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Irrigation history and pruning effect on growth and yield of jatropha on a plantation in southeastern Brazil

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Jatropha is an oilseed culture that has been highlighted due some specific agronomic aspects. This plant produces high oil quantities in its seeds that is used for biodiesel production. One of the major challenges regarding to the Jatropha cultivation is the lack of information on many management techniques, especially the irrigation and pruning management in adult plants in southeastern Brazil. The objective of this study was to study the combined effect of irrigation history and different pruning on Jatropha plant growth and yield. The experiment was conducted during the 4th year of Jatropha growing season at University of Sao Paulo experimental area in Piracicaba, Brazil. The experiment was arranged in randomized block with four replications and treatments were considered the pruning type: No pruning (P1), pruning at 1.5 m high and 2 m canopy diameter (P2), pruning at 2 m high and 2 m canopy diameter (P3). In addition, two water conditions were also evaluated: Irrigated (I) and rainfed conditions (R). Plant growth (height and canopy diameter) and leaf area index (LAI) were evaluated monthly and productive variables were determined at the end of the experiment. Irrigation history influenced canopy diameter, absolute growth rates for plant height and canopy diameter, the relative growth rate for canopy diameter, and all productive variables. Pruning provided differences in all growth variables, where P2 presented the highest average on plant growth rates. The plants under irrigation history conditions showed the highest yield.

Key words: *Jatropha curcas* L., oilseeds, center pivot, water management, biofuels.

INTRODUCTION

The bioenergy exploitation from the biofuels production has become part of the global sustainable development agenda and has received scientific and commercial attention. Bioethanol and biodiesel are considered the

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most important liquid biofuels used and they are derived mainly from agricultural crops such as sugar cane and corn for ethanol, and oilseed for biodiesel (Ye et al., 2009; Jingura, 2011).

One of the alternatives for biodiesel production is Jatropha (*Jatropha curcas* L.), a culture with promising potential of feedstock supply for energy generation. This oilseed belongs to the Euphorbiaceae family and is native from Mexico and Central America, also cultivated in many other countries in Latin America, Asia and Africa (Mishra, 2009). Jatropha is a perennial plant which has attributes such as fast growth, develops in marginal areas and in different rainfall conditions. Its seeds produce viscous oil which can be used as feedstock for cosmetics industry and, more importantly, for biodiesel production (Jongschaap et al., 2007; Kumar and Sharma, 2008; Sujatha et al., 2008).

There is many conflicting information about Jatropha water requirement and the influence of irrigation management on the plant development. According to Behera et al. (2010) and Srivastava et al. (2011), the irrigation frequency does not affect significantly the Jatropha growth, however, Openshaw (2000) reports that this plant increase production with irrigation, also allowing from three to four harvests per year. Despite of Jatropha is considered a water drought tolerant, in some cases water is a limiting factor for an adequate production, which requires regular irrigation during the dry season (Singh et al., 2013). Moreover, the efficient water supply interferes directly in agricultural production process (Evangelista et al., 2011).

According to Rajaona et al. (2011), there are few information about Jatropha development under different management technics such as the fertilizer application, irrigation, and pruning. However, many studies can be found in the literature with Jatropha oil processing technics. The pruning technic can contribute on the plant canopy structure development, reducing disease and insect incidence, improving the air flow within the canopy, and, associated to the irrigation, increasing the number of productive branches (Yarborough, 2006; Oliveira and Beltrão, 2010; Pescie et al., 2011). Moreover, when pruning on Jatropha is not performed, it interferes on the manual harvest efficiency and may decrease the flowering uniformity and increase the fruit maturation time (Alam et al., 2011; Brasileiro et al., 2012; Everson et al., 2013).

Due the atypical events that may occur in a region that usually has a standard climate during the years, mainly by the extended drought period, it is necessary to evaluate the effect of water deficit for crops that were continuously irrigated. In addition to these information, it is still necessary to evaluate the effect of pruning on adult Jatropha trees. The hypothesis of this study were: The irrigation history influences the plant growth and yield even with irrigation interruption and; the differences on pruning levels may change the plant growth index, as well as the Jatropha yield.

The aim of this study was to evaluate the effect of irrigation history on the Jatropha plant growth and yield with four years old, associated with three pruning types under Brazil southeastern climatic conditions.

MATERIALS AND METHODS

Study site

The experiment was performed at University of Sao Paulo research area at Piracicaba city, São Paulo, Brazil (22°41' S and 47°38' W, and 511 m altitude) (Figure 1). The local climate is classified as Cfa according to the Köppen-Geiger world soil classification (Peel et al., 2007), with mean annual temperature of 21.6°C and annual precipitation of 1,328 mm (Marin et al., 2011). The soil was classified as loamy (57.1% clay, 20.9% silt and 22% sand), with 1.4% organic matter content, and density around from 1.4 g cm^{-3}. Meteorological data was determined by an automatic weather station located close to the experimental area (Figure 1). Temperature, relative humidity, net radiation, wind speed and direction, and precipitation data were registered at 15 min, hourly and daily frequency by a datalogger.

Plant establishment and management

Jatropha was cultivated in the experimental area in late December 2011, using 4 months old seedlings (cultivated at greenhouse). It was used a 3 m x 4 m between plant and row spacing, respectively, totalizing 833 plants ha^{-1}. Fertilization was performed in accordance with FACT (2010) recommendations, with three applications during the growing season. Fungicides and insecticides were applied continuously to promote adequate plant development.

Irrigation was performed from December 2011 to May 2014 using a center pivot irrigation system. The Christiansen Coefficient of Uniformity was evaluated and presented 82% for the center pivot used, considered great in the Bernardo et al. (2006) scale. The amount water required was determined according to the soil available water that was measured by two large weighing lysimeters (Flumignan, 2011; Lena, 2013).

