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Response of *Jatropha curcas* L. to water deficits: Yield, water use efficiency and oilseed characteristics

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ABSTRACT

Field experiment was carried out at Enshas Experiment Station; *Jatropha* was transplanted and treated after the second year of the transplanting by different amounts of water stress, viz. 125%, 100%, 75% and 50% of potential evapotranspiration (ETp). The study aims to ensure the multiple benefits of *Jatropha* and its suitability under Egypt's climate in unused lands under scarce water conditions. The results revealed that the average water consumption rate of *Jatropha* is 6 L week^{-1} throughout the growing season, which means that *Jatropha* can survive and produce full yield with high quality seeds under minimum water requirements compared to other crops. The yield of extracted oil was 28.69, 58.39, 30.17 and 22.15 kg ha^{-1} at 125%, 100%, 75% and 50% of ETp, respectively. The lowest values of total lipid (oil) (25% and 24.5% of *Jatropha* seeds) were recorded with *Jatropha* trees that were irrigated by 125% and 50% of ETp, respectively. On the other hand, the treatment that was irrigated by 100% of ETp (control) recorded the highest value of total oil in the seeds (29.93%). The results also revealed that there are no significant differences among the values of the determined oil characteristics due to different water stress ratios. From the results, it could be concluded that the highest characteristics of *Jatropha* seed oil were recorded with 100% of ETp. In addition water stress had no significant effect on the fatty acid composition of *Jatropha* seed oil.

1. Introduction

One of the main crops currently being promoted for biodiesel production in several countries, globally, is *Jatropha curcas* (Linnaeus). There have been substantial political and social pressures to promote the growing of such crops in many countries of the world, as a means of economic empowerment, social uplifting and poverty alleviation within marginalized communities. *Jatropha* is a valuable multi-purpose crop to alleviate soil degradation, desertification and deforestation, which can be used for bio-energy to replace petro-diesel, for soap production and climatic protection, and hence deserves specific attention. *Jatropha* can help increase rural income, self-sustainability and alleviate poverty in women, elderly, children, men, tribal communities and small farmers. It can help as well to increase income from plantations and agro-industries [1].

Jatropha oil cake is rich in nitrogen, phosphorous and potassium and can be used as organic manure [2]. The *Jatropha* oil can be used for soap and cosmetics production in rural areas and all parts of the plant have traditional medicinal uses (both human and veterinary purposes) that are being scientifically investigated. The oil is a strong purgative, widely used as an antiseptic for cough, skin diseases, and a pain reliever from rheumatism. *Jatropha* latex can heal wounds and also has antimicrobial properties. *Jatropha* oil is an important

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product from the plant for meeting the cooking and lighting needs of the rural population, boiler fuel for industrial purposes or as a viable substitute for diesel [3].

Jatropha is easy to establish, grows relatively quickly and is hardy. Being drought tolerant, it can be used to reclaim eroded areas, grown as a boundary fence or live hedge in the arid and semi-arid areas [3–5]. While *Jatropha* grows well in low rainfall conditions (requiring only about 200 mm of rain to revive) it can also respond to higher rainfall (up to 1200 mm) particularly in hot climatic conditions. In Nicaragua for example, *Jatropha* grows very well in the countries under hot climate with rainfall of 1000 mm or more. *Jatropha* is found in the tropics and sub-tropics and likes heat, although it does well even in lower temperatures and can withstand a light frost. *Jatropha* water requirement is extremely low and it can stand long periods of drought by shielding most of its leaves to reduce transpiration loss [2].

Jatropha can handle dryness very well and it is possible to live almost entirely off humidity in the air [1]. Differences are expressed in what is optimum rainfall as some readings say 600 mm and some say 800 mm, while some areas in India reported good crops with rainfall of 1380 mm. Under irrigation 1500 mm, 500–600 mm of rainfall is the limit; below which the production depends on the local water condition in the ground. It will also survive for long periods without water – up to 2 years – and then grow again when rain occurs. During a dry period, the crop is irrigated at 7–15 day interval depending on the requirement. Though the weekly irrigation is preferable, a fortnight interval is compulsory. Drip irrigation is not ideal as it induces too much vegetative growth [6].

