Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol.5, No.12, 2015

Studies on Seed Size and Storage on Germinability and Performance of young Jojoba (Simmondsia Chinensis L.) Seedlings in Semi-arid Areas of Kenya

S.K Inoti[1*] S.A.O Chamshama[2] R Dodson[3] W.M Thagana[4] L.L.L Lulandala[2]
1. Department of Natural Resources, Egerton University, Box 536 - 20115, Egerton, Kenya
2. Department of Forest Biology, Sokoine University of Agriculture. Box 3010, Morogoro, Tanzania
3. Wildlife works. Box 593, Maungu, Voi, Kenya
4. Department of Agricultural Sciences and Technology, Kenyatta University, Box 43844, Nairobi, Kenya
*Email of Corresponding author: Email- inotikinyua@yahoo.com

This research was financed by Wildlife works Ltd, Maungu Kenya

Abstract
Jojoba (*Simmondsia chinesis* L.) is a highly valued desert shrub for its oil which is equivalent to that of Sperm Whale, a threatened species by extinction. Cultivation of Jojoba in arid areas means provision of a cash-crop, environmental conservation and preservation of the Whale. Its seeds vary in size depending on genotype, season and seed lot. An experiment was setup in September 2012 with an objective of characterizing seed and determining the effect of size and storage on germination. The experiment was laid down in a Completely Randomized Design (CRD) with three treatments replicated thrice for the first two experiments. However, the third experiment was a factorial one with eight treatments. The seeds were grouped into three categories which were large (1,047 mg), medium (697 mg) and small (333 mg/seed). The results revealed that large seeds had significantly ($P \leq 0.05$) higher germination percentage (76%) compared with medium (33%) and small (37%) seeds. Large seeds were found to contain large cotyledon size. Large cotyledons provide a large food reserve which is essential for germination and early vigorous growth. Seed length and 100 seed weight were significantly ($P \leq 0.05$) higher for large seed as compared to medium and small seeds. Similarly, large seeds recorded a germination of 93% for a short storage of six months which was superior to that of small seeds which was 17% for the same period. Hence seed length and 100 seed weight were found to be reliable variables for characterizing Jojoba seeds which may be used in predicting germinability. We recommended that for enhanced germination and vigorous growth of seedlings, it is necessary to select and plant large Jojoba seeds which have been stored for period less than one year.
Keywords: Jojoba, seed, characterization, germination, growth

Introduction

Over 80% of Kenya is composed of arid and semi arid lands (ASALs) with only a few crops being grown mainly for subsistence purposes (KARI, 2009). They experience frequent drought leading to crop failure hence overdependence on food relief (Barrow, 1996).

Jojoba (*Simmondsia chinensis* L. Schn.) is a high value shrub growing in the arid areas (NAS, 1984) and it is a promising cash crop for the arid-lands throughout the world. Jojoba is the sole species of the family Simmondsiaceae and it is a native shrub of Sonoran desert of USA and Mexico (Gentry, 1958). It grows on coarse, light and medium textured well drained sandy soils with marginal fertility and acidic to alkaline pH of 5-8 (Undersander *et al*., 1990). It tolerates saline environments with low rainfall (220-400 mm per year) and high temperature range (0-54^{0}C), with optimum temperatures between 27-33^{0}C but is susceptible to frost below -3^{0}C (Stephens, 1994). It is dioecious with male and female plants in the ratio 1:1 in the field when raised from seed.

Jojoba produces nuts with 45-55% of its weight as oil. The oil is similar to that obtained from Sperm Whale which is threatened with extinction (Hogan and Bemis, 1983). It has varied uses ranging from edible oils, lubricants, cosmetics and medicines (Amarger and Mercier, 1996; Hogan and Bemis, 1983).

