H

EGYPTIAN ACADEMIC JOURNAL OF BIOLOGICAL SCIENCES BOTANY

ISSN 2090-3812

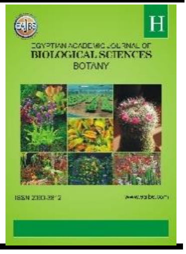
www.eajbs.com

Vol. 12 No.2 (2021)

Citation: Egypt. *Acad. J. Biolog. Sci.* (H. Botany) *Vol.12(2) pp179-189(2022)*
DOI: 10.21608/EAJBSH.2021.246506

Egypt. Acad. Journal Biolog. Sci., 12(2): 179-189 (2021)

Egyptian Academic Journal of Biological Sciences
H. Botany
ISSN 2090-3812
www.eajbsh.journals.ekb.eg.



Cultivation of the Multipurpose Tree, *Jatropha curcas* Using Recycled Water in Saudi Arabia: A forward-looking Study

Haifa Abdulaziz S. Alhaithloul
Biology Department, College of Science, Jouf University, Sakaka 2014, Saudi Arabia.
*E-mail: haifasakit@ju.edu.sa

REVIEW INFO
Review History
Received:29/09/2021
Accepted:25/12/2021

Keywords:
Jatropha, cultivation needs, *Jatropha* adaptability, biofuel trees.

ABSTRACT

The lack of water is one of the most important global and local challenges. Therefore, the use of useful trees which are tolerant to difficult environmental conditions and their cultivation requirements are the least. Hence, the idea of this study is to raise the possibility of using sewage water to grow *Jatropha* trees and exploiting this tree to combat desertification and produce biofuels in Saudi Arabia. In addition, Saudi Arabia invested about US$23 billion in the infrastructure of sewage gathering and treatment. The adaptability of *Jatropha* to cultivation in harsh conditions, with the increasing global demand for renewable fuel sources, put *Jatropha* among the most promising alternative and low-cost feedstocks of biofuel crops. Furthermore, *Jatropha* oil may be utilized in saponification reactions to produce soap. Also, this oil is approved for cooking and lighting. Thus, *Jatropha* system could comprise essential quarters of rustic and regional development. *Jatropha* is cultivated on one million ha worldwide. In addition, many studies recommended *Jatropha* to be planted in poor lands of Egypt using nutritious and recycled treated wastewater, and to be a component of Egyptian strategy for renewable energy production. Overall, this study suggested that *Jatropha* tree is adaptable to the Saudi environment and can be cultivated using treated sewage water. In addition, *Jatropha* cultivation requirements are minimal, while its benefits are maximal.

INTRODUCTION

The Arabian Peninsula (AP) is regarded as the largest peninsula worldwide (3,237,500 km^2). The AP includes Jordan, Iraq, Yemen, Bahrain, Oman, Kuwait, Qatar, United Arab Emirates (UAE), and Saudi Arabia (KSA). KSA covers about 2,250,000 km^2 of the AP. Saudi Arabia is a water-deficit and arid-climate country with limited lasting water bodies, lower rainfall patterns and higher evaporation rates. KSA was classified as the third highest country in daily per capita water use worldwide (GAS, 2016). Besides, the KSA population counted about 35 million by 2020 and is prospective to reach about 56 million by 2050 (Rambo *et al.,* 2017; GAS, 2018). The increasing population and developing economy of KSA led to increasing demand for the finite natural resources of water (aquifers). For the above-mentioned reasons, the exploitation of the natural aquifers is requested to meet the water requirements of the Saudi people. The increasing demand for water consumption over time is illustrated in Fig. (1).

