ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.22, n.2, p.113-118, 2018
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v22n2p113-118

Growth, water use and efficiency of forage cactus sorghum intercropping under different water depths

Lucivania R. Lima[1], Thieres G. F. da Silva[1], Alexandre M. da R. F. Jardim[1], Carlos A. A. de Souza[2], Maria G. de Queiroz[3] & José N. Tabosa[4]

[1] Universidade Federal Rural de Pernambuco/Unidade Acadêmica de Serra Talhada. Serra Talhada, PE. E-mail: lucivania_rodrigues@hotmail.com (Corresponding author); thieres.silva@ufrpe.br; alexandremrfj@gmail.com
[2] Universidade Federal Rural de Pernambuco/Departamento de Engenharia Agrícola. Recife, PE. E-mail: carlosandre08_@msn.com
[3] Universidade Federal de Viçosa/Departamento de Engenharia Agrícola. Viçosa, MG. E-mail: mg.gabi@hotmail.com
[4] Instituto Agronômico de Pernambuco. Recife, PE. E-mail: nildo.tabosa@ipa.br

Key words:
actual evapotranspiration
drip irrigation
land use
semi-arid region

ABSTRACT
The effects of the forage cactus sorghum configuration and different irrigation depths on the growth, water use and efficiency of the forage cactus production system were investigated in this study. The experiment was conducted in the municipality of Serra Talhada, Pernambuco State, Brazil, between the years 2012 and 2013. Forage cactus was distributed in randomized blocks with factorial scheme and four replicates, in split plots (5 x 2), with five irrigation depths (0, 8.75, 17.5, 26.25 and 35% of the reference evapotranspiration, ET_0) and two cropping systems (forage cactus monocropping and forage cactus sorghum intercropping). Crop evapotranspiration was calculated through soil water balance. The ratio between crop and reference evapotranspiration, and land use and water use efficiencies, were estimated. Irrigation depths and the intercropping affected only forage cactus canopy width and cladode biomass. The ratio between crop and reference evapotranspiration increased with the increase of irrigation depths, while the highest water use efficiency based on dry matter occurred at irrigation depths higher than 1,096 mm year^{-1} in the intercropping (21.8 ± 6.8 kg ha^{-1} mm^{-1}). Irrigation depths did not affect land use efficiency (0.83). Water depths from 1,096 to 1,202 mm year^{-1} are recommended in the forage cactus sorghum system.

Palavras-chave:
evapotranspiração real
gotejamento
uso da terra
região semiárida

Crescimento, consumo de água e eficiência do consórcio palma-sorgo sob diferentes lâminas de água

RESUMO
Os efeitos da configuração palma-sorgo e de diferentes lâminas de irrigação sobre o crescimento, consumo de água e eficiência do sistema de produção da palma foram investigados neste estudo. O experimento foi conduzido em Serra Talhada, PE, entre os anos de 2012 e 2013, com a palma disposta em blocos ao acaso, quatro repetições, em parcelas subdivididas (5 x 2) de cinco lâminas (0, 8,75, 17,5, 26,25 e 35% da evapotranspiração de referência) e dois sistemas de cultivo (palma exclusiva e consórcio palma-sorgo). A evapotranspiração real da cultura foi calculada por meio do balanço de água no solo. Estimou-se a razão evapotranspiração real e de referência, além das eficiências do uso da água e da terra. As lâminas de irrigação e a adoção do consórcio afetaram apenas a largura do dossel e a biomassa dos cladódios da palma forrageira. A razão evapotranspiração real e de referência aumentou com o incremento da lâmina de irrigação, enquanto as maiores eficiências do uso da água com base na massa seca ocorreram nas lâminas de água superiores a 1.096 mm ano^{-1} no consórcio (21,8 ± 6,8 kg ha^{-1} mm^{-1}). As lâminas de irrigação não afetaram a eficiência do uso da terra (0,83). No sistema palma-sorgo, recomendam-se lâminas de água entre 1.096 e 1.202 mm ano^{-1}.

