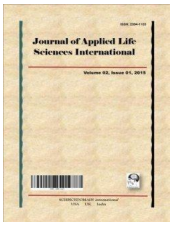

Journal of Applied Life Sciences International

18(1): 1-12, 2018; Article no.JALSI.42332
ISSN: 2394-1103

Selection and Agronomical Evaluation for Some Elite Genotypes of Jojoba

A. Nahla[1*], S. Adawy[2], M. Eliraq[1], A. Abo El-Khasab[1], Y. Abd El-Aziz [1], E. El-Bassel[1], A. S. Esmail[1], M. Attaia[2], S. H. Darwish[2], H. El-Ashry[1] and M. S. Gawish[3]

[1]Horticulture Research Institute, Agriculture Research Center, Egypt.
[2]Agriculture Genetic Engineering Research Institute, Agriculture Research Center, Egypt.
[3]Department of Pomology, Faculty of Agricultural Damietta University, Egypt.

Authors' contributions

This work was carried out in collaboration between all authors. Author AN designed the study. Author HEA performed the statistical analysis. Author AN wrote the protocol and first draft of the manuscript. Authors YAEA, EEB, MA and SHD managed the analyses of the study. Authors ME and AAEK managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JALSI/2018/42332
Editor(s):
(1) Dr. Muhammad Kasib Khan, Department of Parasitology, University of Agriculture, Pakistan.
(2) Dr. Vasil Simeonov, Laboratory of Chemometrics and Environmetrics, University of Sofia "St. Kliment Okhridski", Bulgaria.
Reviewers:
(1) Natalia Georgieva, Institute of Forage Crops, Bulgaria.
(2) Zeynel Dalkiliç, Adnan Menderes University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/25873

Original Research Article

Received 15th May 2018
Accepted 24th July 2018
Published 13th August 2018

ABSTRACT

Aim: Jojoba is a domesticated plant successfully cultivated in the desert of Egypt. The methods used by jojoba farmers in the past have been varied, as there were no real records on the performance of cultivated plants of jojoba. Moreover, cultivated areas of jojoba originated from seed which leads to high variability within plant parameters. The present investigation aimed to identify elite genotypes of jojoba plants to be used as a seed for jojoba germplasm with high seed yields for breeding purposes.

Study Design: Screening of two different orchards located in different locations for jojoba genotypes was performed to select and evaluate elite genotypes. Ten female and two male genotypes were selected from two locations and subjected to vegetative, phenology and yield evaluation during 2014 and 2015.

**Corresponding author: E-mail: nohawad@yahoo.com;*

Methodology: selected genotypes were subjected to evaluation at morphological, seed characterization, yield, pollen viability and molecular identification by ISSR marker.
Results: Female genotypes from two screened locations had similar heights except for one genotype from Elkasassein which scored a height of 624 cm. Phenology parameters were investigated from the beginning of flowering which extended from late November till mid of December. Full bloom extended from mid of January to the first of March. A number of flowers ranged from five to eight flowers per one meter length. Seed weight of female genotypes from the desert road orchard was higher than those of females from the Elkasassein orchard. Generally, seed weight ranged from 0.73 to 1.37 g for strain No.8 and strain No.4, respectively. ISSR based dendrogram revealed different relationships among the tested genotypes.
Conclusion: It could be concluded that there is a wide variation among the tested genotypes of jojoba. These variations are valuable in the breeding program and contribute to the improvement of jojoba plants.

Keywords: Jojoba; evaluation; selection; molecular markers; ISSR; similarity.

1. INTRODUCTION

Jojoba (*Simmondsia chinensis*) is an evergreen shrub that is native to northern México and the southwestern United States. The jojoba plant has economic value because its seeds contain about 50% of a light yellow, odourless wax ester commonly referred to as jojoba oil, which is extensively used in the cosmetic industry due to dermatological properties. Its great resistance to drought allows this shrub to produce a crop with significantly less water than is necessary for traditional crops [1]. Jojoba is a long lived evergreen perennial shrub with extensive deep tap root system which helps to withstand drought conditions. Jojoba oil wax which is not only an alternative to sperm whale oil but also well known for utilization in cosmetics, lubricants and pharmaceuticals etc. Jojoba, being a dioecious plant, does not reproduce true-to-type by sexual propagation [2]. These are serious problems of jojoba cultivation. Molecular marker techniques are among the highly useful ways for determining the sex of dioecious species at an early stage [3]. Hence, the best method for jojoba improvement, in the short term, is the selection of plants with desirable characteristics and propagating them asexually. The objective of this study was to evaluate jojoba plants for agronomic and yield characters to introduce jojoba as a commercial crop with the purpose of selecting superior jojoba genotypes.

Molecular marker techniques are among the highly useful ways for determining the sex of dioecious species at an early stage. The determination of male and female jojoba plants at the young stage is important for a planned plating (5 male: 1 female) in cultivation. A few molecular markers that can be used for sex determination of jojoba [4] as OPG-5 RAPD primer, as UBC-807 ISSR primer [5] and as JMS900 DNA marker [6].