DOI: 10.21608/EAJBSH.2021.246506

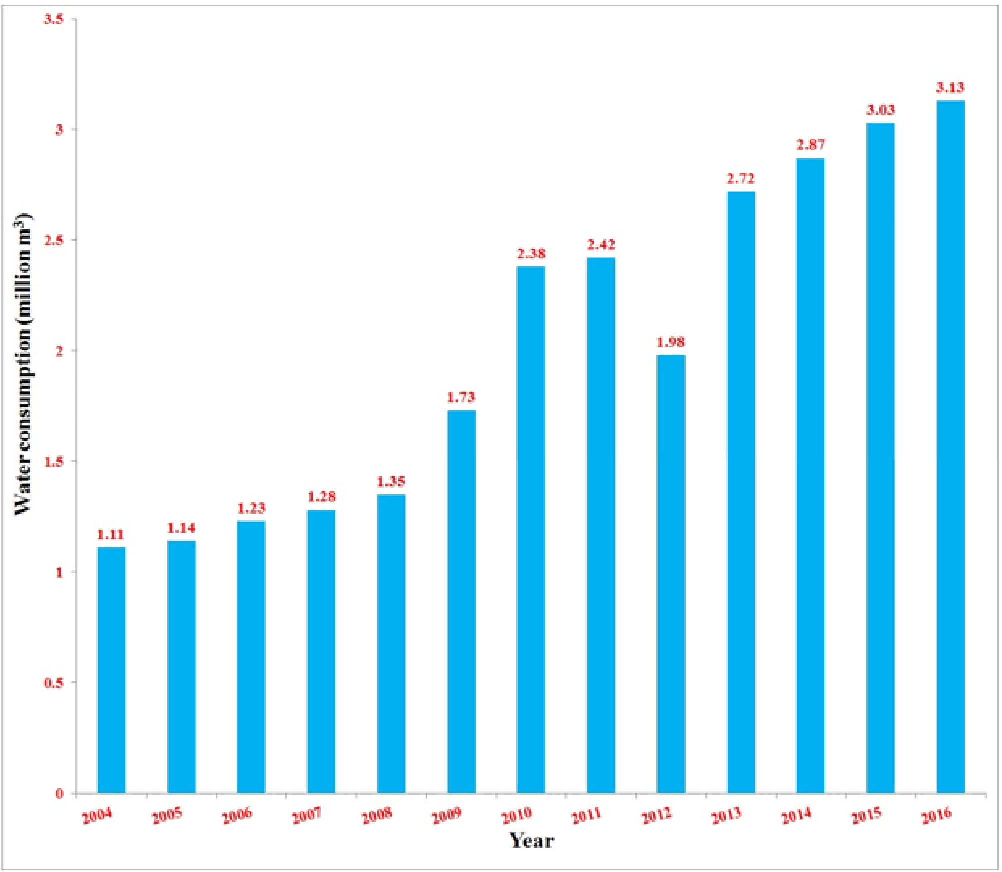


Fig. 1: The pattern of water consumption illustrating the increasing demand on water over time (statistica.com).

In the early eighties, the national agricultural program of KSA started to fulfill the self-sufficiency of food needs. In the last decades, a considerable decrease in groundwater levels and quality were observed. The better management of water resources could restrict careless and irresponsible policies of water consumption in KSA (Lippman, 2014). The daily water consumption of KSA was estimated at 7 billion m^3. Approximately 60% of the consumed water is desalinated (Al-Suhaimy, 2013).

Jatropha curcas is a succulent plant and well-adapted to grow in arid conditions. *Jatropha* is a well-known multipurpose tree, which is cultivated on a large scale in the tropical region. It may be consumed as a medicinal and food crop, or it may be cultivated for the production of biofuel (seeds contain from 27 to 40% oil of its dry weight) or used for the construction of a living fence (Francis *et al.*, 2005; Corte-Real *et al.*, 2016). As it produces many toxins, it is rarely attacked by insects (Alsharhan *et al.*, 2003; Corte-Real *et al.*, 2016). Lower servicing and cultivation requirements, with elevated oil content, made these plants very appealing as cost-effective biofuel feedstocks (Francis *et al.*, 2005).

Sustainable development in KSA is challenged by the increasing water demand and limited water wealth. Therefore, the main objective of this article is to suggest an initiative on the prospective use of sewage wastewater for *Jatropha* trees' cultivation in Saudi Arabia.

The State of Water Resources in Saudi Arabia:

As the KSA is a part of the hot dry region, it is characterized by no rivers, no lasting lakes, lower annual rainfall (lower than 100 mm), temperature variation, higher evaporation rate, and finite groundwater reservoirs (Chowdhury and Al-Zahrani, 2013). Additionally, the master aquifers are going to deplete by the plus exhaustion and lower rainfalls. To meet demands, KSA has increased its freshwater production from traditional (surface and groundwater), and nontraditional (desalinated and recycled treated wastewater) water sources (GAS, 2018). Treated wastewater, desalinated water, groundwater, and surface water are the primary freshwater sources in KSA. Treatment of wastewater provides approximately one percent of the total KSA fresh water supply (Fig. 2).