Ref. 177874 – Received 31 Mar, 2017 • Accepted 19 Sep, 2017 • Published 22 Dec, 2017

Introduction

Forage cactus stands out as an excellent forage species for semi-arid environments, since it can tolerate long periods of water deficit (Silva et al., 2014a). However, adopting the intercropping of forage cactus with other plants favors the supply of diversified food and improves land use efficiency (Stoltz & Nadeau, 2014).

The literature reports intercropping of forage cactus with various other vegetable crops (Silva et al., 2013), and the most common is the rainfed forage cactus sorghum configuration (Farias et al., 2000). Nonetheless, the efficiency of intercropping systems with this species, in comparison to its mono cultivation, depends on the secondary crop and on management (Silva et al., 2013).

The efficiency of forage cactus sorghum intercropping under different conditions of irrigation has still been little researched, but studies demonstrate that using irrigation in forage cactus plantations is an excellent alternative to improve yield (Flores-Hernández et al., 2004; Queiroz et al., 2015). Hence, it is believed that in the forage cactus sorghum intercropping, although there is a reduction in the performance of both crops, the adoption of irrigation events can maximize the production in comparison to the forage cactus monocropping system. This type of information is important to increase the efficiency of the crops, but depends on their evapotranspiration (ET) (Djurovic et al., 2016; Kiremit & Arslan, 2016).

In intercropping systems, ET is commonly higher compared with the monocropping systems (Yang et al., 2011), but in the forage cactus sorghum configuration this trend may not be observed, because the Crassulacean acid metabolism of the forage cactus favors gas exchanges during the nighttime (Queiroz et al., 2015; Scalisi et al., 2016), while for C4 plants (i.e., sorghum), ET is predominant in the daytime period (Wang et al., 2015).

The effects of the forage cactus sorghum configuration and different irrigation depths on the growth, water use and efficiency of the forage cactus production system were investigated in the present study.

Material and Methods

The study was carried out in Serra Talhada, PE, Brazil (7º 59' S, 38º 15' W; 431 m), under BSwh' climate, according to Köppen's classification. In March 2011, when the area was harrowed and furrowed, the experiment was installed in an Red Yellow Argisol with the following physical-hydraulic characteristics: 1.5 kg dm^{-3} (soil bulk density), 2.6 kg dm^{-3} (soil particle density), 40.8% (total porosity), 662.8 g kg^{-1} (total sand), 273.4 g kg^{-1} (silt) and 63.8 g kg^{-1} (clay), determined according to the methodologies described in EMBRAPA (1997).

Forage cactus, cv. 'Orelha de Elefante Mexicana' (*Opuntia stricta* (Haw.) Haw.), was conducted in a rainfed monocropping system until May 2012, when uniformization cut was performed, leaving only basal cladodes. From June 2012 on, the second forage cactus crop cycle started, which corresponded to the experimental period, maintained until June 2013, in a total of 380 days.

Forage cactus was arranged in randomized blocks, in a split-plot factorial scheme (5 x 2), with four replicates, composed of five irrigation depths based on fractions of reference evapotranspiration (ET_0) (0, 8.75, 17.5, 26.25 and 35% ET_0), resulting in 583, 655, 703, 759 and 809 mm $year^{-1}$, which combined with the rainfall of 393 mm $year^{-1}$ led to 976, 1,048, 1,096, 1,152 and 1,202 mm $year^{-1}$, and two cropping systems, one exclusively with forage cactus, and another with the forage cactus sorghum intercropping. Irrigation depth fractions were established based on the crop coefficients for forage cactus cited by Consoli et al. (2013). ET_0 was estimated by the Penman-Monteith method (Allen et al., 1998), using data from an automatic weather station of the National Institute of Meteorology - INMET (www.inmet.gov.br), 300 m away from the studied area.

Each experimental unit was formed by four 6-m-long rows spaced by 1.6 m. In each row, 15 cladodes were planted at spacing of 0.4 m. The two most external rows and the two plants at the ends of the central rows were considered as borders, resulting in total area of 38.4 m^2, evaluation area of 12.8 m^2 with 22 plants, totaling 1,536 m^2.