Jojoba has come at a time when there are dwindling natural resources and increased concern for the environment (Tremper, 1996). Yet, there are certain challenges that need to be addressed and these include low germination, low yields, multiplication and determination of genetic diversity and sex at early stages. Seeds of Jojoba are quite variable in size both within and among seed-lots (Yermanos, 1979) and vary depending on the genotype and season of flowering and seed set. Many plants show considerable plasticity in both seed size and content (Fenner, 1986). Even a modest increase in seed size can have important consequences for successful seedling establishment and competitive ability as well as increased commercial value.

Rapid seedling establishment is an important requirement for successful crop production in dry land farming systems (Balkan, 2012). Larger seeds helps seedlings to establish better in dry conditions (Leishman and Westoby, 1994) due to the fact that they have deeper and fast elongating roots compared with smaller seeds

(Daws *et al*, 2007). This makes the former to have improved survival and more tolerant to environmental stress.

Selection favoring large seeds has been maintained in populations (Stanton, 1985) since larger seeds produce larger plants. Bouaziz and Hicks (1990) also reported that seed size and weight are important criteria for determining seedling vigor and stand establishment in wheat.

This study was aimed at solving the problem of low germination by characterizing seed and determining the effect of size and storage on germination. Seeds are categorized into large, medium and small sizes based on length, width and weight. Seed size is vital in determining the germination and early growth. Three experiments were setup in September 2012 with an objective of characterizing seed and determining the effect of size and storage on germination. Each experiment was laid down in a Completely Randomized Design (CRD) with three treatments replicated thrice. The treatments consisted of large, medium and small seeds

Objectives

The objectives of the trial were to study:

i) The characterization of seed using size criterion

ii) Determine the effect of seed size on germinability and early growth of seedlings

iii) The influence of seed size and storage on germinability

Materials and methods

Site description

The research was conducted in Rukinga Wildlife Works, Maungu, Kenya, where Jojoba bushes have been established. This site is located about 30 km away from Voi urban centre in the coastal province. It lies in semi arid savannahs with an annual rainfall of 596 mm and an altitude of 892 meters. Soils are moderately fertile with sandy loam and gravel texture and pH of 5-7. Temperatures average at 26^0C with moderately high humidity (60-80%) (Kenya Food Security, 2008, Thagana *et al*., 2003).

Experimental description and field management:

Seeds were harvested from a 28 year old Jojoba stand in Maungu, Kenya and then stored in nylon bags for a period of 6 months. In one experiment, the seeds were sorted out into 3 size categories as follows: large (1,047 mg), medium (697 mg) and small (333 mg/seed) (Table 1). An experiment was setup using a completely randomized design with 3 treatments replicated 3 times. The treatments consisted of large, medium and small seed sizes. Five seed samples were randomly selected from each replicate per size category and data was collected on seed length, width and 100 seed weight variables.

Table 1: Jojoba seed characterization

Seed size	Individual seed weight (mg)	Number of seeds per kg
Large	**1,047**	**955**
Medium	**697**	**1,435**
Small	**333**	**3,003**

In the second experiment, the seeds were germinated in a sand media for a period of 30 days in September 2012. The experiment was laid down in a completely randomized design with 3 treatments replicated 3 times. The 3 treatments consisted of large, medium and small sizes of seed. After sowing, watering was done on a daily basis until the completion of germination. Data on germination percentage, germination period, seed vigor index (SVI), cotyledon size and height were recorded.

SVI is an important component of seed quality and was calculated by multiplying germination percent and seedling height (mm). The seed-lot showing higher seed vigor index is considered more vigorous (Abdul-Baki and Anderson, 1973).

The third experiment consisted of two seed sizes (Large and Small) which were then stored for different periods namely 0.5 years, 1 year, 1.5 years and 2 years. The setup was carried out as a factorial experiment laid down in a completely randomized design with 8 treatments replicated 3 times. Data was collected on germination for a period of 30 days.

