperature on plant growth and development occur both directly and indirectly. Extremely high temperatures can have the effect of rendering inactive some enzymes essential for metabolism and of slowing the rates of some reactions necessary for proper growth and maintenance of the plant. The rate of respiration and photosynthesis, after first increasing with an increase in temperature, reaches a point at which it drops below the rate normal for a lower temperature (Greulach, 1973). High transpiration rates which may result from high temperatures can cause desiccation of a plant. Perhaps the most obvious effect of long hours of sunlight, heat and drought is water-stress to plants. It seems reasonable to assume that such water-stress, intensified on south-facing slopes, is of utmost significance in the Arboretum region where vegetation on south vs. north aspects of hills and canyons is often strikingly different.

The greater success of male plants on south-facing slopes may be a result of a selective advantage over female plants which bear the burden of seed production, a hypothesis which led into the present study. Another possible explanation might conceivably be one of leaf physiology as asserted by Sivtsev and Sizov (1972), who suggested that the difference between survival of male and female forms of plants might be a matter of the ability of their respective leaves to adapt to a water shortage. The crucial point in development could possibly be prior to seed-bearing age. An experiment could be designed to obtain optimum germination and growth of seeds from a north slope and seeds from a south slope to compare sex-ratios. Male and female Jojoba plants are virtually indistinguishable when young. Seed that will grow into a female plant is indistinguishable from seed destined to grow into a male plant.

During the course of this study, it became evident

that the aforementioned counts of male and female plants presented by Gentry (1958) were not in accord with the data accumulated by the author of this study. Presumably, the Gibson and Benson counts, as well as those of Gentry, could have been made on south-facing slopes and this alone could explain the discrepancy. It seems unlikely that the population of mature plants could have changed so radically in 25 years, given the average life span of 100 years or so for a plant of the species.

Future study of environmental effects on sex-ratios might involve plantings of known numbers of male and female plants on north-facing and south-facing slopes. Such an experiment would most probably require plantings of cuttings to insure that sex of the bushes planted was known. A plantation of cuttings could provide conclusive evidence provided the success or failure of plants is not determined at a seedling stage bypassed by cuttings. In repeating the present study in the future, to eliminate a possible source of error, slopes could be classified according to amount of available soil moisture during a drought month, rather than by the simple north vs. south criterion.

The present paper makes no claim that the increased percentages of male plants on south-facing slopes confers an adaptive advantage to the population in the Arboretum region. However, it has not gone unrecognized that the species is wind-pollinated and that the prevailing air patterns at the Arboretum (from the southwest) could be expected to cause pollen from plants on south-facing slopes to become airborne and to settle down to the north as the impact of the breeze is muffled by the topography. Whether this is a fortuitous circumstance or is intimately associated with inherited adaptations in the population is not known.

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