The intercropping system was installed in November 2012, with the introduction of one row of dual-purpose forage sorghum (grains and silage), cv. IPA-2502, at spacing of 0.25 m between plants. At this moment, continuous 6-m-long, 0.05-m-deep furrows were opened, and 18 seeds were planted per linear meter. Sorghum was conducted for two crop cycles (plant and ratoon); the first one harvested in February 2013 and the second one in June 2013, totaling 246 days.

Irrigations were applied using a drip system with flow rate of 1.4 L h^{-1} at pressure of 100 kPa and distribution efficiency of 93%. The lines were placed closer to the forage cactus crop, in the monocropping system, and in equidistant points between the rows of forage cactus and sorghum, in the intercropping system. Irrigation events used water from the Açude Saco (http://www.apac.pe.gov.br), and its electrical conductivity varied from 1.1 to 1.6 dS m^{-1} along the cycle of the crops.

From June to November 2012, there was no difference in the irrigation depths, in order to allow initial establishment of the crops. From December 2012 to June 2013, the crops were subjected to different irrigation depths based on ET_0 (0, 8.75, 17.5, 26.25 and 35% ET_0). Fertilization was performed (broadcast) using the formulation 14-00-18 (NPK), according to the soil analysis.

Forage cactus growth was evaluated based on biometric and biomass data collected at harvest, following the procedures described by Silva et al. (2014b).

Cumulative crop evapotranspiration of the forage cactus monocropping system and forage cactus sorghum intercropping system was calculated based on the residual of soil water balance for 14 days, as described by Silva et al. (2014a). In this method, its components were quantified for a 0.60 m control volume. Water inputs and outputs through surface and subsurface runoff were disregarded. Thus:

$$-ET = \Delta S - P - I \pm Q \qquad (1)$$

where:

ET - crop evapotranspiration, mm;

ΔS - soil water storage variation, mm;
P - rainfall, mm;
I - irrigation, mm; and,
Q - vertical water flow in the soil, mm.

ΔS was obtained by the difference between initial and final values of soil water storage in the 14-day interval, monitored through access tubes installed in each experimental subplot, 0.10 m away from the forage cactus and sorghum crops, using a capacitive probe (Diviner@2000, Sentek Pty Ltda. Australia), previously calibrated for the experimental area, as described by Araújo Primo et al. (2015). Readings were taken in relative frequency and automatically converted to water depth at every 0.10 m, until the 0.70 m depth, one layer below the lower limit depth of the control volume (0.60 m). Readings were taken at 3 day intervals, from June 2012 to June 2013.

Phosphorus was measured in the automatic weather station, while I was established based on the treatments of irrigation depth. Darcy-Buckingham equation was used to calculate Q between the 0.50 and 0.70 m layers, which represented deep drainage (negative sign) or capillary rise (positive sign), according to the equations described by Araújo Primo et al. (2015).

ET and ET_0 values were used to calculate the ET/ET_0 ratio.

Water use efficiency was calculated based on the ratio between the yield of the cropping systems under each irrigation depth condition and the cumulative ET:

$$WUE = \frac{Y}{ET} \quad (2)$$

where:

WUE - water use efficiency, t ha^{-1} mm^{-1};
Y - yield, based on fresh or dry matter, t ha^{-1}; and,
ET - cumulative crop evapotranspiration during the 380-day cycle, mm.

Partial land use efficiency (LUEp) was calculated using the following equation:

$$LUEp = \frac{Y(P)_{intercropping}}{Y(P)_{monocropping}} \quad (3)$$

where:

$Y(P)_{intercropping}$ - forage cactus yield in the intercropping system, t ha^{-1}; and,
$Y(P)_{monocropping}$ - forage cactus yield in the monocropping system, t ha^{-1}.

For WUE and LUE calculations, the yields of both systems were obtained based on total weight and number of plants in the evaluation area of the experimental plot, plant density at harvest (15,625 plants ha^{-1}) and dry matter content. Five cladodes per subplot were sampled and weighed, to determine the individual fresh matter of the cladode (FM), and then dried in a forced-air oven until constant weight, to determine the individual dry matter of the cladode (DM). FM/DM ratio was used to calculate the dry matter content.