2. MATERIALS AND METHODS

Fifteen female and five male strains were selected from two different orchard locations (El-Kasasin and Cairo-Alexandria road). Trees are cultivated in sandy soil at distance 3x3. The selected strains were evaluated for their morphological and genetical characteristics during 2014 and 2015 seasons using the following parameters.

2.1 Morphological Parameters

- Plant height recorded from the ground to the highest point of the tree.
- Leaf area was measured manually using the equation 2/3 length x width.
- Leaf color - Stem color (winter) -Stem flexibility - Stem toughness
- Shoot length (cm) - Leaf number/shoot - Number of internodes
- Growth habit.

2.2 Characterization of Seeds Physically

The following data were estimated for seeds:

- Seed length (cm): average seed length of three replicates, each replicate consists of ten seeds
- Seed diameter: average seed diameter of three replicates, each replicate consists of ten seeds
- Seed weight (gm.): by weighing 100 seeds and calculate the average weight/ seed

- Seed volume: by immersion of 100 seeds in beaker contain water and determine the volume and calculate the average volume/seed.
- A number of ridges per seed.

2.3 Pollen Variability Estimation

The dehiscent pollens were lightly tapped on a drop of acetocarmine stain on a slide. Six slides were made for each type, for each slide ten microscopic fields were chosen at random and pollen grains were counted and graded as viable and aborted in two classes. Pollen grains which darkly stained and round were considered viable, while those lightly stained or shrinkage was considered aborted[7].

2.4 DNA Fingerprint

Total DNA was isolated from collected strains using DNAeasy Plant Mini Kit (Qiagen, Santa Clarita, CA) (Cat no. 69104).

2.4.1 Inter Simple Sequence Repeats (ISSRs)

ISSR markers involve PCR amplification of DNA using a single primer composed of a microsatellite sequence such as (GA)8 anchored at the 3′ or 5′ end by 2 – 4 arbitrary, often degenerate, nucleotides. The sequences of repeats and anchored nucleotides are randomly selected.

2.4.2 ISSR-PCR Reaction and thermocycling profile

PCR was performed in 25 ul reaction volume containing 1X PCR buffer, 1.75 mM MgCl2, 5 mM of each dNTPs, 40 pM oligonucleotide primer, 25ng genomic DNA and 1 Unit of Taq DNA polymerase. A high stringency touchdown and hot start thermocycling profile was used. This was performed to avoid any mismatch between the primer and the template as follows: an initial denaturation step for 5 min at 94ºC followed by one cycle at 94ºC for 30 seconds, 65ºC for 45 second and 72ºC for 1min. The annealing temperature was lowered each cycle 1ºC during nine cycles. This gave a touchdown phase of ten cycles. This was followed by thirty-five cycles performed at 94ºC for 30 seconds, 55ºC for 45 second and 72ºC for 1 min and an extension cycle at 72ºC for 7 min. The PCR products were separated on 2% agarose gel in 1X TBE buffer containing ethidium bromide and photographed using Gel-documentation system.

2.5 Statistical Analysis

Experimental complete randomize was designed. Agronomical data was subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1980). Differences between means were compared by Duncan's multiple rang test described in the SAS (SAS, 1986).

3. RESULTS AND DISCUSSION

3.1 Morphological Measurements

The studied females of jojoba differ in its growth habit (Table 1). It was spread vigor growth habit (1, 2, 6, 9, 10, 11, 12, 14 and 15). However, straight vigor habit was noticed with clones (3, 4, 5, 7 and 13). Only three clones are of dwarf type; two of these clones are spread (8 and 9) and the remainder is straight (13). Variation in stem texture was also observed within the selected strains. Strain No. 2, 3, 4, 6, 8, 9, 10, 13, 14 and 15 have a rough texture. Another four clones detected a semi-rough texture (1, 5, 11 and 12); only clone No.7 showed a semi-soft texture.

Meanwhile, three out of the fifteen selected strains have flexible stem (1, 13 and 15) and the twelve strains left were inflexible. No differences were observed with both leaf and stem color, leave have a green color, while the stems have a light brown color.

On the other hand, selected male strains revealed rough stem texture, strong stem toughness, green leaf color and grey stem color except for strain No. 2 (brown).

Data revealed that vegetative parameter was differing with a wide range among the tested female strains. Plant height e.g. ranged from 160 cm to 280 cm (K15 and C16, respectively). On the other hand, the lowest value of an average number of branches (Table 2) was recorded by C2 (1.75) and the highest value was revealed by C10 and K25 (5.25).

A great variation was noticed in leaf area (Fig.5), it was ranged from 3.20 cm^2 to 9.22 cm^2 (C1 and C16, respectively). Average shoot length ranged from 11.66 cm to 25.08 cm for C1 and K15, respectively. Moreover, average leaf number (Table 2) ranged from 14 - 46 for C4 and K15, respectively.