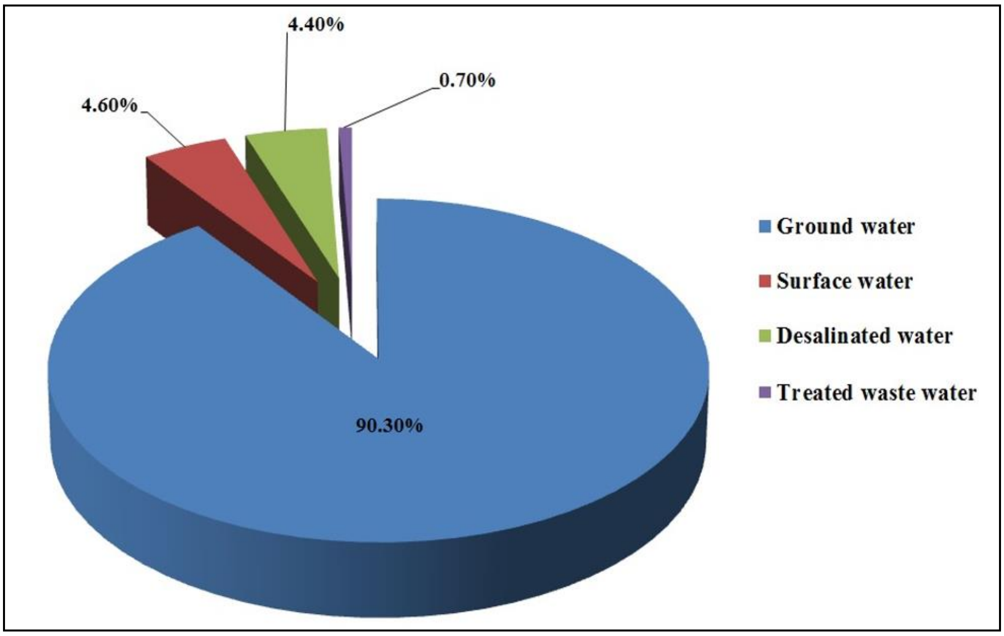


Fig. 2: The state of water resources in Saudi Arabia (Al-Saud, 2013).

Treated Wastewater in Saudi Arabia:

It is well-known that recycled wastewater is securely used in refrigeration, industry, and agriculture. Recycled wastewater is a cornerstone resource that has to be counted in the operated water system, especially, in the case of water scarcity. In the case of KSA, the total quantity of recycled wastewater (≈17%) used during 2015 was 610,000 meter^3/ day, and ≈66% of which was utilized in agriculture (NWC, 2016). Low-quality treated wastewater resulted from the treatment plants because of their high-level operation. For increasing the percentage of compiled wastewater (≈60% in 2015), the collection system must be upgraded (Tchobanoglous, 1995; NWC, 2016; 2018). In addition, KSA invested about US$23 billion in the infrastructure of sewage gathering and treatment (Kajenthira *et al.*, 2012; Al-Saud, 2013; Chowdhury and Al-Zahrani, 2013; SAWR-Q4, 2013; Scotney, 2014; Enssle and Freedman, 2017; USDE, 2017).

Generally, the utilization of recycled treated wastewater can minimize the dependency on freshwater wealth, and also lower the influx of water into the habitat. This influx could increase the deposition of nutritious materials (organic and mineral) into water systems, causing excessive richness and rapid growth of algae which contaminate the existent water bodies (Toze, 2004). A total of 30% of desalinated water was estimated by Global Water Intelligence to be lost during dissemination (GWM, 2017). Several cities in KSA, such as Riyadh, Jeddah, Jubail, Dhahran and Taif, have been cultivated with different plant species (date palms, foraging crops, landscape plants, trees, and grasses) by using recycled treated wastewater (Ouda, 2014a; 2014b). Its utilization in agriculture can save energy, and expenses and reduce the water footprint of crop cultivation. Additionally, it can minify fertilizer utilization by providing the crop needs of nutrients, and thus increasing crop productivity (Aljaloud, 2010). For example, Saudi Arabia could increase the yield of alfalfa and wheat by the utilization of treated wastewater (Aljaloud, 2010).

Jatropha curcas:

Jatropha curcas is a worldwide-distributed and highly tolerant woody tree. It is a member of the family Euphorbiaceae. This tree has multiple names in various countries of the world (*e.g.* goat nuts, physic nut, barbados nut, purging nut, and nettle spurge) (Wurdack *et al.,* 2005). *Jatropha* was reported as a native species in America (Pecina-Quintero *et al.*, 2014). *Jatropha* is greatly adapted to cultivation in several agro-climatic and stressful conditions, like arid, semi-arid conditions, lower nutrient supply, drought, and soil salinity. This plant can grow in peripheral and marginal lands (Henning, 2004; Azam *et al.*, 2005; AbouKheira and Atta, 2009; Swanberg, 2009). Also, *J. curcas* was successfully cultivated by treated wastewater. It was suggested for biofuel mass production as a substitute for eatable crops (Henning, 2004; Gamal-Fakhry *et al.,* 2016). This biofuel crop is characterized by a short life cycle, and its seeds have ≈40% oil content. *Jatropha* oil was successfully used to produce biofuel with improved characteristics which meet the international standards (Francis *et al.*, 2005; AbouKheira and Atta, 2009; King *et al.,* 2009; Divakara *et al.,* 2010). The adaptability of *Jatropha* to cultivation in harsh conditions, with the increasing global demand for renewable fuel sources, put *Jatropha* among the most promising alternative and low-cost feedstocks of biofuel crops (Arruda *et al.*, 2004).