Data analysis

Data of the measured variables was analyzed using SAS statistical package (SAS, 1996) while the means were separated using LSD at $P< 0.05$

Results and discussions

Characterization of Jojoba seed

Seeds are categorized by sizes of large, medium and small according to parameters of weight, length and width (Plate 1). Mean weight ranged from 955-3,033 seeds/kg of large seed and small seed respectively (Table 1). On the other hand, the medium seed was 2/3 the size in weight of large seed. Earlier works by Nord and Kadish

(1974) reported a mean seed weight range of 660-3,300 seeds/kg whilst Ismail (1988) showed seeds/kg range of 1,060-2,300 which were similar to the current findings.

Plate 1: Different sizes of Jojoba seed collected at Maungu, Kenya

Seed length and 100 seed weight were significantly (P≤0.05) higher for large seed as compared to medium and small seeds (Table 2). Similarly, medium seeds were also significantly superior for seed length and 100 seed weight compared with small seeds. Mean seed length ranged from 11.9-16.9 mm for small and large seeds respectively which were comparable to those reported by Ismail (1988) which ranged from 9.3-18.4 mm. 100 seed weight followed a similar trend as in mean weight. Work on Jojoba by Virender *et al* (2005), reported similar results which also showed significant variation in Jojoba seed parameters such as length, width and 100 seed weight. However, seed width had lower variation between the various seed sizes.

Table 2: Effect of seed size on seed length, width and 100 seed weight of jojoba seeds.

Seed size		Seed length(mm)	Seed width(mm)	100 seed weight(g)
Large		16.1a	8.5a	104.7a
Medium		13.7b	7.5ab	69.7b
Small		11.9c	6.3b	33.3c
CV		4.5	7.8	5.6
LSD		1.4	1.3	8.8

Figures followed by the same letters in each column shows that they are not significantly different with each other at P≤ 0.05

Seed size on germination and cotyledon size.

Larger seeds showed significantly higher germination percentage (76%) compared with medium and small size seed which were lower and similar at 33 and 37% respectively (Table 3). Earlier work by Virender *et al* (2005), supported these results by stating that germination percentage was influenced by seed size which varied from 58.65 to 86.33%. Rana *et al* (2003) also recorded germination percentage between 62.2 to 78.9% of the same Species.

Table 3: Effect of seed size on cotyledon size, germination and early growth of jojoba seedlings.

Seed size	Cotyledon Length(mm)	Cotyledon width(mm)	Height (mm)	Germination%	Germination period(days)	Seed vigor index(SVI)
Large	19.3a	13.7a	68.7a	76.0a	7.7a	5250.3a
Medium	17.3b	11.0b	57.7a	33.3b	8.0a	1745.0b
Small	15.5c	9.0c	47.0a	38.0b	12.0a	2679.0ab
CV	0	0	34.6	30.5	27.4	33.2
LSD	0	0	57.5	33.7	6.8	3066.5

Figures followed by the same letters in each column shows that they are not significantly different with each other at P≤ 0.05

Seed vigor index (SVI) showed similar trend as in germination percentage with medium seed showing significant difference with the large seed (Table 3). However, small seed did not show any significant difference with the larger seed. Germination period is referred to as the time taken in days to start and complete and it ranged from 7.7 to 12 days from large to small seed but was not significantly different to each other. Mut and Akay (2010) reported that decreasing seed size increased mean germination time but decreased final germination percentage, root length and shoot length in oats.

Seed size significantly (p≤0.05) affected cotyledon length and width with the larger seed having a bigger cotyledon compared with the small seed (Table 3). Larger seeds had cotyledon length of 19.3 mm which was significantly higher than medium (17.3 mm) and small seed (15.5 mm). This gives a similar trend for

