JOJOBA (*Simmondsia Chinensis*) (LINK) SCHNEIDER

SEED GERMINATION AND SEEDLING ESTABLISHMENT UNDER SUDAN CONDITIONS

By

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To those who got me in this life and taught me that to fetch the truth and never give up…
My great wonderful father and dearest sweet mother

To my lovely brothers ... Eyhab and Ziriab

To my real friends who always give me the courage to continue...

To Uncle “Osman” angelic soul ..
(GOD mercy be upon him)

To all of them with love and pleasure I dedicate this work wishing them a nice life as they are always nice people..
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## List of Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGMENT</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF CONTENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>ABSTRACT (ARABIC)</td>
<td>ix</td>
</tr>
<tr>
<td>ABSTRACT (ENGLISH)</td>
<td>xi</td>
</tr>
<tr>
<td><strong>CHAPTER ONE: INTRODUCTION</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>CHAPTER TWO: LITERATURE REVIEW</strong></td>
<td>4</td>
</tr>
<tr>
<td>2.1 Classification</td>
<td>4</td>
</tr>
<tr>
<td>2.2 Varieties</td>
<td>5</td>
</tr>
<tr>
<td>2.3 Jojoba in Sudan</td>
<td>5</td>
</tr>
<tr>
<td>2.4 Botanical Description</td>
<td>6</td>
</tr>
<tr>
<td>2.5 Jojoba Seeds</td>
<td>8</td>
</tr>
<tr>
<td>2.6 Seed Contents</td>
<td>8</td>
</tr>
<tr>
<td>2.7 Seed Oil</td>
<td>9</td>
</tr>
<tr>
<td>2.8 Jojoba seeds storage</td>
<td>10</td>
</tr>
<tr>
<td>2.9 Seed Germination</td>
<td>11</td>
</tr>
<tr>
<td>2.10 Seedling Growth</td>
<td>12</td>
</tr>
<tr>
<td>2.11 Soil type</td>
<td>13</td>
</tr>
<tr>
<td>2.12 Temperature</td>
<td>13</td>
</tr>
<tr>
<td>2.13 Irrigation</td>
<td>14</td>
</tr>
<tr>
<td>2.14 Root Growth</td>
<td>15</td>
</tr>
<tr>
<td>2.15 Cultivation</td>
<td>16</td>
</tr>
<tr>
<td><strong>CHAPTER THREE: MATERIALS AND METHODS</strong></td>
<td>17</td>
</tr>
<tr>
<td>3.1 General Description of the experimental site</td>
<td>17</td>
</tr>
<tr>
<td>3.2 Seed Source</td>
<td>17</td>
</tr>
<tr>
<td>3.3 Soil Types</td>
<td>17</td>
</tr>
<tr>
<td>3.4 Experimentation</td>
<td>18</td>
</tr>
<tr>
<td>3.4.1 Germination Test</td>
<td>18</td>
</tr>
<tr>
<td>3.4.1.1 Germination percentage</td>
<td>19</td>
</tr>
<tr>
<td>3.4.2 Moisture content</td>
<td>19</td>
</tr>
<tr>
<td>3.4.3 Oil content</td>
<td>19</td>
</tr>
<tr>
<td>3.4.4 Protein Content</td>
<td>20</td>
</tr>
<tr>
<td>3.4.5 Seedlings growth</td>
<td>21</td>
</tr>
<tr>
<td>3.4.5.1 Effect of direct sun or shade, soil type, irrigation interval, and seed</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER FOUR: RESULTS

4.1 Germination

4.1.1 Effect of Seed Longevity on Germination, Seed Weight, Oil, Protein and Moisture Content of Jojoba Seeds

4.2 Seedlings Growth

4.2.1 Effect of Irrigation Interval, Soil Type, Seed Condition, and Direct Sun Light or Shade on Jojoba Seedlings Growth

4.2.2 Effect of Irrigation Interval X Soil Type Interaction on Jojoba Seedlings Growth

4.2.3 Effect of Irrigation Interval X Direct Sun or Shade Interaction on Jojoba Seedlings Growth

4.2.4 Effect of Irrigation Interval X Seed Condition on Jojoba Seedlings Growth

4.2.5 Effect of Soil Type X Direct Sun Light or Shade on Jojoba Seedlings Growth

4.2.6 Effect of Soil Type X Seed Condition on Jojoba Seedlings Growth

4.2.7 Effect of Irrigation Interval X Soil Type X Direct Sun Light or Shade on Jojoba Seedlings Growth
4.2.8 Effect of Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedlings Growth
    a- Seedlings Height ................................................. 38
    b- Seedlings Leaf Number ........................................... 41
4.2.9 Effect of Direct Sun Light or Shade X Seed Condition on Jojoba Seedlings Growth
    a- Seedlings Height ................................................. 42
    b- Seedlings Leaf Number ........................................... 42
4.2.10 Effect of Direct Sun Light or Shade X Irrigation Interval X Seed Condition on Jojoba Seedlings Growth
     a- Seedlings Height ................................................. 42
     b- Seedlings Leaf Number ........................................... 43
4.2.11 Effect of Direct Sun Light or Shade X Soil Type X Seed Condition on Jojoba Seedlings Growth
     a- Seedlings Height ................................................. 45
     b- Seedlings Leaf Number ........................................... 45
4.2.12 Effect of Direct Sun Light or Shade X Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedlings Growth
     a- Seedlings Height ................................................. 47
     b- Seedlings Leaf Number ........................................... 49
4.3 Seeds Storage ....................................................... 49
4.3.1 Effect of Storage condition of Jojoba seeds on Seedlings Growth ...
     a- Seedlings Height ................................................. 49
     b- Seedlings Leaf Number ........................................... 52
4.4 Establishment of Jojoba Seedlings ...................................... 52
    4.4.1 Root Growth .................................................... 52
    4.4.2 Shoot Growth ................................................... 52
CHAPTER FIVE: DISCUSSION ............................................. 54
5.1 Effect of Jojoba Seed Longevity on Germination % ................. 54
5.2 Effect of Jojoba Seed Longevity on Moisture Content, Fresh Weight and Dry Weight ................................................. 54
5.3 Effect of Jojoba Seed Longevity on Oil Content % ............... 55
5.4 Effect of Jojoba Seed Longevity on Protein Content % ........... 55
5.5 Effect of Irrigation Interval on Jojoba Seedlings Growth .......... 55
5.6 Effect of Soil Type on Jojoba Seedlings Growth ..................... 56
5.7 Effect of Direct Sun Light or Shade on Jojoba Seedlings Growth ........ 57
5.8 Effect of Seed Condition on Jojoba Seedling Growth ..................... 57
5.9 Effect of Irrigation Interval X Soil Types on Jojoba Seedlings Growth.... 58
5.10 Effect of Irrigation Interval X Direct Sun Light or Shade on Jojoba Seedlings Growth ......................................................... 58
5.11 Effect of Irrigation Interval X Seed Condition on Jojoba Seedlings Growth ........................................................................ 59
5.12 Effect of Soil Type X Direct Sun light or Shade on Jojoba Seedlings Growth ........................................................................ 59
5.13 Effect of Soil Type X Seed Condition on Jojoba Seedling Growth ...... 59
5.14 Effect of Irrigation Interval X Soil Types X Direct Sun Light or Shade on Jojoba Seedlings Growth ............................................. 60
5.15 Effect of Irrigation Interval X Soil Types X Seed Condition on Jojoba Seedlings Growth ......................................................... 60
5.16 Effect of Direct Sun Light or Shade X Seed Condition on Jojoba Seedlings Growth ................................................................. 61
5.17 Effect of Direct Sun Light or Shade X Irrigation Interval X Seed Condition on Jojoba Seedlings Growth ........................................ 61
5.18 Effect of Direct Sun Light or Shade X Soil Type X Seed Condition on Jojoba Seedlings Growth ..................................................... 62
5.19 Effect of Direct Sun Light or Shade X Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedlings Growth ........................... 62
5.20 Effect of Storage condition of Jojoba seeds on Seedlings Growth....... 62
5.21 Establishment of Jojoba Seedlings measured as Root Growth .......... 63
5.22 Establishment of Jojoba Seedlings measured as Shoot Growth .......... 63

CONCLUSION .......................................................................................... 65

REFERENCES ......................................................................................... 66
List of Tables

Table 1. Effect of Seed Longevity on Germination, Seed Weight, Oil, Protein and Moisture Content

Table 2. Effect of Irrigation Interval, Soil Type, Seed Condition, and Direct Sun Light or Shade on Jojoba Seedling Growth
   a) Seedlings Height
   b) Seedlings Leaf Number

Table 3. Effect of Irrigation Interval X Soil Type Interaction on Jojoba Seedling Growth
   a) Seedlings Height
   b) Seedlings Leaf Number

Table 4. Effect of Irrigation interval X Direct Sun or Shade Interaction on Jojoba Seedlings Growth
   a) Seedlings Height
   b) Seedlings Leaf Number

Table 5. Effect of Irrigation Interval X Seed Condition on Jojoba Seedling Growth
   a) Seedlings Height
   b) Seedling Leaf Number