Botanical:

The Flowering *Jatropha* tree, flowers, fruits and seeds were illustrated in Fig. (3). *Jatropha* genus is native to tropical America (Makkar *et al.*, 1998; Divakara *et al.*, 2010). It is a deciduous shrub with oily seeds. The height of a mature tree is seven to thirteen meters. *Jatropha* has green, heart-shaped, and long-necked leaves, and greenish-yellow small flowers. The green fruits turn yellowish-brown at maturity. Each fruit holds two to three black egg-shaped oily seeds (Kaushik, 2003; Brittaine and Lutaladio, 2010).

Fig. 3: Illustrating photography of: A: Flowering *Jatropha* tree, B: flowers of *Jatropha*, C: fruits of *Jatropha* and D: seeds of *Jatropha*.

Flowering and Pollination:

Generally, *J. curcas* produces unisexual flowers as usual (monoecious plant). Male (masculine) flowers may surround a centric female flower. Sometimes, few numbers of masculine flowers were recorded during the inflorescence period. All flowers open simultaneously facilitating cross-pollination to happen (Kumar *et al.,* 2017). Twice flowering per year was reported in Egypt (Soliman and He, 2015).

The floral sex ratio of *Jatropha* is crucial in seed yield (Gangwar *et al.,* 2018). Targeting genes that are responsible for increasing female flowering and/ or male flowering inhibition is a promising approach to increasing female flowering in *Jatropha* (Gangwar *et al.,* 2018).

Yield and Crop Production:

Factors influencing the crop yield of *J. curcas* are varied. The crop productivity could be increased by providing water and fertilizer needs. Water lacks and/ or insufficient nutritional supply at specific growth stages were reported to reduce crop productivity of *Jatropha* (Michael, 1978). Additionally, branching complexity and height of the shrub were regarded to increase fruits, capsules, seeds, and in turn, oil content. Previous studies concluded that seed production varied in accordance with genotype and cultivation conditions (Francis *et al.,* 2005).

Propagation:

Jatropha is cultivated in several ways including seeds, stem cutting and tissue culture (Corte-Real *et al.,* 2016). To ensure higher yield, planting materials have to be selected from well-known strong and healthy parental trees (Corte-Real *et al.,* 2016).

a) Seed Propagation:

Selection of seeds with improved characteristics like elevated oil content and high crop yield, to be cultivated in nourished nursery beds would guarantee superior germination and performance rates. This could be fulfilled by starting seedlings' growth in controlled conditions before the field plantation process (Kaushik, 2003). Other farmers preferred direct field seedlings by increasing the starting number of cultivated seeds, in order to compensate for the loss caused by the decrease in germination (Heller, 1996).

b) Vegetative or Cutting Propagation:

Propagation by cuttings is advantageous, especially in improved cultivars, because of fast establishment, higher performance rate, earlier yield, and genetic uniformity. In order to improve the production rate, cuttings of 25-40 cm, from one-year-old branches are selected and cultivated in seedbeds or polybags (Kaushik and Kumar, 2004; Achten *et al.,* 2010; Dasumiati *et al.,* 2017).

c) Tissue Culture:

Tissue culture technology is usually used in scientific research and up to our knowledge, *Jatropha* was not commercially produced by such technology.

Fertilizing:

A key factor in improved *Jatropha* productivity is the utilization of the proper fertilizers in the proper timing and quantity. Although fertilizer application has positive effects, it also increased the cost of crop rotation. To maximize process effectiveness, *Jatropha* manuring should start with adding some fertilizers to the planting pit at the cultivation time, then the proper fertilizers are applied after the full establishment of the tree. Additionally, it is essential to provide the proper quantity of NPK fertilizers (containing nitrogen, phosphorus, and potassium) to operate the entire power of *Jatropha* crop (Kumar *et al.,* 2017). Up to our knowledge, no recommended fertilization program has been established for *J. curcas*.

Irrigation:

J. curcas performance under drought-stress conditions has been investigated, extensively (Achten *et al.,* 2010). *J. curcas* could survive in arid or semi-arid environments. Additional to the very low water needs of *Jatropha*, it could reduce transpiration by leaf dropping. Meanwhile, water shortage reduced crop yield and growth measures of the tree including the development of leaves (Maes *et al.,* 2009; Genhua *et al.,* 2012).