For sorghum, the fresh weight of ten plants was considered, final plant density by counting the number of individuals per linear meter at harvest in the plant and ratoon cycles, and the dry matter content was obtained after drying three plants per subplot, considering their respective fresh weights.

Productive performance of the intercropping system was expressed, in t ha^{-1}, by the sum of forage cactus and sorghum yields in both crop cycles.

In total, seven structural features were evaluated in the plants (canopy height and width, total number of cladodes, number of first-, second- and third-order cladodes and cladode area index) and 21 in the cladodes (length, width, thickness, perimeter and area of first-, second- and third-order cladodes, and individual fresh and dry biomass of first-, second- and third-order cladodes), besides the water balance components (ET, ΔS and Q), ET/ET_0, WUE and LUEp. Normality and homoscedasticity tests and analyses of variance were applied. When there was effect of the factors irrigation depths and cropping systems, the variables were subjected to the LSD test (Least significant difference, 5%).

Results and Discussion

There was no isolated effect of irrigation depths on plant growth and cladode growth of forage cactus ($p > 0.05$). On the other hand, effect of the intercropping was only noted on forage cactus canopy width ($p < 0.05$) (Figure 1) and there was no alteration in most features of the cladode, demonstrating that, in this configuration of cultivation, the sorghum crop did not affect forage cactus features. Nevertheless, Silva et al. (2013) cite that forage cactus response may vary according to the intercropping.

The only structural feature of the cladode affected by the intercropping was its individual biomass, with lower values, based on fresh and dry matter, at water depth of 1096 mm $year^{-1}$ (703 + 393) (Table 1). Scalisi et al. (2016) report that cladode growth is more related to plant water status. Under conditions of full water regime, its dynamics depends more on the temperature.

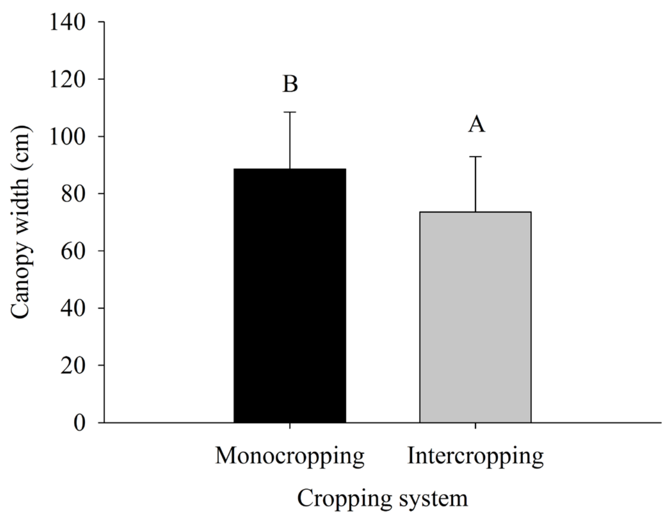


Figure 1. Effect of forage cactus sorghum intercropping on forage cactus canopy width under irrigation depths (mean of 583, 655, 703, 759 and 809 mm $year^{-1}$ plus rainfall of 393 mm $year^{-1}$)

Table 1. Effects of the interaction between irrigation depths (583, 655, 703, 759 and 809 mm $year^{-1}$ plus rainfall of 393 mm $year^{-1}$) and cropping system (forage cactus monocropping and forage cactus sorghum intercropping) on forage cactus cladode growth

Cropping systems	Irrigation depths + Rainfall (mm $year^{-1}$)				
	583 + 393 976	655 + 393 1048	703 + 393 1096	759 + 393 1152	809 + 393 1202
	Fresh biomass of first-order cladode (g)				
Monocropping	656.0 Ab	581.9 Ab	858.0 Aa	572.7 Ab	622.6 Ab
Intercropping	669.3 Abc	679.4 Abc	509.8 Bc	559.7 Abc	725.7 Aab
	Dry biomass of first-order cladode (g)				
Monocropping	68.1 Abc	67.1 Bbc	80.0 Aa	65.5 Abc	69.9 Abc
Intercropping	67.5 Abc	74.6 Aa	66.2 Bc	66.4 Abc	70.7 Aabc

Means followed by the same uppercase letters in the column do not differ statistically within the same water depth, while means followed by the same lowercase letters in the row do not differ statistically within the same cropping system, at 0.05 significance level by the LSD test

There was no effect of cropping system and its interaction with irrigation depths on the water balance components and ET/ET_0 ratio ($p > 0.05$). Isolated effect of irrigation depths modified soil water storage variation (ΔS) and actual evapotranspiration of forage cactus (ET) ($p < 0.05$) and, consequently, ET/ET_0. Increment in the water regime increased the magnitudes of ΔS and ET (Figures 2A and B).

ET values ranged from 889 to 1070.4 mm $year^{-1}$, higher than those reported by Han & Felker (1997) for *Opuntia ellisiana* L., under rainfed cultivation in the semi-arid region of Kingsville, Texas, USA, with total ET of 499 mm $year^{-1}$ under rainfall of 833 mm $year^{-1}$. Silva et al. (2015), studying *Opuntia stricta* (Haw.) Haw., in single-crop system, under rainfed condition with rainfall of 928 mm $year^{-1}$, reported ET equivalent to 888 mm $year^{-1}$.

Highest ET/ET_0 values occurred at higher irrigation depths (759 + 393 and 809 + 393 mm $year^{-1}$), but did not differ from those relative to irrigation depths of 583 + 393 and 655 + 393 mm $year^{-1}$ (Figure 3). On average, ET/ET_0 ratio was equal to 0.50, regardless of irrigation depth and cropping system, indicating that there is no need to change forage cactus water management because of the introduction of sorghum. Under full conditions of water and nutrients, ET/ET_0 represents the crop coefficient (Kc). Consoli et al. (2013) found mean Kc of 0.40 for 10-year-old fruiting forage cactus, in monocropping system, under Mediterranean conditions in Italy.

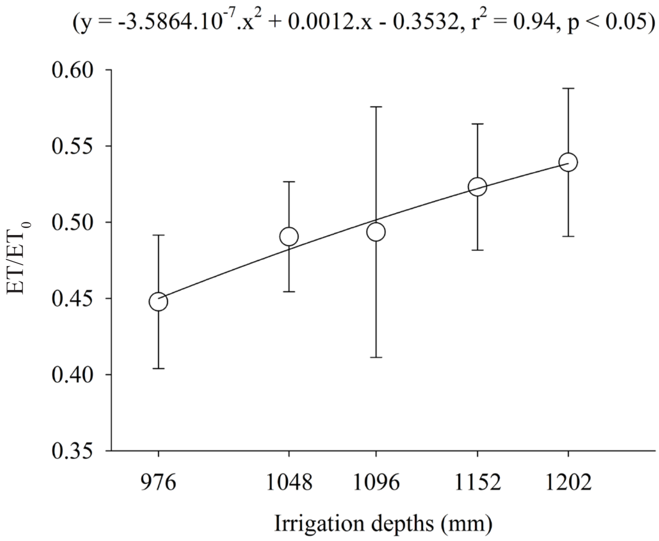


Figure 3. Effect of irrigation depths (mean of 583, 655, 703, 759 and 809 mm $year^{-1}$ plus rainfall of 393 mm $year^{-1}$) on the ET/ET_0 ratio of forage cactus

Irrigation depth and its interaction with the cropping system also did not affect WUE based on fresh matter ($p > 0.05$), resulting in average of 132.9 ± 54 kg of FM ha^{-1} mm^{-1}. In addition, there was no effect of irrigation depth on WUE based on dry matter (13.7 ± 7.8 kg of DM ha^{-1} mm^{-1}).

The effects of cropping systems and its interaction with irrigation depths ($p < 0.05$) demonstrated that the adoption

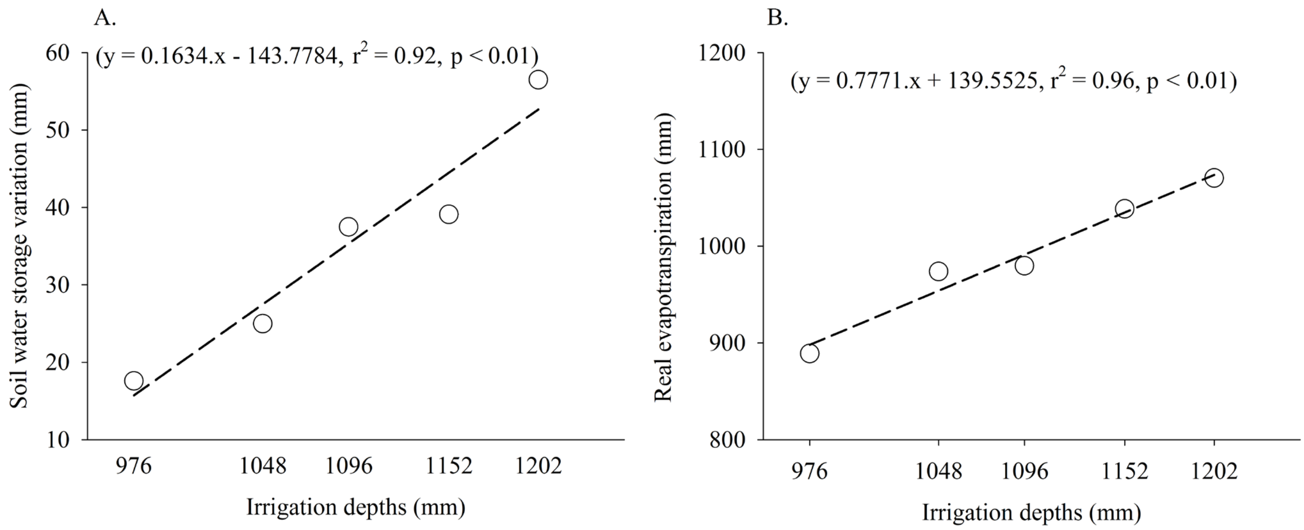
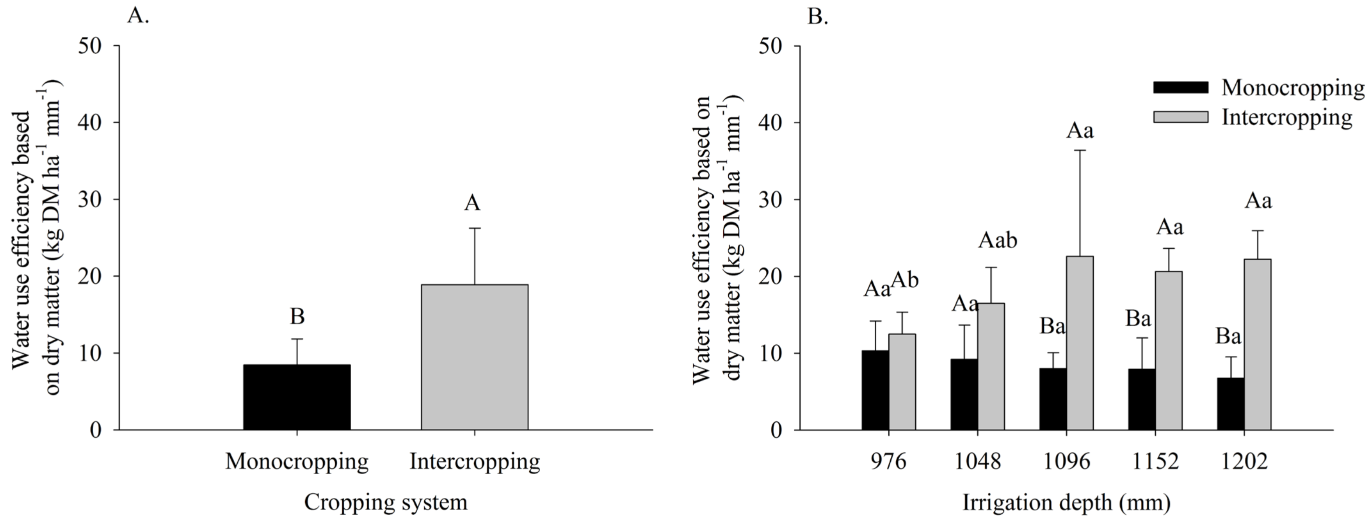


Figure 2. (A) Effect of irrigation depths (mean of 583, 655, 703, 759 and 809 mm $year^{-1}$ plus rainfall of 393 mm $year^{-1}$) on soil water storage variation and (B) actual evapotranspiration of forage cactus



Columns followed by the same uppercase letters do not differ in the cropping systems. Columns followed by the same lowercase letters do not differ in the irrigation depths (LSD test, 0.05)

Figure 4. (A) Effects of forage cactus sorghum intercropping and (B) of its interaction with irrigation depths plus rainfall of 393 mm year^{-1} on water use efficiency based on dry matter

of intercropping led to increment in WUE (Figure 4A), reaching 18.9 ± 7.4 kg of DM ha^{-1} mm^{-1}, higher than that for monocropping (8.4 ± 3.4 kg of DM ha^{-1} mm^{-1}). Literature results indicate higher WUE in intercropping systems compared with the monocropping systems (Miriti et al., 2012; Wang et al., 2015). Highest WUE values were obtained by the intercropping with irrigation depths above 1,096 mm year^{-1} (703 + 393 mm year^{-1}) (Figure 4B), in which the average was 21.8 ± 6.8 kg DM ha^{-1} mm^{-1}.

Silva et al. (2014a), in forage cactus, cv. *Opuntia stricta* (Haw.) Haw., based on ET, found WUE of 10.8 kg DM ha^{-1} mm^{-1}, under rainfed condition and rainfall of 791 mm year^{-1}.

The LUEp was not affected by the different irrigation depths ($p > 0.05$), based on both fresh and dry matter, resulting in average of 0.83 ± 0.31. Silva et al. (2013) reported intercropping systems with forage cactus, showing that forage cactus yield is reduced due to the competition with the secondary crop.

Conclusions

1. Adopting irrigation depths and forage cactus sorghum intercropping system did not affect forage cactus growth (except canopy width) and cladode growth (except individual fresh and dry biomass of the cladodes).

2. Irrigation depths changed soil water storage variation and actual evapotranspiration of forage cactus in monocropping and intercropping systems.

3. Water use in the forage cactus cropping system did not increase due to the introduction of dual-purpose forage sorghum.

4. Adopting forage cactus sorghum intercropping system increased water use efficiency based on dry matter, and irrigation depths from 1,096 to 1,202 mm year^{-1} are recommended, while the different water regimes did not change the partial land use efficiency.

Acknowledgments

To the National Council for Scientific and Technological Development (CNPq) for the financial support (Process n°. 475279/2010-7) and to the Science and Technology Support Foundation of Pernambuco (FACEPE) for granting the Postgraduate scholarship (Process n° IBPG-0547-5.01/12).

Literature Cited

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Crop evapotranspiration: Guidelines for computing crop water requirements. 1.ed. Rome: FAO, 1998. 301p.

Araújo Primo, J. T. de; Silva, T. G. F. da; Silva, S. M. S. e; Moura, M. S. B. de; Souza, L. S. B. de. Calibração de sondas capacitivas, funções físico-hídricas e variação do armazenamento de água em um argissolo cultivado com palma forrageira. Revista Ceres, v.62, p.20-29, 2015. https://doi.org/10.1590/0034-737X201562010003

Consoli, S.; Inglese, G.; Inglese, P. Determination of evapotranspiration and annual biomass productivity of a cactus pear [*Opuntia ficus-indica* L. (Mill.)] orchard in a semiarid environment. Journal of Irrigation and Drainage Engineering, v.139, p.680-690, 2013. https://doi.org/10.1061/(ASCE)IR.1943-4774.0000589