Experimental design and treatments

The treatments were divided into two water management and three pruning types. The water management was divided into irrigated (or irrigation history treatment) from late-2011 to mid-2013 (I) and rainfed (R), considered the two main experimental areas. In each water management area, it was applied the pruning treatments considering no pruning (P1), pruning at 1.5 m height and 2 m canopy diameter (P2), and pruning at 2 m height and 2 canopy diameter (P3). Pruning was performed at the end of 3rd growing season in early-September 2014, coinciding with leaf senescence growing stage which is considered the most efficient moment for improving new branches production (Behera et al., 2010). In each water management treatment, it was divided into 4 blocks in which there were 1 replication with 16 plants for each pruning treatment. For analysis, it was used only the four internal plants in each replication (Figure 1).

Plant growing parameters

The plant height (cm), canopy diameter (cm) and leaf area index

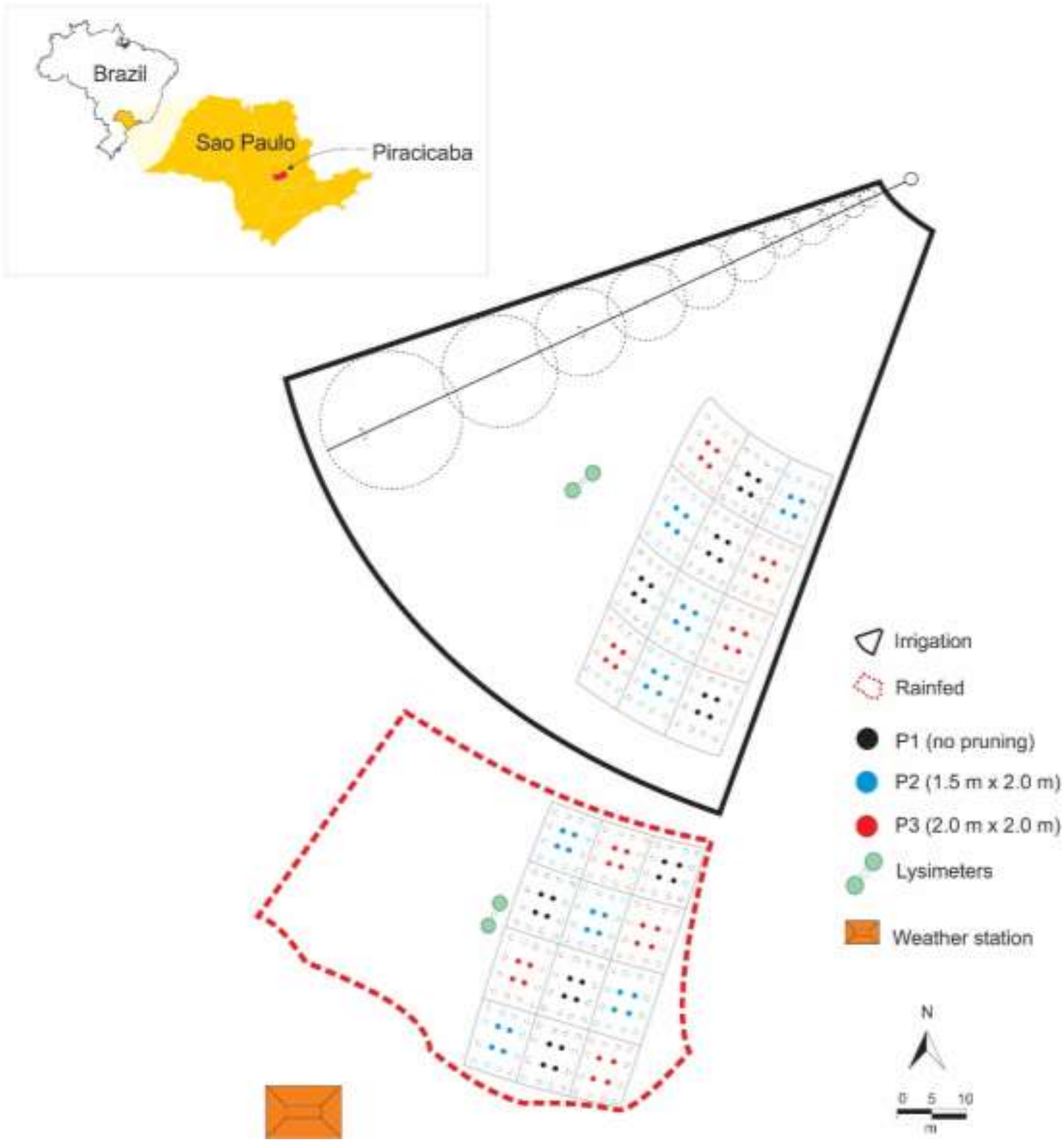

Figure 1. Location of the *Jatropha curcas* L. study site and plot treatments details.

(LAI, dimensionless) were determined from 1 to 210 days after pruning (DAP) every 30 days. Plant height was determined using a scale considering the distance between the soil level and the highest leaf of the plant and canopy diameter by the mean of perpendicular and parallel reading of plant row direction. LAI index was determined using the LAI-2200 plant canopy analyzer. Using the monthly data of plant height and canopy diameter, it was calculated the absolute growing rate for height (AGR_H) and canopy diameter (AGR_D), and relative growing rate for height (RGR_H) and canopy diameter (RGR_D) (Benincasa, 2003).

Harvest and yield

Harvest was performed from January to May 2015. Since Jatropha has different fruit maturation level in the same plant (green, yellow, yellow-brown, and brown) (Kumar and Sharma, 2008), the harvest was performed manually multiples times during the productive period choosing only fruits that were from yellow to brown maturation level (Pessoa et al., 2012). After harvest, all fruits were kept to dry at ambient temperature for 7 days or until all fruit were at brown maturation process (around 8% humidity). The fruits were weighted for each treatment separately, and it was determined the fruits and seed weight (kg $tree^{-1}$ and kg ha^{-1}), and fruits and seed number per tree.