Table 1. Description of growth nature of jojoba female and male strains. Vegetative growth parameters

Female no.	Growth habit	Stem texture	Stem toughness	Stem flexibility	Leaf color	Stem color
1	Spread-vigor	Semi-rough	Strong	flexible	All the strains have the same color (green)	All the strains have the same color (light brown)
2	Spread-vigor	Rough	Very-strong	Inflexible		
3	Straight-vigor	Rough	Strong	Inflexible		
4	Straight-vigor	Rough	Very-strong	Inflexible		
5	Straight-vigor	Semi-rough	Semi-strong	Inflexible		
6	Spread-vigor	Rough	Strong	Inflexible		
7	Straight-vigor	Semi-soft	Strong	Inflexible		
8	Spread-dwarf	Rough	Very-strong	Inflexible		
9	Spread-dwarf	Rough	Very-strong	Inflexible		
10	Spread-vigor	Rough	Very-strong	Inflexible		
11	Spread-vigor	Semi-rough	Very-strong	Inflexible		
12	Spread-vigor	Semi-rough	Strong	Inflexible		
13	Straight-dwarf	Rough	Semi-strong	flexible		
14	Spread-vigor	Rough	Semi-strong	Inflexible		
15	Spread-vigor	Rough	strong	flexible		
Male no.						
1	Semi-straight	Rough	Strong	flexible	All males have green color	**Gray**
2	Straight	Rough	Strong	flexible		**Brown**
3	Spread-dwarf	Rough	Strong	Inflexible		**Gray**
4	Straight	Rough	Strong	Inflexible		**Gray**
5	Spread	Rough	strong	flexible		**Gray**

The disparity in an average number of internodes was observed. A maximum average number of internodes were found with K15 (Table 2) while, C4 recorded the lowest average number of internodes.

For male strains (Table 2), it was noticed that M1 recorded the highest value for both plant height and average leaf number. The vice versa was true for M5 plant height, average leaf number and average leaf area detected the lowest record among the tested males (Table 2).

Evaluation and comparison of agronomical characteristics for seven jojoba female clones under Central of Saudia Arabia and found highly significant differences for plant height, number of branches per plant and leaf area. He stated that these significant variations in growth and physiological parameters among the genotypes might reflect, partially, their different genetic background [10,11]. Variability in different morphological traits such as plant height, number of branches, number of internodes, leaf shape and area was demonstrated by [12,13,14].

In respect to flowering, females represent a wide range of flowering time length. Strain C10 showed approximate 20 days of flowering; while C25 revealed 44 days of flowering (Table 2). It is preferable to select strains to have short flowering length because of yield and fruiting with consecutive yield harvesting.

Moreover, a number of flowers per shoot (Fig.1) ranged from 4 (C1, C4, C5, C16 and K7) to 7 (C22). On the other hand, flowering length of males was short in comparison with females. It was ranged from 22 days (M1and M5) to 28 (M4). The highest number of inflorescences (Fig.2) was recorded by M2 (11); while the lowest number was obtained from M5 (4). Fertility percentage was high with all of the selected males; it was ranged between 94.87 (M2) to 96.12 (M4) could be harvested once time while a long period of flowering gives sequential fruit set. Studied on the impact of climatic changes on the performance of some selected jojoba varieties in five different sites (Goondiwindi, Hillston, Wirrinya, Kerang and Nildottie) and concluded that the pattern of flowering was more or less as expected at most locations, however the plants at Goondiwindi behaved differently compared to those at other sites. Moreover, there was great variation in peak flowering time between years at each site and this is due largely to seasonal climate differences, but there was reasonable consistency in phase development between lines each year [15].

Table 2. Vegetative growth parameters of selected female and male (during 2014 and 2015 seasons)