Table 6. Effect of Soil Type X Direct Sun Light or Shade on Jojoba Seedling Growth
   a) Seedlings Height
   b) Seedlings Leaf Number

Table 7. Effect of Soil Type X Seed Condition on Jojoba Seedling Growth
   a) Seedlings Height
   b) Seedlings Leaf Number

Table 8. Effect of Irrigation Interval X Soil Type X Direct Sun Light or Shade on Jojoba Seedling Growth
   a) Seedlings Height
   b) Seedlings Leaf Number
| Table 9. Effect of Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedling Growth |
|-------------------------------------------------|------------------|
| a) Seedlings Height                             | 40               |
| b) Seedlings Leaf Number                        | 40               |

| Table 10. Effect of Direct Sun Light or Shade X Seed Condition on Jojoba Seedling Growth |
|-------------------------------------------------|------------------|
| a) Seedlings Height                             | 43               |
| b) Seedlings Leaf Number                        | 43               |

| Table 11. Effect of Direct Sun Light or Shade X Irrigation Interval X Seed Condition on Jojoba Seedling Growth |
|-------------------------------------------------|------------------|
| a) Seedlings Height                             | 44               |
| b) Seedlings Leaf Number                        | 44               |

| Table 12. Effect of Direct Sun Light or Shade X Soil Type X Seed Condition on Jojoba Seedling Growth |
|-------------------------------------------------|------------------|
| a) Seedlings Height                             | 46               |
| b) Seedlings Leaf Number                        | 46               |

| Table 13. Effect of Direct Sun Light or Shade X Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedling Growth |
|-------------------------------------------------|------------------|
| a) Seedlings Height                             | 48               |
| b) Seedlings Leaf Number                        | 48               |

| Table 14. Effect of Storage condition of Jojoba seeds on Seedlings Growth |
|-------------------------------------------------|------------------|
| a) Seedlings Height                             | 51               |
| b) Seedlings Leaf Number                        | 51               |

| Table 15. Establishment of Jojoba Seedlings  |
|-------------------------------------------------|------------------|
| a) Root Growth                                  | 53               |
| b) Shoot Growth                                 | 53               |
الإجراء

نهاية-

الدراسة

هذه أجرية التجريبية الحقلية الزراعية في كلية شمبات - جامعة عام في الخرطوم 2001-2002 وتأثير ألوسة البذور، ونمو الزيتون المحتوي نسبة البذور نسبة على تخزين النتائج أظهرت أن الزيتون نسبة في نطاق تدريجي من قص هنا كثامًا، أطول السنوات البذور عمر زيادة وبروتين

. قانون التجريبية الزراعية في العام 2000 أ.ع. 97، 1999، 2000 (البستانية إدارية بورتسودان في الأحمر البحرية بولاية الزراعة عن) حيث بورتون في الأسبانيا أوزانة الأركويت منطقة في الأسابيع المختلفة.

واستخدام الأسماء مرة تتم 3 درجة وحيدة، مدة 3 أيام، 6 أيام (حالتين في البذور) في الدراسة بكج. وقد كان التجربة مكررة ثلاثية.

والدراسة

البذور في تخزين ونسبة الحياة نسبة أن الدراسة النتائج أظهرت أن الزيتون نسبة في نطاق تدريجي من قص هنا كثامًا، أطول السنوات البذور عمر زيادة وبروتين

. قانون التجريبية الزراعية في العام 2000 أ.ع. 97، 1999، 2000 (البستانية إدارية بورتسودان في الأحمر البحرية بولاية الزراعة عن) حيث بورتون في الأسبانيا أوزانة الأركويت منطقة في الأسابيع المختلفة.
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- The month after the plant’s growth period is in meaning different from the increase of the water and the rain which leads to the plant in the month of three and the month of two.

- The leaves and the number of the plant are in meaning different from the increase of the water and the rain in the plant in the month of three and the month of two.

- Climate whether it is dry or humid in the main soil for the work of the plant.

- The purchase of the plant and the time of the year is in meaning different from the increase of the growth of the foliage and the height of the leaves.

- The acquisition of the work is in meaning different from the time of the year and the humidity in the main soil for the growth of the plant in the main soil.

- The growth of the plant and the time of the year is in meaning different from the increase of the growth of the foliage and the height of the leaves.

- The growth of the plant and the time of the year is in meaning different from the increase of the growth of the foliage and the height of the leaves.
Abstract

- The experiments of this study were conducted in the Faculty of Agriculture-University of Khartoum demonstration farm (2001/2002), to study the Jojoba seeds germination and the effect of seeds’ storage in germination percentage, oil and protein contents of seeds and seedling growth. The study also include seedling establishment under different environmental factors such as irrigation intervals, soil types, direct sun light or shade, and seed condition.

- Seeds from different seasons (1997, 1999, and 2000) were obtained from Horticultural Department in Red Sea State, where they have been collected in Arkaweet in eastern Sudan from the experimental farm and been stored at open shed in sacs according to season of harvest.

- Seedlings were planted in a degradable cellulose bags (Damoriah) using three soil types (West Omdurman – light coarse soil), (North Gezira – saline soil), and (Shambat – heavy clay soil). Three irrigation intervals were kept conducted (one, three, and six days). Seeds were of two different conditions (pre-germinated and un-germinated). Half of the experimental bags were kept under direct sun light and the other half were under shade. Randomized block design was used; every treatment was replicated three times with different interactions for the tested factors.
- The results revealed that seed germinability decreased in the old harvested seeds, also there was a gradual decrease in the oil and protein contents in these seeds compared to newly harvested seeds.

- The cold storage seeds for one year gave seedlings of higher growth rate compared to seedlings that were produced from ordinary storage conditions at the same period of time.

- The short irrigation interval had no significant effect on plant height measured one month from germination, while there was significant increase in plant height after three months from germination. On the other hand, there was no significant increase in leaf number after one and three months from germination.

- Seedlings planted in West Omdurman soil – the light sandy, well-aerated soil - resulted in a significant increase in plant height and leaf number.

- Seedlings planted under direct sun light were significantly taller compared to those planted under shade.

- Pre-germinated seeds producing taller seedlings with more leaves compared to seedlings from un-germinated seeds.

- Pre-germinated seeds which were planted in West Omdurman soil, treated with short irrigation intervals under direct sun light resulted in highly significant increase in seedlings growth rates.

- Length of jojoba roots increased faster than shoot length at the same period of time.
Jojoba (*Simmondsia chinensis*) (link) Schneider, pronounced ho-ho-ba, is an evergreen shrub which grows wild in the semi-arid region of the Sonoran desert which covers parts of Northern Mexico and South-Western USA.

Jojoba is xerophytic long-lived plant (100-200 years). It bears seeds that contain from 40-60% of a unique liquid vegetable wax. The only natural liquid wax in established use is sperm whales oil for which jojoba oil has been suggested as a substitute.

The most notable difference of jojoba oil from other vegetable oils such as soybean, corn, olive and peanut oil is that it is composed of fatty acids connected directly to fatty alcohols, while in other oils fatty acids are connected to a glycerol molecule.

The chemical structure of the oil does not vary appreciably with plant type, growing location, soil type rainfall or latitude. The oil is a light – gold fluid, has few impurities contains no resins, tars or alkaloids, normally low in free fatty acids and, so it is unnecessary to be neutralized. It is easy to work with, non-toxic, biodegradable and dissolves readily in common organic solvents except methanol and acetone. It has a good keeping quality and exceptional shelf life and this is due to the presence of natural anti-oxidants, which keep the oil from becoming rancid. Jojoba oil and its derivatives seem to have potential for uses in products as diverse as cosmetics, pharmaceuticals, lubricants, foods, electric insulators and many other industries.
The residual meal from extraction contains 30-35% protein and is acceptable as livestock feed. Seeds can also be boiled to make a well-flavoured drink similar to coffee. In California and Arizona the foliage and young twigs are being relished by cattle, goats and deer, hence the name "goat - nut".

In nature jojoba grows between 600-1500m elevation in the desert down to the sea level near the coast, between latitude 25° and 31° N.

There are major efforts underway in the U.S.A and Mexico to domesticate jojoba. Reports indicate that it has been planted in Argentina, Australia, Brazil, Costa Rica, Egypt, Haiti, Paraguay, Rhodesia and South Africa.

Both direct seeding and seedling plants are used to establish the trees. The two practices are, however, poorly investigated. Sudan was one of the pioneer countries to introduce jojoba in 1974 through a combined work between the U.N Developmental Program and the University of California–Riverside. The issue was to introduce a new cash crop in addition to provide a green cover to stop desertification and also to help nomads' settlement and create a new income source. Many areas of different climates and soil types such as Erkwit, Eddamer, Sagelneiam, Bara, Dungla, Elhudeiba and ELrwakib have been selected as experimental sites. The results were very successful and the plant growth exceeded its growth in native areas and proved to be well adapted to Sudan climate. The plant flowered after only two years in the different selected areas, whilst it needs 3-5 years in its natural habitat.