Statistical analysis

The data were analyzed by analysis of variance (ANOVA) using both R 2.15.1 (R Development Core Team, Vienna, Austria) and SAS 9.2 (SAS Institute Inc., Cary, NC, USA) softwares. It was used a 0.05 level of probability as the decision level for the acceptance or rejection of statistical significance in all analysis. If a statistical

Table 1. Analysis of variance for irrigation (I), pruning type (P) and days after pruning (DAP) for tree height (cm), canopy diameter (cm), absolute growth rate in height (AGR_H, cm day^{-1}) and canopy diameter (AGR_D, cm day^{-1}), relative growth rate in height (RGR_H, cm $cm^{-1}day^{-1}$) and canopy diameter (RGR_D, cm $cm^{-1}day^{-1}$) and leaf area index (LAI, dimensionless) for *Jatropha curcas* L..

Source of variation[a]	DF	F values						
		Height	Canopy diameter	AGR_H	AGR_D	RGR_H	RGR_D	LAI
I	1	1.03[ns a]	3.73[ns]	1.04[ns]	3.84[ns]	0.33[ns]	1.23[ns]	1.61[ns]
P	2	21.95***	15.14**	58.79***	8.35**	132.46***	13.48**	5.89*
DAP	6	363.97***	556.56***	194.88***	172.86***	113.42***	147.85***	541.19***
I × P	2	1.06[ns]	0.38[ns]	1.59[ns]	1.26[ns]	2.12[ns]	0.33[ns]	1.30[ns]
I × DAP	6	0.51[ns]	3.85*	3.23**	2.63*	0.79[ns]	2.94*	2.02[ns]
DAP × P	12	16.2***	5.45***	18.66***	8.77***	26.01***	10.04***	3.04***
I × P × DAP	12	1.81[ns]	1.61[ns]	1.45[ns]	1.21[ns]	1.88*	0.94[ns]	2.08*
General mean		262.03	283.36	0.5	0.85	0.002	0.004	1.76
CV (%)		7.67	6.46	39.78	33.43	40.87	36.03	15.87

[a] Level of significance: *0.01<P< 0.05; **0.001<P<0.01; ***P<0.001. ns., no significant difference. DF, degree of freedom; CV, coefficient of variation.

significant effect was found, means were compared using Tukey's multiple comparison test. All plant growing parameters data were analyzed by mixed model where the variance and covariance structures were rejected, selecting those with lowest AIC and BIC information criteria.

RESULTS AND DISCUSSION

Effect of treatments on plant growth parameters

The average of all variables analyzed was different significantly by F test between pruning types and DAP (Table 1). It was observed significantly difference between water management and DAP for canopy diameter, AGR_H and AGR_D and for RGR_D by the ANOVA analysis results.

The increasing of plant height was different between pruning types, observed by an increment of 73, 142.7, and 102 cm for P1, P2, and P3, respectively, representing 29, 95, and 51% in comparison to the beginning of the experiment (1 DAP) (Figure 2A). During all experimental period, plant height varied significantly over time, in which only at 150 DAP the plant height was the same for all pruning types (P>0.05). In each pruning type, plant height differed over time, but plant height difference was not observed from 180 to 210 DAP for P2 and P3.

The canopy diameter followed the same trend observed for plant height with increase of 78, 128, and 125% for P1, P2, and P3, respectively, in comparison to the beginning of experiment (1 DAP) (Figure 2B). From 150 DAP, the canopy diameter did not present statistical difference between pruning types. It was observed that there were significant effect for canopy diameter at 120, 150, and 180 DAP, where plant for these treatments presented the highest averages (Figure 2C). Faria et al. (2011), studying the influence of different water management and fertilizer levels, also found a positive irrigation effect on the Jatropha plant canopy diameter, showing the high influence of water management in the plant development. The fast increase in plant height and canopy diameter over time was explained due the fast Jatropha plant development, in which it can reach easily 5 m height in adequate soil and climate conditions (Openshow, 2000; Arruda et al., 2004).

AGR_H were higher for more drastic pruning (P2), observed by the statistical differences at 60 and 90 DAP in comparison to P1 and P3. It indicates that P2 was more efficient on the vegetative growth (Figure 3A). In the literature it is possible to observe that plants which received more drastic pruning presented higher vegetative growth when it was performed during winter (Scarpere Filho et al., 2011; Rufato et al., 2012), corroborating with the results presented in this study. For the crop management, the fast vegetative development is not considered adequate because reduces yield due the high nutrient demand to produce new branches and leaves as well as making it difficult the disease and past control and the harvest (Laviola and Dias, 2008). However, pruning in high density vegetative canopy may promote better sunlight interception and the plant waste material can be used in other sectors such as for industry energy (material burn) (Prueksakorn et al., 2010).

Between irrigation history and rainfed treatments, it was observed significantly difference for AGR_H only at 30 DAP (Figure 3B). Behera et al. (2010) reported that Jatropha required frequent irrigation to improve canopy development and yield. According to Singh et al. (2013), Jatropha has its development affected in areas with high drought potential, requiring water from irrigation during the driest period of the year.

