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Establishment and Early Growth of Some Jojoba Clones in Al-Qassim Region

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Abstract: The present investigation was carried out to evaluate and compare agronomical characteristics of jojoba clones under Central Region of Saudi Arabia, using seven diverse female jojoba genotypes. Survival rats ranged between 91.7 to 98.0%. Highly significant differences among time periods, clones and their interaction were found for plant height and number of branches per plant. Plant height ranged from 30.5 cm in April 1st 2009 to 52.8 cm in February 1st, 2010 and branches ranged from 11.9 to 58.7 branches per plant in same period. The clones significantly differed in all studied traits. Genotypes, HA_9 and HD_1 recorded the highest and lowest values for plant height, respectively. For number of branches per plant, genotype HB_2 had the highest value while, genotype HD_1 had the lowest one. Clones HB_8 and MD_8 had almost similar values in most traits. For stem diameter clone HB_2 recorded the highest value, while HD_1 had the lowest one. Chlorophyll content ranged from 62.5 (HB_2) to 73.9 (HB_6). Genotype HB_6 recorded the largest leaf area, the heaviest dry leaf and lowest value of specific leaf area while, genotype HA_9 had the smallest leaf. Clone HB2 recorded the lowest and highest values of leaf dry weight and specific leaf area; respectively the genotypes HB_8, MD_8 and HD_1 flowered early, while clones HA_9 and HB_2 were late in flowering. The results obtained in this work indicate that there is a large genetic variability among jojoba clones established at Al-Qassim Region which could permit improvement by selection and breeding.

Key words: Jojoba clones, *Simmondsia chinensis*, genotype, plant survival. leaf area, chlorophyll pigment, growth analysis

INTRODUCTION

Jojoba (*Simmondsia chinensis* (Link) Schneider) is an evergreen shrub that is native to northern México and the southwestern United States. Its natural distribution falls between latitudes 25 and 34 in an area which closely approximates the Sonorant Desert (Gentry, 1958). The jojoba plant has economic value because its seeds contain about 50% of a light yellow, odorless 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. According to Yermanos (1982), 250-450 mm of annual rainfall was adequate for survival of natural jojoba population. In experimental farms, however, vegetative growth and its components were reported to vary with the intensity of drought stress (Nerd *et al*., 1982; Benzioni and Nerd, 1985; Nerd and Benzioni,1985; Malende, 1989; Nelson *et al*.,1993; Nelson, 1996; Osman and Abo-Hassan, 2002). Moreover, Jojoba is relatively salt tolerant, Roussos *et al*. (2007) reported that jojoba explants tolerate salinity up to a level of sodium chloride concentration (113 mM), without showing any stress symptoms. In addition, Roussos *et al*. (2006) found that, jojoba shoots deriving from explants growing under saline conditions rooted as well as those growing under salt free conditions.

It is well known, shortage of irrigation water is one of the main factors that limits crop production in arid and semi arid environment. Consequently, utilization of drought tolerant shrubs in sand stabilization and landscaping and greenification projects, in establishing open natural range lands and national parks will save adequate amounts of fresh water that can be used for cultivation of traditional field crops. Osman and Abohassan (1997) reported that jojoba in Western Saudi Arabia, as its original habitat had maintained positive growth under high drought stress. The ability to withstand drought could be attributed to its capability to cope with environmental changes through morphological modification such as reduction in leaf area and increase in leaf thickness or leaf weight. The growth of jojoba is controlled by various agro-climatic factors e.g., temperature, soil type, salinity level of soil, water and methods of sowing (Rana *et al*., 2003). Many researchers studied growth characters in jojoba (Nelson and Bartels, 1998; Benzioni *et al*., 1999; Tobares *et al*., 2004; Bashir *et al*., 2007, 2009; Prat *et al*., 2008).

