Jojoba – Genetically Controlled Botanical Traits

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ABSTRACT AND SUMMARY

The discovery of correlations between botanical traits and wax quantity and quality in the seed would facilitate early detection and elimination of undesirable genotypes in a jojoba breeding program. The traits studied were: (a) branching; upright, spherical, and prostrate strains were found. (b) Leaf size; variability in mean leaf size is continuous ranging from 14 x 6 mm (long x short leaf axis) to 39 x 16 mm. (c) Leaf color; a light yellow leaf mutant was found. (d) Earliness; strains were found with early flowering and seed development which might escape unfavorable effects of winter frosts. (e) Number of fruit per node; strains were selected which instead of single fruit have clusters of two to ten fruit in more than 50% of the inflorescences. (f) Fruiting pattern; strains with a flower at each node instead of at every other node were found. (g) Male to female ratio; a significant deviation from a 1:1 ratio was found in favor of male plants.

Botanical traits of oil-producing plants are often studied not because they themselves are the objective of an investigation, but because they are sometimes correlated with the amount and quality of oil stored in the seed. Several cases are reported in the literature in which large seed size, thin hull, and late maturity are positively correlated with high seed oil content (1,2). In flax, light colored seed coat is correlated with high degree of unsaturation of the oil (D.M. Yermanos, unpublished data).

Jojoba is a perennial species which stores wax instead of triglycerides in its seed (3). Seedlings propagated from seed rarely flower before they are 18 months old. Thus, the progeny of seeds selected for their desirable quantitative and qualitative wax characteristics cannot be evaluated until 2 years from the time of planting the parental generation. The discovery of correlations between botanical traits and wax production would facilitate early detection and elimination of undesirable types of plants in a jojoba breeding program resulting in a considerable saving in research time and effort. Correlation studies are not possible at this time, however, because no published information is available on genetically controlled botanical characteristics of jojoba. Correlations between various botanical characteristics and wax content and composition calculated from data obtained from natural populations of jojoba contain both a genetic and an environmental component. To differentiate between the two and to assess the magnitude of the genetic correlations only, a breeder should have populations of jojoba plants of identical age, in a uniform planting arrangement, given identical cultural care, and growing on a uniform piece of land. A 6-acre, 4-year-old jojoba planting on the Riverside campus is now making such studies possible for the first time in the U.S.

Following is a brief history of this planting. Jojoba seeds were planted in 1-gal pots in 1973; since it was impossible to identify the sex of jojoba seedlings prior to anthesis, four seeds were planted per pot so as to have at least one male and one female plant with a probability of 87%. In the spring of 1973, the potted seedlings were transplanted on a

FIG. 1. Jojoba plants with (a) upright and (b) compact type of growth habit.

FIG. 2. Strain of jojoba with clusters of flowers.

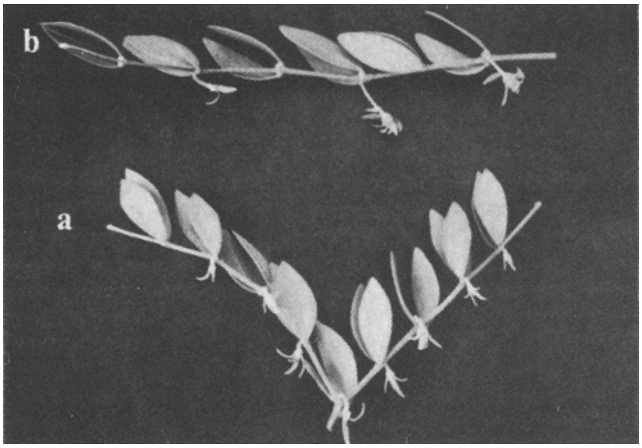

FIG. 3. Jojoba branches with flowers at (a) every node or (b) every other node.

uniform piece of land on rows 10 ft apart and on hills 5 ft apart down the row. The seeds used in this experiment had been harvested from visually selected high yielding plants in the natural populations of Southern California. Each row was planted with seed coming from a particular maternal wild plant. Because jojoba is dioecious, however, the seeds of a given maternal plant may be fertilized with pollen coming from several paternal plants. Thus, genetic variability among plants exists within rows as well as among rows of this planting. In view of the common environment surrounding these plants, persistent differences in botanical traits were considered to be of genetic origin in this study. Seeds from these plants will not be harvested until the end of 1977; at that time the first attempt will be made to identify correlations between botanical traits and wax characteristics. Seven botanical traits were recorded as being genetically controlled: branching, leaf size, leaf color, earliness, number of fruit per node, fruiting pattern, and male to female ratio. Following is a summary of observations made on these traits.