***Jatropha* Cultivation:**

For field cultivation, 45 cm^3 pits were done in the fields and transplanted with *Jatropha* seedlings at a density of 1330 to 1600 plants/ ha (2.5m intra-tree spacing and 2.5-3m within rows). *Jatropha* grew rapidly between March and October. In autumn, trees shed leaves and remained in a hibernal dormancy till the next February (Maes *et al.,* 2009).

Climate and Soil Needs:

Jatropha could cultivate in a wide range of latitudes and altitudes (500 m above sea level). The tree grows in the optimum temperature range from 20 °C to 28 °C. However, an extremely hot climate inhibits flower fertilization and crop yield. Also, *Jatropha* could not resist the extremely cold climate.

Jatropha was successfully grown in aerated loamy sandy and heavy clay soils at ≈45cm depth (Gour, 2006). *Jatropha* was able to develop in soils with pH values of 6.0-8.5. Good drainage is necessary for the cultivation of *Jatropha* because it cannot tolerate water-saturated soils. *Jatropha* succeeded in cultivation in environments with poor-quality water supply. But these conditions have negative effects on the crop yield (Santos and Silva, 2016).

Uses of *Jatropha*:

Jatropha is a multiuse tree, having a great advantage as biofuel plants worldwide (Gour, 2006). The elevated oil content of seeds (63.2- 66.4%) made them ideal for biodiesel and biofuel production (AbouKheira and Atta, 2009). *Jatropha* seeds contain a higher oil quantity than palm kernel seeds (44.6%), linseeds (33.3%), and soybean seeds (18.6%) (Hamzah *et al.,* 2020). Furthermore, *Jatropha* oil may be utilized in saponification reactions to produce soap. Also, this oil is approved for cooking and lighting. Thus, *Jatropha* system could comprise essential quarters of rustic and regional development: providing household and rural energy needs; women's promotion via household soap production; minimizing poverty by creating job opportunities (*e.g.*, soap industry, selling seeds and oil); and control of desertification via planting hedges of *Jatropha*, which is the animal repellent plant (Francis *et al.*, 2005; Corte-Real *et al.,* 2016). In addition, centralized processing of *Jatropha* system is unnecessary (King *et al.,* 2009). Several usages for the other parts of *Jatropha* were suggested. Press cake byproduct of *Jatropha* still has a considerable amount of oil and nutritious materials. Biogas production (Augustus *et al.,* 2002), and natural fertilizers were reported from press cake (Barceloux, 2008). Additionally, the ground seed coat of *Jatropha* can be utilized for adsorbing heavy metals from wastewater (Hsu *et al.,* 2014). A diagrammatic representation of *Jatropha* system for rustic and regional development is shown in Fig. (4).

***Jatropha* Cultivation Trials Worldwide:**

Jatropha is cultivated on one million ha worldwide, from which 800,000 ha in Asia, 120,000 ha in Africa, and 20,000 ha in America (Henning, 2004). *Jatropha* is a major producer of second-generation biofuels (obtained from non-food crops and plant residuals). *Jatropha* suits cultivation in idle, marginal and degraded lands (Barceloux, 2008). This tree is a strong, rapid and easily grown, desiccation-tolerant, pest-resistant and unappetizing plant to animals. In tropical countries, hedges of *J. curcas* were constructed to protect croplands from domesticated foraging animals. Additionally, *Jatropha* could survive with minimal environmental input in extremely harsh conditions (Divakara *et al.,* 2010).

Fig. 4: Diagrammatic representation of *Jatropha* system for rustic and regional development.

***Jatropha* in Egypt:**

Keeping afforestation in Egypt addresses a number of environmental key issues. The safe and primary use of treated wastewater in reducing desertification is a major environmental issue. It is also harmonious with the increasing biomass production for potential biofuel production (A-CEAS Consulting, 2009). A starting area of 160,000 feddans in marginal desert lands is accessible for cultivating different plants. About 88,000 Feddans are appointed to hold a multi-branch company for wastewater recycling projects, and ≈11,000 Feddans are cultivated with several plants including *Jatropha* (Michael, 1978). The *Jatropha* experimental cultivation in Egypt started in 1997, using Indian seeds. Results encouraged the governmental section to expand the planted area of *Jatropha*. The cultivated area of *Jatropha* reached 100 Feddans in 2001. This area was principally drip-irrigated with treated sludge water. New Valley and Upper Egypt deserts are convenient for *Jatropha* implantation. Presently, more than 2000 Feddans of poor lands have been dedicated for *Jatropha* cultivation in Egypt (Hayder and Rakotondramanga, 2011). In addition, many feasibility studies recommended *Jatropha* be planted in poor lands of Egypt using nutritious and recycled treated wastewater, and to be a component of Egyptian strategy for renewable energy production (Gamassy, 2008; Gamal-Fakhry *et al.,* 2016). In addition, “the national program for safe use of treated sewage water for afforestation” established *Jatropha* cultivation in Upper Egypt using treated sludge water. For germinating seedlings, *Jatropha* seeds were cultivated in greenhouses using black polyethylene bags, transferred to holes 30*30*30 cm of desert soils (spacing of 3*3 m), and drip-irrigated by treated sludge water (EC 1.04 and PH 7.47), without fertilization. Higher rates of growth and productivity than other countries were reported (Gamal-Fakhry *et al.*, 2016).

