Use of pruning in the agricultural management of *Jatropha curcas* (jatropha) for the plant flower development, in Costa Rica

Uso de podas en el manejo agrícola de Jatropha curcas (tempate) sobre la expresión floral de la planta, en Costa Rica

Ileana Moreira-González[1], Elizabeth Arnáez-Serrano[2], Marvin Castillo-Ugalde[3], Elemer Briceño-Elizondo[4], Dagoberto Arias-Aguilar[5]

Fecha de recepción: 29 de setiembrede 2017
Fecha de aprobación: 2 de febrero de 2018

Moreira-González, I; Arnáez-Serrano, E; Castillo-Ugalde, M; Briceño-Elizondo, E; Arias-Aguilar, D. Use of pruning in the agricultural management of *Jatropha curcas* (jatropha) for the plant flower development, in Costa Rica. *Tecnología en Marcha*. Vol. 32-1. Enero-Marzo 2019. Pág 68-76.

DOI: https://doi.org/10.8845/tm.v32.i1.4119

1 Biology School, Instituto Tecnológico de Costa Rica. Cartago, Costa Rica. E-mail: imoreira@itcr.ac.cr
2 Biology School, Instituto Tecnológico de Costa Rica. Cartago, Costa Rica. E-mail: earnaez@itcr.ac.cr.
3 Forest Engineering School, Instituto Tecnológico de Costa Rica. Cartago, Costa Rica. E-mail: mcastillo@itcr.ac.cr
4 Forest Engineering School, Instituto Tecnológico de Costa Rica. Cartago, Costa Rica. E-mail: ebriceno@itcr.ac.cr
5 Forest Engineering School, Instituto Tecnológico de Costa Rica. Cartago, Costa Rica. E-mail: darias@itcr.ac.cr. ORCID: https://orcid.org/0000-0002-3056-9172

Keywords

Pruning; floral expression; *Jatropha curcas*; jatropha.

Abstract

The species *Jatropha curcas* (jatropha) is characteristic of the Mesoamerican region, with its center of origin found in Mexico. It has been adapted for its use as hedge rows and also exploited, based on traditional knowledge for medicinal applications. Currently, it is classified as a valuable species for the production of oils; for biofuels or as paint diluents. In Costa Rica, since 2005, studies have been performed to achieve the positive domestication for the use of this species as an agro-energetic crop along with another food crop. However, the crop management processes are still very recent and it is required to deepen in this subject to obtain a crop of a high economic value. At the Estación Fabio Baudrit, a crop was established, using seeds from the Comayagua variety and an assay was established, in which a strict assessment was performed to random blocks, of the plants length in order to execute the first prune at 40 cm. Later, the blocks were also tracked, to evaluate the branches until the flowering and harvesting stages. The yield of green fruits behaved similarly to the inflorescence and the female flower production. The pruned plants did not present a significant difference in terms of fruit yield for the first year; but in the second year, they exceeded the production of the unpruned plants.

Palabras clave

Podas; expresión floral; Jatropha curcas; tempate.

Resumen

La especie Jatropha curcas (tempate) es típica de la zona mesoamericana, su centro de origen se ha establecido en México. Ha sido domesticada para ser utilizada en el establecimiento de cercas vivas y por su valor medicinal según el conocimiento tradicional. En la actualidad se cataloga como una especie de alto valor para la producción de aceites que pueden tener uso en biocombustibles o como diluyente de pinturas. En Costa Rica desde el año 2005 se han iniciado estudios para lograr una domesticación favorable para la utilización de esta especie en cultivos agroenergéticos en alternancia con algún cultivo agroalimentario. Sin embargo, los procesos de manejo del cultivo aún son incipientes y se debe profundizar en este tema para lograr una cosecha de mayor valor económico. En la Estación Fabio Baudrit se estableció una plantación proveniente de semilla de la variedad Comayagua y se estableció un ensayo de bloques al azar a los que se le dio un seguimiento estricto en longitud para aplicar una primera poda a los 40 cm y posteriormente un seguimiento a las ramas hasta que inicie la floración y la cosecha. La producción de frutos verdes se comportó de manera similar a la producción de inflorescencias y flores femeninas. Las plantas podadas no mostraron una diferencia significativa de producción de frutos en el primer año, pero en el segundo año, superan a las plantas no podadas.