The conditions required for successful seed germination and seedling establishment were not adequately studied in Sudan; hence the objectives of this study are to:
1- Study the effect of seed longevity on germination.
2- Study the seedling establishment under different soil types and different climatic conditions.
3- Study the water requirement for seedling establishment.
4- Study the effect of seeds storage on seedling growth.
5- Study the seedling shoot and root growth.
CHAPTER TWO
Literature Reviews

Jojoba, (*Simmondsia Chinensis* (Link) Schneider), belongs to the family Simmondsiaceae. It is a new semi-arid, oil-producing industrial crop that has attracted much attention in recent years.

Jojoba oil’s composition and physical properties are close enough to those of sperm oil to ensure its suitability as a substitute for it in many applications (Anon, 1985a). The greatest impetus to Jojoba domestication came in 1969 when the 'Endangered Species Conservation Act', was passed and sperm whales were put on the protected species list. In 1971, the U.S.A banned the import of sperm whale oil, and the industry was forced to search for a substitute.

Jojoba is native to a triangle of the Sonoran desert in Northern America whose corners are roughly, Los Angeles "California" phoenix "Arizona", and the Southern tip of Baja California "Mexico" (Anon, 1985a).

2.1 Classification:

The first taxonomic description appeared in 1822 when Johann Link of the Berlin Botanical Garden named it as *Buxus chinensis*. Thomas Nuttal, an American Botanist, later changed it to *Simmondsia californica* to honor the English naturalist, F. W. Simmonds. Finally in 1912 the Austrian botanist, Camillo Karl Schnieder, renamed it as *Simmondsia chinensis* (Anon, 1985a).

Earlier botanists placed Jojoba in the family Buxaceae, based on anatomical studies of Buxaceae, while Melikyan (1968) placed Simmondsia in a separate monotypic family *Simmondsiaceae*. This supports the contention of Van Tieghem the Belgian botanist in 1898 who suggested on
the basis of the dioecious breeding system, floral morphology, and wood
anatomy that jojoba be put into the family of its own, Simmondsiaceae
(Anon, 1985a) and this was later supported by Scogin (1979).

Sherbrook (1976a) reported that based on the international rules of
botanical nomenclature the only valid scientific name for jojoba is
*Simmondsia chinensis* (link) Schneider).

2.2 Varieties:

Many varieties of jojoba are known. However, in the U.S.A usually
wild seeds are used in many farms. In Australia, which is the only country
where jojoba plantations are being established within the recognized
cropping zones (Milthorpe, 1995), three female varieties of jojoba have been
selected as suitable for most Austarian conditions. These are Baindji, Wadi
wadi, and Waradgery. They have been selected for their consistent high
yields and are freely available for commercial production. Two male
varieties – Dadi dadi and Guyambul-, which are prolific producers of
compatible pollen, are well suited for pollinating the female varieties
selected (Milthorpe, 1998)

2.3 Jojoba in Sudan:

Sudan has become a leader in introducing jojoba to Africa. Test plots
were scattered a cross the arid northern half of the country, some of these
sites with furnace-like heat, desiccating winds blowing sand, and almost no
rain fall. Jojoba has survived all these adversities, although most of the
plants have received at least modest irrigation, (Anon, 1985a).

Jojoba was first introduced into the Sudan in 1974. The program was
aimed to have 200 acres established in the most promising potential sites of
Western and Eastern Sudan. Four experimental plots of about 3 to 5 acres each were established in the semi-arid areas of central Sudan.

All the initial plantings were being irrigated, but irrigation and other cultural treatments were applied after establishment of young plants.

Two-years-old plants measured about 2 feet and started flowering at about this age or six months earlier. Scale insects had been a major pest. Aphids were minor pests. As a soil conservation plant and source of unique liquid wax, jojoba has received special attention from the Sudanese Government and the international organizations operating inside the country, (Khairi, 1979). In the Red Sea hills area, jojoba growth rates were high. Plants survived solely on rainfall, however irrigation greatly improved growth. Locusts, grasshoppers, termites and caterpillars were a problem (Khairi et al., 1982).

Although the production has so far been limited, Sudan's early success in obtaining seed from the crop indicates that jojoba might have a significant commercial future elsewhere in the Middle East and the Sahelian zone of Africa, (Anon, 1985a).

2.4 Botanical Description:

Jojoba is an evergreen dioecious woody shrub or small multi-stemmed tree. The small evergreen tree or shrub grows to about 13 feet high with leathery, bluish-green leaves and small, yellowish wind-pollinated flowers (Van and Wink, 2004). It can grow to a height of 10-15 ft. (3 - 4.5m) in wet watered sites and plantations (Anon, 1985a), or remain as a low mound 8-20 inches (20-50cm) tall (Brooks, 1978). The form varies in different environments; the more erect form is generally found on moist sites, whereas the semi-prostrate form is found in desert sites (Nord and kadish,
Gentry (1958) reported that several stems arise from the root crown and branching is profuse. The leaves are thick and leathery, and are generally 2-4cm long as reported by Hickman (1993).

Anon (2004) added that the up-right leaves of jojoba are angled to minimize the amount of direct sunlight received by the plant during hottest part of the day and the dark thick bluish green leaves have a waxy cuticle that works to reduce water losses.

Jojoba leaves may be shed during severe drought, but generally they live two or three seasons depending on moisture and shade condition (Brooks, 1978). Wallace and Rudel (1979) reported that leaves on female shrubs have characteristically larger sizes, greater specific weights and greater water-holding capacity than male leaves in desert habitat, and this was also supported by Anon (2004) who reported that female plants have larger thicker leaves which have higher water content than their male counterpart. Female plants also have a more open structure, which allows more photosynthesis to take place. Female’ flowers are axillary and usually solitary, small pale green inconspicuous and without petals while male flowers are grouped in dense clusters (Nord and Kadish, 1974), they are yellow and larger up to 10-12 stamens per flower. Pollination occurs via wind or insects (Undersander et al, 1990). Drought is the strongest factor inhibiting the formation of flower buds, but cold temperatures may also reduce flowering (Gentry, 1958). Jojoba fruits are dehiscent green capsules generally one-seeded, but may contain up to three acorn-like seeds, (Buchman, 1987). Jojoba may have several taproots that develop by forking below the root crown. The maximum depth of taproots is not known, but they have been observed at depth of 10m. The life span of jojoba is over 100 years and may exceed 200 years (Brooks, 1978).
2.5 Jojoba Seeds:

When examined with electron microscope, jojoba seeds appeared ultra-structurally similar to other oil-seeds, even though liquid wax rather than tri-glycerides comprises the reserve lipid of the seed (Muller et al, 1975). According to Anon (1985a) mature jojoba seeds are mahogany brown, grooved, and about the size of small olives, the seed weight is about 300-1000 seeds/lb and have a thin hard seed coat. They are usually 12-18 mm long and 6-12 mm in cross-section, which is often roughly triangular. Jojoba seeds are quite variable in size, both within and among seed lots (Yermanos, 1979). Nord and Kadish (1974) reported that mean seed weight ranged between 660 to 3300 seeds/kg. Ismail (1988) separated stored seeds of a single lot into 3- size classes (small, medium and large) he found that the mean number of seeds/kg of the three classes was 2,300, 1,300, and 1,060 respectively, while the seed length in cm was 0.93, 0.38, and 1.84 respectively.

One hundred seed weight can vary from 40 to 80g and the mean seed weight was found by Clarke and Yermanos (1980) to be 0.56 g/seed.

Seed weight and wax content of the seed are significantly correlated as reported by Yermanos and Duncan (1976). Plants with smaller-sized seeds produced greater seed yields than plants producing larger-sized seeds (Ramonet, 1980).

2.6 Seed Contents:

Jojoba is the only known plant species whose seeds contain a large amount of intracellular wax esters in the cotyledons (Moreau and Huang, 1981). Anon (1985a) reported that protein content of jojoba seed meal is
about 30% as well as carbohydrates and fiber. The major proteins in jojoba seed were Albumin (65%) and Globulin (21%) fractions (Cardoso, 1980).

The oil content reported by Clarke and Yermandos (1980) was 53.2%. After germination there is a linear decrease in the amount of wax to approximately 10% at 30 days (Rost, 1978). Moreau and Huang (1977) reported that during germination there was a gradual decrease in the wax content of seeds with a concomitant rise in soluble carbohydrates, suggesting that the wax played the role of a food reserve. The seed contains a unique toxic cyanogenic glucoside (simmondsin), which is particularly toxic to humans (Sherbooke, 1976b)

2.7 Seed Oil:

In 1935, research chemists at University of Arizona found that the oil in jojoba seeds was totally unlike that secreted by any other plant. Conventional oilseed crops, such as soybean, corn, olive, and peanut, produce glyceride oils, in which fatty acids are connected to a glycerol molecule. Jojoba oil on other hand contains no glycerides or glycerol. It is composed of fatty acids connected directly to fatty alcohols (Anon 1985a).