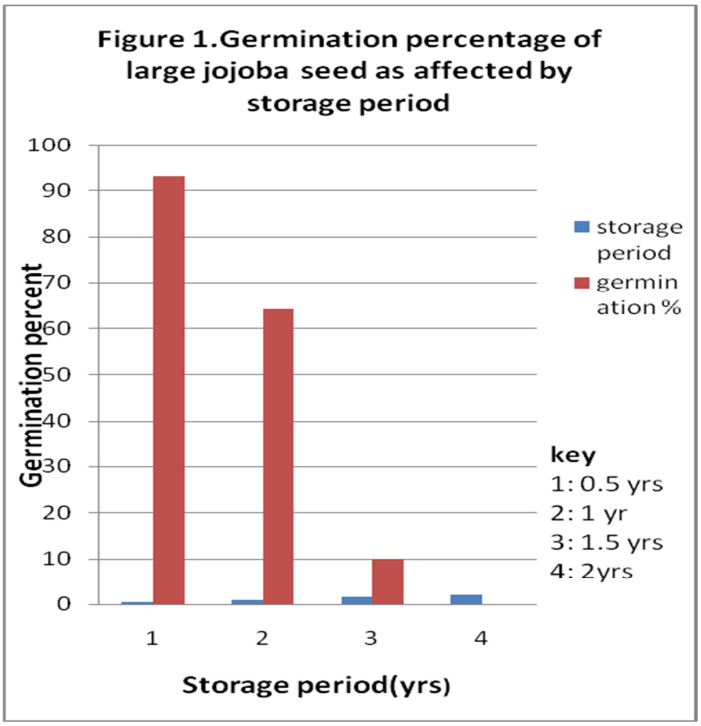
cotyledon width ranging from 13.7 mm for larger seed to 9.0 mm for the small seed.

Growth in height

Height growth ranged from 68.7 to 47 mm respectively for large to small seed but not significant, showing that shoot growth at the early stages of development is influenced by seed size. Large seeds germinate faster than the smaller seeds. According to Virender *et al* (2005), plants with larger seeds invest more resources into those seeds and normally produce fewer seeds. They give a seedling a faster start for germination and seedling growth hence producing larger, more established seedlings after germination (Kosinki, 2007; Shannon *et al*, 1996; Zhang, 2012). Larger seeds of bread wheat gave higher dry shoot biomass, root biomass, shoot length and emergence rate as compared to smaller seeds (Kara and Akman, 2007).

Seed size and storage period and its influence on germination

Large seeds stored for a short period of 6 months gave germination percentage of 93%, 1year (64%) while 1.5years (10%) (Figure 1). Similarly, Small seeds gave 17%, 14% and zero germination respectively (Figure 2). The germination period both for large and small seeds showed a similar trend with germination starting at 11 days , continuing to 13th day and attaining a plateau at the 15th day (Figure 3 and 4). Seed lots of large seeds germinated more quickly and to higher percentages than did lots of small seed (Figure 1 and 2) as was also reported by Ismail (1988) and Nik *et al* (2011), suggesting that seed size is associated with germination polymorphism.



