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SELECTION OF SOME PROMISING JOJOBA (*Simmondsia chinensis*) GENOTYPES: EVALUATION OF TREE GROWTH AND PRODUCTIVITY

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ABSTRACT

The current study was conducted at the Experimental Desert Station Farm of Faculty of Agriculture, Cairo University, for selecting some promising jojoba genotypes from jojoba populations that were raised by seed. The evaluation depends on plant growth, yield and seed oil content. High differences among growth of genotypes were found for plant height and canopy volume. Line No. 12 and 7 recorded the highest and lowest values of plant height respectively. Line No. 1 and 15 recorded the lowest plant volume while line No. 23 recorded the highest plant volume. Tree yield and yield per unit area showed high variation between the selected jojoba genotypes and seasons. Seed weight ranged from (0.56 g) in line No. 30 to 1.17 in line 3 and 9. High oil content in seeds was found in most of the selected jojoba plants. Oil content ranged from 29.6 to 50.7%. Also the studied genotypes showed different degrees of alternate bearing behavior. According to the results reported in this research, line 36 appear to be the best jojoba genotypes with selection index (0.77) followed in descending order by lines 7, 8, 19 and 21 which offer good production prospects and may be recommended for commercial production.

Key words**:** ***Jojoba, Simmondsia chinensis, Selection, Yield, Seed weight, Oil content***

INTRODUCTION

Jojoba (*Simmondsia chinensis* Schneider) is an evergreen shrub that is native to northern México and the south western United States. (Yermanos 1982). The jojoba has an economic value; its seeds contain about 50% of wax ester commonly known as jojoba oil (Purcell *et al*. 2000). Jojoba oil is used extensively in cosmetic industries due to its dermatological properties (Al-Soqeer 2014). Its great resistance to drought allows this shrub to produce a crop with significantly less water compared with the traditional crops. In systematic germplasm collection, clonal evaluation, variety trials, and cultivar selection are the keys to successful jojoba production (Purcell and Purcell 1988).

Jojoba is a dioecious species and propagates by seeds which resulted in highly heterogeneous plants that provide a wide range of hybrid vigor and fertility. Average yields from these first selections were 600 g per plant by the 7th year (Palzkill and Hogan, 1982 and Yermanos, 1982). However, only a small proportion of the seedling have the potential of acceptable yields (Purcell and Purcell 1988). Hence, the best method for jojoba improvement is the selection of plants with desirable characteristics and propagating them asexually. Whereas jojoba's initial introduction faltered because of low and inconsistent yields (McKelvie *et al* 1994). Selection from a wide range of genotypes provides a basis to cultivar establishment.

Well selected plants of jojoba can yield more than three times that of a seeded plantation. Thereby the main objective of the current study is selection of jojoba genotypes with high yield and good agronomic parameters.

MATERIALS AND METHODS

Plant materials and field experimental site

The present study was carried out during two successive seasons (2013-2014) on nine-years old jojoba plants grown at Agricultural Experiments Desert station of Faculty of Agriculture, Cairo University located at Wadi El Natrun in Beheira Governorate (located between 30º32'30" and 30º33'0" N and between 29º57'15" and 29º58'15" E with an altitude of 31 and 59 m). The jojoba was planted at 2.5 x 4 meters apart in sandy soil, under drip irrigation system. Physical and chemical properties of the experimental soil as well as chemical analysis of irrigation water are presented in Tables (1 and 2). Meteorological data at the experimental site during the growing seasons were obtained from the meteorological station near the Experimental Farm, and data are shown in Table (3).

Table 1. Physical and chemical analysis of experimental orchard soil

Physical properties		Chemical properties			
Sand %	92.50	Soil (pH)	7.53	Available N (mg kg^{-1})	8.6
Silt %	4.78	Ec (dS/m)	5.36	Available P (mg kg^{-1})	2.24
Clay %	2.72	Organic Matter (%)	0.25	Available K (mg kg^{-1})	180
Texture	Sandy	Total $CaCo_3$ (%)	5.96		

Table 2. Chemical analysis of water samples.

pH Unit	EC dS/m	Ions concentration (meq/l)						
		HCO_3+CO_3	Cl	SO_4	Na	K	Ca	Mg
7.35	4.1	3.8	27.2	14.58	35.1	0.48	6.0	4.0

Table 3. Monthly mean of climatic data at experimental site in Wadi El-Natroon* during 2013 and 2014 years.