As occurs in other crops, the jojoba industry faces the challenge of finding ways to improve productivity and quality of the products. Jojoba is a difficult species to domesticate because it is highly variable as a result of its being dioecious and an obligatory cross- pollinated species. Only a small proportion (less than 1%) of the plant population originating from seeds of native plants has the potential of yielding economically acceptable yields (Purcell and Purcell, 1988). Hence, the best method for jojoba improvement, in the short term, is the selection of plants with desirable characteristics and propagating them asexually. Our objective was to evaluate and compare agronomical characteristics of jojoba clones with the purpose of selecting the superior jojoba genotypes under Al-Qassim Region in Saudi Arabia.

MATERIALS AND METHODS

Field experiment: The field experiment cared out in the Experimental Farm of the College of Agriculture and Veterinary Medicine, Al-Qassim University. 26° 18' N latitude and 43° 58' E longitude and 725 m above sea level, in central Saudi Arabia, from Oct. 2008 to February 2010 Meteorological data at experimental site during the growing seasons are shown in Table 1.

Table 1: Monthly mean air temperature (At °C), mean relative humidity (RH%) and rainfed (mm/month) at the experimental sites from Oct. 2008 to February 2010*

	Temperature (°C)					
	Mean		Extreme			
Month	Min.	Max.	Min.	Max.	RH (%)	Rainfed (mm)
Oct.	18.0	34.7	14	39	39	5.6
Nov.	13.0	25.1	9	31	73	56.4
Dec.	5.8	21.8	-1	27	53	0.0
Jan.	4.4	19.5	-2	27	54	0.0
Feb.	10.6	25.7	5	33	45	2.1
Mar	12.9	27.5	7	35	26	0.0
Apr	17.5	33.5	9	42	35	10.3
May	23.7	39.2	18	44	25	47.1
Jun	27.4	43.5	24	46	19	0.4
Jul	25.2	43.5	23	47	18	0.0
Aug	26.7	45.6	23	47	18	0.0
Sep	24.1	42.6	21	47	23	0.0
Oct	17.9	36.3	12	40	40	0.0
Nov	13.7	28.4	5	37	73	44.4
Dec	9.2	22.3	5	28	53	15.4

*Source, according to Presidency of Meteorology and Enviroumental Protection

Plant material and experimental design: Plant material (male and female) were provided by Faculty of Meteorology-King Abdulaziz University. The materials for this study comprised seven diverse female jojoba genotypes (*Simmondsia chinensis.)* selected for their characters. In the last decade, a comprehensive jojoba selection program was conducted at Faculty of Meteorology-King Abdulaziz University. In this program, promising individual plants were vegetatively propagated and planted at some regions in Saudi Arabia (Al-Medinah, Hail, Hada Al-Sham). The most promising clones, based on the selection criteria, were propagated by cuttings. Seven clones were chosen based on their desirable characters. The female genotypes HD_1, HA_9, HB_2, HB_4, HB_6, HB_8 and MD_8 were planted. The plants were established in the field experiment between October 27 and 30, 2008. Sixty plants per clones were planted in completely randomized block design with five replication to study the growth of jojoba cultivars. Each replicate consisted of 4 rows, each containing 26 plants (21plants represent seven clones, two and three plant as border for west and east direction, respectively). Distances between rows and within plants in rows were 3 and 2 m, respectively. Rows ran in an east-west direction. Male plants were repeated one row every six female rows of mixed males and female plants developed from seeds derived from a mixed population. Before sowing, an irrigation drip system was installed in the experimental area. Fertilizer and weed control were done as necessary.

Parameters

Survival: Survival was defined as the percentage of established plants in the end week of October 2008 of the total number of living plants 3 months after planting (end week of January 2009) for each clone.

Growth analysis: For each genotype, five plants per block (from the inner rows) were randomly chosen and tagged for growth measurements. At March 1st 2009, measurements were taken and repeated monthly, for Plant height above the ground and branching. Branching was defined as the total number of branches (with leaves longer than 1 cm) per shrub. In addition stem diameter at 5 cm above the ground was measured once in the first week of February 2010 only.