Based on the previous trials which proved superior adaptability of *Jatropha* plant to grow in environments with minimal agricultural needs, and based on the availability of these needs in the Al-Jouf region, our study recommended the use of treated wastewater in the cultivation of *Jatropha* trees to maximize its multiple benefits in sustainable development programs in Al-Jouf region.

CONCLUSION

Recently, *J. curcas* tree has received the worth attention as a multiuse oil tree. It is regarded as a biofuel source and it reduces environmental pollution as well. This tree has been used to combat desertification and reduce soil degradation in arid and peripheral marginal areas. *Jatropha* may grow at altitudes of up to 500 meters above sea level and thus grow in extremely harsh conditions. It can withstand drought for a long time by shedding its leaves. Meanwhile, it grows in alkaline soil but adapts to the cold climate with less capacity. Moreover, it does not parasitize on food crops and could grow in marginal lands and produces oilseeds under the lowest amount of water and soil requirements compared to other crops. *Jatropha* also grows well with treated wastewater. Overall it is a multi-purpose plant and has various advantages like short life span, minimum water and soil requirement. Also, *Jatropha* can reduce soil degradation and desertification in arid areas.

REFERENCES

AbouKheira, A.A. and Atta, N.M.M. (2009): Response of *Jatropha curcas* L. to water deficit: yield, water use efficiency and oilseed characteristics. *Biomass and Bioenergy,* 33 (10): 1343-1350.

Achten, W.M.; Maes, W.H. and Reubens, B. (2010): Biomass production and allocation in *Jatropha curcas* L. seedlings under different levels of drought stress. *Biomass and Bioenergy,* 34(5): 667-676.

Agra CEAS Consulting (2009): Potential for Biofuel Production in FEMIP Countries FTF/REG/04/2006. European Investment Bank, Luxembourg.

Aljaloud, A.A. (2010): Reuse of wastewater for irrigation in Saudi Arabia and its effect on soil and plant. The 19^{th} World congress of soil science, soil solutions for a changing world, Brisbane, Australia.

Al-Saud, M.I. (2013): Ministry of Water and Electricity, National water strategy: The roadmap for sustainability, efficiency, and security of water future in the KSA National water strategy, A presentation for Water Arabia, 2013. www.sawea.org/pdf/waterarabia2013/Tue_Panel_Discussion/National_Water_Strategy.pdf.

Alsharhan, A.S.; Fowler, A.; Goudie, A.S.; Abdellatif, E.M. and Wood, W.W. (2003): Desertification in the third millennium. Lisse Balkema. Pp: 151-172.

Arruda, F.P.; Macedo, B.N.; Pereira, A.A.; Pereira, W. and Soares, S.L. (2004): Cultivation of pine nut (*Jatropha curcas*) as an alternative to the northeastern semiarid. *Rev Bras OlFibros,* 8(1): 789-799 (article in *Spanish*).

Augustus, G.D.; Jayubalan, M. and Seiler, G.J. (2002): Evaluation and bioinduction of energy components of *Jatropha curcas. Biomass and Bioenergy,* 23: 161-164.

Azam, M.M.; Waris, A. and Nahar, N.M. (2005): Prospects and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. *Biomass and Bioenergy,* 29: 293-302.

Barceloux, D.G. (2008): Medical toxicology of natural substances foods, fungi, medicinal herbs, plants, and venomous Animals. John Wiley & Sons, Inc.: Hoboken, NJ, USA.

Brittaine, R. and Lutaladio, NB. (2010): *Jatropha*: a small holder bioenergy crop. *Integrated Crop Management,* 8: 1-96.

Chowdhury, S. and Al-Zahrani, M. (2013): Implications of climate change on water resources in Saudi Arabia. *Arabian Journal for Science and Engineering*, 38(8): 1959-1971.

Corte-Real, N.; Endres, L.; Santos, K.P.O.; Figueirêdo, R.C.B.; Arruda, E.C.P. and Ulisses, C. (2016): Morphoanatomy and ontogeny of the fruit and seeds of *Jatropha curcas* L.: A promising biofuel plant. In: Segura-Campos, M.R.; Betancur-Ancova D. editors. The Promising Future of *Jatropha curcas*: Proprieties and potential applications. Hauppauge, NY: Nova Science Publishers, Inc. Pp: 141-58.