Month	Temperature (°C)		Relative humidity(%)		Wind speed (km h^{-1})
	Max.	Min.	Max.	Min.	
2013					
January	22.14	20.77	78.21	49.43	7.34
February	22.89	20.80	76.00	44.00	7.71
March	23.14	13.92	79.19	45.85	8.30
April	24.87	14.24	79.71	41.85	6.72
May	27.20	14.97	82.31	41.55	6.01
June	28.29	15.05	84.13	47.91	6.10
July	28.61	15.49	87.67	54.98	6.48
August	29.47	16.94	87.56	56.72	6.07
September	29.02	19.26	84.54	51.04	5.66
October	27.63	20.41	80.51	51.49	6.40
November	25.30	20.00	77.96	50.05	6.40
December	24.60	19.75	80.95	49.61	5.21
2014					
January	22.50	20.54	78.22	49.00	7.20
February	22.75	20.66	77.00	43.00	7.40
March	23.16	14.01	79.15	45.92	8.22
April	24.89	14.23	79.73	41.84	6.74
May	28.12	14.96	82.22	41.74	6.22
June	28.25	15.08	84.13	47.85	6.09
July	28.74	15.39	87.59	54.78	6.51
August	29.77	16.96	87.66	56.88	6.08
September	29.17	19.23	84.61	51.12	5.62
October	27.58	20.14	80.45	51.76	6.43
November	25.05	20.11	77.56	50.12	6.45
December	24.43	19.90	80.10	49.50	5.24

*** Data obtained from the Central Laboratory for Agriculture Climate (CLAC), Agricultural Research Center, Egypt**

The measurements

Plant height (cm).

Plant height (cm) was estimated from soil surface to the top of the tree

Plant canopy volume (m^3).

The canopy volume (m3) was measured by the following equation (Turell 1946).

Canopy volume (m^3) = 0.5238 H* D^2.

Where H and D refer to tree height and width, respectively

Plant yield (kg).

Calculated by the following formula:

Yield (g/m^3) = yield (g)/ canopy volume (m^3)

Seed weight (g)

Samples of 100 seed from each tree were collected randomly to determine average seed weight (seed weight = sample weight/ 100)

Seed oil content (dry weight) (%)

To determine oil content, sample of dried seeds of each genotype was randomly selected, weighed and the oil was extracted for 16 h with a Soxhlet apparatus

Alternate-bearing behavior

The severity of alternate-bearing can be calculated according to Monselise and Goldschmidt (1982):

Alternate bearing index (I) = (year 1 yield) - (year 2 yield)/(year 1 yield + year 2 yield), where I = 0 is no alternate bearing and I = 1.0 is complete alternate bearing

Selection index

SI = Seed yield (kg per plant) × seed weight (g) ×wax content (%dry weight).

Statistical analysis

The collected data were statistically analyzed according to analysis of variance (ANOVA) for augmented design (Federer, 1956). When a significant F-test was found, the mean values were separated using Duncan's multiple range tests. All analyses of variance were computed using the SAS program.

RESULTS AND DISCUSSION

According to data in Table (4) plant growth (height and volume) showed a high variation among the selected jojoba genotypes. Line 7, 13, and 25 recorded the lowest plant height with value ranging from 110 cm (line 7 in the 1st season) to 120 cm (line 25 in the 2nd season). The highest value was recorded for line 12 in both seasons (220 and 240 cm). Line 1, 15 and 26 recorded the lowest plant volume while line 23 recorded the highest plant volume.

Table 4. Plant height and canopy volume of the studied jojoba genotypes.