Physiological measurements: In the first week of February 2010, from the five plants, five leaves were collected (The 5th leaves from the top of the shoot) and measurements of leaf area and leaf dry weight were recorded. Leaf area was measured using a LI-3100 (LI-COR, Lincoln, Nebraska, USA) leaf area meter. Leaf dry weight was determined by weighed and dried at 70°C. The drying process was repeated until the difference between two successive weightings was less than 1 mg. Specific leaf area (i.e. leaf area leaf^{-1} dry weight) was also determined. Chlorophyll pigment was measuring on the 5th leaf from the top of the shoot using a SPAD-501 Chlorophyll Meter (Konica Minolta, Co. Ltd., Japan).

Flowering percentage: In December 1st 2009, every 10-12 days, the number of plants which bearing open floral buds (with a visible stigma) of each clone were recorded until February 10, 2010. Then, the flowering percentage was calculated and presented as cumulative percentage of flower plants.

Statistical analysis: The original data of branching were transformed using square root scale ($\sqrt{X+0.5}$). Data collected for Plant height and branching statistically analyzed according to the technique of analysis of variance (ANOVA) for one factor randomized complete block design combined over growth periods (the months) and one factor Randomized Complete Block Design (RCBD) for each month to test the differences among growth period and clones within each month, respectively . Moreover, data for other characters were analyzed statistically using RCBD. Where a significant F-test was found the mean values were separated using Duncan's multiple range test. All analyses of variance were computed using the MSTATC microcomputer program (MSTATC, 1990).

RESULTS AND DISCUSSION

Survival rats: Survival rats ranged between 91.7 to 98.0% for the seven clones, absent holes were replanted from the stock for each clone.

Growth analysis: Growth and development of a plant is considered the result of a number of ontogenetic processes which regarded as a reflection of direct and accumulated metabolic reactions. Therefore, such information on the growth can help to understand the genetic variation in growth and jojoba development.

Effects of growth period (the months) on plant height above ground and number of branches per plant ate 12 dates in seven jojoba genotypes are presented in Table 2. Based on the combined analysis of variance, the results revealed the presence of highly significant differences among months (M and) clones (C) for the two studied traits. These indicate that, the behavior of the same genotype differed from month to another and at the same month, the genotypes differed in their traits.

Data in Table 2 revealed that, plant height ranged from 30.5 cm (April 1st) to 52.8 cm (February 1st). Moreover, in this period number of branches per plant ranged from 11.9 to 58.7 branches per shrub. The average growth increment of plant height from April 1st 2009 to February 1st 2010 was 22.3 cm (about 73.1%). Meanwhile, the average growth increment number of branches per plant in same period was 46.8 branch per plant (about 393%). The maximum growth increment values of plant height and number of branches per plant were through October and May for two characters, respectively. For plant height, no significant differences ($p<0.05$) among months from March 1st to June 1st. This result might be due to plant growth was on the direction of produce high number of branches and/or death plants were replanted and data were recorded on some plants differed in their age.

Table 2: Effect of growth period and genotypes on plant height above ground and number of branch per plant, for seven jojoba genotypes from March 1st 2009 to Feb 1st 2010

Treatment	Plant height (cm)	No. of branches per plant
Month (M)		
Mar. 1st 2009	31.1i	8.9h
Apr. 1st 2009	30.5i	11.9g
May 1st 2009	30.8i	14.1g
June 1st 2009	30.9i	23.2f
July 1st 2009	32.3h	26.7f
Aug. 1st 2009	34.3g	35.7e
Sep. 1st 2009	36.3f	42.0d
Oct. 1st 2009	39.8e	45.5cd
Nov. 1st 2009	45.6d	48.9bc
Dec. 1st 2009	47.8c	52.5ab
Jan. 1st 2010	50.1b	54.2ab
Feb. 1st 2010	52.8a	58.7a
F-tes	**	**
Clone (°C)		
HD_1	35.6e	24.3e
HA_9	41.4a	34.2c
HB_2	37.4d	47.7a
HB_4	38.4c	24.4e
HB_6	39.5b	27.5d
HB_8	38.6c	44.4ab
MD_8	38.6c	44.1ab
F-test	**	**
CV%	6.76	13.71