Strain	Plant height (M)		Average no. branch		Average leaf area (cm^2)		Average shoot length (cm.)		Average leaf no./shoot		Average No. internodes	
no.	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
C1	1.85	1.90	3.25	3.20	3.20	3.10	11.66	10.93	16.00	16.10	7.75	6.98
C2	2.20	2.52	1.75	1.80	4.96	4.99	18.29	17.98	16.00	15.96	8.00	8.21
C3	2.25	2.40	3.00	3.24	3.56	3.66	16.98	16.47	17.00	16.95	8.50	7.69
C4	2.20	2.41	3.75	3.74	4.38	4.61	18.34	17.85	14.00	15.01	6.25	6.31
C5	2.45	2.52	3.00	2.93	4.15	4.24	12.79	11.97	18.00	18.00	10.5	10.10
C7	2.20	2.29	2.10	2.41	5.07	4.90	15.78	16.21	15.00	14.95	9.32	8.75
C10	2.00	2.15	5.25	3.24	6.55	5.99	14.87	15.10	34.00	32.65	17.00	18.21
C16	2.80	2.87	4.32	5.01	9.22	6.97	26.67	26.00	34.00	33.94	10.56	11.00
C18	2.55	2.61	3.40	3.15	5.34	5.01	23.11	22.96	21.00	20.98	13.06	12.97
C19	1.90	2.05	2.43	2.51	5.67	4.93	15.72	15.40	29.00	30.41	12.76	12.37
C21	1.75	1.83	3.20	2.99	6.32	5.87	12.65	11.78	27.00	25.94	15.90	15.37
C22	1.85	1.92	4.32	4.32	5.27	5.21	21.78	21.34	29.00	30.01	15.65	14.97
C25	2.70	2.75	4.15	4.09	6.53	6.44	16.83	17.52	23.00	24.00	14.76	15.77
K7	2.20	2.24	2.10	2.30	5.07	5.21	15.78	15.21	15.00	17.01	9.32	8.97
K15	1.60	1.68	5.25	5.19	5.32	5.37	25.08	24.99	46.00	39.99	23.00	22.87
Male no.												
M1	3.70	3.78	3.41	3.00	4.04	4.21	20.33	19.23	29.11	25.32	8.00	10.11
M2	2.70	2.84	2.21	2.10	4.05	3.99	42.00	40.24	17.12	16.33	8.10	12.32
M3	2.80	2.85	2.23	3.42	4.73	4.82	37.00	34.21	22.14	28.14	14.00	13.97
M4	3.50	3.56	3.22	2.32	5.82	4.91	29.50	25.12	15.47	17.54	11.00	16.21
M5	2.70	2.74	3.25	3.74	1.99	2.52	23.33	27.33	14.12	14.35	10.33	9.24
L.S.D	0.95	0.99	1.10	1.05	1.31	1.65	5.23	4.98	10.52	8.47	3.54	5.18
P = 5%												

Table 3. Flower beginning date, the full blooming date for some selected jojoba female and male

Female flowering					Male flowering				
Strain no.	2014		2015		Strain no.	2014		2015	
	Beginning date	Beginning date	Full bloom date	Full bloom date		Beginning date	Beginning date	Full bloom date	Full bloom date
C1	22/12	19/12	22/1	20/1	M1	30/12	1/1	14/1	20/1
C2	12/1	12/1	15/2	13/2	M2	10/1	10/1	3/2	3/2
C3	14/1	15/1	20/2	15/2	M3	10/1	10/1	5/2	3/2
C4	25/12	1/1	25/1	20/1	M4	7/1	5/1	4/2	3/2
C5	25/12	27/12	29/1	25/1	M5	25/12	23/12	20/1	15/1
C7	21/1	21/1	15/2	16/2					
C10	1/2	29/1	20/2	19/2					
C16	25/1	27/1	25/2	20/2					
C18	28/1	30/1	28/2	29/2					
C19	28/1	28/1	5/3	5/3					
C21	15/1	10/1	23/2	20/2					
C22	30/12	25/12	30/1	23/1					
C25	20/12	20/12	2/2	5/3					
K7	17/1	12/1	10/2	12/2					
K15	23/1	20/1	28/2	25/2					

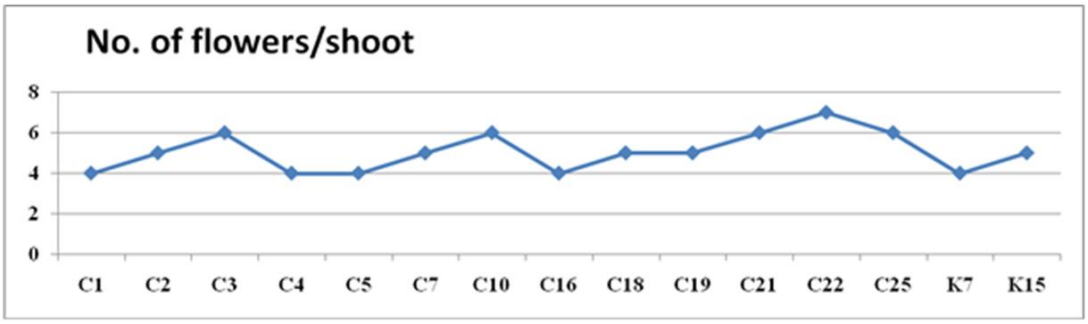

Fig. 1. Average number of flowers for fifteen selected genotypes of jojoba female during 2014 and 2015

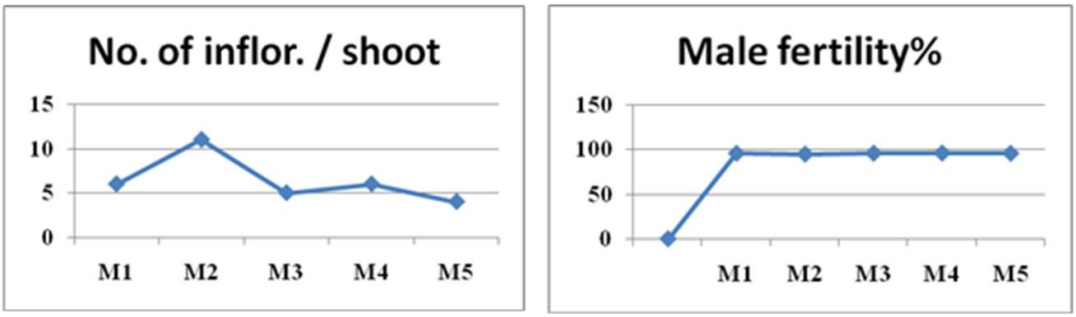

Fig. 2. Average number of flowers and average percentage of male fertility for five selected genotypes of jojoba male during 2014 and 2015