The oil is a light-gold colored liquid wax ester making up to 50% of the seed's dry weight. As reported by Wells and Tomoff (1973) the exact timing of seed picking is not an important factor in the quality of the oil obtained from the seeds. The physical properties of jojoba oil are: high viscosity, high flash and fire point, high dielectric constant, high stability and low volatility. Its composition is little affected by temperatures up to 570°F (300°C). The extracted oil is relatively pure, non-toxic, biodegradable, and resistant to rancidity (Anon, 1985a). Most Jojoba oil produced today in U.S is sold at a high price for use in cosmetics and hair care products. It may
also be used as a high temperature, high-pressure lubricant. The stability of jojoba oil makes it attractive to the electronic and computer industries and since it contains no cholesterol or triglycerides and not broken down by normal metabolic pathways, the oil may become an important low calori oil for human consumption. It is also used as an anti-foam agent in antibiotics production and as a treatment for skin disorders. Other proposed uses include candles, plasticizers, detergents, fire retardants, transformers oil, and for the leather industry (Undersander et al, 1990).

2.8 Jojoba seeds storage:

Most seeds, if properly handled, are 90-95 % fertile. In cool, dry storage they remain viable enough for planting for 5 years or more (Anon, 1985a). Jojoba seeds with less than 9% moisture may be stored for extended periods of time, although seed viability declines, the oil quality remains unaltered (Yermanos et al., 1977).

Jojoba seed that has been dried to around 10% moisture and protected from pest damage will keep for several years (Undersander et al, 1990).

Jojoba seeds lose viability rapidly in laboratory storage at room temperature from 100% to < 60% after 2 years, but they are apparently still orthodox in storage behavior. When stored at low moisture content and temperature 3C°, seed lots have retained high viability for 10 to 12 years (Nord and Kadish 1974).

Under natural conditions, Jojoba seeds do not form a persistent seed bank; all seeds either germinate, lose viability, or are consumed within a year of production (Castellanos and Molina, 1990).
2.9 Seed Germination:

The optimal conditions for seed germination are darkness, constant moisture supply and temperature of 26°C to 30°C (Burden, 1970).

Maximum seed germination in jojoba was 100% germination in the controlled laboratory temperature of 21°C and 28°C after 17 and 9 day respectively. The higher rate and efficiency of germination observed at 28°C indicated that this temperature was optimum for jojoba seed germination. The narrow range of warm temperature for germination reflected the relatively restricted warm climate distribution of jojoba (Mccleery, 1974).

Experiments carried out in the Department of Agronomy in University of Minnesota 1990 showed that when germinate seeds in vermiculite or sand at about 80°F (26°C), emergence occurs in 15 to 20 days and the seedlings were ready for transplanting when they were 6–12 in. tall after 8–10 weeks (Undersander et al., 1990).

Jojoba seeds require no pre-treatment and are usually readily germinable immediately after harvest (Nord and Kadish 1974; Rao and Lyenger. 1982). It takes 3 days for the first emergence of the radicle at 20/30°C and 7 days at 10/20°C. Seed lots of large seeds germinate more quickly and to a higher percentage than did lots of small seeds, suggesting that seed size is associated with germination polymorphism (Ismail, 1988). This may function to reduce germination risk under field conditions by spreading out germination across rain events (Castellanes and Molina, 1990). Nord and Kadish (1974) reported that jojoba seeds could germinate at 5°C to 10°C but only after an 8-hours pretreatment at 20°C.

Seed should be placed one–half to one inch below the soil surface. The soil should be kept moist at or near field capacity, until the shoot emerges. The radicle emerges from the seed about a week after planting, and
the shoot breaks ground after about three weeks. When the shoot emerges, watering can be reduced but for optimum growth soil moisture should remain high. Poorly drained, water–saturated soil may cause the seed to rote or kill the seedling (Anon, 1980).

2.10 Seedlings Growth:

The critical period for jojoba survival is the seedling stage. Many years may pass without suitable conditions for germination, and years when conditions are favorable for seedling establishment are even fewer (Gentry, 1958). Most seedling mortality is caused by physical factors such as dry soil and freezing temperatures with predation only amounting to a small percentage of death (Costellanoose and Molina, 1990). Growth and nutrient uptake of jojoba seedlings are best at higher temperatures and in well aerated soils as reported by Reyes et al (1977).

Seedlings may also readily be produced as container stock; seedlings emerge in 7–10 days at 60 to 75°C. The plants may be held in 3–8 litre pots outdoors for 8–24 months (Yermanos, 1974). To produce a seedling that is suitable for transplanting takes from 2 to 4 months in the nursery. Jojoba may be direct–seeded if the plots are protected from seed predation and seedling grazing by rodents. Mature plants can tolerate some freezing, but seedlings are perish at temperature below 2°C (Nord and Kadish, 1974). Jojoba seedlings emerge in response to autumn, winter, or spring rains (Sherbrooke 1977; Castellanos and Molina, 1990). Male plants are thought to be more stress–tolerant as seedlings and thus to have higher survival rates under natural conditions. Seedling survival depending principally on weather patterns (Castellanos and Molina, 1990)
2.11 Soil type:

Jojoba is an endemic plant of Sonoran desert of North America. It prefers well-drained, coarse desert soils (Gentry, 1958). Areas with heavy soils will be unsatisfactory because of plant mortality due to water logging (Dunstone, 1979).

Jojoba grows on a diversity of soil, from porous rocks to clay, in slightly acid to alkaline soils, on mountain slopes and in valleys, but it is always found on well-aerated soils (James, 1994).

Most wild jojoba populations occur on coarse, light or medium textured soils with good drainage and good water infiltration. Planting on heavy soil results in later blooming, slower growth and more problems with fungal disease (Undersander et al, 1990). Jojoba is mostly limited to well–drained, coarse mixtures of gravel’s and clays. These mixtures may be derived from igneous materials such as granite and other volcanics (Brooks, 1978). Soils are usually neutral to alkaline, high in phosphorous, and subject to annual drying (Gentry, 1958). Jojoba can tolerate high levels of salinity, but its flowering capabilities may be reduced on such sites (Francois, 1986) also Yermanos et al (1967) reported that jojoba can withstand high levels of soil salinity during the first two years of development without major injury. Elmardi et al (1982) reported that for nursery-grown seedling in Sudan, the best soil mix is composed of equal parts sand, river soil and leaf mold.

2.12 Temperature:

Native jojoba populations can be found in areas receiving an annual precipitation of 80 – 450mm and having temperature ranging from 9°C to 50°C (Gentry, 1958). Sites where temperature frequently falls below -5°C for prolonged periods should never be planted to jojoba. Seedlings are
damaged or killed at temperatures of -9 to -3°C. Hardened plants can endure -9°C without sustaining long-term damage, but flower buds and newly set seed can be damaged at -2°C and killed at -6°C (Anon, 1985a).

The optimum constant temperature for jojoba germination was found to be 82.4°F (28°C). 57°F (14°C) was the lower limit for germination, and 93°F (34°C) the upper limit. It is recommended that the soil temperature should be kept between (21 - 30°C) for best germination (Anon, 1980).

Undersander et al (1990) reported that jojoba is very tolerant of high temperatures and is best suited to areas that are frost free and is not grown in the northern midst when temperature drop below 20°F (7°C), flowers and terminal portions of young branches of most jojoba plants are damaged. During early seedling development, excessive cold may kill an entire plantation. Frost may not damage taller plants to the same degree, but it can reduce yield.

2.13 Irrigation:

Jojoba is extremely drought tolerant. Mature plants can do with irrigation twice a year (Anon, 2004). Natural stands of jojoba occur in areas that receive 3 to 18 inches of precipitation annually. Irrigation produces more luxuriant vegetative growth. The plant requires water most during late winter and early spring (Undersander et al, 1990).

El Mardi et al (1982) reported that for germination, water is applied twice per day; while to prepare seedlings for transplanting, water should be applied once per week.

For satisfactory growth and production, jojoba seems to need only a third “or less” of the moisture that crops such as citrus or cotton require (Anon, 1985a).
Although jojoba is an arid zone crop and survives with only 100mm of rain/annum, it responds well to extra water. The distribution of water appears important; adequate moisture during the winter and spring seasons and at time of seed germination and seedling establishment are particularly significant. Jojoba is tolerant to highly saline water and this is an important factor if irrigation under desert condition is considered. Tolerance of high salinity, however, is dependent upon good soil drainage (Walters et al., 1979).

Jojoba tolerates water of low quality, provided its application is wisely managed and the soil drainage is adequate. During the first 2-3 months, irrigation must be applied constantly to maintain moisture near the soil surface, thereby ensuring good root establishment later, irrigation may be employed at monthly intervals to supply the field with a total of about 1.5 acre-feet of water, over watering can be disastrous (Anon, 1985a).

2.14 Root Growth:

In natural stands, the roots grow deep and vertically to levels providing sufficient moisture to insulate the plants from changes in climate and precipitation. Irrigation causes the roots to grow laterally (Reyes and Juvenal, 1982.)

Jojoba's root system grows vertically with only a small amount of lateral growth; thereby occupying little horizontal spaces as reported by Canales (1982). To help survive drought, the plants have an exceptionally deep root system that taps under ground moisture. Bushes 1-2 years old have been found with root 4-5m deep. Seedlings devote most of their energy to produce a taproot, which is a natural survival mechanism in deserts where surface soil dries out rapidly (Anon, 2004).
A seedling’s taproot may grow as much as 2.5cm a day. Often young plants have roots 10 times longer than the height of the plant above ground. Seedlings normally take about 21 days to break through the soil, by which time they can have roots 46cm deep (Anon, 1985a).