plant code	Plant height (cm)			Canopy volume (m^3)		
	1st season	2nd season	Average	1st season	2nd season	Average
1	200 c	210 b	205.0 C	1.87 g	2.10 g	1.98 G
2	130 n	142 l	136.0 T	0.87 x	1.14 w	1.00 X
3	160 j	170 i	165.0 M	1.47 j	1.62 l	1.54 L
4	180 g	180 g	180.0 I	1.65 i	1.74 k	1.69 I
5	150 k	170 i	160.0 N	1.05 r	1.30 r	1.17 U
6	210 b	210 b	210.0 B	2.28 b	2.45 d	2.36 D
7	110 r	150 k	130.0 V	1.03 s	1.48 n	1.25 P
8	195 d	210 b	202.5 D	2.18 d	2.84 b	2.51 B
9	170 h	170 i	170.0 L	1.13 p	1.26 t	1.19 T
10	150 k	170 i	160.0 N	1.10 q	1.36 p	1.23 R
11	133 m	150 k	141.5 S	0.97 u	1.18 u	1.07 W
12	220 a	240 a	230.0 A	2.20 c	2.60 c	2.40 C
13	123 p	140 m	131.5 U	0.98 t	1.28 s	1.13 V
14	150 k	190 e	170.0 L	1.25 m	1.90 i	1.57 K
15	125 o	160 j	142.5 R	0.91 w	1.09 x	1.00 Y
16	170 h	195 d	182.5 G	1.42 k	1.79 j	1.60 J
17	180 g	183 f	181.5 H	1.20 o	1.59 m	1.39 M
18	170 h	178 h	174.0 J	1.84 h	2.08 h	1.96 H
19	165 i	180 g	172.5 K	1.98 e	2.40 e	2.19 E
20	150 k	150 k	150.0 P	1.23 n	1.35 q	1.29 O
21	150 k	160 j	155.0 O	1.20 o	1.28 s	1.24 Q
22	189 f	200 c	194.5 F	1.94 f	2.34 f	2.14 F
23	191 e	200 c	195.5 E	2.71 a	2.90 a	2.80 A
24	150 k	160 j	155.0 O	1.25 m	1.44 o	1.34 N
25	120 q	140 m	130.0 V	1.28 l	1.16 v	1.22 S
26	140 l	150 k	145.0 Q	0.93 v	1.08 y	1.00 X

Means followed by the same letters in the same column are not significantly different at P < 0.05

Similar trend was observed by Al-Soqeer (2014) who indicated that highly significant differences among growth seasons and genotypes were found for jojoba plant height. Plant volume is an indication of vegetative growth that is linearly correlated to the potential yield (Benzioni 1988).

Data in Table (5) indicated that tree yield and yield per tree volume showed high variation between the selected jojoba genotypes and seasons. Line 23 recorded the highest yield in the 1st season followed by line 24 and 19 while line 10, 5, and 26 recoded the lowest yield. In the 2nd season line 8 produced the highest yield followed by line 13 and 12 while the lowest yield was recorded for line 1, 15 and 23. In the 1st season line 23, 24 and 7 produced the highest yield per tree volume while line 5, 6 and 8 recorded the lowest value, in the second season line 13, 21 and 8 produced the highest value while the lowest yield recorded for line No. 1, 15, 18 and 23. In pervious studies, Ayerza (1996) reported that average yield from selected jojoba clones ranged from 148g to 705 g/plant.

Table 5. Tree yield and yield per tree volume of the studied jojoba genotypes.

Plant code	Tree yield (g)			Yield per unit area (g/m^3)		
	1st season	2nd season	Average	1st season	2nd season	Average
1	258 u	20 y	139.0 Y	138.09 v	9.52 y	73.81 Z
2	368 q	689 i	528.5 M	424.24 m	605.97 d	515.11 G
3	537 m	673 j	605.0 J	365.81 n	416.35 k	391.08 K
4	1032 e	245 r	638.5 I	624.90 f	140.68 t	382.79 M
5	132 w	190 t	161.0 X	125.60 x	145.65 r	135.63 X
6	310 r	869 g	589.5 K	136.14 w	354.38 m	245.26 T
7	1000 f	980 e	990.0 D	973.16 c	663.81 c	818.49 A
8	273 t	1405 a	839.0 G	125.26 y	495.15 h	310.21 S
9	310 r	485 m	397.5 S	273.29 q	384.32 l	328.81 Q
10	121 x	107 w	114.0 Z	109.90 z	78.61 u	94.26 Y
11	157 v	314 q	235.5 W	162.68 t	267.00 n	214.84 V
12	755 h	1116 c	935.5 E	342.88 o	428.85 i	385.87 L
13	514 n	1287 b	900.5 F	521.89 j	1001.96 a	761.93 C
14	900 g	139 u	519.5 P	719.36 d	73.09 v	396.23 J
15	609 k	20 y	314.5 U	669.86 e	18.28 x	344.07 O
16	619 j	431 n	525.0 N	436.55 l	240.90 p	338.73 P
17	375 p	229 s	302.0 V	312.22 p	144.26 s	228.24 U
18	1038 d	132 v	585.0 L	563.12 i	63.51 w	313.32 R
19	1230 c	1029 d	1129.5 B	620.66 g	428.37 j	524.52 F
20	710 i	336 p	523.0 O	579.08 h	248.67 o	413.88 H
21	581 l	950 f	765.5 H	483.74 k	741.53 b	612.64 E
22	419 o	388 o	403.5 R	215.74 s	166.14 q	190.94 W
23	3765 a	25 x	1895.0 A	1390.20 a	8.61 z	699.41 D
24	1278 b	833 h	1055.5 C	1021.49 b	577.96 e	799.73 B
25	290 s	666 k	478.0 Q	225.77 r	573.63 f	399.70 I
26	132 w	614 l	373.0 T	141.30 u	570.65 g	355.98 N