The number of *Jatropha* trees per hectare of planting will range from 1600 to 2200; wider spacing is reported to give a larger yield of fruit, 794 kg ha^{-1} and 318 g $shrub^{-1}$ [7]. In equatorial regions where moisture is not a limiting factor (i.e., continuously wet tropics or under irrigation), *Jatropha* can bloom and produce fruit year long. A drier climate has been found to improve the oil yield of the seeds, thought to withstand times of extreme drought. The *Jatropha* plant will shed leaves in an attempt to conserve moisture, which results in somewhat decreased growth [8].

Analysis of the unsaponifiable matter of *Jatropha* oilseed by GLC technique shows that it contained 40.40% and 32.05% total hydrocarbons and 59.60% and 64.63% total sterols in first and second harvest, respectively. However, the squaline compound was the highest amount of total hydrocarbons (17.75% and 14.88%) while β-sitosterol was the major component or compound of total sterols (46.78% and 43.57%) in first and second harvest, respectively. The predominant unsaturated fatty acid of *Jatropha* oilseed was oleic acid also and the major saturated fatty acid was palmitic acids [9]. The chemical composition of *Jatropha* seeds cultivated in Egypt was moisture (6.20%), protein (18.0%), fat (38.0%) carbohydrates (17.0%) fiber (15.5%) and ash (5.3%) [2].

The overall goal of this study is to investigate the potential of cultivating and disseminating of *Jatropha* as a promising source of biodiesel in Egypt. The specific objectives are to study the effect of water stress on the yield and water use efficiency of *Jatropha* and to measure oilseed physical and chemical characteristics as affected by deficit irrigation.

2. Materials and methods

The field experiment was conducted at Enshas Experiment Station (EES), Water Management Research Institute (WMRI), National Water Research Center (NWRC), Ministry of Water Resources and Irrigation (MWRI), Sharkiya Governorate, Egypt.

2.1. Experimental site

The experimental site had the following characteristics: longitude 31.35° E, latitude 30.24° N and altitude 25.5 m. The soil texture is sandy with field capacity of 8.04%; wilting point 3.7%, soil bulk density of 1.49 g cm^{-3} and infiltration rate 12.47 cm h^{-1}. The irrigation water source was surface water (Al-Esmaliya Canal). The chemical analysis of irrigation water is presented in Table 1 and soil physical and chemical properties are shown in Tables 2 and 3.

2.2. Experimental procedure

Jatropha transplantings were obtained from the Ministry of Agriculture, Egypt, where the transplanting department cultivated the *Jatropha* cuttings in small pots under a greenhouse and then moved it to the open field. The *Jatropha* transplant height was 1 m before transplanting. *Jatropha* was transplanted on 12/3/2003 and was irrigated by Microsprinkler irrigation system, one sprinkler for each tree (Fig. 1). *Jatropha* trees were treated by different irrigation water amounts, which were 125%, 100%, 75% and 50%, of the potential evapotranspiration (ETp). The trees were planted 2 m apart on the row with 2 m in spacing between rows. The trees were irrigated directly after transplanting. The recommended dozes of fertilizer, weed and pest control by the Ministry of Agriculture were applied to the trees, where farmyard manure and NPK were added to the planting hole and yearly top dressings of fertilizers. The weeds controlled manually and the recommended dozes of the pesticides were applied two times during flowering and at the end of the season. Each

Table 1 – Chemical analysis of the water used in irrigation of Jatropha during the growing season of 2005 at Enshas, Sharkiya, Egypt.

pH	EC (dS m^{-1})	Cations (meq L^{-1})				Anions (meq L^{-1})				SAR[a]
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	
7.55	0.38	1.8	0.67	1.04	0.15	–	3.38	0.56	0.13	0.99

a SAR = sodium adsorption ratio.