It is known that thirty days after germination only 10% of the oil remains in the seed. It is apparent then that seedlings use this oil to quickly send down a taproot to ensure it can draw moisture from the soil. Young leaves and shoots follow but appear at a much slower rate. (Anon, 2004)

2.15 Cultivation:

Jojoba can be planted by direct seeding or by transplanting seedlings to the field. Using 2x4m spacing in planting would permit the planting of about 500 female and 50 male pollinating plants per hectare. To obtain the proper female: male ratio (6:1), it is advisable to over plant (7 to 9 lb/ acre of seeds) and rogue out excess males later (Undersander et al, 1990).
CHAPTER THREE
Materials and Methods

3.1 General Description of the experimental site:
This study was carried out during 2000/2001 and 2001/2002 seasons in the Faculty of Agriculture University of Khartoum, Shambat (latitude 15° 40N, longitude 32° 32E and altitude 280m above sea level). The soil of the site is a heavy clay (48% clay) montmorillonitic, moderately alkaline (pH 7.8 – 8.5) and of very low permeability (Saeed, 1986).

The climate of Khartoum State is a tropical semi–desert, with low relative humidity. The mean annual rainfall is about 160mm and the daily mean maximum temperature is more than 40°C in summer and around 21°C during the winter. The climate of the area result in a high rate of water evaporation from open water moistened soil. In plant-covered areas transpiration rates are also high (Oliver, 1965)

3.2 Seed Source:
The seeds were obtained from the Department of Horticulture, Ministry of Agriculture, Red Sea State. They maintain a farm in Erkawit area in which jojoba is grown. The seeds represent seed lots from three seasons. The first lot represents seeds harvested in season 1997, the second lot represents seeds harvested in season 1999 and the third lot represents seeds harvested in season 2000.
3.3 Soil Types:

Seeds were tested under three types of soils representing different arid conditions. Soil analysis was obtained from the Department of Soil and Environment Science, Faculty of Agriculture, University of Khartoum according to Soil Classification System (1970) as follows:

1/ Soil type I was obtained from Northern Gezira to represent soils from arid saline regions, which after analysis was found to be a fine, montmorillonitic, hypercermic typic torrert. (Gabir, 1984)

2/ Soil type II was obtained from western Omdurman to represent a sandy light soil which after analysis was found to be a sandy clay loam, mixed iso hypercermic, kaolinitic, typic comborthid. (Elhiraka, 1993)

3/ Soil type III was obtained from Shambat to represent a clay soil that was found to be a fine, montmorillonitic, iso hypercermic, entic chromustert. (El-Habib, 1998)

3.4 Experimentation:
3.4.1 Germination Test:

Preliminary germination test was carried out using sand according to the method described by ISTA (1976). The sand was washed and sterilized in an oven to kill the bacteria and fungi and, water was subsequently added to keep the soil moist. This test was carried to examine the seeds viability using one tray for each lot and planting 50 seeds in each tray. It turned out from the preliminary test that all the seeds of the first lot of season 1996 were not viable. Therefore, no further tests were carried out in that lot. Seeds for the test were chosen by the halving method according to Anon (1985b).
3.4.1.1 Germination percentage:

A randomly selected seed sample of season 2000 was treated by the fungicide Thiram and planted in a sterilized sand in a tray containing 50 seeds spaced 2cm apart and replicated four times. The same was done for the sample of season 1999. The trays were kept under shade and watered for 21 days.

Germination percentage was obtained according to following equation:

\[
\text{Germinated seeds} \times 100 \\
\text{Total number of seeds}
\]

The average was then calculated.

3.4.2 Moisture content:

Seeds from the two lots were chosen by the halving method (Anon, 1985b). Four replicates each of 50 seeds were used to determine the fresh weight, which was obtained using a sensitive balance. Then the seeds were dried in the oven at 80°C till the constant dry weight was obtained. Calculations were based on the fresh weight basis as follows:

\[
\text{MC}\% = \frac{(M1 - M2) \times 100}{M1}
\]

Where:

MC: is the moisture content

M1: is the weight in grams of the fresh sample

M2: is the weight in grams of the dry sample
3.4.3 Oil content:

This experiment was carried out in the Department of Biochemistry, Faculty of Agriculture, University of Khartoum.

Total oil content of the seeds from the three seasons (1997, 1999, and 2000) has been determined according to AOAC (1984) in which three replicates of finely grounded seeds were extracted by petroleum ether (b.p 40–60°C) as a solvent in a continuous soxhlet. The finely ground sample (2g) was accurately weighed in an empty thimble of known weight, plugged with a piece of cotton wool, then the thimble with the material was placed is the soxhlet extractor. A dry and accurately weighed round bottom flask was filled to approximately two thirds. The flask, the extractor, and the condenser were fitted together. Water was allowed to flow in side the condenser and heat was continued for 8 hours. The apparatus was carefully dismounted and the solvent in the flask was evaporated to dryness in an air oven at 105°C.

\[
\text{Oil content \%} = \frac{W_2 - W_1}{S}
\]

Where:

- \( W_2 \): weight of the flask plus extracted oil (g)
- \( W_1 \): weight of the empty flask (g)
- \( S \): Original weight of the sample (g)

3.4.4 Protein Content:

This experiment was also carried out in the Department of Biochemistry, Faculty of Agriculture, University of Khartoum.

The crude protein was determined by semi micro Kjeldahi method as described by Person (1981) where 0.2 g of the sample was weighed in a
semi-microdigestion flask. One g of the catalyst (sodium sulphate + cupric sulphate 20:1 by weight) and 3.5 ml of concentrated nitrogen free sulphuric acid were added, and the contents were heated for two hours, till a clear solution was obtained. The solution was transferred to the distillation unit and the flask was rinsed with water. 20 ml of 40% sodium hydroxide solution were added after which the mixture was steam-distilled in a receiver containing 10 ml of 2% boric acid and few drops of mixed indicator (methylene blue + methyl red). After 7 minutes the solution was titrated against 0.02 N hydrochloric acid.

\[
\text{Protein \%} = \frac{TV \times N \times 14 \times 6.25 \times 100}{W \times 1000}
\]

Where:

- TV: titration volume (in ml) of hydrochloride acid
- N: normality of hydrochloric acid
- W: weight of original sample (g)

The total nitrogen percentage was multiplied by the factor 6.25 to convert it to crude protein percentage.

3.4.5 Seedlings growth:

3.4.5.1 Effect of direct sun or shade, soil type, irrigation interval, and seed condition on seedling height and leaf number:

A split block design was used for this experiment, a total of 128 degradable cellulose bags were filled with the three types of soils.

Half of the bags were placed under direct sun and the other half placed under shade. Two seed conditions were used. Pre-germinated where seeds were firstly sown in a wetted sac and left for two weeks till the radicle
emerge, then they transferred to the bags; and the other condition was ungerminated seeds, where seeds were directly sown in the bags.

Each soil type was further allotted to three irrigation treatments: every day, every three days, and every six days.

Plant height was measured using a ruler from the soil surface to the plant apex after one month from germination and a second reading was taken after three months from germination when the seedlings were ready for transplanting. Leaf number was also counted at the same time.

3.4.6 Effect of seeds storage condition on seedlings growth:

In this experiment two types of seed storage were investigated. The first type of storage condition was cold storage, in which seeds stored in refrigerator (temperature of about 4°C) for one year, while the second type was ordinary storage, in which seeds were left in the laboratory under room condition (ambient temperature) for one year also.

A completely randomized design was used in this experiment. A total of 8 plots each measuring 1m x 1m were used. 4 plots were allocated to each treatment. 32 seeds were planted in each plot at a rate of 2 seeds/hole. The plots were watered every other day during the first month. Thereafter, they were irrigated at weekly intervals.

Plant height was measured weekly using a ruler from the base of the stem at ground level to the tip of the youngest leaf then the average of every 16 plants was taken. Average of leaf number was also calculated weekly.
3.4.7 Jojoba Seedlings Establishment:

3.4.7.1 Root and Shoot Growth:

An experiment was conducted to study the root and shoot growth. A total of 30 long sacs of approximately 1m length for each sac were used. Every sac was filled with soil from the demonstration farm. Two seeds were planted in each sac. Watering was carried out immediately after sowing. After the first 3 weeks from sowing, 5 sacs were torn open, the roots freed carefully, washed and root length was measured from the soilsurface to the tip of the main root using a ruler, the same was done for the shoot length using the ruler from the top surface of the soil to the first young leaf. Thereafter this process was repeated every 2 weeks for every 5 sacs. Fresh and dry weights were obtained for roots and shoots.

3.4.8 Statistical Analysis:

Data were statistically analyzed using the analysis of variance (ANOVA) method according to Gomez and Gomez (1984).
CHAPTER FOUR

Results

4.1 Germination:

4.1.1 Effect of Seed Longevity on Germination, Weight, Oil, Protein and Moisture Content of Jojoba Seeds:

Table (1) shows the effect of jojoba seed longevity on seed germination, seed weight, oil, protein and moisture content. Fresh seeds harvested in season 2000 had a higher germination percentage compared to those of season 1999, while the percentage was zero for seeds of season 1997.

Seed fresh weight, seed dry weight and moisture content were slightly different between seeds of the three seasons 2000, 1999 and 1997.

Oil and Protein contents were higher in the freshly harvested seeds compared to other seeds.

4.2 Seedling Growth

4.2.1 Effect of Irrigation Interval, Soil Type, Seed Condition, and Direct Sun Light or Shade on Jojoba Seedlings Growth:

The effect of irrigation interval, soil type, seed condition and direct sun light or shade on jojoba seedling growth after one and three months after emergence are presented in Table (2 a and b).

a/ Seedlings Height:

Significant differences between seedlings height were observed for the different irrigation treatments both one and three months after emergence (Table 2 a). One month after emergence there was no difference observed in height between seedlings watered every day and those watered every three
days. Seedlings under both treatments were, however, significantly taller than those watered every six days.

However, after three months seedlings growth was significantly decreased as the irrigation interval was progressively increased from one day to six days.

The three soil types significantly affected the seedling height. The tallest seedlings one and three months after emergence were those grown in West Omdurman soil, while the shortest seedlings were found to be those grown in Shambat soil. However, three months after emergence there was no significant difference in plant height between those grown in Shambat soil and others grown in North Gezira soils.

Direct sun light produced the tallest seedlings compared to those grown under shade one and three months after sowing. Pre-germinated seeds gave the tallest seedlings compared to un-germinated seeds.

**b/ Leaf Number:**

There was no significant difference in seedling leaf number due to irrigation treatment. However, the highest leaf number was recorded both after one and three months after emergence when seedlings were watered every day or every three days and the lowest leaf number was recorded when seedlings were watered every six days (Table 2 b).

West Omdurman soil was superior in producing the highest leaf number after one and three months after emergence, while the lowest leaf number was produced in Shambat and North Gezira soils after one month after emergence. But after three months after emergence the lowest leaf number was produced only in Shambat soil.
4.2.2 Effect of Irrigation Interval X Soil Type Interaction on Jojoba Seedling Growth:

Table (3 a and b) shows a significant interaction effect of Irrigation interval X soil type on jojoba seedlings growth one and three months after emergence.

a/ Seedling Height:

When seedlings were watered daily or every three days, West Omdurman soil was superior both one and three months after emergence.

The soils of Shambat and North Gezira had the lowest seedling height when irrigated every six days. However, the superiority of West Omdurman soil was maintained only during the first month of growth, and no significant difference between the three soil types was observed after three months of emergence.

The tallest seedlings were obtained under the treatment where seedlings growing in soil from West Omdurman were watered daily, while the shortest seedlings were those growing in Shambat soil and watered every six days one and three months after emergence.

b/ Seedlings Leaf Number:

The greatest records were observed when seedlings were planted in West Omdurman soil and watered every day or every three days in both one and three months after emergence, while the lowest records were obtained one month after emergence when seedlings were planted in Shambat and North Gezira soils and watered every six days. Three months after emergence the lowest records were obtained only in Shambat soil when watered every six days.
4.2.3 Effect of Irrigation interval X Direct Sun or Shade Interaction on Jojoba Seedlings Growth:

Effect of irrigation interval x direct sun or shade interaction on jojoba seedlings growth one and three months after emergence is illustrated in Table (4 a and b).

a/ Plant Height:

The tallest seedlings were those under direct sun light watered every three days one month after emergence, while three months after emergence the highest value of seedlings height was obtained under direct sun when watered every day and every three days.

The shortest seedlings after one and three months from germination were obtained under shade when watered every six days.

b/ Seedlings leaf Number:

The highest leaf number was obtained from seedlings grown under direct sun light when irrigated every day and every three days, while the lowest leaf number was from seedlings planted under shade and irrigated every six days one and three months after emergence.

There was no significant difference in leaf number when seedlings were grown under shade and irrigated every day or every three days one and three months after emergence.

4.2.4 Effect of Irrigation Interval X Seed Condition on Jojoba Seedlings growth:

Table (5a and b) shows the effect of irrigation interval and seed condition interaction on Jojoba Seedlings growth one and three months after emergence.
a/ Seedlings Height:

One and three months after emergence the tallest seedlings were those produced from pre-germinated seeds and watered daily. There was no significant difference between seedlings from un-germinated seeds when irrigated every day or every three days during the first month of growth. However, the shortest seedlings were those obtained from un-germinated seeds watered every six day one and three months after emergence.

b/ Seedlings Leaf Number:

The highest leaf number was produced when pre-germinated seeds were watered every day one and three months from germination, while the lowest leaf number was obtained from un-germinated seeds watered every six days one month after emergence and from both pre-germinated and un-germinated seeds watered every six days three months after emergence.

There was no significant difference in leaf number between un-germinated seeds watered every day or every three days and pre-germinated seeds watered every six days one and three months after emergence.

4.2.5 Effect of Soil Type X Direct Sun Light or Shade on Jojoba Seedling Growth:

The effect of soil type and direct sunlight or shade interaction on jojoba seedlings growth one and three months after emergence is presented in Table (6 a and b)

a/ Seedlings Height:

The tallest seedlings were observed when seedlings were grown in West Omdurman soil under direct sun light both one and three months after emergence. The shortest seedlings were recorded when grown seeds in Shambat soil and kept under shade.
b/ Seedlings Leaf Number:

The highest jojoba seedlings leaf number was produced when seedlings were grown in West Omdurman soil under direct sun light one and three months after emergence, while the lowest seedlings leaf number was obtained when grown in both Shambat and North Gezira soils under shade during the first month after emergence. After three months of growth the lowest leaf number was recorded only for North Gezira soil under shade.

There was no significant difference in leaf number of seedlings grown in Shambat and North Gezira soils under direct sun light one and three months after emergence.

4.2.6 Effect of Soil Type X Seed Condition on Jojoba Seedling growth:

Data in Table (7 a and b) show a significant interaction effect of soil type and seed condition on jojoba seedling growth one and three months after emergence.

a/ Seedlings Height:

The tallest seedlings were obtained in the treatments where pre-germinated and un-germinated seeds were grown in West Omdurman soil and measured one month after emergence, while the shortest seedlings were those arising from un-germinated seeds in Shambat soil one and three months after emergence.

b/ Seedlings Leaf Number:

The highest seedlings leaf number was obtained when pre-germinated seeds were planted in West Omdurman soil one and three months after emergence, while the lowest leaf number one month after emergence was observed in Shambat soil planted with pre-germinated and un-germinated seeds, and also, in North Gezira soil planted with un-germinated seeds.
Three months after emergence the lowest leaf number was recorded only in Shambat soil planted with un-germinated seeds.

**4.2.7 Effect of Irrigation Interval X Soil Type X Direct Sun Light or Shade on Jojoba Seedling growth:**

A significant interaction effect between watering, soil type and sun light or shade was recorded for jojoba seedling growth (Table 8 a and b).

*a/Seedlings Height:*

The tallest seedlings were those grown in West Omdurman soil watered every day and planted under direct sun, while the shortest seedlings were those planted in Shambat soil watered every six days under shade both one and three months after emergence.

*b/ Seedlings Leaf Number:*

The highest values were observed in seedlings planted in West Omdurman soil under sun light when watered every day or every three days one and three months after emergence, while the lowest values were found one month after emergence in Shambat and North Gezira soils under shade when watered every six days. Three months after emergence the lowest values were obtained only in Shambat soil under shade when watered every six days.

**4.2.8 Effect of Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedling growth:**
Table (9 a and b) illustrates a significant interaction effect between watering, soil type and seed condition on jojoba seedling growth one and three months after emergence.

**a/Seedlings Height:**

Maximum seedlings height was recorded for treatments in which pre-germinated seeds were planted in West Omdurman soil, watered every day and measured one and three months after emergence. On the other hand, the shortest seedlings one month after emergence were obtained from the treatment in which un-germinated seeds were planted in Shambat soil and watered every six days, while three months after emergence the lowest height was obtained when planting un-germinated seeds in North Gezira soil and watered every six days.

**b/ Seedlings Leaf Number:**

West Omdurman soil was superior in producing more leaves when planted with pre-germinated seeds and watered every day or every three days one month after emergence; while three months after emergence the highest leaf number was produced in West Omdurman soil planted with pre-germinated seeds when watered daily in addition to seedlings from pre-germinated and un-germinated seeds planted in West Omdurman soil and watered every three days.

The lowest leaf number was found in seedlings raised in North Gezira soil planted when un-germinated seeds grown and watered every six days one month after emergence. Three months after emergence, the lowest leaf number was obtained when pre-germinated or un-germinated seeds planted in Shambat soil were watered every six days.
4.2.9 Effect of Direct Sun Light or Shade X Seed Condition on Jojoba Seedling growth:

The effect of direct sun light or shade and seed condition interaction on jojoba seedling growth measured one and three months after emergence is presented in Table (10 a and b).

a/Seedlings Height:

The tallest seedlings were those from pre-germinated seeds planted under direct sun light, while the shortest seedlings were observed when un-germinated seeds were planted under shade both one and three months after emergence.

b/ Seedlings Leaf Number:

The highest leaf number was obtained from pre-germinated and un-germinated seeds grown under direct sun light, while the lowest leaf number was obtained from un-germinated seeds grown under shade one and three months after emergence.

4.2.10 Effect of Direct Sun Light or Shade X Irrigation Interval X Seed Condition on Jojoba Seedlings growth:

Highly significant interaction effects between direct sunlight or shade, watering interval, and seed condition in seedlings growth are revealed in Table (11a and b).

a/Seedlings Height:

The tallest seedlings were observed in the treatment where pre-germinated seeds were planted under direct sun and watered every day, while the un-germinated seeds grown under shade and watered every six days produced the shortest seedlings one and three months after emergence.
b/ Seedlings Leaf Number:

The highest records were observed when pre-germinated seeds were planted under direct sun and watered every day measured one month after emergence, and also when pre-germinated and un-germinated seeds under direct sun light were watered every three days, while three months after emergence the highest leaf number was only produced when pre-germinated seeds growing under direct sun light were watered every day.

The lowest records one and three months after emergence were observed in the treatment where un-germinated seeds were planted under shade and watered every six days.

4.2.11 Effect of Direct Sun Light or Shade X Soil Type X Seed Condition on Jojoba Seedlings Growth:

Direct sunlight or shade, soil type and seed condition interaction effects on jojoba seedling growth were significant one and three months after emergence as was shown in Table (12 a and b).

a/Seedlings Height:

The tallest seedlings were obtained from pre-germinated seeds in West Omdurman soil under direct sun light, while the shortest seedlings were those from un-germinated seeds planted in Shambat soil under shade and growing for both one and three months after emergence.

b/ Seedlings Leaf Number:

One month after emergence, the highest leaf number was obtained when pre-germinated seeds were planted in West Omdurman soil and kept under direct sun light, while the lowest leaf number was obtained when un-germinated seeds were planted in Shambat or North Gezira soils and kept under shade.
Three months after emergence the highest seedling leaf number was produced from pre-germinated and un-germinated seeds grown in West Omdurman soil under direct sun light, while the lowest leaf number was observed in Shambat soil planted with un-germinated seeds under shade.

There was no significant difference one and three months after emergence between seedling leaf number from pre-germinated seeds planted in Shambat soil and un-germinated seeds planted in North Gezira soil and both kept under shade condition.

4.2.12 Effect of Direct Sun Light or Shade X Irrigation Interval X Soil Type X Seed Condition on Jojoba Seedling Growth:

a/ Seedlings Height:

Table (13a) shows the effect of direct sun light or shade, watering interval, soil type and seed condition interactions on jojoba seedling height one and three months after emergence.

The tallest seedlings were produced in the treatment where pre-germinated seeds were planted in West Omdurman soil under direct sun light and watered every day after one and three months after emergence.

The shortest seedlings after one month after emergence were obtained when un-germinated seeds were planted in Shambat soil under shade, and watered every three days or every six days, while three months after emergence the shortest seedlings were obtained from un-germinated seeds under shade when planted in Shamabat or North Gezira soil and watered every three and six days.

b/ Seedlings Leaf Number:
Data in Table (13b) show the interaction effect between direct sunlight or shade, irrigation interval, soil type and seed condition on seedling leaf number after one and three months from germination.

One month after emergence the highest leaf number was produced when pre-germinated seeds were planted in West Omdurman soil and watered every day under direct sunlight, while the lowest leaf number was produced when un-germinated seeds were planted in North Gezira soil and watered every six days under shade.

The highest leaf number three months after emergence was obtained when pre-germinated and un-germinated seeds planted in West Omdurman soil were watered every day under direct sunlight and also when pre-germinated seeds planted in West Omdurman soil were watered every three days under direct sunlight, while the lowest leaf number was obtained when un-germinated seeds planted in Shambat soil were watered every three or six days under shade.

4.3 Seeds Storage:

4.3.1 Effect of Storage condition of Jojoba seeds on Seedlings Growth:

a/ Seedlings Height:

Table (14 a) shows the effect of seed storage on seedling height. The tallest seedlings were produced from seeds stored under cold conditions for one year compared to seeds stored under room temperature at the same period of time, which produce the shortest seedlings.

b/ Seedling Leaf Number:
Data in Table (14b) presented a significant difference between the leaf number of seedlings obtained from cold storage seeds and those stored under room temperature.

The highest leaf number was observed in seedlings from cold storage seeds, while the lowest leaf number was from seedlings produced from seeds stored under room temperature.

4.4 Establishment of Jojoba Seedlings:

4.4.1 Root Growth:

The growth of the root system measured as root length, root fresh and dry weight is presented in Table (15a).

Root length increased with time till the third week then decreased in the fourth and fifth weeks and increased again in the sixth week.

Root fresh weight increased with time then decreased in the fifth week and reached the highest value in the sixth week and so did the root dry weight.

4.4.2 Shoot Growth:

Table (15b) shows the changes in Shoot Length, Fresh and Dry Weight with Time Shoot length has reached the highest value in the fifth week while the shoot fresh and dry weights proceeded in increasing rate with time and reached the highest value in the last week.

Although the growth of root length was much faster compared to shoot length, root fresh weight was much smaller than shoot fresh weight.
5.1 Effect of Jojoba Seed Longevity on Germination %:

Seed samples were obtained from Arkaweet in Eastern Sudan. They were of different sizes (not uniform) and kept in open shed, where seeds from different seasons were kept in separate lots.

The germination percentage was different for samples from the different seasons. The highest percentage was for the most fresh sample of season 2000 followed by the second sample from season 1999, and the last sample of season 1997 was of zero percentage indicating death of embryos of all seeds from that season. The conditions of seed storage mentioned above which is normal temperature and high air humidity -characteristics of that part of Sudan- with out any protection treatments possibly caused losses in germinability. Castellanos and Molina (1990) reported that under natural conditions, jojoba seeds do not form a persistent seed bank; all seeds either germinate, lose viability or are consumed within a year of production. These results were also supported by Undersander et al (1990) who found that jojoba seeds, which has been dried to around 10% moisture and protected from pest damage, will keep for several years.

5.2 Effect of Jojoba Seed Longevity on Moisture Content, Fresh Weight and Dry Weight:

The moisture content and fresh weight were slightly higher in seeds of season 2000 and 1999 than season 1997, while there was no observed difference in the dry weight between seeds from the three examined seasons.
The mean dry weight was 0.8g; approximately similar results were reported by Clarke and Yermanos (1980).

5.3 Effect of Jojoba Seed Longevity on Oil Content %:

The oil content analysis of seeds from seasons 2000, 1999, and 1997 was 49.6%, 45.0%, and 44.7% respectively. This decline may be attributed to the consumption of some of the oil reserves in embryo respiration. Moreau and Huang (1977) suggested that jojoba wax plays the role of food reserve, which may thus be consumed during normal embryo respiration.

5.4 Effect of Jojoba Seed Longevity on Protein Content %:

The protein contents for seed samples of season 2000, 1999, and 1997 were 18.6%, 18%, and 17.2% respectively. There was steady decline in protein contents and this was probably due to seed deterioration and the protein consumed in respiration (Harrington, 1964).

5.5 Effect of Irrigation Interval on Jojoba Seedling Growth:

Plant Height was not significantly affected by irrigation intervals after one and three months from germination but, there was a slight increase under the short interval after one month. The lack in response to irrigation interval is probably due to less evapotranspiration and so less water absorption and hence lower rate of growth. However, after three months from germination a noticeable decrease in growth with increasing the irrigation intervals was observed, this is supported by Wallace and Rudel (1979) who reported that adequate moisture at time of germination and seedling establishment are particularly significant.
Leaf number was significantly affected by irrigation interval in both periods of time. The highest leaf number was obtained under one and three days irrigation interval and the lowest under the six days interval. Same results were found by Anon (1980) that to ensure optimum growth and maximum production, some irrigation will probably be needed in most desert areas.

Although jojoba is a plant native to arid environments and can then endure water stress as adult plants, yet the results of this study highlighted the importance of adequate irrigation at the seedling stage. At that stage a difference of only three days may significantly affect plant growth.

It would be reasonable to suggest that irrigating every three days would be sufficient to maintain seedling growth.

5.6 Effect of Soil Type on Jojoba Seedling Growth:

Plant height was significantly affected by the soil types. The tallest seedlings were obtained from seeds planted in West Omdurman soil; the sandy well aerated and fine textured soil, which is ideal for jojoba growth as was reported by James (1994) and also by Undersander *et al* (1990).

Planting in the heavy Shambat soil resulted in the shortest seedlings. This is supported by Undersander *et al* (1990) who reported that planting in heavy soils results in slower growth. However, after three months from germination, there was no significant difference in plant height between Shambat and North Gezira soils and it was slightly less than West Omdurman soil. This may have been due to the possibility that plants were well established by that time and due to the fast root growth characteristic of jojoba during the early stages of growth (Anon, 2004), thus making water available for equal rates of growth under the three soil types.
It would therefore, seem reasonable to suggest that for quick seedling establishment it would always be better to grow seedlings under light soils before transferring them to heavier soil.

Jojoba can tolerate high levels of salinity (Francois, 1986) and this matches with the readings obtained in North Gezira soils.

On the other hand, the highest leaf number was also obtained under West Omdurman soil both after one and three months from germination. There was no significant difference in leaf number between North Gezira and Shambat soils after one month from germination. However, after three months from germination there was a significant difference between the three soil types.

5.7 Effect of Direct Sun Light or Shade on Jojoba Seedling Growth:

Plant height and leaf number were highest in seedlings grown under direct sun light compared to those growing seedlings under shade both after one and three months from germination. Direct sun light may thus offer the optimum conditions for growth even at the seedling stage or under nursery conditions where shade is usually the preferable environment for seedling establishment.

5.8 Effect of Seed Condition on Jojoba Seedling Growth:

Although jojoba seeds require no pre-treatment and are usually readily germinable immediately after harvest as found by Nord and Kadish (1974) and Rao and lyenger (1982), yet when seeds were pre-germinated the results were highly positive in terms of plant height and leaf number both after one and three months from germination.
5.9 Effect of Irrigation Interval x Soil Types on Jojoba Seedling Growth:

The significant increase in plant height and leaf number due to irrigation interval x soil type interaction for seeds germinated in West Omdurman soil under the three watering intervals compared to Shambat and North Gezira soils under the same intervals is supported by the report of Wallace and Rudel (1979), probably due to the better drainage and aeration of the coarse soil.

5.10 Effect of Irrigation Interval x Direct Sun Light or Shade on Jojoba Seedling Growth:

The taller plants and of more leaves were obtained when watering every day under direct sun after one month from germination. While after three months from germination the highest growth was obtained when watering every day and every three days under direct sunlight.

It seems possible that after three months more leaves were produced enhancing the transpiration process enabling the plant to attract water from a deeper soil level in the three days irrigation intervals and this may have not been possible one month after germination and so no significant difference between one and three days irrigation interval was obtained after three months.

The lowest plant height and leaf number were obtained under shade when seedlings were watered every six days. This may be due to low temperatures during growth, which may have been lower than the optimum reported by Anon (1980) who highlighted the importance of temperature for germination and growth.
5.11 Effect of Irrigation Interval x Seed Condition on Jojoba Seedling Growth:

After one and three months from germination the tallest seedlings and highest leaf number were from pre-germinated seeds watered every day while the shortest seedlings were obtained from un-germinated seeds irrigated every six days. Thus it seems that for quick seedling establishment it might be better to pre-germinate the seeds before planting.

5.12 Effect of Soil Type x Direct Sun light or Shade on Jojoba Seedling Growth:

West Omdurman soil under direct sun light produced the highest seedlings and leaf number; these results are supported by the findings of Reyes et al (1977) who reported that growth and nutrient uptake of jojoba seedlings are best at higher temperatures and in well aerated soils, and by Anon (1980) who reported that jojoba seedlings tolerate direct sun light.

5.13 Effect of Soil Type x Seed Condition on Jojoba Seedling Growth:

The tallest seedlings and maximum leaf number were obtained in West Omdurman soil after one month from germination regardless of the seed condition. Similar findings were reported by Nord and Kadish (1974) and Rao and lyenger (1982).

In Shambat soil the un-germinated seeds gave the shortest seedlings. This may indicates that soil is the effective factor rather than seed condition.
5.14 Effect of Irrigation Interval x Soil Types x Direct Sun Light or Shade on Jojoba Seedling Growth:

Plant height and leaf number were highest after one month from germination when planting in West Omdurman soil and watering every day or every three days under direct sun light. Soil type seems to be the effective factor, while after three months the highest height was under the same conditions of soil and sun light but only when watered every day.

The lowest seedlings growth was obtained under Shambat soil watered every three days under shade after one month; while after three months lowest growth was obtained in Shambat and Northern Gezira soil when watered every three days under shade and also in the three soil types when watered every six days under shade.

The limiting factor seems to be the soil type and direct sunlight for the plant height and this supports the requirement for a fine textured soil and direct sunlight for raising jojoba seedlings.

5.15 Effect of Irrigation Interval x Soil Types x Seed Condition on Jojoba Seedling Growth:

The highest growth rate was obtained in West Omdurman soil planted with pre-germinated seeds and watered every day as was mentioned before. However, leaf number highest value was obtained under the same soil and seed conditions but under both one and three days watering interval. This may have been due to the fact that stem growth is a continuous process that may changes daily, while increase in leaf number, on the other hand, is a slow process.

The lowest records for plant height were observed in Shambat and Northern Gezira soils planted with un-germinated seeds and watered every
six days. The soil seems to be the limiting factor in leaf number where the lowest values were obtained from un-germinated seeds watered every six days in Shambat and North Gezira soils.

5.16 Effect of Direct Sun Light or Shade x Seed Condition on Jojoba Seedling Growth:

Although no pre-treatment is needed for jojoba seeds before planting as was reported by Nord and Kadish (1974) and Rao and lyenger (1982), the highest plant height was obtained when planting pre-germinated seeds under direct sun light compared to un-germinated seeds under shade; however, for leaf number the highest value was obtained under direct sun light regardless seed condition.

The lowest values for both plant height and leaf number were obtained when pre-germinated seeds were planted under shade. This may suggest that direct sunlight or shade is the main effective factor in this interaction.

5.17 Effect of Direct Sun Light or Shade x Irrigation Interval x Seed Condition on Jojoba Seedling Growth:

After one month from germination, the highest value of plant height and leaf number were obtained when pre-germinated seeds were planted under direct sun light and irrigated every day or every three days, while after three months from germination, the highest values were obtained under the same conditions but only when irrigated daily, this may reflect the higher water requirements by the seedlings during the period of establishment (Anon, 1985a).
Watering every six days under shade for un-germinated seeds resulted in the lowest plant height and leaf number.

Irrigation interval seems to be the effective factor in this interaction regardless of direct sunlight or shade and seed condition.

5.18 Effect of Direct Sun Light or Shade x Soil Type x Seed Condition on Jojoba Seedling Growth:

West omdurman soil when planted with pre-germinated seeds under direct sun light gave the highest seedling growth, while the lowest rates of growth were in Shambat soil planted with un-germinated seeds under shade. In this interaction soil type was the effective factor regardless of the two other factors.

5.19 Effect of Direct Sun Light or Shade x Irrigation Interval x Soil Type x Seed Condition on Jojoba Seedling Growth:

The highest rates of growth were obtained when planting pre-germinated seeds in West omdurman soil watered every day under direct sun light which were found to be the most optimum condition for seedling growth in this study, while the poorest conditions for growth resulted from un-germinated seeds in Shambat soil watered every six days under shade.

This may point to the fact that under heavy soils such as that of Shambat more frequent irrigation under sun light may be required for fast seedling establishment when planting un-germinated seeds.

5.20 Effect of Storage condition of Jojoba seeds on Seedlings Growth:

The seedlings produced from cold storage seeds were taller than those stored under room conditions. Also, leaf number of seedlings resulting from
the cold storage seeds was more than that of seedlings produced from seeds stored under room temperature.

Cold storage retards respiration rates and maintains higher seed viability; hence, more stored seed materials are therefore, available for growth of seedlings from cold storage seeds. Similar results were found by Nord and kadish (1974) who reported that when stored at low moisture content and temperature of about 3°C, seed lots have retained high viability for 10 to 12 years.

The deleterious effects of high temperature and moisture during storage on seed condition and the beneficial effects have been highlighted by many workers (Louis, 1973; Figueiredo, 1984; Kabeeri and Taligoola, 1984).

5.21 Establishment of Jojoba Seedlings measured as Root Growth:

Jojoba, being an arid zone plant, is noted for its fast rate of root growth (Anon, 2004). This was confirmed under the condition of this study where root length has reached 28cm in only six weeks. Under water limited conditions fast root growth during seedling establishment is a definite advantage, which enhances seedlings survival. Anon (1985a) reported that seedlings devote most of their energy to produce a taproot which is a natural survival mechanism in deserts where surface soil dries out rapidly.

5.22 Establishment of Jojoba Seedlings measured as Shoot Growth:

The shoot length increased at a slow rate compared to root length, this was obviously due to the fact that a larger proportion of growth material was directed towards the root growth at the early stages of growth. Same results were reported by Anon (1985a) that often young plants have roots 10 times
longer than the height of the plant above ground. Seedlings normally take about 21 days to break through the soil, by which time they can have roots 46cm deep. Anon (2004) also reported that young leaves and shoots follow up root growth but appear at a much slower rate.
CONCLUSION

From the experimental results of this study the following conclusions are drawn:

1. Although jojoba is a desert plant, more frequent irrigation during seedling establishment is more beneficial than long irrigation intervals.

2. Pre-germinated seeds are highly positive in terms of seedling growth.

3. For quick seedling establishment it would always be better to grow seedlings under light soils.

4. For oil production fresh seeds are of higher oil contents than those stored for many years.

5. Seedling growth is better under direct sun light than under shade.

6. Seeds stored in low temperature retain higher viability and result in higher seedling growth than those stored under ambient temperature.

7. Interaction of short irrigation interval with light well drained soil under direct sun light when using pre-germinated seeds are the best conditions for jojoba seed germination and seedling establishment.
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