3.2 Yielding and Seeds Characterization

Table (4) showed the characterization of jojoba seeds and the yielding of each genotype. It is obvious that strain C10 has the potential to produce the highest yield (7.700 kg). Meanwhile, strain C4 produces the lowest yielding (0.400 kg). Another five strains (C16, C18, C19, C21 and C25) were superior in their production (5.650 kg, 5.550 kg, 5.800 kg, 5.350 kg and 7.150 kg,

respectively) in the first season this could be attributed to their origin as seedy plants.

Seed weight was highest within strain C10 (1.85 g.), at the same time strain C21 showed the lowest average weight of seeds (0.84 g.). Seed volume ranged from 0.80 cm^3 (strain 20) to 1.80 cm^3 (strain C2 and C10). There is no variation among the tested strains concerning seed diameter. Strain C3 and strain C21 detected the highest value (15.25 mm and 13.86 mm, respectively).

A vice versa trend was noticed for seed length, strain C2 raise the highest value (20.33 mm) of average seed length, however, strain C21 showed the lowest average seed length (15.63 mm). A number of ridges were three for most of the selected; only strains (C10, C22 and C25) detected four ridges within seeds (Fig.5).

In this respect, the selection will depend upon seeds with a weight greater than or equal to one gram at least. Viability of seed less than one gram is often weak, moreover, oil content of such seeds is very low and oil content (percentage of oil within the seeds) is what we search for and finally, seed weight affected on yielding, there is a retardant relationship between yielding and seed weight, increasing of seed weight lead to increasing of yielding. Seed yield of jojoba plants ranged from 0.02 to 0.5 kg per plant from 4-year-old in Alata, Mersin, Turkey [16]. Moreover, average seed yield varied from 0.18 to 0.59 kg per plant at the Hail region in the fourth and fifth year, respectively [17].

Plant growth, yield and seed oil content and demonstrated that yield per unit area showed high variation between the selected jojoba genotypes and seasons and stated that seed weight ranged from 0.56 to 1.17 g [18].

3.3 ISSR Markers

3.3.1 Polymorphism detected by ISSR marker

Twelve ISSR primers were tested with the DNA (Fig.4) of twenty jojoba strains (fifteen female and five males). These primers produced multiple band profile which ranged from 6 to 17 amplicon (Table 5). A total number of amplicons amplified by the twelve primers was 148 with an average 12.3 amplicon/ primer (Table 5). The number of polymorphic bands ranged from 0 (ISSR2) to 14 (ISSR10), representing the percentage of polymorphism ranged from 0 to 100%. The size of the amplified bands varied according to the used primers, it was ranged from 155bp (ISSR1) to 1056bp (ISSR3).

Nineteen ISSR primers were used with jojoba plants. The nineteen primers amplified 119 bands, 76 of the 119 were polymorphic. The number of amplification bands per primer varied between 2 and 11. They concluded that dinucleotide repeat (GA)n and (AG)n primers had more bands than the other primers, likely because of its greater abundance in jojoba genome [19]. On the other hand, eleven 10-mer primers were employed with jojoba, four primers exhibited polymorphism among jojoba plants, one primer did not exhibit polymorphism, and the other six primers did not produce amplification patterns [20].

3.3.2 Cluster analysis

Dendrogram obtained from UPGMA cluster analysis of genetic distances (Fig.3) introduce five clusters. The first cluster includes four genotypes of males (17,18,19 and 20) meanwhile, only one male (16) was grouped with one female genotype (12) in the second cluster. The third cluster contains female genotypes (1 and 3). However, the fourth cluster was divided into two groups each of them collected two female genotypes (2 and 10), (6 and 9). The last cluster gathered nine female genotypes in two groups, one of these groups combined five genotypes (4,15,5,7 and 8) while, the remaining was located in the second group (11,13 and14).

In this respect, A dendrogram generated using the pooled ISSR data divided the jojoba genotypes into two main clusters. The first cluster was divided into three sub-clusters that included the following: (i) genotype HB2, (ii) genotypes HB4, HB8, and MD8, and (iii) genotype HD1. The second cluster consisted of genotype HB6. They also noted that no significant differences were detected between genotypes HB8 and MB8 in the studied chemical traits. These genotypes (HB8 and MD8) were found in the same sub-cluster using ISSR primers [19].