No statistical differences were observed in almost all periods for all pruning types for AGR_D during experimental period. Statistical differences were observed only at 120 and 30 DAP for P1 and P2 respectively, exhibited the lowest values (Figure 3C). It

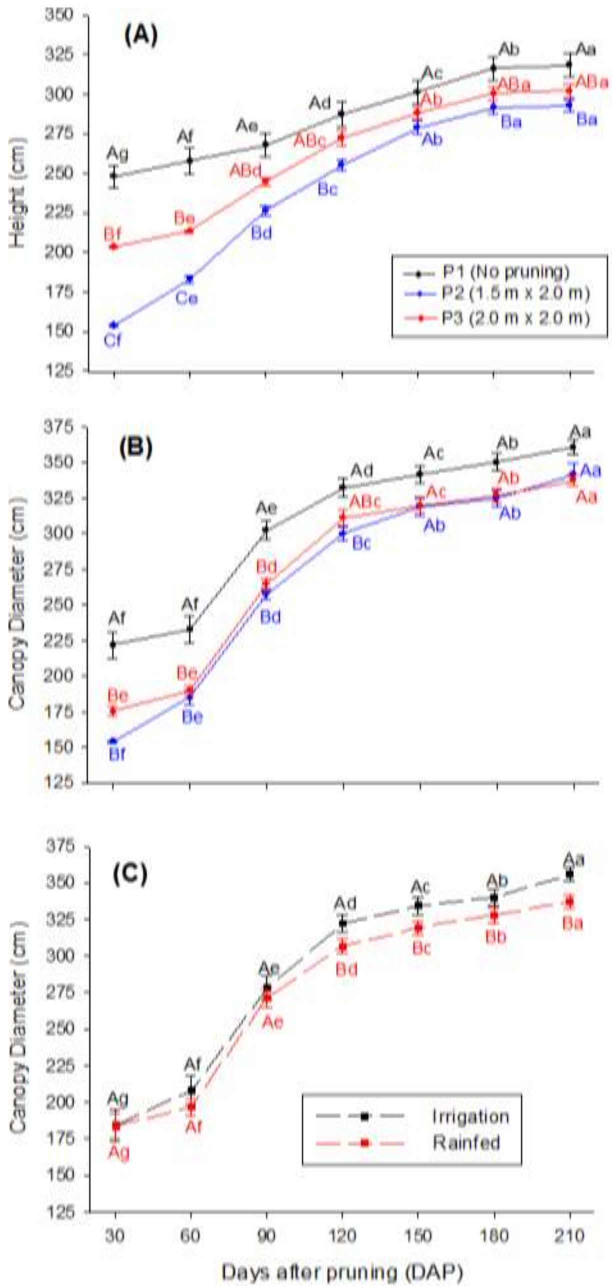

Figure 2. Effect of treatments on (A) tree height and (B, C) canopy diameter at days after pruning. Different letters indicate differences between pruning type or water management (capital letters) and days after pruning (small letters) according to Tukey's test (P<0.05). Vertical bars indicate the mean standard error.

was observed difference between the interaction of I and R x DAP at 60, 120, and 210 DAP, with higher growing rates for I (Figure 3D). In both water management treatments, the higher growing rates was observed at 90 DAP for all pruning types.

Both RGR_H and RGR_D had the same pattern of AGR_H and AGR_D results as described previously, but P2 presented significant differences for RGR_H (Figure 4A) in relationship to other pruning types at 60 and 90 DAP. For RGR_D, differences were observed only at 30 DAP with P3 having higher rates compared to P1 and P2 (Figure 4B). Regarding irrigation, RGR_D values were different from the 120 and 210 DAP, which were higher in irrigated plants (Figure 4C).

RGR is a measurement of production efficiency from new dry matter to those that has already been stablished, also called specific growing rate (Silva et al., 2000). Moreover, this measurement is considered very important indicative of genetics materials under different stress conditions (Benincasa, 2003). The plant height and canopy diameter growing rates had a similar pattern, showing a higher increasing between 60 and 120 DAP, characterized by the leaves emergency and development, as already observed by Ghezehei et al. (2015). This increase was also associated to the climate factors during the experiment, which was observed high amount of precipitation (Figure 5).

The higher growing rates values for I treatment is explained by the irrigation history. Since the plants from this treatments were being adequately irrigated until the end of 3rd growing season, it contributed for a better physiological performance and plant growing rates in comparison to the rainfed treatment, showing that Jatropha has a better development when the water availability is adequate, as already observed by other authors (Nery et al., 2009; Carvalho et al., 2011; Ghezehei et al., 2015). In the same experimental area, Lena (2013) determined evapotranspiration rates (ET_c) for center pivot and rainfed water management for Jatropha nut from 1st to 2nd growing season and observed that center pivot treatment presented 35% higher ET_c rates in comparison with rainfed treatment. During the 4th growing season, ET_c values were around 20% higher for I treatment (not irrigated but with irrigation history) than R treatment (Table 2), which is explained by the higher plant height and LAI index, as well as observed by Lena (2013). Therefore, although Jatropha is considered a drought tolerant plant, adequate water available is a limiting factor for the plant development, especially when associated with temperature and photoperiod (Saturnino et al., 2005; Bianchini et al., 2006).

During the experimental period, it was observed that plants presented a trend to reduce the growing index from 90 DAP which is explained by the interruption of vegetative development due the high productive development, as also observed by Larcher (2000) and Carvalho et al. (2013).

LAI is an important information that can be used to describe the plant photosynthetic activity (Kara and Mujdeci, 2010), as well as to be used in models for growth and yield prediction (Lizaso et al., 2003; Xiao et al., 2006). The LAI fluctuation between P2 and P3 were very similar, with values varying from 0.6 to 3.4 for P2 and from 0.5 to 2.9 for P3 (Figure 6A) and highest values