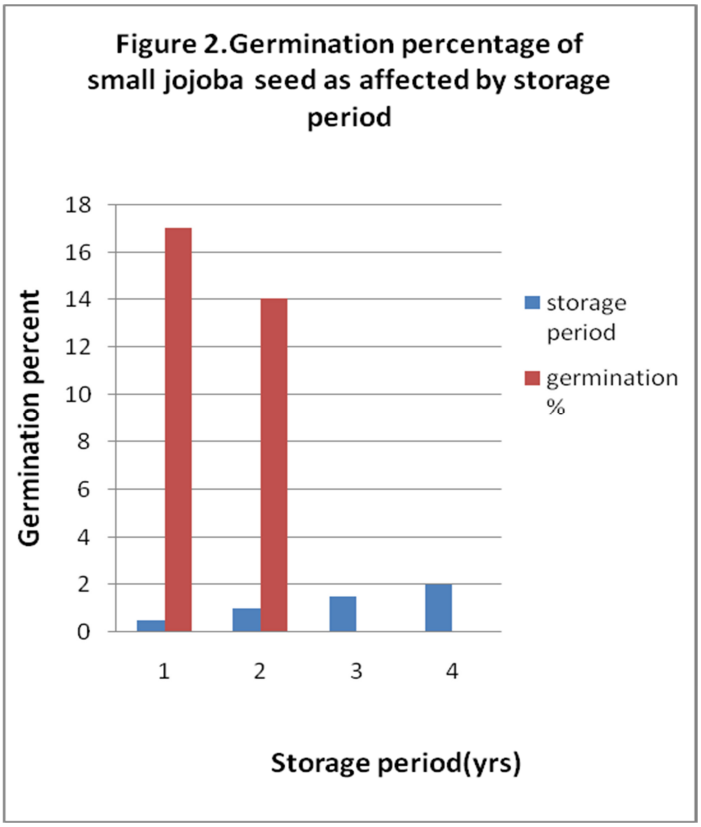


Figure 2.Germination percentage of small jojoba seed as affected by storage period
Germination percent
18
16
14
12
10
8
6
4
2
0
1
2
3
4
storage period
germination %
Storage period(yrs)

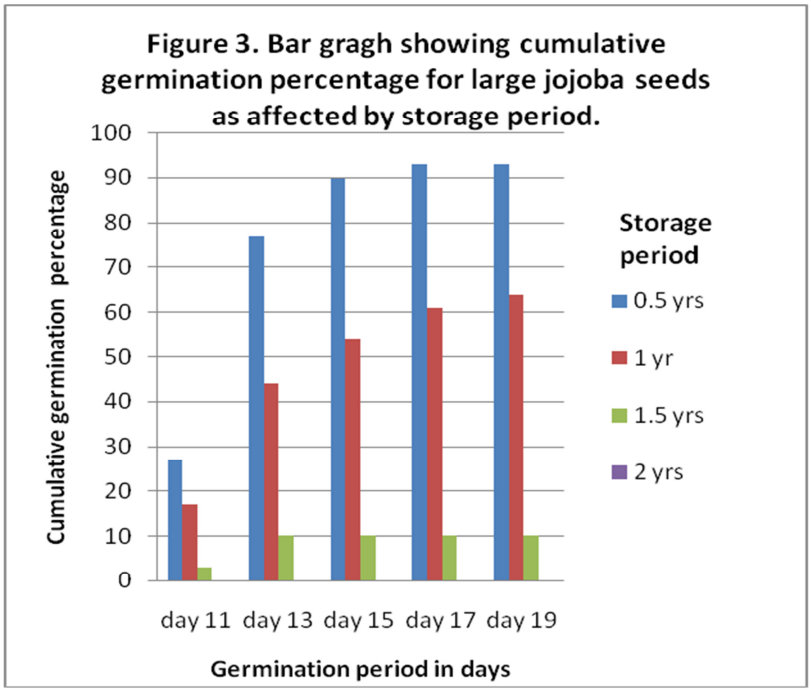
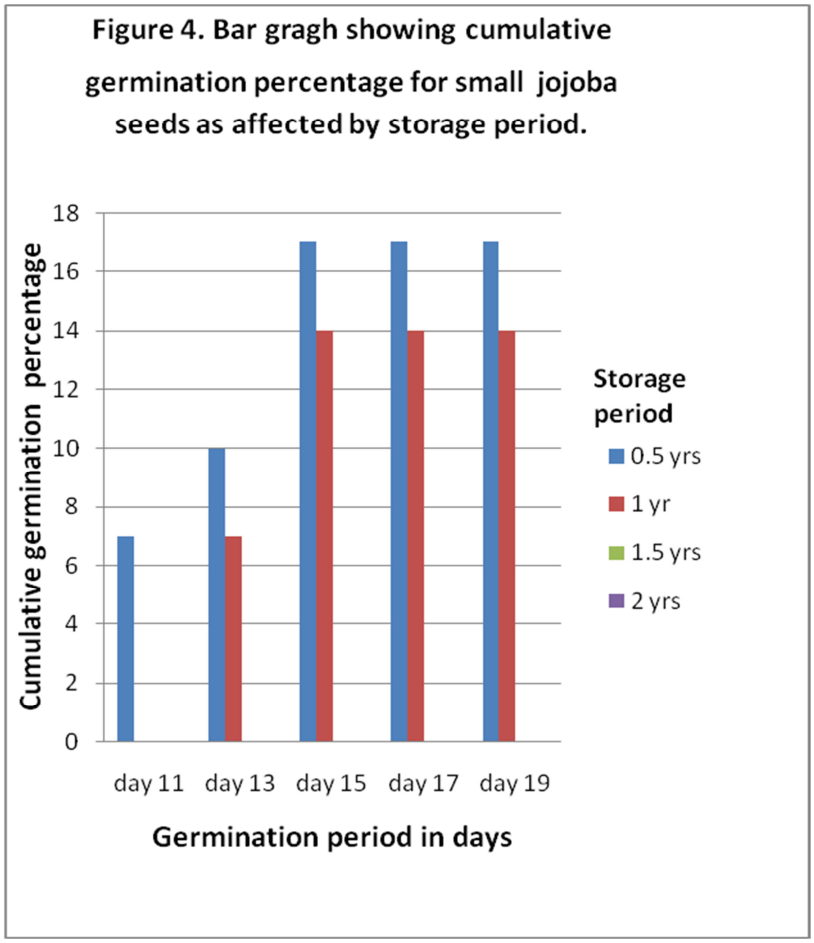