3.3.3 Genetic similarity

The genetic similarity (Table 6) ranged from 0.78 (strain No.3 and strain No.12), (strain No.15 and both of strain No.11& 12) to 0.91 (strain No.7 and strain No.8). A high value of genetic similarity

Table 4. yielding and seeds characteristics of some selected jojoba female strains

Strain No.	Yield		Av. seed weight (gm.)		Av. seed volume (cm^3)		Av. seed diameter (mm)		Av. seed length(mm)		Number of ridges	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
C1	1.250	2.120	1.04	1.01	1.00	1.00	13.86	12.95	17.47	15.45	3	3
C2	2.250	2.450	1.78	1.32	1.80	1.30	15.25	15.62	20.33	19.65	3	3
C3	1.550	2.340	1.73	1.51	1.70	1.51	13.86	11.98	18.16	15.24	3	3
C4	0.400	1.145	1.05	1.06	1.30	1.10	10.80	11.09	16.76	16.11	3	3
C5	1.500	1.920	0.99	1.21	1.00	1.15	12.63	10.39	19.74	17.32	4	4
C7	2.900	3.210	1.26	1.23	1.40	1.20	12.32	12.99	17.01	16.12	3	3
C10	7.700	3.550	1.85	1.50	1.80	1.46	11.83	12.12	17.27	15.21	4	4
C16	5.650	3.650	0.93	1.31	1.10	1.25	10.60	13.14	18.50	20.10	3	3
C18	5.550	2.430	0.93	1.41	1.00	1.50	9.37	10.21	17.72	16.1	3	3
C19	5.800	3.300	0.93	1.20	1.00	1.21	11.40	13.11	16.24	14.95	3	3
C21	5.350	3.120	0.84	1.05	1.00	1.10	11.10	12.34	15.63	16.11	3	3
C22	2.900	2.310	1.09	1.21	1.30	1.20	11.75	12.15	18.55	17.33	4	4
C25	7.150	2.145	1.10	1.24	1.29	1.25	12.66	12.65	19.78	17.93	4	4
K7	3.100	2.640	1.45	1.35	1.30	1.35	10.63	11.74	17.20	15.95	3	3
K15	3.670	1.250	1.79	1.54	1.54	1.50	12.2	12.2	17.6	17.6	3	3
L.S.D *P* = 5%	1.02	0.91	0.29	1.00	0.99	0.86	3.21	4.54	5.41	3.24	1.10	1.10

Table 5. Polymorphism and its percentage as detected by ISSR marker

Primer	Monomorphic amplicons	Polymorphic amplicons	Unique amplicon	Total no. of amplicons	Percentage of polymorphism
ISSR1	**6**	**5**	0	**11**	**45**
ISSR2	6	0	0	6	0
ISSR3	6	6	1	13	54
ISSR4	5	7	0	12	58
ISSR5	10	2	0	12	17
ISSR6	2	11	4	17	88
ISSR8	5	5	2	12	58
ISSR9	1	10	2	13	92
ISSR10	0	14	1	15	100
ISSR11	9	4	0	13	31
ISSR12	7	4	0	11	36
ISSR13	8	5	0	13	38
Total	65	73	10	148	
Mean	5.42	6.08	0.83	12.33	