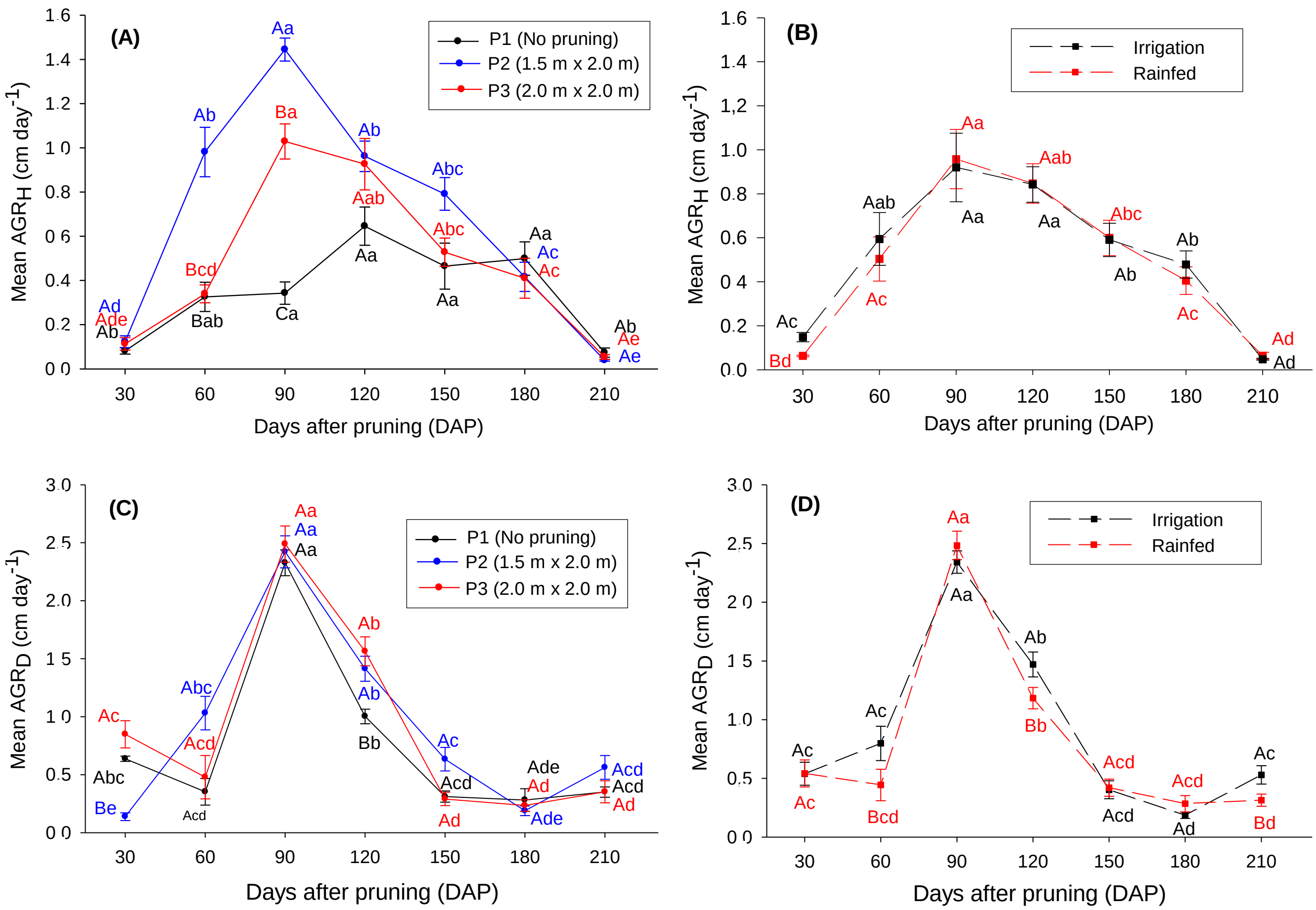

Figure 3. Mean absolute growth rate in height (AGR_H) and canopy diameter (AGR_D) under (A, C) pruning types and (B, D) water management at days after pruning. Different letters indicate differences between pruning type or water management (capital letters) and days after pruning (small letters) according to Tukey's test ($P<0.05$). Vertical bars indicate the mean standard error.

observed at 120 DAP. There were significantly difference between P2 and P3 only at 90 DAP, period where P2 presented the highest LAI values. Values were higher from 90 to 150 DAP for all pruning treatments, in which P2 was around 1.8 higher than others treatments ($P<0.001$). LAI behavior during the study period may be explained by high amount of precipitation during this period, mainly from December 2014 (90 DAP) to January 2015 (120 DAP). LAI values presented similar trend in comparison with plant growth rate, indicating that the vegetative growth increased the plant total leaf area. Tjeuw et al. (2015) observed that LAI, as well as the canopy density, decreased around 40% with pruning at 0.75 m height. According to this authors, it is difficult to compare the pruning effect with others findings due some studies did not include the no pruning treatment (Everson et al., 2013; Suriharn et al., 2011).

The LAI reduction due the water drought stress in Jatropha was already observed in the literature (Petropoulos et al., 2008; Ghanbari et al., 2013; Mofokeng et al., 2015), showing that strong influence of water for the plant development. As the leaf area increases, LAI also increases, demonstrating that the reduction of water available promotes reduction of leaf area for Jatropha plant (Silva et al., 2011; Horschutz et al., 2012), castorbean (Barros Júnior et al., 2008) and sugarcane (Farias et al., 2008). However, in the present study, it was not observed LAI differences between I and R treatments, that is, the water management did not affect this parameter (Figure 6B). One of explanation for these findings is supported by the Jatropha water drought stress tolerance. According to Maes et al. (2009), the Jatropha metabolism must receive some attention, since there is the possibility that the plants do not have a full C3 metabolism, with Crassulacean Acid Metabolism (CAM) inside the stem and a change from C3 to CAM in water drought condition (Ting et al., 1983; Luttege, 2008), also observed for *Frerea indica* (Lange and Zuber, 1977). According to Hokmalipour and Darbandi (2011), the leaf area has an important role in the sunlight interception of a crop canopy, as well as the water demand (Liu and Stutzel, 2002).

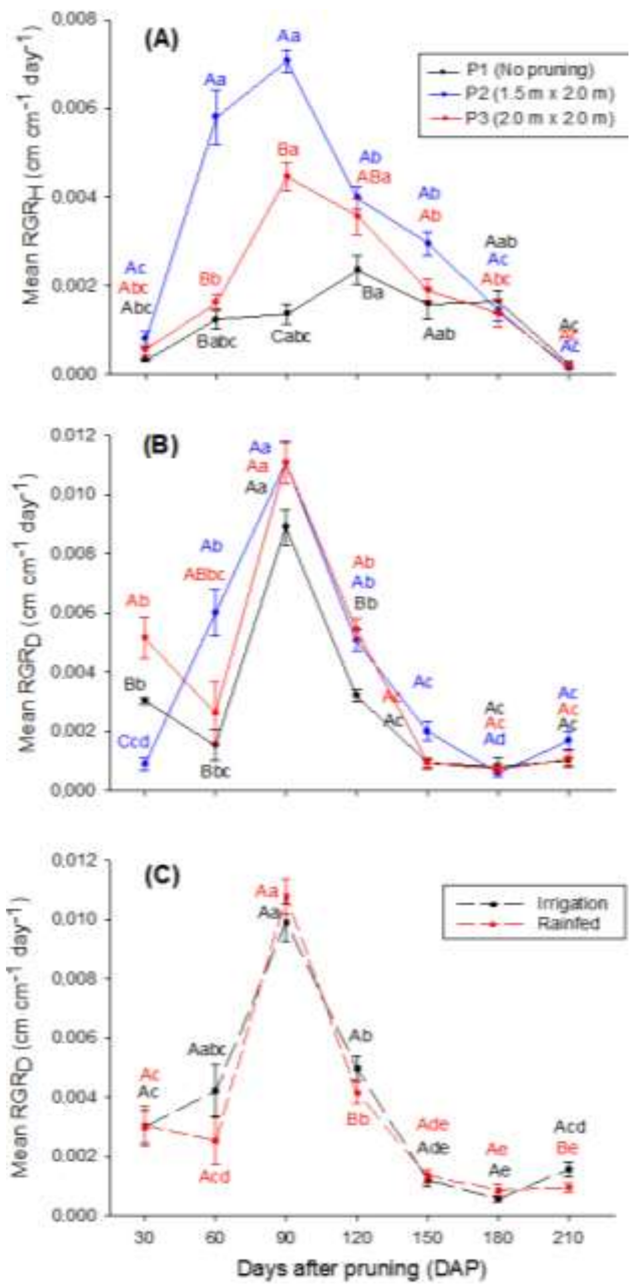

Figure 4. Mean relative growth rate in height (RGR_H) and canopy diameter (RGR_D) under (A, B) pruning types and (C) water management at days after pruning. Different letters indicate differences between pruning type or hydric conditions (capital letters) and days after pruning (small letters) according to Tukey's test (P<0.05). Vertical bars indicate the mean standard error.

Effect of treatments on fruit and seed yield

The statistical analysis results for fruit and seed yield, and number of seeds, presented influences only for the water management at 0.1% significance level (Table 3). However, it was observed significant effect in I and P for seed yield.

By Tukey's mean test, it was observed that I treatment was higher than R in all production characteristics analyzed (Table 4). Plants from I treatment produced 947.1 fruits tree^{-1}, 3.2 kg fruits tree^{-1}, and average yield of 2,651.3 kg fruits ha^{-1}, presenting increase of 45.6, 45.4 and 45.2%, respectively, in comparison to R treatment (Table 4). For seed yield, it was observed 2,638.3 seed tree^{-1}, 2.1 kg seed tree^{-1}, and 1,761.1 kg seed ha^{-1} for I treatment, following the same proportion of fruit production in comparison to R treatment, representing, respectively, 46.3, 50 and 48.2%. In the literature, some studies have described that Jatropha yield can vary from 0.2 to 2 kg seeds tree^{-1} and from 2,000 to 5,000 kg seeds ha^{-1} depending on the climate condition and crop management (Foidl et al., 1996; Heller, 1996; Francis et al., 2005; Tewari, 2007). In India, Jatropha under irrigation conditions presented an increase of harvest fruits (Daniel, 2008), with some reports of two times high yield for irrigated plant in comparison with rainfed (Ariza-Montobbio and Lele, 2010). Kheira and Atta (2009), Singh et al. (2013), and Tikkoo et al. (2013) also found that seed yield was higher with the better water availability to the Jatropha plants. Some studies in Brazil also reported that Jatropha under irrigation presented better plant development in growth and yield (Oliveira et al., 2012; Evangelista et al., 2011; Faria et al., 2011).

The yield results presented in this current study were higher than those presented by Prajapati and Prajapati (2005), and Tomomatsu and Brent (2007), presenting Jatropha yield in rainfed condition (R) of 1,200 kg ha^{-1} and up to 60% higher when irrigated. In India, the highest yield found for three years old Jatropha tree was 750 and 450 kg ha^{-1} for irrigated and rainfed conditions, respectively, with possibility to increase up to 1,200 kg ha^{-1} during the 6th growing season under irrigation (Behera et al., 2010). According to Jongschaap et al. (2007), depending on the crop management, such as seedling density, fertilizer, pruning types, and other, interfere on the understanding of Jatropha yield characterization.

The difference between P2 and P3 was observed only for plants of I treatment (p=0.0365) (Table 4). For R treatments, P2 presented the highest seed production (1.7 kg seeds tree^{-1} and 1,436.6 kg seeds ha^{-1}). The pruning effect observed in this study was very different to those presented by Ghosh et al. (2011), where plants without pruning had better yield than those under pruning. Tjeuw et al. (2015) verified that pruning reduced around 75% on yield in comparison with plants without pruning. On the other hand, Singh et al. (2013), trying to standardize the agronomics technic for Jatropha production, did not observed influence of pruning on yield.

The plant architecture changing due the pruning technic can be used as objective of modifying the source/drain relationship to increase yield (Guimarães et

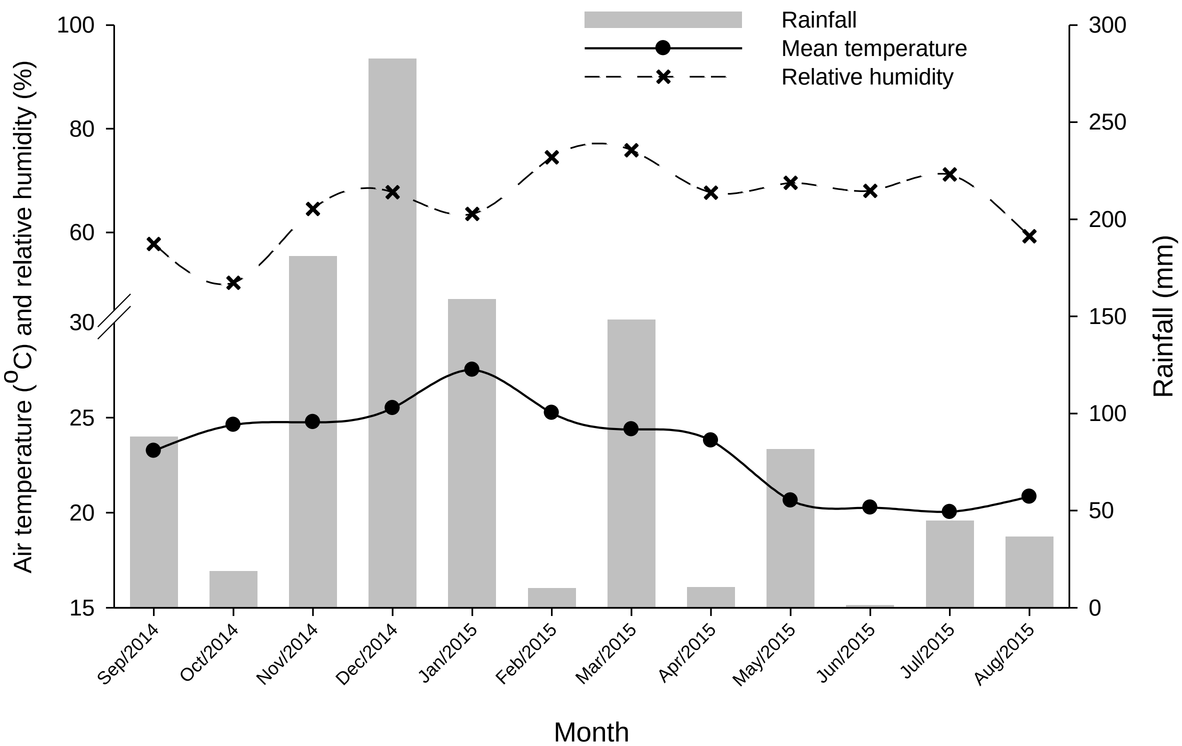

Figure 5. Monthly values of total rainfall and mean temperature at experimental site during the study period.

Table 2. Monthly values of total evapotranspiration (ETc, mm) of *Jatropha curcas* irrigated by center pivot and rainfed.

Month/year	Irrigation	Rainfed
Sep/2014	61.6	64.5
Oct/2014	74.7	65.7
Nov/2014	140.4	99.6
Dec/2014	181.2	120.9
Jan/2015	152.4	135
Feb/2015	206.7	147
Mar/2015	130.6	123
Apr/2015	92.7	74.1
May/2015	29.7	37.2
Jun/2015	30.1	22.8
Jul/2015	29.6	27
Aug/2015	28.5	25.5
General mean	96.5^{ns}	78.5^{ns}

ns, no significant difference.

al., 2007). The pruning effect on yield for P2 and R can be explained due the more intrusive pruning promotes a significant reduction of apical dominance, inducting to new shoots formation on the cut segment (Raven et al., 2001). Moreover, the vertical braches reduction due the pruning technic, the horizontal branches become predominant, improving yield since the horizontal branches are more associated to the reproductive buds (Scarpare Filho et al., 2011). One of the reason of lower yield results for R treatment is due the higher auto canopy shading (Azevedo et al., 2013), decreasing the plant sunlight interception and due the high amount of unproductive branches.

Conclusions

The analysis of pruning effect and irrigation on the Jatropha plant growth and yield is important to understand and characterize some plant management. The results presented in this study indicate that the irrigation history has influenced on a higher plant growth and yield of Jatropha during the 4th growing season. Even with irrigation interruption, the irrigation history was essential to improve the plant ability to increase in growth during some period of the year and to improve yield. This information is important to identify the plant behavior when irrigation is interrupted in region where climate may change and water became scarce. The pruning influenced significantly all variable analyzed, in which the more drastic pruning (1.5 m × 2 m) presented the highest plant height for both water management and best yield for rainfed area. Since Jatropha is a perennial plant, it is necessary to find more reliable information about the pruning effect on the plant growth and production.

However, due the lack of standardized management

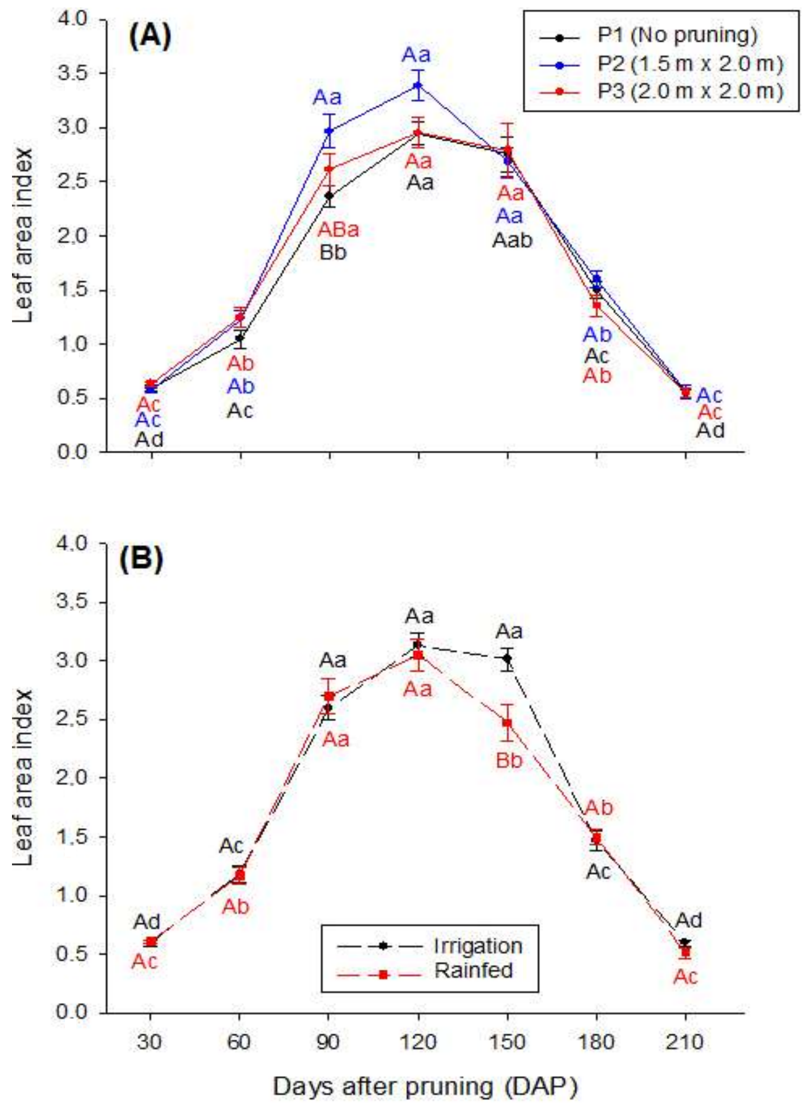

Figure 6. Mean leaf area index (LAI) under (A) pruning types and (B) hydric condition at days after pruning. Different letters indicate differences between pruning type or water management (capital letters) and days after pruning (small letters) according to Tukey's test (P<0.05). Vertical bars indicate the mean standard error.

Table 3. Analysis of variance for irrigation (I), pruning type (P) and days after pruning (DAP) on yield and number (No) of fruits and seeds for *Jatropha curcas* L.

Source of variation [a]	DF	Fruit			Seed		
		Yield		No. tree^{-1}	Yield		No. tree^{-1}
		(kg tree^{-1})	(kg ha^{-1})		(kg tree^{-1})	(kg ha^{-1})	
I	1	30.06***	30.06***	33.11***	39.39***	39.39***	36.62***
P	2	0.85^{ns}	0,85^{ns}	0.90^{ns}	0.92^{ns}	0.92^{ns}	0.84^{ns}
Block [I]	6	3.57*	3.57*	4.11*	3.68*	3.68*	3.25*
I x P	2	3.33^{ns}	3.33^{ns}	3.25^{ns}	4.12*	4.12*	3.53^{ns}
General mean		2.69	2,238.43	3,195.04	1.77	1,474.74	8,883.23
CV (%)		16.60	16.48	15.80	14.90	15.16	15.22

[a] Level of significance: *0.01<P< 0.05; **0.001<P<0.01; ***P<0.001. ns., no significant difference. DF, degree of freedom; CV, coefficient of variation.

Table 4. Number of fruits and seeds per tree, and yield for fruits and seeds for *Jatropha curcas* L.

Treatments[a]	P1 (no pruning)	P2 (pruning at 1.5 m × 2.0 m)	P3 (pruning at 2.0 m × 2.0 m)	Mean
		Number of fruits		
Irrigated	952	907	982.25	947.1[A]
Rainfed	632.5	781.5	537.25	650.4[B]
Mean	792.3[a]	844.3[a]	759.7[a]	
		Fruits yield (kg tree^{-1})		
Irrigated	3.2	3.0	3.3	3.2[A]
Rainfed	2.1	2.6	1.8	2.2[B]
Mean	2.7[a]	2.8[a]	2.5[a]	
		Fruits yield (kg ha^{-1})		
Irrigated	2685.7	2518.3	2,750	2,651.3[A]
Rainfed	1780.9	2203.6	1,492	1,825.5[B]
Mean	2,233.3[a]	2,360.9[a]	2,121[a]	
		Number of seeds		
Irrigated	2,607.5	2,534	2,773.5	2,638.3[A]
Rainfed	1,760.7	2,154.2	1,495	1,803.3[B]
Mean	2,184.1[a]	2,344.1[a]	2,134.2[a]	
		Seeds yield (kg tree^{-1})		
Irrigated	2.1[Aa]	2.0[Aa]	2.2[Aa]	2.1
Rainfed	1.4[Bb]	1.7[Aa]	1.2[Bb]	1.4
Mean	1.7	1.9	1.7	
		Seeds yield (kg ha^{-1})		
Irrigated	1,744.9[Aa]	1,682.1[Aa]	1,856.3[Aa]	1,761.1
Rainfed	1,159.1[Bb]	1,436.5[Aa]	969.5[Bb]	1,188.4
Mean	1,452	1,559.3	1,412.9	

[a]Capital and small letters indicate differences between pruning types and hydric conditions, respectively according to Tukey's test ($P<0.05$).

technics for this culture, it is necessary others studies with the Jatropha behavior under field condition in different regions.

Conflict of Interests

The authors have not declared any conflict of interests.

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