Means in column within each factor designated by the same latter are not statistically different at p<0.05 level according to Duncan's multiple range test

In this connection, Bashir *et al*. (2007) recorded different growth parameters among jojoba strains; they found that there was different response to auxins application between jojoba strains. Also, Prat *et al*. (2008) studied the effect of plant growth regulators on Jojoba and recorded that, the total growth increment of plant height ranged from 18.6 to 26.8 cm at 360 days post-application. Moreover, Nelson and Bartels (1998) reported that, Plant height measurements showed that growth was rapid in April and May, decreased in June and July and then generally remained slow until the following spring. The conflicting reports about the period which growth rate is rapid of plant height measurements by earlier workers may be due to differences in the environments and materials used in those studies.

The genotypes were significantly differed in plant height and number of branches per plant based on average of all months (Table 2). Therefore, the comparisons between genotypic means are valid. Plant height above ground presented significant variation among jojoba genotypes and ranged from 35.6 cm (clone HD_1) to 41.4 (clone HA_9), based on average over months (Table 2). Genotypes, HA_9 and HD_1 recorded the highest and lowest values for plant height, respectively. No significant differences among clones HB_4, HB_8 and MD_8 were detected.

For number of branches per plant genotype HB_2 had the highest value (47.7) while, genotype HD_1 had the lowest one (24.3). No significant differences among clones HB_2, HB_8 and MD_8 were detected. The clones HB_8 and MD_8 were possessed same values for plant height and number of branches per plant (Table 2).

Genetic differences among genotypes in plant height and branches have previously been reported (Botti *et al*., 1998; Benzioni *et al*., 1999; Tobares *et al*., 2004; Prat *et al*., 2008).

Benzioni *et al*. (1999) found that, some clones exhibited excellent vegetative traits related to yield potential, such as, rapid growth and extensive branching.

Significant variation among genotypes was observed within each month from July 1st 2009 to February 2010 (Table 3). Clone HA_9 was tallest genotype in most months while, clone HD_1 was shortest one in most cases. Clones HB_8 and MD_8 had almost similar values in most cases. Rana *et al*. (2003) stated that the germination and growth of jojoba is controlled by various agro-climatic factors such as temperature, soil type, salinity level, water and method of sowing.

Significant variation among genotypes was observed for number of branches per plant within each month (Table 4). Genotype HB_3 had the highest values at most dates, while genotype HD_1 and HB_4 had the lowest values. No significant differences between the two clones MB_8 and MB_8 were detected for all growth periods. This result confirmed the previous finding which indicated that, these two clones had similar values for plant height and number of branches per plant.

Table 5 shows the mean performance of stem diameter for seven jojoba clones. Significant differences were observed among genotypes. Clone HB_2 recorded the highest value (5.3 cm) while HD_1 had the lowest one (4.1 cm). These results are similar to report on the presence of significant differences among clones on stem diameter (Botti *et al*., 1998).

Physiological measurements: Table 5 shows the mean performance of chlorophyll content, leaf area, leaf dry weight and specific leaf area (leaf area per unit dry weight) for seven jojoba clones. Significant differences were observed among genotypes for these characters. Chlorophyll content presented significant variation among jojoba genotypes and ranged from 62.5 (HB_2) to 73.9 (HB_6).