Figure 3. Bar gragh showing cumulative germination percentage for large jojoba seeds as affected by storage period.
Cumulative germination percentage
100
90
80
70
60
50
40
30
20
10
0
day 11
day 13
day 15
day 17
day 19
Germination period in days
Storage period
0.5 yrs
1 yr
1.5 yrs
2 yrs



Conclusion

Larger seeds have a higher germination percentage and also vigor index which is correlated with large cotyledon size. The latter gives a larger food storage reserve which is essential for early germination and growth of the seedling. However, seed storage greatly affects the germinability depending on the seed size.

Based on the above results it is suggested that categorizing of Jojoba seed before planting is necessary. Then select and plant large seeds which have been stored for a short period of less than one year in the nursery or in the field for better germination and growth of seedlings.

The researchers wish to thank all the Technicians and scientists who assisted in data collection and processing.

References

Abdul-Baki, A.A. & Anderson, J.D. (1973), "Vigor determination in Soyabean by multiple criteria", *Crop Science* 13, 630-637.

Amarger, V. & Mercier, L. (1996), "Nuclear ribosomal DNA unit length variation: a putative marker of genetic diversity in Jojoba", *International Journal of Plant Science* 157(3), 296-302.

Balkan, A. (2012), "Effect of artificial drought stress on seed quality of bread wheat", *Iranian Journal of plant physiology* 2(2), 403-412.

Barrow, E.G.C. (1996), "The dry lands of Africa: local participation in tree management", Initiatives Publishers, Nairobi, Kenya. pp. 268.

Bouaziz, A. & Hicks, D.R. (1990), "Consumption of wheat seed reserves during germination and early growth as affected by soil water potential", *Plant and soil* 128, 161-165.

Daws, M.I., Ballard, C., Mullins, C.E., Garwood, N.C., Murray, B., Pearson, T.R.H. & Burslem, D.F.R.P. (2007). "Allometric relationships between seed mass and seedling characteristics reveal trade-offs for neotropical gap-dependent species", *Oecologia* 154, 445-454.

Fenner, M. (1986), "Environmental influences on seed size and composition", *Horticultural Review* 13(5), 183-207.

Gentry, H.S. (1958), "The Natural History of Jojoba (*Simmondsia chinensis*) and its Cultural Aspects", Econ-*Bot* 12, 261-291.

Hogan, I. & Bemis, W.P. (1983), "Buffalo gourd and Jojoba: Potential new crops for arid lands", *Advances in*

Agronomy 36, 317-349.

Ismail, A.M.A. (1988), "The ecological and agronomic role of seed polymorphism in *Simmondsia chinensis", Journal of Arid Environments* 14, 35-42.