BRANCHING

Three types of branching were observed. (a) Plants have an open type of growth with primary branches only, growing from the crown up with very few, minor, secondary branches. It would appear that such types could be trained faster and easier to acquire a tree type of growth (Fig. 1a). (b) Plants have a compact, spherical appearance with many fine, short, secondary and tertiary branches (Fig. 1b). In spite of profuse branching these plants still grow upright. (c) Plants have a prostrate growth habit, branching and growing laterally rather than upright. These plants came from seed obtained from coastal populations in Del Mar, California, characterized by this prostrate type of growth. At first, it was thought that coastal jojoba populations acquired a prostrate growth habit because of the persistent, strong ocean breezes which forced them to grow like ground cover. Current observations indicate that these differences in growth habit are not of environmental origin; it appears that distinct ecotypes with prostrate types of growth have evolved under coastal conditions which maintain this type of growth even when grown in inland areas.

LEAF SIZE

Although a great deal of variability of leaf size is present within plants, major differences in average leaf size among plants can easily be observed both within and among rows. Variability in mean leaf area among plants is continuous; therefore, individual plants cannot be assigned to distinct classes unambiguously. In the Riverside planting, mean leaf size varies from 14 x 6 mm (long x short leaf axis) to 39 x 16 mm. Mean leaf size was calculated from leaves of all ages on each plant.

LEAF COLOR

Jojoba leaves are usually dark green; several degrees of color intensity are encountered from light green, mostly in the young leaves, to light blue. Color intensity appears to be influenced by age, soil moisture, and air temperature. A light yellow leaf mutant strain, distinctly outside the above

TABLE I

Ratio of Male and Female Individuals in 4045 Jojoba Seedlings on the Second (1975) and Third (1976) Year of Growth

Accession			Seedlings flowering		No. of seedlings flowering		Percentage of seedlings		x^{2a}
No.	Designation	Year	Number	Percent	Male	Female	Male	Female	Calculated
									(1:1 ratio)
1	Delmar-4	1975	245	69.0	171	74	69.8	30.2	38.4
		1976	110	31.0	50	60	45.5	54.5	0.9
		Total	355	100.0	221	134	62.2	37.8	21.3
2	Vista I-3	1975	756	67.2	455	301	60.2	39.8	31.4
		1976	369	32.8	157	212	42.5	57.5	8.2
		Total	1125	100.0	612	513	54.4	45.6	8.7
3	Vista G-14	1975	541	52.3	326	215	60.3	39.7	22.7
		1976	493	47.7	213	280	43.2	56.8	9.1
		Total	1034	100.0	539	495	52.1	47.9	1.9
4	Aguanga-11	1975	99	39.1	79	20	79.8	20.2	35.2
		1976	154	60.9	68	86	44.2	55.8	2.1
		Total	253	100.0	147	106	58.1	41.9	6.6
5	Vista I-15	1975	1110	86.8	613	497	55.2	44.8	12.1
		1976	168	13.2	68	100	40.5	59.5	6.1
		Total	1278	100.0	681	597	53.3	46.7	5.5
	All accessions	1975	2751	68	1644	1107	59.7	40.3	
		1976	1294	32	556	738	42.9	57.1	
		Total	4045	100	2200	1845	54.3	45.7	

[a]Tabular x^2 value, 5% level, 1 degree of freedom = 3.84.

TABLE II

Ratio of Male to Female Individuals in 3480 Jojoba Seedlings on the Third Year of Growth (1976)

Accession			No. of seedlings		Percentage of seedlings		x^{2a}
No.	Designation	Flowering	Male	Female	Male	Female	Calculated
							(1:1 ratio)
6	Riverside-3	916	477	439	52.1	47.9	1.6
7	Delmar-5	422	205	217	48.6	51.4	0.3
8	Aguanga-12	702	434	268	61.8	38.2	39.3
9	Aguanga-1	460	184	276	40.0	60.0	18.4
10	Aguanga-5	95	49	46	51.5	48.5	0.1
11	Vista-A-5	118	73	45	61.8	38.2	6.6
12	Vista-B-1	104	70	34	67.3	32.2	12.5
13	Aguanga-7	87	51	36	58.5	41.4	2.6
14	Aguanga-8	81	45	36	55.5	44.5	1.0
15	Aguanga-9	115	68	47	59.1	40.9	3.8
16	Vista-D-1	100	69	31	69.0	31.0	14.4
17	Vista-I-5	95	54	41	56.8	43.2	1.8
18	Vista-A-5	185	94	91	50.8	49.2	0.1
	All accessions	3480	1873	1607	53.8	46.2	20.3

[a]Tabular x^2 value, 5% level, 1 degree of freedom = 3.84.

TABLE III

Comparison Between Total Number of Seedlings Grown and Number of Seedlings Flowering in the Third Year (1976) of Growth

Accession		No. of seedlings		
No.	Designation	Total	Flowering	Percentage flowering
1	Delmar-4	495	355	71.7
2	Vista-I-3	1473	1125	76.4
3	Vista-G-14	1240	1034	84.1
4	Aguanga-11	332	253	76.2
5	Vista-I-15	1460	1278	87.5
6	Riverside-3	968	916	94.0
7	Delmar-5	470	422	89.7
8	Aguanga-12	972	702	72.2
9	Aguanga-1	480	460	95.8
10	Aguanga-5	120	95	79.2
11	Vista-A-5	161	118	73.3
12	Vista-B-1	161	104	64.6
13	Aguanga-7	97	87	89.7
14	Aguanga-8	89	81	91.0
15	Aguanga-9	119	115	96.6
16	Vista-D-1	116	100	86.2
17	Vista-I-5	118	95	80.5
18	Vista-A-5	191	185	96.8
		9062	7525	83.0

color range, has been found with long narrow leaves (mean dimensions: 21 x 5 mm). The wax composition of this strain does not deviate from the typical one reported in the literature (4).

EARLINESS

In most jojoba plants observed in Southern California, fertilization and seed development start in January or February. Thus, low temperatures occurring prior to fertilization (November to February) may damage the flowers severely and cause crop failures. Two strains have been identified in which fertilization occurs in October-November, prior to the onset of low temperatures. Preliminary observations indicate that developing jojoba seeds are much less susceptible to frost damage than are flowers. Earliness in this case is tantamount to cold tolerance.

NUMBER OF FRUIT PER NODE

The typical fruiting pattern of jojoba is to have a single fruit at every other node. Cases of two or three fruit growing together in a cluster are extremely rare and are considered as accidental morphological deviations from the norm. One strain is now available which consistently produces clusters of two to ten fruit in more than 50% of the inflorescences of each plant (Fig. 2). The importance of this type in terms of seed yield and wax content has not been determined yet.

FRUITING PATTERN

As a rule, jojoba branches bear fruit at every other node. A strain has been identified which bears fruit at every node (Fig. 3).

MALE:FEMALE RATIO

A small number of botanists (H.S. Gentry, personal communication) who attempted counts of male and female jojoba plants to determine the sex ratio in natural populations have reached differing conclusions. Although this ratio has always been close to 1:1, in some cases male plants were more frequent than female; in others, the reverse was true. These discrepancies could be due to sampling error where small numbers of individuals were tabulated. Greater and more consistent discrepancies would be expected, however, if male and female jojoba plants had slightly different adaptation requirements. Freeman et al. (5) reported that in a study involving five dioecious wind-pollinated species representing five plant families, male plants were more abundant on xeric microsites, while females were more frequent on moister parts of each environment. No information is available to indicate that a similar situation prevails in jojoba populations. If, however, male and female jojoba plants had different ranges of adaptation across environmental gradients, the sex ratio would be expected to change along these gradients; samples taken along a linear direction connecting opposite extremities of such a group would obviously lead to conflicting conclusions.

A detailed breakdown of the flowering data from the Riverside planting is given in Tables I, II, and III. Table I covers 4045 out of the total of 9062 seedlings studied, it shows separately how many seedlings of five accessions flowered in the second year (1975) and how many in the third year (1976) after planting. In accessions 1, 2, and 5, 67-86% of the seedlings flowered in the second year. By contrast, in accession 4 only 39% of the seedlings flowered in the second year. Turning to the ratio of male to female seedlings, the great majority of seedlings flowering in the second year of growth in all accessions were male. The reverse is true in the third year of growth. Also, the majority of males started blooming in the second year of growth. Combining the figures of all accessions, we note that if the experiment was terminated in 1975, males would account for 59.7% and females for 40.3% of the seedlings. The additional data collected in 1976 reduce the discrepancy between the number of males and females, and the respective percentages become 54.3% and 45.7%. If the seedlings that did not flower by 1976 were not rogued out and given the tendency of female seedlings to flower later, if flowering data were taken in 1977, it is conceivable that the majority of these seedlings would be female. This would bring the overall male:female ratio closer to 1:1.

Table II covers 3480 seedlings from accessions that were late flowering. Less than 20% of these seedlings flowered in the second year of growth; thus flowering data were collected only on the third year. In all cases, except accessions 7 and 9, the number of males was greater than that of females. Pooling all accessions, we obtain 1873 male seedlings and 1607 female seedlings, or a ratio of 53.8% to 46.2%, respectively.

Table III provides a comparison between the number of seedlings that flowered by the end of the third year of growth and the total number of seedlings available in the 18 accessions. These accessions differ considerably among themselves, in terms of date of bloom which is a major consideration in planning commercial plantations. Pooling all accessions together we find that 7525 out of 9026 seedlings, or 83% of the total, flowered by the end of the third year of growth. Of the 7525 seedlings that flowered, 4073 or 54.1% were male and 3452 or 45.9% were female. The data point to a statistically significant deviation from a 1:1 ratio and an excess of male plants. This, however, might be due to the fact that 1537 seedlings (13% of the total) that did not flower by the end of the third year of growth were not sexed.

Three basic conclusions result from the Riverside field planting. (a) Male seedlings flower earlier than female ones and mostly during the second year of growth. (b) Jojoba plants differ in the length of time required for anthesis. (c) Data collected on male:female ratio over the first 3 years of growth show that there is a significant deviation from a 1:1 ratio in favor of males; indications are that if flowering data collection was continued for an additional year, this ratio would move closer to 1:1.

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