Significant differences were observed among genotypes for leaf area (Table 5). Genotype HB_6 recorded the largest leaf (8.2 cm^2), the heaviest dry leaf (0.248 g) and lowest value of specific leaf area (33.1 cm^2g^{-1}) while, genotype HA_9 had the smallest leaf (5.16 cm^2). Clone HB_2 recorded the lowest and highest values of leaf dry weight and specific leaf area, respectively (Table 5). No significant differences were detected between clones HB_8 and MB_8 for the five studied traits.

The observed significant variation for growth and physiological characters among the genotypes might reflect, partially, their different genetic backgrounds.

These results are similar to reports on the presence of significant differences among clones on leaf dry weight and specific leaf area (Osman and Abohassan,1997) and leaf area (Botti *et al*., 1998).

Flowering percentage: Flowering percentage varied among the genotypes (Fig. 1). The genotypes HB_8, MD_8 and HD_1 flowered early, reaching about 93, 83 and 83% flowering respectively, in the January 1st 2010. Meanwhile, clones HA_9 and HB_2 reaching about 17 and 57% flowering, respectively, in the same period. Ulger *et al*. (2002), found that, the selected male and female plants flowered between 20 February and 25 March. They also concluded that, each type has a

Table 3: Mean performance of plant height above ground for seven jojoba genotypes from March 1st 2009 to Feb. 1st 2010

	Clone							
Month	HD_1	HA_9	HB_2	HB_4	HB_6	HB_8	MD_8	CV (%)
Mar. 1st	30.3a	33.9a	30.0a	31.4a	33.7a	29.6a	28.6a	6.24
Apr. 1st	30.4a	32.9a	29.0a	31.6a	34.7a	27.5a	27.7a	9.23
May 1st	30.7a	33.2a	29.5a	31.6a	34.6a	27.3a	28.6a	8.93
June 1st	29.9a	32.5a	29.6a	31.0a	33.7a	29.9a	29.7a	9.86
July 1st	30.7d	33.8ab	31.0cd	32.5bc	34.3a	32.1cd	31.6cd	3.92
Aug. 1st	31.9c	36.4a	33.5bc	34.2b	35.1ab	34.7ab	33.7bc	4.41
Sep. 1st	32.1c	40.1a	36.1b	35.6b	36.4b	38.3ab	35.7b	7.20
Oct. 1st	36.6c	43.9a	39.6bc	37.2c	39.7bc	41.0ab	40.7ab	5.97
Nov. 1st	40.2b	49.3a	44.8ab	44.8ab	44.6ab	47.6a	47.9a	7.15
Dec. 1st	42.9d	51.0a	46.5c	47.4abc	46.9bc	49.7abc	50.4ab	5.46
Jan. 1st	45.6c	52.7a	48.3bc	50.1ab	49.2abc	51.8ab	52.9a	5.69
Feb. 1st	46.5c	56.6a	51.4bc	54.0ab	51.9abc	54.1ab	55.5a	5.69

Means in each row designated by the same latter are not statistically different at $p<0.05$ level according to Duncan's multiple range test

Table 4: Mean performance of number of branch per plant for seven jojoba genotypes from March 1st 2009 to Feb. 1st 2010

	Clones							
	HD_1	HA_9	HB_2	HB_4	HB_6	HB_8	MD_8	CV (%)
Mar. 1st	6.9c	8.3bc	14.1a	6.3c	7.3c	8.5bc	11.1ab	11.7
Apr. 1st	10.3cd	12.6abc	17.0a	8.2d	10.2cd	10.9bcd	14.4ab	11.4
May 1st	11.1c	14.6abc	19.4a	10.7c	12.8bc	13.4bc	17.1ab	12.0
June 1st	15.8c	22.4abc	32.4a	18.4bc	20.4bc	26.5ab	26.8ab	13.1
July 1st	18.6b	26.4ab	35.8a	20.5b	22.0b	31.4a	32.3a	12.1
Aug. 1st	23.4b	34.3ab	49.8a	26.7b	27.7b	44.4a	43.8a	13.4
Sep. 1st	27.6c	39.4bc	58.8a	28.5c	34.2c	54.8ab	50.9ab	12.9
Oct. 1st	30.5c	43.3bc	62.2a	30.6c	35.8c	59.6ab	56.5ab	12.9
Nov. 1st	33.3b	47.3ab	65.6a	32.8b	37.5b	64.5a	62.0a	13.3
Dec. 1st	36.2b	51.2ab	69.0a	34.9b	39.1b	69.3a	67.6a	13.7
Jan. 1st	37.6b	53.2ab	70.7a	36.0b	39.9b	71.7a	70.3a	14.0
Feb. 1st	40.0b	57.2ab	77.7a	39.1b	42.8b	78.3a	76.1a	14.1

Means in each row designated by the same latter are not statistically different at $p<0.05$ level according to Duncan's Multiple Range Test

Table 5: Mean performance of stem diameter, chlorophyll content, leaf area, leaf dray weight (g) and specific leaf area for seven jojoba genotypes

Clone	Stem diameter (cm)	Chlorophyll content	Leaf area (cm^2)	Leaf dry weight (g)	Specific leaf area ($cm^2 g^{-1}$)
HD_1	4.1c	66.2bc	7.56ab	0.214ab	35.3bc
HA_9	5.0ab	69.1b	5.16c	0.138cb	37.0bc
HB_2	5.3a	62.5c	5.34c	0.126b	42.4a
HB_4	4.4bc	67.9b	6.48bc	0.18bcd	37.3bc
HB_6	4.8ab	73.9a	7.58ab	0.194abc	39.2ab
HB_8	4.8ab	68.1b	8.2a	0.248a	33.1c
MD_8	4.8ab	64.3bc	8.02ab	0.226ab	36.2bc
CV %	9.9	5.5	16.5	22.2	8.3

Means in each column designated by the same latter are not statistically different at $p<0.05$ level according to Duncan's Multiple Range Test

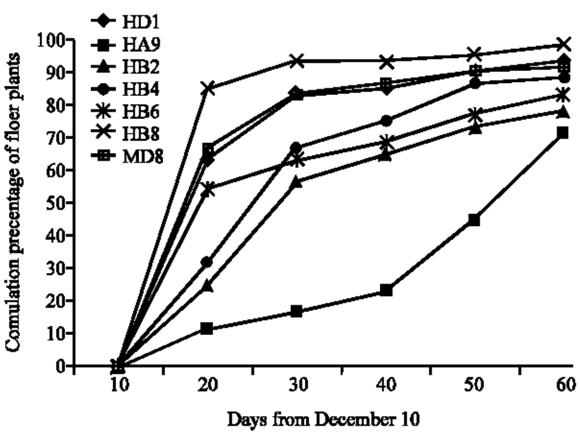

Fig. 1: Flowering pattern of jojoba clones in the field during December 1st 2009 to February 10, 2010

different genetic character and their responses vary with climatic and soil conditions depending on genetic type. Different response among jojoba varieties in flowering was observed for water salinity levels (Rana *et al*., 2003).

CONCLUSIONS

The variations observed in the studied characters were principally due to clone differences. We conclude that jojoba shows good establishment under Al-Qassim Region in Saudi Arabia. Genotypes, HA_9 recorded the highest value for plant height. For number of branches per plant, genotype HB_2 had the highest. Clones HB_8 and MD_8 had almost similar values in most traits. For stem diameter clone HB_2 recorded the highest value. Genotype HB_6 recorded the largest leaf area, the heaviest dry leaf and lowest value of specific leaf area. Clone HB2 recorded the lowest and highest values of leaf dry weight and specific leaf area; respectively the genotypes HB_8, MD_8 and HD_1 flowered early. The results obtained in this work indicate that there is a large genetic variability among jojoba clones established at Al-Qassim Region which could permit improvement by selection and breeding.

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