Introduction

The crops for biofuels correspond to a wide range of plant species, that present differences in terms of productivity, oil quality, adaptability to climate change, and other ecosystem benefits, such as the ability increase or keep the fixation of carbon in biomass and the soil. The energy projections for Costa Rica anticipate that the country's traditional energy sources will not be able to continue increasing after 2032. Therefore, it is necessary to promote research on plant

species such as *Jatropha curcas* (jatropha), that being a plant from Mesoamerican origins with a high quality oil, has a considerable potential in the energetic field.

In Costa Rica, the National Biofuels Programme has the overall objective of developing a biofuel industry that contributes to the energy safety and efficiency, the climate change mitigation, the reactivation of the farming sector, and the local and national socioeconomic development [12]. Their plan of action includes a proposal for an environmental sustainability model; which would allow the development of different agricultural resources for biofuel and biomass production. Therefore, the National Biofuels Programme (2008) includes a proposal of areas with farming potential for selected bioenergy crops; according to the soil type, altitude, as well as other guidelines for the linkage with industry, industrialization, commercialization, and marketing.

During the last 6 years, a multidisciplinary research group from the country's state universities has developed systematic studies on the *Jatropha curcas* (jatropha) crop [7] for its commercial use as an oil source for biofuel production.

The studies on jatropha domestication have been performed in collaboration with businessmen and farmers that have been involved in farming jatropha, used as hedge rows or for the generation of small plantations to obtain seeds. One of the main limitations at a global level is the absence of improved high-performance varieties, as well as the lack of flower synchronization and the irregular fruit production.

Globally, there is a considerable interest in jatropha (*Jatropha curcas*) as an oleaginous plant, for its use as an energy source [1] [3] [5] [8] [12], since the good oil characteristics can be exploited for biodiesel production. The oil can also be used as a baseline for soap manufacturing. Additionally, the residue for seed pressing is considered a good fertilizer and can also be used for biogas production [4]. This oleaginous plant species is characterized for its resistance to drought, it is a fast growing plant species, of easy propagation, and a short life cycle [1] [6] [7] [9]. Its yield depends on plant-associated factors such as the distribution of the dry biomass; the female/male flower proportion; the weight and size of the seeds; the oil content of the seeds; the oil quality; toxicity; flower induction; and the flower synchronization. Other factors relate to the crop site, such as the number of branches, flowers, fruits and seeds [3]. These factors are strongly influenced by the environmental and genetic effects, the adequate farming locations and the appropriate agricultural management techniques for the crop [8]. In regards to the genetic effect, the origin assays and the studies using molecular markers have shown a low genetic variability [4] [3] [11] [2]. The study aims to establish a pruning method that ensures the *Jatropha curcas* (jatropha) farmer, a potentially profitable crop.

The objective of this study is to analyze the effect of pruning as part of the agricultural management of *Jatropha curcas* on the floral expression.

Materials & Methods

The study was developed in the Estación Experimental Fabio Baudrit, found at La Garita, Alajuela, Costa Rica located at 800 msnm, starting during the month of October, 2013. The soil was mechanically prepared for farming (ploughed, racked and hilllocked). A total of 80 seeds for the Comayagua accession were planted, directly and with a 4 meters distance between rows and between plants. The irrigation was performed twice a week until January, 2014, and from February on, the irrigation was reduced to once a week until the end of the study. The dead plants were substituted by others, grown in the greenhouse, and which have same age. Additional jatropha plants were planted around the assay field, to eliminate the border effect. In the first development stages, a manual weeding was performed, but when the plants reached a height of 40cm, a scythe was used.

On February 2014, a bifactorial experimental design was established, with random complete blocks and 4 repetitions, and identifying each block as corresponded. Treatment 1 and 2 consisted of plants which were pruned; while treatments 3 and 4 presented unpruned jatropha plants (figure 1). From that day on, the height of the plants was measured and the respective blocks were pruned when the plants reached a height of 40cm. The same was done when the branches resulting from that initial pruning reached 50cm. After that, pruning was left until after the plant's flowering and fruiting stages; when the plants received their first formation pruning, and were left with a maximum height of 1.30 m (figure 2). The number of inflorescences, female flowers, green and ripe fruits were counted; and from the harvested fruits, the number of seeds were also counted and their fresh and dried weight was also determined.

The data from the dates of the first and second semester of 2014 and 2015 presenting the highest yields of green fruit, inflorescences and female flowers was used for the analysis. The results obtained from the four treatments were evaluated though an analysis of variance (ANOVA) following a random block experimental design, in which it was evaluated whether there were any significant differences found between blocks (to discard any significance in the results due to this variable) and between treatments. When differences were found, a Tukey test with a significance of 0.05 was performed. In regards to growth, an ANOVA was performed once again for each date, to define the differentiation between treatments in terms of growth. All the statistical analysis was performed using the software STATISTICA 9.0

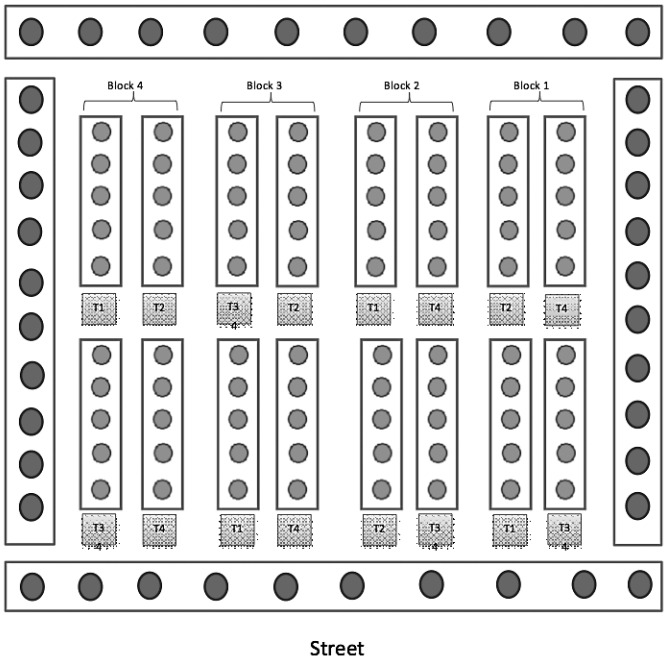

Figure 1. Design map with the distribution of the *Jatropha curcas* pruning assay.

Figure 2. Plants with their second pruning, at a plant's height of 1.30m.

Results & Discussion

The plants' growth rate was of 1 cm per week in the initial stage, with flowering occurring 7 months after planting, which was performed in November, 2013.

No significant differences were found in the growth of the jatropha plants through time; however the growth was not evaluated during 2015, since after performing the plant pruning, there is a loss in the growth rate since this plants must start their growth from the point where they were pruned (figure 3).

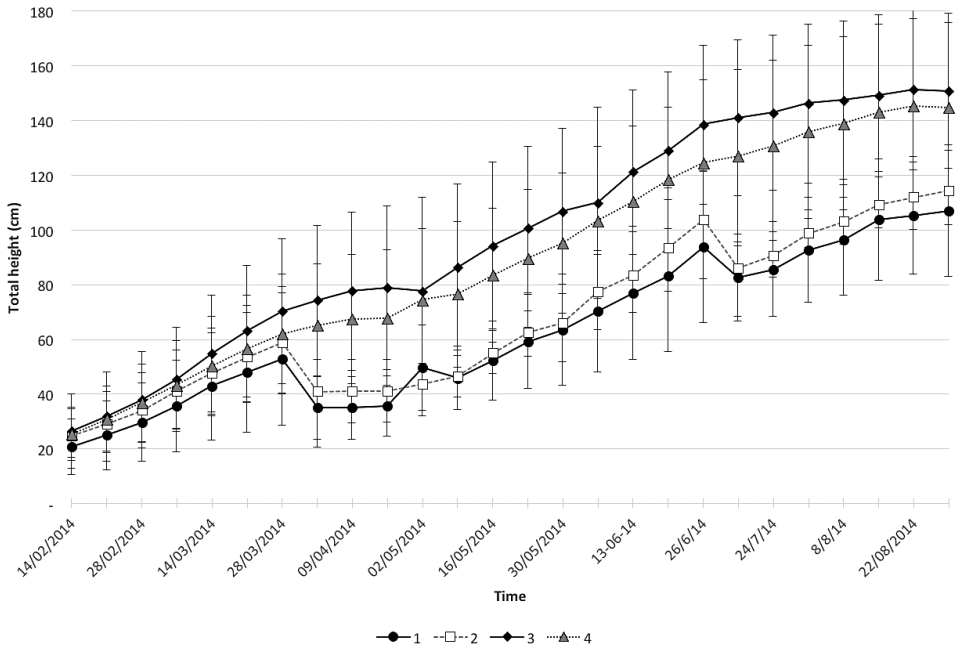

Figure 3. Average vegetative growth, considering the height of jatropha plants, during 2014

In figure 4, below it is possible to observe the average number of inflorescences per plant, according to the treatment; where during the first two harvests, Treatment 1 and 2 did not present any inflorescences, due to the fact that pruning leads to stress and the plant development focuses on branch and leaf growth, rather than generating inflorescences.

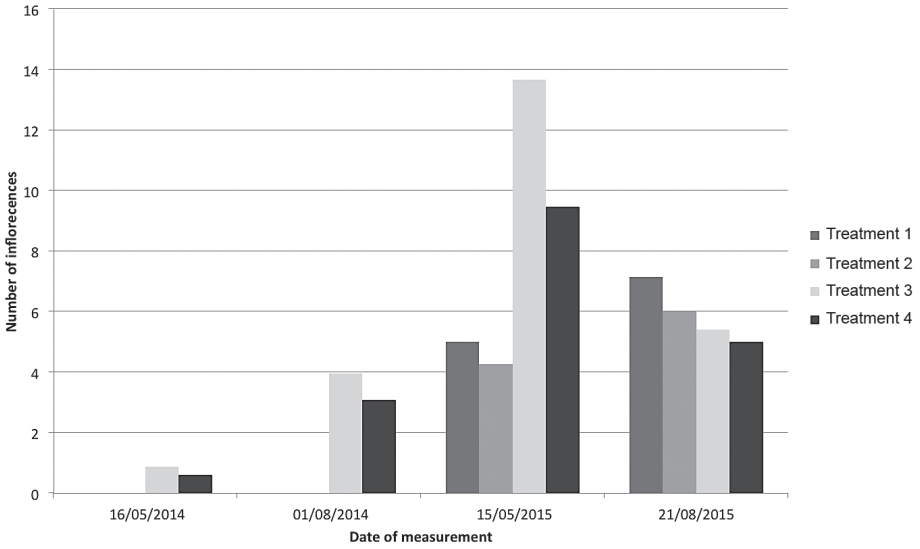

Figure 4. Average number of inflorescences according to the treatment of the pruning assay

Based on the results observed, it can be stated that the inflorescence production from May 2015 was higher than the one reported in August of the same year; but Treatment 1 and 2 increased their yield.

The analysis of variance performed with the data from the dates which presented the maximum inflorescence productivity, is shown in table 1, below.

Table 1. Analysis of variance for the inflorescence production per hectare, from the *Jatropha curcas* pruning assay.

Treatment	16/05/2014	01/08/2014	15/05/2015	21/08/2015
1	0 A (0)	0 A (0)	8000 A (1973)	11413 A (1327)
2	0 A (0)	0 A (0)	6827 A (1794)	9600 A (5431)
3	1387 B (465)	6293 B (960)	21867 A (5490)	8640 A (4049)
4	960 B (325)	4907 B (959)	15147 A (5435)	8000 A (4401)

*Treatment 1 and 2 were pruned in the first two dates, hence there is no production data. SAME LETTERS INDICATE THAT THERE ARE NO SIGNIFICANT DIFFERENCES BETWEEN TREATMENTS

The pruned plants produced very few fruits in their first harvest; however the plants from Treatments 3 and 4, which were not pruned, produced more female flowers and more fruits, since their growth was not interrupted (figure 5).

The data analysis showed that the inflorescence production only presented significant differences between treatments, and not between blocks, during the first two flowering periods (table 2). It is evident that during the first growth stages, the unpruned plants produce a greater number of inflorescences per hectare, but as the plants grow, this difference becomes less obvious. This change can be due to the fact that the plants have the required nutrients accumulated through the photosynthesis, which provide vigor to the first leafs; it was determined that on average 27 leafs per branch were sufficient for the plant to achieve the development of the first floral sprouts.

Figure 5 shows the average female flowers produced per plant, where it can also be observed that the pruned plants do not present female flowers in the first year of growth; but in the second year, there is an increase in the number and they exceed the unpruned plants.

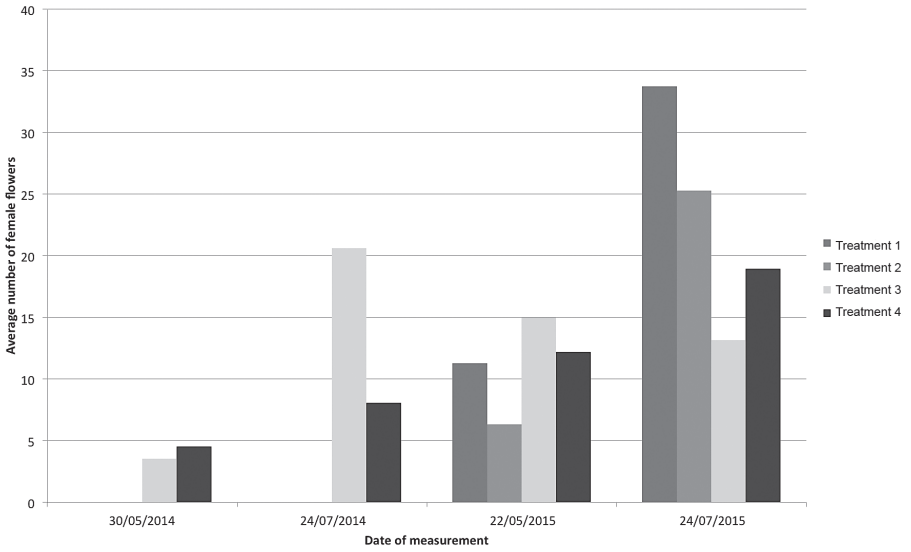

Figure 5. Average number of female flowers per treatment, during the jatropha plants pruning assay.

The behavior of the plants and their response to the treatment vary in terms of the emergence of female flowers through time; therefore, significant differences between treatments were found in the first two, as well as the last date of flowering, but not on the third date assessed, as shown table 2.

Table 2. Analysis of variance for the female flower production per hectare during the pruning assay performed to *Jatropha curcas*.

TREATMENT	30/05/2014	24/07/2014	22/05/2015	24/07/2015
1	0 A (0)	0 A (0)	18027 A (15381)	53973 A (14432)
2	0 A (0)	0 A (0)	10133 A (11535)	40427 A (12192)
3	5653 B (1771)	32960 B (4848)	24000 A (14971)	21013 B (19775)
4	7253 B (6285)	12907 B (7203)	19520 A (13918)	30293 B (15497)

Note: Same letters indicate that there are no significant differences berween treatments.

The production of green fruit behaved similar to the production of inflorescences and flowers, where in the first year the pruned jatropha plants did not present a considerable fruit production, but in the second year the production was higher than that of the unpruned plants (figure 6).

In regards to the fruit production, there are significant differences found between treatments, but not between blocks (table 3). These differences vary along time, since the pruned plants response starts to be observed in the second year of growth.

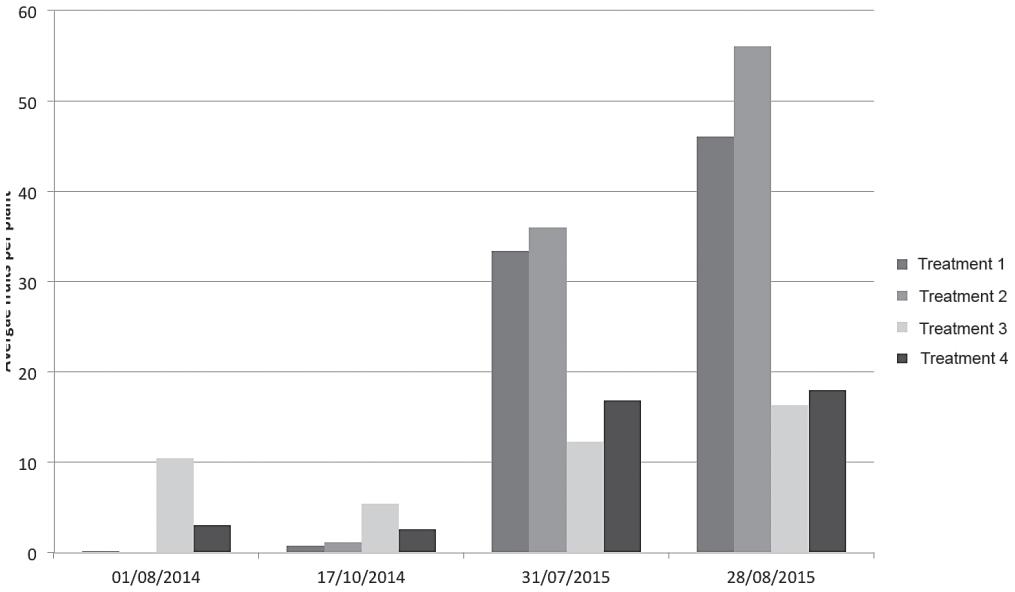

Figure 6. Average number of green fruits per treatment, for the jatropha pruning assay.

Table 3. Analysis of variance for the green fruit production per hectare in the *Jatropha curcas* pruning assay.

TREATMENT	01/08/2014	17/10/2014	31/07/2015	28/08/2015
1	213 A (106)	1173 A (1056)	53333 B (3331)	73600 B (10560)
2	0 A (0)	1706 A (1100)	57493 B (2544)	89706 B (9874)
3	16640 B (2533)	8533 B (2410)	19627 A (5049)	26027 A (4018)
4	4800 A (1056)	4053 AB (1489)	26880 A (7410)	28693 A (4104)

Note: Same letters indicate that there are no significant differences berween treatments.

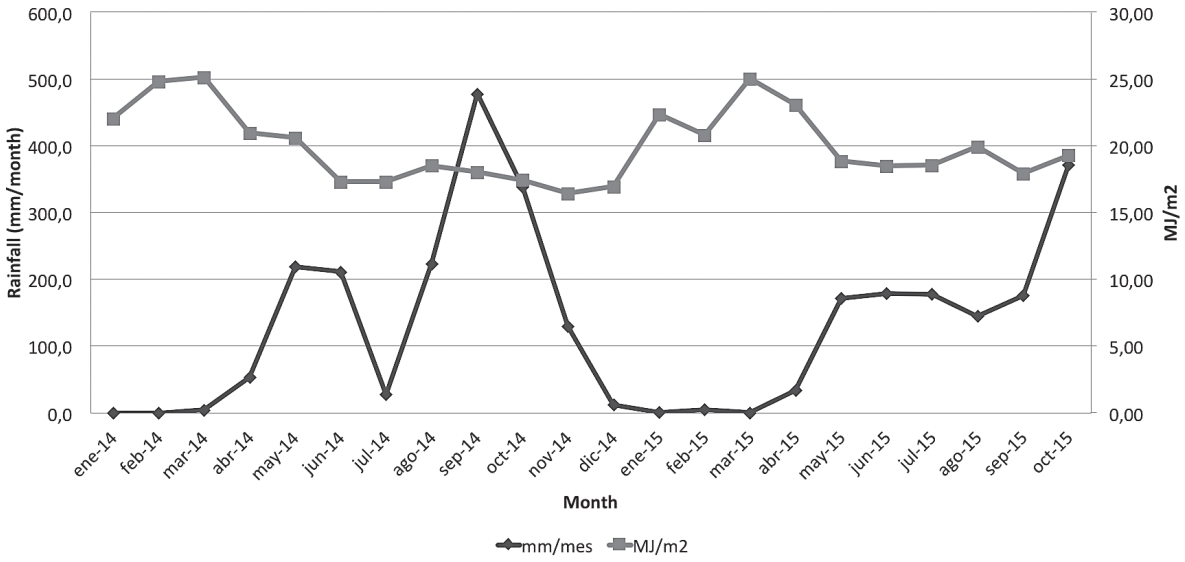

Figure 7. Mean monthly rainfall (mm/month) and average solar radiation (MJ/m^2) from the meteorology station of the IMN, located at the Estación Experimental Fabio Baudrit.

Figure 7 shows the values of mean monthly rainfall (mm/month) and average solar radiation (MJ/m^2), obtained from the meteorology station located at the Estación Experimental Fabio Baudrit of the Instituto Meteorológico Nacional (IMN). As it can be observed, the values of higher solar radiation occur in the months of February and March, while for 2015, these values are found during March and April. For the rainfall, a reduction was evidenced in the months of July, 2014 and on January and March of 2015; while a considerable increase in rainfall took place on September, 2014 (figure 7).

Acknowledgement

The authors would like to acknowledge PhD. Charles Aker, as the general project manager, for his technical support and the arrangements in the search for external funding, with the proposal presented for Costa Rica, Mexico, Nicaragua, Colombia and Brazil, named: “Regulation of the flowering of *Jatropha curcas* to improve the sustainability of biofuel feedstock production by farmers in Latin America and the Caribbean” and approved by LAC-Brazil.

The authors would also want to express their gratitude to PhD. Werner Rodríguez, Director of the Estación Experimental Fabio Baudrit and Engineer Jesús Hernández (MAG-UCR Agreement), for their technical and logistics assistance in the execution of the assays.

References

[1] R. Jongschaap, W. Corré y P. Bindraban, «Claims and facts on Jatropha curcas L., global *Jatropha curcas* evaluation, breeding and propagation programme.,» de *Plant Research International Report*, Netherlands, 2007, p. 66.

[2] C. Yi, C. Reddy, F. Varghese, T. Bui, S. Zhang, M. Kallath, B. Kunjachen, S. Ramachandran y Y. Mong, «A new *Jatropha curcas* variety (JOS2) with Improved Seed Productivity Sustainability,» 2014, pp. 4355-4368.

[3] J. Chikara, A. Prakash, S. Mastan y A. Ghosh, Jatropha, Challenges for a New Energy Crop, New York, USA: Springer Science+Business Media, 2013.

[4] FACT, The Jatropha Handbook: from cultivation to application., Eindhoven, The Netherlands: FACT Foundation, 2010.

[5] A. King, L. Montes, J. Clarke, J. Affleck, Y. Li, H. Witsenboer, E. van der Vossen, P. van der Linde, Y. Tripathi, E. Tavares, P. Shukla, T. Rajasekaran, E. van Loo y I. Graham, Linkage mapping in the oilseed crop jatropha curcas L. reveals a locus controlling the biosynthesis of phorbol esters which cause seed toxicity., Plant Biotechnology Journal 11, 2013.

[6] S. Kumar y S. Singh, Variability assessment of seed traits in Jatropha curcas L. for improvement of oil yield, International Journal of Genetics and Molecular Biology 6(January), 2014.

[7] J. Loaiza, E. Arnáez, E. Moreira, F. Herrera, A. Ureña y H. J, Guía técnica para el establecimiento y producción de Jatropha curcas (tempate) en Costa Rica., Cartago, Costa Rica: Editorial Tecnológica de Costa Rica, 2012.

[8] M. Martin y J. Montes, Quantitative genetic parameters of agronomic and quality traits in a global germplasm collection reveal excellent breeding perspectives for Jatropha curcas L., GCB Bioenergy 2014, 2014.

[9] Ministerio de Agricultura y Ganadería, Aspectos Técnicos sobre Cuarenta y Cinco Cultivos Agrícolas de Costa Rica, San José, Costa Rica.: Ministerio de Agricultura y Ganadería, 1991.

[10] J. Montes, F. Technow, B. Bohlinger y K. Becker, Seed quality diversity, trait associations and grouping of accessions in Jatropha curcas L., Industrial Crops and Products, 2013.

[11] L. Montes Osorio, A. Torres Salvador, R. Jongschaap, C. Azurdia Perez, J. Berduo Sandoval, L. Trindade, R. Visser y E. van Loo, High level of molecular and phenotypic biodiversity in Jatropha curcas from Central America compared to Africa, Asia and South America, BMC plant biology, 2014.

[12] Ministerio del Ambiente y Energía, PROGRAMA NACIONAL DE BIOCOMBUSTIBLES, República de Costa Rica: Ministerio de Agricultura y Ganadería, 2008.