Means followed by the same letters in the same column are not significantly different at $P < 0.05$

Moreover Dunstone and Begg (1983) indicated that the first significant harvest was possible 4 years after planting with yields about 100-200 g per plant.

According to Yermanos (1979) 613 g yield/per plant could be obtained in the seventh year. Also, the average yield varied greatly between years (Osman and Abohassan, 2013). Seed yields attained in the current study indicate that most of the selected genotypes is acceptable for establish of commercial cultivars.

As shown in Table (6) seed weight ranged from (0.57 g) in line 20 to 1.18 in line 3 and 9. Al-Soqeer (2014) noted that jojoba seed weight ranged

Table 6. Seed weight and oil percentage of the studied jojoba clones

Plant code	Seed weight (g)			Oil percentage%		
	1st season	2nd season	Average	1st season	2nd season	Average
1	0.84 g	0.83 k	0.83 N	40.60 n	41.70 l	41.15 P
2	0.73 l	0.70 o	0.71 H	46.32 h	44.50 i	45.41 K
3	1.18 a	0.79 l	0.98 C	48.96 c	43.46 j	46.21H
4	1.07 b	0.79 l	0.93 M	42.58 m	45.44 f	44.01 L
5	0.80 i	0.79 l	0.80 B	50.28 b	41.26 o	45.77 J
6	0.87 f	0.93 f	0.90 A	50.72 a	49.18 a	49.95 A
7	0.98 c	0.78 m	0.88 G	47.20 g	44.56 h	45.88 I
8	0.94 d	0.99 d	0.97 E	48.08 e	45.22 g	46.65 F
9	1.18 a	1.05 b	1.11 L	43.46 l	42.90 k	43.18 N
10	0.87 f	0.96 e	0.91 M	42.58 m	45.22 g	43.9 M
11	0.70 n	0.70 o	0.70 D	48.30 d	46.32 d	47.31 C
12	0.68 p	0.68 p	0.68 D	48.30 d	46.10 e	47.2 D
13	0.69 o	0.78 m	0.73 G	47.20 g	46.32 d	46.76 E
14	0.79 j	0.70 o	0.75 J	45.44 j	49.18 a	47.31 C
15	0.71 m	0.83 k	0.77 R	34.44 r	41.60 m	38.02 S
16	0.90 e	1.14 a	1.02 U	29.60 u	33.78 t	31.69 X
17	0.69 o	0.88 i	0.78 T	32.46 t	35.32 r	33.89 V
18	0.57 t	0.61 r	0.59 P	38.40 p	35.10 s	36.75 U
19	0.94 d	0.78 m	0.86 O	38.84 o	35.76 q	37.30 T
20	0.58 s	0.73 n	0.65 K	43.90 k	41.50 n	42.70 O
21	0.69 o	1.02 c	0.86 E	48.08 e	47.20 b	47.64 B
22	0.60 r	0.87 j	0.74 F	47.42 f	46.10 e	46.76 E
23	0.83 h	0.92 g	0.88 I	46.10 i	47.00 c	46.55 G
24	0.69 o	0.64 q	0.67 N	40.60 n	38.62 p	39.61 Q
25	0.76 k	0.78 m	0.77 Q	35.20 q	32.24 u	33.72 W
26	0.66 q	0.89 h	0.77 S	34.00 s	44.56 h	39.28 R

Means followed by the same letters in the same column are not significantly different at P < 0.05

from 0.57 to 0.80 g also, Ayerza (1996) reported that seed weight (100 seeds) ranged from 48 to 116g. The seed size appears to be affected by alternate bearing and environmental factors such as temperature and water stress.

High-yielding plants with larger seeds appeal to jojoba plant selectors because larger seeds are easier to harvest and handle (Purcell *et al* 2000). Regarding the oil content in jojoba seeds (Table 6) a high content was found in most of the selected jojoba lines. Oil content ranged from 50.7 to 29.6%. According to Thomson (1982), jojoba genotypes show great difference with respect to oil content. The oil concentration of the seed at maturity ranges from 38 to 62% of seed weight (Miwa and Spencer 1976).

The data in Table (7) indicate that the selected genotypes showed different degrees of alternate bearing. The studied genotypes can be classified to the following categories:

Table 7. Selection index and alternate bearing index of the studied jojoba genotypes

Plant code	Selection index	Alternate bearing index
1	0.05 u	0.86 c
2	0.17 l	0.30 n
3	0.28 g	0.11 t
4	0.26 i	0.62 h
5	0.06 t	0.18 s
6	0.27 h	0.47 I
7	0.40 b	0.01 x
8	0.38 c	0.67 f
9	0.19 j	0.22 p
10	0.05 u	0.06 v
11	0.08 s	0.33 m
12	0.30 f	0.19 r
13	0.31 e	0.43 j
14	0.18 k	0.73 e
15	0.09 r	0.94 b
16	0.17 l	0.18 s
17	0.08 s	0.24 o
18	0.13 o	0.77 d
19	0.36 d	0.09 u
20	0.15 m	0.36 l
21	0.31 e	0.24 o
22	0.14 n	0.04 w
23	0.77 a	0.99 a
24	0.28 g	0.21 q
25	0.12 p	0.39 k
26	0.11 q	0.65 g

Means followed by the same letters in the same column are not significantly different at $P < 0.05$

Regular bearing: with alternate bearing index less than 0.2 including lines 12, 5, 16, 3, 19, 10, 22 and 7.

Partially regular bearing: with alternate bearing index from 0.2 to less than 0.5 including lines 6, 13, 25, 20, 11, 2, 21, 17, 9 and 24.

Irregular bearing: with alternate bearing index from more than 0.5, including lines 23, 15, 1, 18, 14, 8, 26, and 4.

The alternate bearing behavior of jojoba was reported by Purcell et al. (2000). According to the selection index (Table 7) the jojoba line 23 appear to be best jojoba genotype with selection index (0.77) followed by lines 7, 8, 19 and 21 which offer good production prospects and maybe recommended for commercial production in regions under similar conditions. Based on results of the related studies (Ayerza, 1996, Botti et al. 1998, Benzioni et al. 1999 and Purcell et al. 2000) seed production and seed weight appear to be the major criteria for selecting jojoba clones. Wax is the commercial product of jojoba, so its content in the seed is important factor for selection.

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إنتخاب بعض سلالات مبشرة من الجوجوبا: تقييم نمو الأشجار والإنتاجية

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أجريت الدراسة الحالية في محطة البحوث الصحراوية بوادي النطرون – كلية الزراعة جامعة القاهرة، لانتخاب بعض التراكيب الوراثية الواعدة للجوجوبا من نباتات جوجوبا بذرية. أعتمد التقييم على نمو النبات والمحصول ومحتوى البذور من الزيت. وجدت اختلافات كبيرة بين الطرز الوراثية في ارتفاع النبات وحجم المجموع الخضري. السلالة 12 و 7 سجلت أعلى و أقل قيم لارتفاع النبات على التوالي. السلالة رقم 1 و 15 سجلت أقل حجم للمجموع الخضري في حين سجلت السلالة 23 أعلى حجم للمجموع الخضري. أظهرمحصول الشجرة والمحصول لوحدة المساحة تباين كبير بين الطرز الوراثية للجوجوبا ومواسم الدراسة. وزن البذور تراوح بين 0.56 جم في السلالة 18 حتي 1.18 جم في السلالتين 3 و9. وجد أن بذور معظم نباتات الجوجوبا التي تم دراستها أحتوى علي نسبة مرتفعة من للزيتو الذي تراوح بين 29.6 – 57.7٪.كما أظهرت دراسة التراكيب الوراثية درجات مختلفة من سلوك تبادل الحمل. وفق النتائج هذا البحث، فأن السلالة 23 هي أفضل سلالات الجوجوبا التي تم دراستها مع مؤشر إنتخاب (0.77)،يليه بالترتيب التنازلي السلالات 7، 8 و 19 و 21 والتي تظهر مؤشرات إنتاج جيدة ويمكن التوصية بها للإنتاج التجاري.