Dasumiati, M.; Triadiati, T. and Hartana. A. (2017): Sex types in flowering of *Jatropha curcas*. *Biodiversitas*, 18(1): 442-446.

Divakara, B.N.; Upadhyaya, H.D.; Wani, S.P. and Laxmipathi, G.C.L. (2010): Biology and genetic improvement of *Jatropha curcas L.*: a review. *Applied Energy*, 87(3): 732-742.

Enssle, C. and Freedman, J. (2017): Addressing water scarcity in Saudi Arabia: policy options for continued success. www.suezwatertechnologies.com.

Francis, G.; Edinger, R. and Becker, K. (2005): A concept for simultaneous wasteland reclamation, fuel production, and socioeconomic development in degraded areas in India: need, potential and perspectives of Jatropha plantations. *Natural Resources Forum*, 29(1): 12-24.

Gamal-Fakhry, M.; Azazz, N.A.E.; Abdel-Monem, A. and Mohamedin, A. (2016): Use of waste water and treated water for *Jatropha curcas* cultivation and the possibility of oil seed use as a biofuel. *Minia Journal of Agricultural Research and Development*, 36(2): 245-269.

Gamassy, D.I.E. (2008): Feasibility Study on Growing *Jatropha* Utilizing Treated Wastewater in Luxor. International Resources Group, Washington DC.

Gangwar, M.; Shankar, J. and Chauhan, R.S. (2018): Genomics of Female Flowering and Seed Yield in *Jatropha curcas* L. Ph.D. Thesis, Jaypee University of Information Technology, Solan.

General Authority for Statistics (2016): Percentage of water extracted or produced from fresh water by source (surface, underground, desalinated, treated) in Saudi Kingdom in 2010-2016. Available at: https://www.stats.gov.sa

General Authority for Statistics (2018): Environmental indicators. Statistics on water resources of Saudi Arabia. Available at: https://www.stats.gov.sa/en/node/10131.

Genhua, N.; Rodriguez, D.; Mendoza, M.; Jifon, J. and Ganjegunte, G. (2012): Responses of *Jatropha curcas* to Salt and Drought Stresses. *International Journal of Agronomy*, 2012: 1-7.

Global Water Market (2017): Meeting the world's water and wastewater needs until 2020. Volume 4: Middle East and Africa. Saudi Arabia, Pp: 1379-1385.

Gour, V.K. (2006): Production Practices Including Postharvest Management of *Jatropha curcas*. "Toward Energy Independence-Focus on Jatropha", edited by Singh, B.; Swaminathan, R. and Ponraj V., Proc. of the Biodiesel Conference, 223-251. New Delhi, India: Rashtrapati Bhawan.

Hamzah, N.H.C.; Khairuddin, N.; Siddique, B.M. and Hassan, M.A. (2020): Potential of *Jatropha curcas* L. as Biodiesel Feedstock in Malaysia: A Concise Review. *Processes,* 8: 786.

Hayder, M. and Rakotondramanga, S. (2011): Oil Trees for Energy in the near East Region. Food and Agriculture Organization, Cairo.

Heller, J. (1996): Physic nut *Jatropha curcas* L. Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research (IPGRI), Gatersleben/International Plant Genetic Resources Institute, Rome, Italy, Pp: 66.

Henning, R.K. (2004): The *Jatropha* system: An integrated approach of rural development." Working paper, Bagani GBR, Weissensberg, Germany, 2004".

Hsu, S.; Huang, C.; Chung, T.W. and Gao, S. (2014): Adsorption of chlorinated volatile organic compounds using activated carbon made from *Jatropha curcas* seeds. *Journal of the Taiwan Institute of Chemical Engineers*, 45(5): 2526-2530.

Kajenthira, A.; Siddiq, A. and Anadon, L.D. (2012): A new case for promoting wastewater reuse in Saudi Arabia: bringing energy into the water eq. *Journal of Environmental Management*, 102: 184-192.

Kaushik, N. (2003): Effect of capsule maturity on germination and seedling vigour in *Jatropha curcas. Seed Science and Technology,* 31: 449-454.

Kaushik, N. and Kumar, S. (2004): *Jatropha curcas* L. Silviculture and Uses. Agrobios (India), Jodhpur.

King, A.J.; Wei, H.; Cuevas, J.A.; Freudenberger, M.; Ramiaramanana, D. and Graham, I.A. (2009): Potential of *Jatropha curcas* as a source of renewable oil and animal feed. *Journal of Experimental Botany,* 60(10): 2897-2905. https://doi.org/ 10.1093/jxb/erp025.