Kara, B. & Akman, Z. (2007), "The effect of different grain size and sowing depth of wheat roots and shoot organs on the first development stages", *Akdeniz University, Journal of Agricultural Faculty* 20(2), 193-202.

KARI (2009), "Kenya Agricultural Research Institute strategic plan 2009-2014", KARI, Nairobi, Kenya.

Kenya Food Security (2008), Taita Taveta District report: Long rains Food Security Assessment", *[Online]. Available: file:///G:/Taita Taveta district landuse.htm* [Accessed 12th October 2011].

Kosinki, I., (2007), "Long-term variability in seed size and seedling establishment of *Maianthemum bifolium", Plant Ecology* 194(2), 149-156.

Leishman, M.R. & Westoby, M. (1994), "The role of large seeds in seedling establishment in dry soil conditions-experimental evidence from semi-arid species", *Journal of Ecology* 82, 249-258.

Mut, Z. & Akay, H. (2010), "Effect of seed size and drought stress on germination and seedling growth of naked oats", *Bulg. J. Agric.Sci.* 16(4), 459-467.

National Academy of Sciences (NAS), (1984), "Jojoba. *In: Undeveloped tropical plants with promising economic value", Washington, D.C*. Pp. 105-110.

Nik, M.M., Babaeian, M. & Tavassoli, A. (2011), "Effect of seed size and genotype on germination characteristic and seed nutrient content of wheat", *Sci. Res. Essays* 6(9), 2019-2025.

Nord, E.C. & Kadish, A. (1974), "*Simmondsia chinensis* (Link) Scheid; Jojoba. In: Schopmeyer, C.S, Tech. Coord. Seeds of Woody plants in the United States", *Agric. Handbook. 450. Washington, D.C: USDA Forest Service,* 774-776.

Rana, M.Y., Bashir, M.A., Asad, M.N. & Iqbal, A.M. (2003), "Effect of various agro-climatic factors on germination and growth of Jojoba in Pakistan", *Pakistan Journal of Biological Sciences* 6(16), 1447-1449.

Analytical System SAS. (1996), "SAS Users Guide: *Statistical", SAS Inc, Cary N.C*.

Shannon, D.A., Isaac, L. & Brockman, F.E. (1996), "Assessment of hedgerow species for seed size, stand establishment and seedling height", *Agroforestry Systems* 35(1), 95-110.

Stanton, L.M. (1985), "Seed size and emergence, time within a stand of wild radish (*Raphanus raphanistrum* L.): the establishment of a fitness hierarchy", *Oecologia* 76(1), 524-531.

Stephens, J.M. (1994), "*Simmondsia chinensis* (Link) S. *University of Florida", Cooperative extension service.* Pp. 3.

Thagana, W.M., Riungu, T.C. & Inoti, S.K. (2003), "Report on Jojoba (*Simmondsia chinensis*) cultivation in Kenya", Pp. 10.

Tremper, G. (1996), "The history and promise of Jojoba. In: Jojoba: new crop for arid raw materials for industry", *National research council. Armchair world. Jojoba Obispo. USA. New lands,* Pp. 116.

Undersander, D.J., Oelke E.A., Kaminski, A.R., Doll, J.D., Putnam, D.H., Combs, S.M. & Hanson, C.V. (1990), "Alternative field crop manual", *University of Wisconsin- Madison and Minnesota, St. Paul, USA.*

Virender, D., Dhillon, R.S., Nikhil, S. & Dhanda, S.K. (2005), "Polymorphism in seed parameters, oil content and nursery performance of different genotypes of Jojoba (*Simmondsia chinensis*)", *Indian Journal of Agroforestry* 7(2), 62-65.

Yermanos, D.M. (1974), "Agronomic Survey of Jojoba in California", *Economic Botany* 28, 161-174.

Zhang, H. (2012), "Seed germination and early growth of *Cynanchum bungei* Decne (Asclepiadaceae) in response to photoperiod, temperature and seed size", *Hortscience* 47(9), 1338-1341.

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar