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Research Article

Biometric Development of *Jatropha Curcas* Subjected to Different Irrigation Systems and Depths

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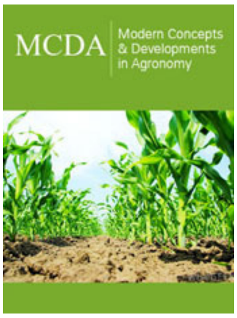

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Abstract

The objective of this experiment was to evaluate the vegetative development of *Jatropha curcas* under different irrigation depths and to compare two irrigation systems. The experiment was carried out at the EPAMIG Experimental Field in Jaíba, municipality of Jaíba, MG, Brazil. *Jatropha curcas* was planted by seeds in holes of 0.75x0.75m with depth of 0.5m at spacing of 4x2m. The experimental design was randomized in three blocks with 10 treatments, in 2x5 factorial, with two irrigation systems (micro-sprinkler and trickle irrigation) and five irrigation depths (40%, 60%, 80%, 100% and 120% of reference evapotranspiration). There were two evaluations, with one and two years after planting, when stem diameter and plant height were measured. Over the years there was a trend of increase in stem diameter and plant height with increasing water depth, and the best results were obtained with irrigation depths corresponding to 100% and 120% of reference evapotranspiration. Trickle irrigation system was better for *Jatropha curcas* development.

Keywords: Jatropha; Reference evapotranspiration; Trickle irrigation; Micro-sprinkler

Introduction

After the oil crisis in the 1970s, which raised awareness about the high degree of pollution caused by fossil fuels (oil and coal), and the current concern about the greenhouse effect and global warming, the use of vegetable oils for fuel purposes became one of the immediate solutions, and *Jatropha curcas* aroused interest from producers, the government and research institutions, for being a very promising source [1,2].

This species develops well in both dry tropical regions and humid equatorial areas, in addition to arid and rocky soils, reaching an average height of 2 to 3m and average stem diameter of 0.20m. It is found from sea level up to 1,200m altitude and can withstand long periods of droughts [3]. In regions with water scarcity and poor soils, such as semi-arid ones, the development of crops in general, as well as *J. curcas*, can be compromised. In these regions it is necessary to resort to the use of irrigation. Veras et al. [4] state that the use of irrigation will ensure increased production. Carvalho et al. [5] indicate 735mm as a sufficient water depth to produce 3.52kgm^{-3} in the city of Crateús in the State of Ceará. However, the collection of this information is still little explored and lacks further studies in other regions and scenarios.

According to Oliveira et al. [6], and later corroborated by Padilha et al. [7], the agronomic aspects of *J. curcas* require investigation, since the available literature on this crop is insufficient, and there are no defined cultivars [2]. Padilha et al. [7] conducted tests in the initial stage and found a positive effect of irrigation on plant height, which showed an exponential response at 42 DAE, that is, the higher the availability of water, the greater the plant growth.

Teixeira [8] cites *J. curcas* yield of 5t ha^{-1} and mentions references of up to 12t ha^{-1} as long as the conditions are favorable. Considering the climatic conditions of northern Minas Gerais with a hot and dry climate, with average precipitation around 800mm, but with low regularity, the production with water supply via irrigation may show a behavior very different from that obtained under rainfed regime, with development, yield and longevity better than those known to date.

Based on the assumption that, for a crop to obtain satisfactory production, making it viable, it is necessary to have a good biometric development (stem diameter and plant height), the objective of this study was to evaluate the vegetative development of *J. curcas* subjected to different irrigation depths and to compare two localized irrigation systems.

Material and Methods

The experiment was conducted in an open environment, from October 2007 to February 2010, in the Experimental Field of Jaíba (CEJA), located in the municipality of Jaíba, belonging to EPAMIG Norte, in Nova Porteirinha, MG, Brazil. The characteristics of the site are average annual temperature of 28 ºC, average annual rainfall ranging from 750 to 800mm, alternately dry and humid tropical climate, altitude of 483.2m, latitude of 15º16'20" S, longitude of 43º40'23" W and wind from southeast to northwest, with climate classified as Aw (tropical savannah), according to Köppen [9].

Jatropha curcas L. was sown on October 18, 2007, by means of seeds in holes of 0.75x0.75m and at depth of 0.5m at spacing of 4x2m. The soil of the locality is classified as *Latossolo vermelho distrófico* (Oxisol), chemically corrected based on soil analysis (Tables 1&2).

Table 1: Soil chemical analysis (macronutrients).

Layer (m)	pH[1]	OM[2]	P[3]	K[3]	Na[3]	Ca[4]	Mg[4]	Al[4]	H+Al[5]	SB	t	T	V	m
		dag/Kg	---mg/dm³--		-----------------------------cmolc/dm³-------------------------								-------%----	
0 - 0.2	5.9	3.1	8.6	188	0.2	6.6	1.2	0	2.1	8.4	8.4	10.5	80	0
0.2 – 0.4	6.1	2.3	4.5	69	1.2	6.6	1.7	0	1.9	8.7	8.7	10.6	82	0

Table 2: Soil chemical analysis (micronutrients).

Layer (m)	B[6]	Cu[3]	Mn[3]	Zn[3]	S[7]	Prem[8]	EC
	mg/dm³					mg/L	dS/m
0-0.2	0.7	1.5	8	111	3.1	21.7	1.3
0.2-0.4	0.8	1.5	8.3	119.8	1.9	20.2	0.7

1/pH in water; 2/Colorimetry; 3/Extractant: Mehlich-1; 4/Extractant: 1 mol/L KCl; 5/pH SMP; 6/Extractant: $BaCl_2$; 7/Extractant: Ca (H_2PO_4), 500mg/L of P in 2mol/L HOAc; 8/P equilibrium solution; SB, sum of bases; t, effective CEC; T, CEC at pH 7; V, Base saturation; m, Aluminum saturation; P-rem, Remaining phosphorus; EC, electrical conductivity. Dag/kg = %; mg/dm³ = ppm; cmolc/dm³ = meq/100 cm³.

Soil tillage was performed in July and August 2007, when plowing, subsoiling and harrowing were performed. Then furrows were opened with a subsoiler, at a depth of 0.5m. The soil of the experimental area was sampled at depths of 0.2 and 0.4m and then sent to the EPAMIG laboratory located in Nova Porteirinha, MG, for soil analysis.

Basal fertilization was performed with MAP, FTE BR-12 and bovine manure. The compounds applied were urea, ammonium sulfate and potassium chloride. Four seeds were sown per hole at a depth of 0.02m and covered with soil. Ten days after germination of the seedlings, thinning was performed, leaving one plant per hole. Top-dressing fertilization was performed at 30 days after planting.

An automatic weather station located 360 meters from the experimental area was mainly used to collect rainfall data, which were essential for irrigation management. Irrigation management was carried out using reference evapotranspiration (ETo) data obtained daily from evaporation of the class A pan. Data were collected using a portable computer, and an electronic spreadsheet was used to calculate the depths necessary for irrigation. The experimental design was randomized with two treatments (irrigation system and depth), in a 2x5 factorial, with three replicates. The irrigation systems and depths were randomized within each block.

The two irrigation systems were: micro-sprinkler, with one emitter for every two plants and flow rate of 47Lh^{-1}, located at 1.0m from the trunk, and drip, with one line of emitters and flow rate of $2Lh^{-1}$ spaced apart by 0.60m, forming a wet strip along the planting row. The plots were composed of 12 plants (totaling $96m^2$) and eight plants were considered as useful plot. Regarding the irrigation depths, five levels were applied, referring to the values of ETo and multiplicative coefficients, being equal to 40% (L1), 60% (L2), 80% (L3), 100% (L4) and 120% (L5) of ETo. On average, 2.51mm day^{-1} in L1, 3.80mm day^{-1} in L2, 5.11mm day^{-1} in L3, 6.46mm day^{-1} in L4 and 7.84mm day^{-1} in L5 of water were applied during the 847 days of the experiment.

Vegetative (biometric) evaluations performed in the field were: stem diameter and plant height

Stem diameter was measured in the first evaluations using a caliper and later a tape measure. It was found that, over the months, stem diameter became more uneven, thus making the use of the caliper impossible; after some time, a metal tape measure needed to be used to better characterize it, measuring in this case the circumference and transforming it to diameter.

Regarding plant height, it was measured with a tape measure and graduated ruler, from the soil to the last leaf of each plant. Two evaluations were performed, the first one on January 27, 2009 (455 DAP), and the second one on February 9, 2010 (850 DAP). Analysis of variance by the F test, the Scott Knott's means comparison tests at 5% significance level and the regression analyses were performed with the computational application SISVAR [10].

Result and Discussion

The results of the analysis of variance (ANAVA) for stem diameter under drip and micro-sprinkler irrigation depths are found in Table 3. As can be observed, in the first evaluation there was a significant effect (P<0.05), by the F test, of the irrigation depth (% ETo) on stem diameter and there was no significant effect (P<0.05) of the interaction between irrigation depths and irrigation systems. In the second evaluation, there was no significant effect (P>0.05) for irrigation depths and for the interaction between irrigation depth and system. In the individual analysis of irrigation systems, there was no significant effect (P>0.05) on the stem diameter of *J. curcas* in the first evaluation. In the second evaluation, there was a significant effect (P<0.05) of the irrigation systems on stem diameter, which was confirmed by the Scott-Knott test (Table 4), in which the plants under drip irrigation obtained an average of 0.1976m and those irrigated by micro-sprinkler obtained an average of 0.1875m.

Table 3: Analysis of variance for the stem diameter of *Jatropha curcas* under drip and micro-sprinkler irrigation depths.

SV	Pr > Fc	
	01/27/2009	02-09-10
Depth	0.0292*	0.6077ns
System	0.0568ns	0.454*
Depth* System	0.1752ns	0.5082ns
CV (%)	13.34	14.12

(*) significant at 5% probability level, by the F test.
(**) significant at 1% probability level, by the F test.

(ns) not significant at 5% probability level, by the F test.

Table 4: Stem diameter as a function of drip and micro-sprinkler irrigation systems.

Systems	Means (cm)	
	01/27/2009	02-09-10
Drip	0.0520 A	0.1976 A
Micro-sprinkler	0.0496 A	0.1875 B

Means followed by the same letter in the column do not differ by the Scott-Knott test at 5% significance level.

The ANAVA data of the regression of the irrigation depths for stem diameter data (Table 5) show that in the first evaluation there was a significant linear effect (P<0.05) of irrigation depths on stem diameter, with no significant quadratic effect and deviation (P>0.05). Albuquerque et al. [11], evaluating the stem diameter of *J. curcas*, found that the linear effect is the one that best fits to the levels of water available in the soil, corroborating the results of the present study.

Table 5: Analysis of stem diameter regression models for irrigation depth in micro-sprinkler and drip systems.

Causes of variation	01/27/2009		02-09-10	
	Pr > Fc	R^2	Pr > Fc	R^2
X	0. 0200*	50.05%	0. 337^{ns}	34.18%
X^2	0.1310^{ns}	70.65%	0.413^{ns}	59.09%
Deviation	0.1970^{ns}		0.575^{ns}	

(*) significant at 5% probability level, by the F test; (**) significant at 1% probability level, by the F test; (ns) not significant at 5% probability level, by the F test. (X) linear model; (X^2) quadratic model.

Except for the irrigation depth corresponding to 40% ETo, there was an increase in stem diameter with the increase in irrigation depth (Figure 1), and the best results were obtained with irrigation depths corresponding to 100 and 120% ETo, indicating that greater depths in the first year of planting have a positive effect on the stem development of *J. curcas* plants, so the use of these irrigation depths is recommended.

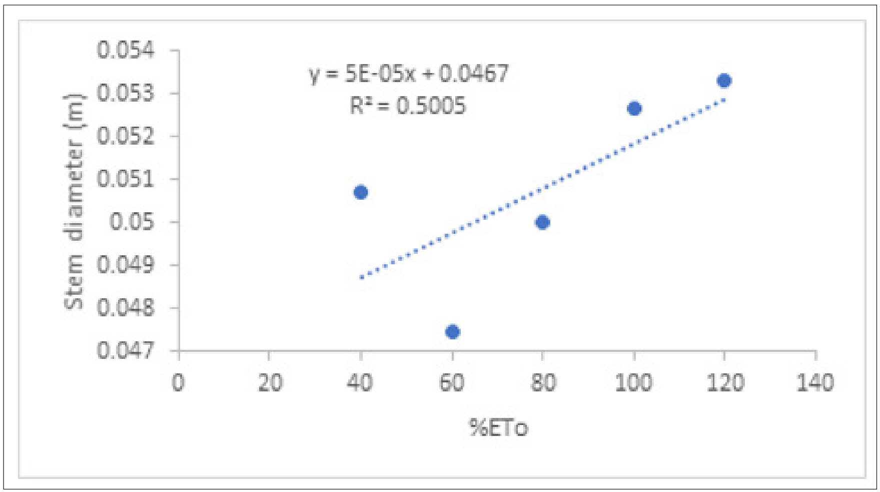

Figure 1: Regression analysis for stem diameter as a function of irrigation depths with one year and three months after planting for both drip and micro-sprinkler systems.

Regarding plant height (Table 6), in the first evaluation there was a significant effect, by the F test ($P<0.05$), of the irrigation depths, and there was no significant effect ($P>0.05$) of the interaction between irrigation depths and systems. In the second evaluation, there was no significant interaction and effect of the irrigation depths on plant height. In the analysis of plant height, regarding the irrigation system, there was a highly significant effect ($P<0.01$) for the first evaluation and a significant effect ($P<0.05$) for the second evaluation. As for stem diameter, the results found with the use of the drip system were higher than those found with the use of micro-sprinkler in the evaluation of plant height (Table 7).

Table 6: Analysis of variance for height of *Jatropha curcas* plants under micro-sprinkler and drip irrigation depths.

SV	Pr > Fc	
	01/27/2009	02-09-10
Depth	0.0464*	0.2952^{ns}
System	0.0067**	0.0319*
Depth*System	0.0739^{ns}	0.6796^{ns}
CV(%)	8.36	6.98

(*) significant at 5% probability level, by the F test.

(**) significant at 1% probability level, by the F test.

(ns) not significant at 5% probability level, by the F test.

Table 7: Plant height as a function of drip and micro-sprinkler irrigation systems.

Systems	Means (m)	
	01/27/2009	02-09-10
Drip	2.9050 A	4.2692 A
Micro-sprinkler	2.7850 A	4.1526 B

Means followed by the same letter in the column do not differ by the Scott-Knott test at 5% significance level.

According to the regression analysis, there was a highly significant linear effect (P<0.01) in the first evaluation (Table 8), with no significance for the quadratic effect and deviation of regression. Thus, the linear model explains the variation in plant height found in this period. Plant height (Figure 2) increased with the increment in irrigation depth, and the one corresponding to 40% ETo led to the lowest plant height, while the irrigation depths of 100% and 120% ETo, as also observed for stem diameter, resulted in superior results, showing that higher irrigation depths positively influence the first year of planting.

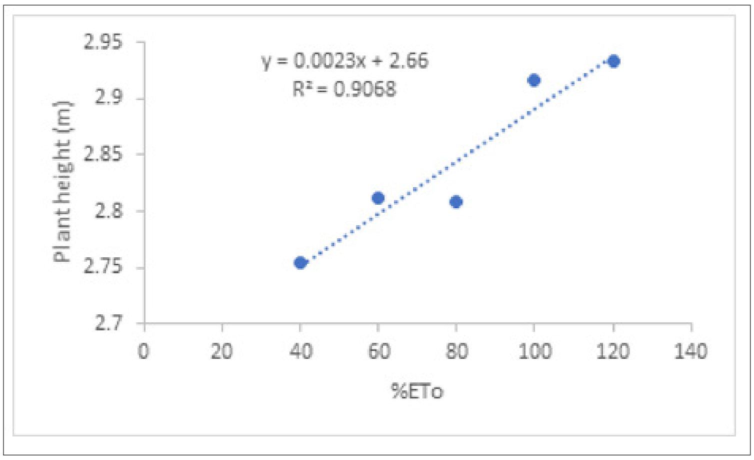

Figure 2: Regression analysis for plant height as a function of irrigation depths one year and three months after planting for both drip and micro-sprinkler systems.

Table 8: Analysis of plant height regression models for irrigation depth.

Causes of Variation	01/27/2009		02-09-10	
	Pr > Fc	R2	Pr > Fc	R2
X	0.0030**	90.68%	0.3600^{ns}	16.92%
X^2	0.8730^{ns}	90.93%	0.0980^{ns}	72.89%
Deviation	0.6360^{ns}		0.5100^{ns}	

(*) significant at 5% probability level, by the F test; (**) significant at 1% probability level, by the F test; (ns) not significant at 5% probability level, by the F test. (X) linear model; (X^2) quadratic model.

Albuquerque et al. [11], working with water available in the soil, found a linear response for *J. curcas* plant height as a function of the amount of water available in the soil. Drumond et al. [3] obtained results close to 3.00m under irrigation and 1.60m under rainfed conditions, results that are close to those found in the present study, whose evaluation was carried out exactly one year and three months after planting. These authors studied the agronomic performance of *J. curcas* genotypes cultivated in the municipality of Santa Maria da Boa Vista (Pernambuco), under drip irrigation, and found that the plants had average heights of 1.3m at three months of age and 2.59m at 12 months, showing a similarity with the results obtained with the present study in the evaluations performed approximately one year after planting.

Conclusion

1. Stem diameter and plant height tend to stabilize regardless of the irrigation depth.
2. The best results of the biometric development of *J. curcas* were observed in the drip irrigation system, which should be preferred over the micro-sprinkler system; however, before its recommendation, the region and soil need to be characterized accurately, as well as the quality of water.

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