Kumar, A.A.; Patil, N.S.; Kumar, R. and Mandal. D. (2017): Irrigation Scheduling and Fertilization Improves Production Potential of *Jatropha (Jatropha curcas). International Journal of Current Microbiology and Applied Sciences,* 6(5): 1703-1716.

Lippman, T.W. (2014): Biggest Mideast crisis: Growing water scarcity. Business Mirror. Available at: http://www.ipsnews.net/2014/05.

Maes, W.H.; Achten, W.M.; Reubens, B.; Raes, D.; Samson, R. and Muys, B. (2009): Plant-water relationships and growth strategies of *Jatropha curcas* L. seedlings under different levels of drought stress. *Journal of Arid Environments*, 73(10): 877-884.

Makkar, H.P.S.; Aderibigbe, A.O. and Becker, K. (1998): Comparative evaluation of non-toxic and toxic variety of *jatropha curcas* for chemical composition, digestibility, protein degradability and toxic factors. *Food Chemistry*, 62(2): 207-215.

Michael, A.M. (1978): Crop response to water at different stages of growth. Irrigation theory and practice, Vikas publishing house Pvt. Ltd. Pp: 560.

National Water Company (2016): Ministry of Environment, Water and Agriculture, National Water Strategy. Available at: https://mewa.gov.sa/en/ Ministry/ Pages/default.aspx.

National Water Company (2018): National Water Company. Treated waste effluent. Available at: https://www.nwc.com.sa/Arabic/Pages/default.aspx.

Ouda, O.K. (2014a): Impacts of agricultural policy on irrigation water demand: A case study of Saudi Arabia. *International Journal of Water Resources Development*, 30(2): 282-292.

Ouda, O.K. (2014b): Water demand versus supply in Saudi Arabia: Current and future challenges. *International Journal of Water Resources Development*, 30(2): 335-344.

Pecina-Quintero, V.; Anaya-López, J.L.; Zamarripa-Colmenero, A. and Núñez-Colín, C.A. (2014): Genetic structure of *Jatropha curcas* L. in Mexico and probable centre of origin. *Biomass and Energy,* 60: 147-155. http://dx.doi.org/10.1016/j. biombioe. 2013.11.005.

Rambo, K.A.; Warsinger, D.M.; Shanbhogue, S.J. and Ghoniem, A.F. (2017): Water-energy Nexus in Saudi Arabia. *Energy Procedia,* 105: 3837-3843.

Santos, M.R. and Silva, M.J. (2016): Growth and development of *Jatropha curcas* seedlings using Terracotem soil conditioners under different irrigation levels. *Emirates Journal of Food and Agriculture*, 28(5): 326-331.

Saudi Arabia Water Report-Q4 (2013): In: Saudi Gazette (2016a): Business Monitor International, New water tariff to be acceptable to all: Fadli. http://saudigazette.com.sa/article/155166/New-water-tariff-to-be-acceptable-to-all-Fadli.

Scotney, T. (2014): Global Water Market 2014 (Saudi Arabia), Global Water Intelligence (GWI), Media Analytics Ltd., April 2013. Also see: KAUST, 2010-11, Staff writer. Water Resources. Royal embassy of Saudi Arabia, Washington, DC. Available at: https://www.saudiembassy.net/about/country_information/agriculture_water/Water_Resources.aspx.

Soliman, W.M. and He, X.R. (2015): The Potentials of *Jatropha* Plantations in Egypt: A Review. *Modern Economy*, 6: 190-200. http://dx.doi.org/10.4236/me.2015.62016.

Swanberg, K. (2009): Economic Feasibility of Alternative Crops with Potential for the Reuse of Treated Waste water in Egypt. International Resources Group, Washington DC.

Toze, S. (2004): Reuse of effluent water benefits and risks. “New directions for a diverse planet.” In: Proceedings of the 4th international crop science congress, Brisbane, Australia.

U.S. Department of Energy (2017): The State of the Environment, Responsibilities and achievements, The Water-Energy Nexus: Challenges and Opportunities, Department of Energy. Available: http://www.energy.gov/downloads/water-energy-nexus-challenges-and-opportunities.

Wilderer, P.A. and Schreff, D. (2000): Decentralized and centralized wastewater management: A challenge for technology developers. *Water Science and Technology*, 41(1): 1-8.

Wurdack, K.J.; Hoffmann, P. and Chase, M.W. (2005): Molecular phylogenetic analysis of uniovulate euphorbiaceae (*euphorbiaceae sensustricto*) using plastid RBCL and TRNL-F DNA sequences. *American Journal of Botany*, 92(8): 1397-1420.