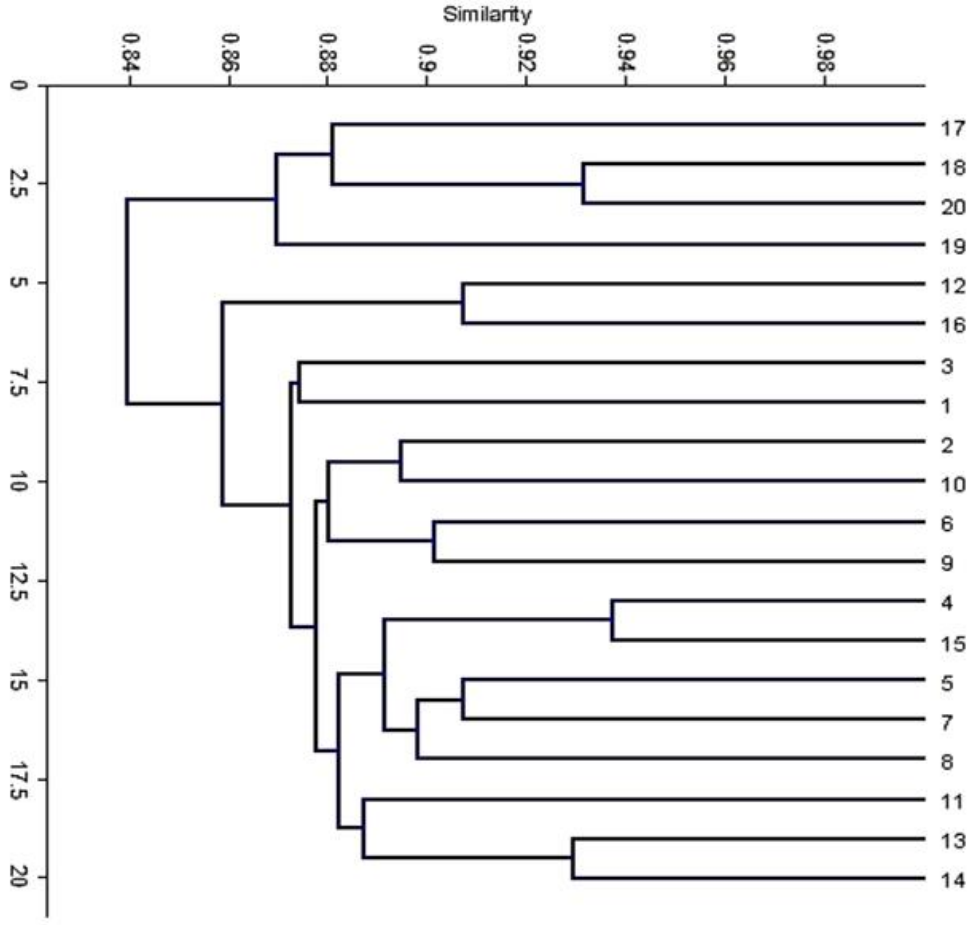

Fig. 3. Dendrogram using average linkage (between groups)

(0.90) was also observed between the strains (10 and both of 3&5), (14 and both of 5&13), (4 and 15) and (3 and 19) reflecting a common genetic background.

On the other hand, strains (12&17) and (10&20) showed a lower value of genetic similarity (0.79).

Table 6. Genetic similarity as detected by ISSR markers within twenty genotypes of jojoba

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.00																			
2	0.88	1.00																		
3	0.86	0.86	1.00																	
4	0.84	0.85	0.86	1.00																
5	0.85	0.88	0.89	0.88	1.00															
6	0.83	0.87	0.86	0.85	0.86	1.00														
7	0.84	0.84	0.89	0.84	0.88	0.86	1.00													
8	0.85	0.81	0.87	0.87	0.86	0.84	0.91	1.00												
9	0.84	0.85	0.83	0.88	0.85	0.86	0.83	0.86	1.00											
10	0.83	0.89	0.90	0.84	0.90	0.87	0.89	0.87	0.86	1.00										
11	0.84	0.86	0.86	0.84	0.86	0.86	0.85	0.86	0.87	0.86	1.00									
12	0.82	0.80	0.84	0.78	0.87	0.81	0.85	0.82	0.82	0.86	0.87	1.00								
13	0.85	0.86	0.87	0.81	0.87	0.80	0.85	0.84	0.85	0.89	0.87	0.89	1.00							
14	0.86	0.87	0.87	0.83	0.90	0.83	0.83	0.82	0.84	0.85	0.84	0.87	0.90	1.00						
15	0.88	0.81	0.86	0.90	0.85	0.81	0.87	0.86	0.84	0.83	0.82	0.85	0.86	0.86	1.00					
16	0.80	0.76	0.78	0.80	0.83	0.80	0.82	0.83	0.81	0.81	0.78	0.85	0.78	0.80	0.81	1.00				
17	0.83	0.83	0.83	0.87	0.87	0.80	0.82	0.85	0.87	0.82	0.83	0.79	0.82	0.84	0.84	0.82	1.00			
18	0.81	0.80	0.83	0.82	0.86	0.82	0.84	0.83	0.83	0.82	0.80	0.80	0.78	0.81	0.82	0.83	0.88	1.00		
19	0.85	0.87	0.90	0.85	0.89	0.86	0.89	0.85	0.83	0.85	0.83	0.81	0.81	0.83	0.84	0.80	0.86	0.87	1.00	
20	0.86	0.84	0.86	0.86	0.87	0.83	0.86	0.84	0.85	0.87	0.79	0.80	0.84	0.85	0.87	0.82	0.87	0.90	0.89	1.00

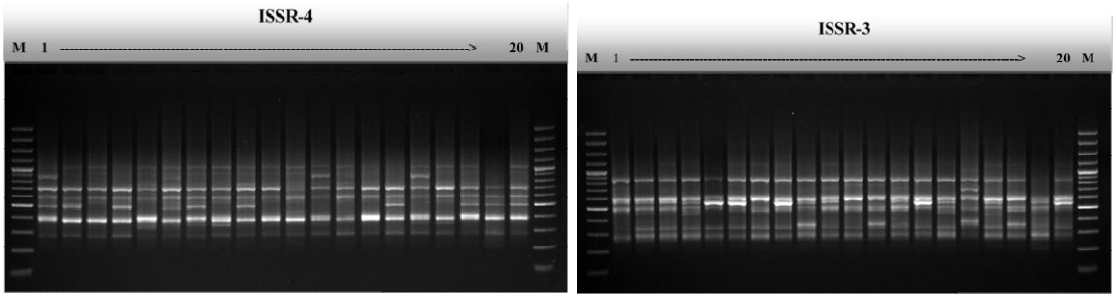

Fig. 4. Polymorphism detected by ISSR marker with fifteen jojoba female genotypes (1-15) and five jojoba male genotypes. M: Ladder molecular weight marker

Fig. 5. Seeds and leaves of different jojoba genotypes

4. CONCLUSION

It could be concluded that, there is a wide variation among the tested genotypes of jojoba regarding the tested characters such as plant shape, leaf size, and growth rate, duration of flowering, seed productivity and even genetic analysis. These variations are valuable in the breeding program and contribute to the improvement of jojoba plants.

ACKNOWLEDGEMENT

This research project was carried out in Horticulture Research Institute and funded by the Science and Technological Development Fund (STDF) under the Contract No. 4972 titled "Jojoba (Simmondsia chinensis) Plant as a Novel Source for Energy Production".

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Abdulrahman Al-Soqeer. Evaluation of seven jojoba (*Simmondsia chinensis*) clones under Qassim Region conditions in Saudi Arabia. International Journal of Agricultural Science Research. 2014; 3(10):203-212.
2. Muhammad AB, Muhammad AK, Hamid R. In vitro propagation of some promising genotypes of jojoba (*Simmondsia chinensis*). African Journal of Biotechnology. 2008;7(21): 3878-3886.
3. Öncel Z, Erişen S. Clonal Propagation of jojoba by *in vitro* culture and determination of sexuality of the regenerates. The Journal of Animal & Plant Sciences. 2017; 27(2):567-574.
4. Agrawal V, Sharma K, Gupta S, Kumar R, Prasad M. Identification of sex in *Simmondsia chinensis* (Jojoba) using RAPD markers. Plant Biotechnol Rep. 2007;1:207–210.
5. Sharma K, Agrawal V, Gupta S, Kumar R, Prasad M. ISSR marker -assisted selection of male and female plants in a promising dioecious crop: Jojoba (*Simmondsia chinensis*). Plant Biotechnol Rep. 2008;2: 239–243.

6. İnce AG, Karaca MA, Onus AN. A reliable gender diagnostic PCR assay for jojoba (*Simmondsia chinensis* (Link) Schneider). Genet Resour Crop Evol. 2010;57:773–779.
7. Effect of type and storage of pollen on fertility of Khudari dates. 1st Sym on dare pallm. 2010;102-106.
8. Snedecor GW, Cochran WG. Statistical methods. 7th ed. Iowa. State Univ. Press, Ames, Iowa, USA. 1980;507.
9. Sas, Institute. SAS, Users Guide Statistics. Version 6 Ed SAS Institute Inc. Cary. NC. USA; 1986.
10. Al-Soqeer M. Establishment and early growth of some jojoba clones in Al-Qassim region. Journal of Agronomy. ©Asian Network for Scientific Information. ISSN: 1812- 5379.
11. Evaluation of seven jojoba (*Simmondsia chinensis)* clones under Qassim region conditions in Saudi Arabia. International Journal of Agricultural. Science Research. 2010;3(10):203-212.
12. Tobares L, Frati M, Guzmán C, Maestri D. Agronomical and chemical traits as descriptors for discrimination and selection of jojoba (*Simmondsia chinensis*) clones. Ind. Crops Prod. 2004;19:107-111.
13. Fayek MA, Shabaan EA, Zayed NS, El-Obeidy AA, Taha RA. Effect of salt stress on chemical and physiological contents of jojoba (*Simmondsia chinensis* (Link) Schneider) using *in vitro* culture. World J. Agric. Sci. 2010;6:446-450.
14. Esmail AE. Genaidy, Amira KG. Atteya, Adss IAA. Increase the economic value of the jojoba (*Simmondsia chinensis)* yield using evaluation of distinctive clones grown under the Egyptian environmental conditions. Journal of Agricultural Technology. 2016;12(1):145-165.
15. Peter M. Evaluation of jojoba germplasm in different environments. Australian Government. Rural industries research and Development Cooperation; 2006.
16. Ulger S, Akdeþür O, Baktir U. Selection of promising jojoba (*Simmondsia chinensis* Link schneider) types in terms of yield and oil content. Turk. J. For. Agric. 2002;26: 319-322.
17. Osman HE, Abohassan AA. Introducing jojoba in the Arabian desert: 1. Agronomic performance of nine jojoba clones selected in Makkah area in Northern and Western Saudi Arabia. Int. J. Theor. Appl. Sci. 2013;5(1):37-46.
18. Abd El Mohsen MA, Abd Allatif AM. Selection of some promising jojoba (*Simmondsia chinensis*) genotypes: Evaluation of tree growth and productivity. Egypt. J. Plant Breed. 2015;19(6):1953–1962.
19. Al-Soqeer A, Motawei MI, Al-Dakhil R, El-Mergawi Al-Khalifah N. Genetic variation and chemical traits of selected new jojoba (Simmondsia chinensis (Link) Schneider) genotypes. Journal of the American Oil Chemists' Society. 2012;89(8):1455–1461.
20. Aly MAM, Al-Badawy AA. DNA fingerprinting and fatty acids analysis of jojoba [*Simmondsia chinensis* (Link) Schneider] plants and induced somatic embryos. In: The Seventh Annual UAE University Research Conference. 2005;25–33.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/25873