Djurović, N.; Ćosić, M.; Stričević, R.; Savić, S.; Domazet, M. Effect of irrigation regime and application of kaolin on yield, quality and water use efficiency of tomato. Scientia Horticulturae, v.201, p.271-278, 2016. https://doi.org/10.1016/j.scienta.2016.02.017

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Manual de métodos de análise de solo. 2.ed. Rio de Janeiro: Centro Nacional de Pesquisa de Solos, 1997. 212p.

Farias, I.; Lira, M. de A.; Santos, D. C. dos; Tavares Filho, J. J.; Santos, M. V. F. dos; Fernandes, A. de P. M.; Santos, V. F. dos. Manejo de colheita e espaçamento da palma forrageira em consórcio com sorgo granífero no Agreste de Pernambuco. Pesquisa Agropecuária Brasileira, v.35, p.341-347, 2000. https://doi.org/10.1590/S0100-204X2000000200013

Flores-Hernández, A.; Orona-Castillo, I.; Murillo-Amador, B.; García-Hernández, J. L.; Troyo-Dieguez, E. Yield and physiological traits of prickly pear cactus 'nopal' (*Opuntia* spp.) cultivars under drip irrigation. Agricultural Water Management, v.70, p.97-107, 2004. https://doi.org/10.1016/j.agwat.2004.06.002

Han, H.; Felker, P. Field validation of water-use efficiency of the CAM plant *Opuntia ellisiana* in south Texas. Journal of Arid Environments, v.36, p.133-148, 1997. https://doi.org/10.1006/jare.1996.0202

Kiremit, M. S.; Arslan, H. Effects of irrigation water salinity on drainage water salinity, evapotranspiration and other leek (*Allium porrum* L.) plant parameters. Scientia Horticulturae, v.201, p.211-217, 2016. https://doi.org/10.1016/j.scienta.2016.02.001

Miriti, J. M.; Kironchi, G.; Esilaba, A. O.; Heng, L. K.; Gachene, C. K. K.; Mwangi, D. M. Yield and water use efficiencies of maize and cowpea as affected by tillage and cropping systems in semi-arid Eastern Kenya. Agricultural Water Management, v.115, p.148-155, 2012. https://doi.org/10.1016/j.agwat.2012.09.002

Queiroz, M. G. de; Silva, T. G. F. da; Zolnier, S.; Silva, S. M. S. e; Lima, L. R.; Alves, J. de O. Características morfofisiológicas e produtividade da palma forrageira em diferentes lâminas de irrigação. Revista Brasileira de Engenharia Agrícola e Ambiental, v.19, p.931-938, 2015. https://doi.org/10.1590/1807-1929/agriambi.v19n10p931-938

Scalisi, A.; Morandi, B.; Inglese, P.; Bianco, R. L. Cladode growth dynamics in *Opuntia ficus-indica* under drought. Environmental and Experimental Botany, v.122, p.158-167, 2016. https://doi.org/10.1016/j.envexpbot.2015.10.003

Silva, G. dos S.; Oliveira, R. A. de; Queiroz, N. L.; Silva, M. N. B. da; Sousa, M. F. de; Silva, S. A. da. Desempenho agronômico de algodão orgânico e oleaginosas consorciados com palma forrageira. Revista Brasileira de Engenharia Agrícola e Ambiental, v.17, p.975-981, 2013. https://doi.org/10.1590/S1415-43662013000900010

Silva, T. G. F. da; Araújo Primo, J. T. de; Moura, M. S. B. de; Silva, S. M. S, e; Morais, J. E. F. de; Pereira, P. de C.; Souza, C. A. A. de. Soil water dynamics and evapotranspiration of forage cactus clones under rainfed conditions. Pesquisa Agropecuária Brasileira, v.50, p.515-525, 2015. https://doi.org/10.1590/S0100-204X2015000700001

Silva, T. G. F. da; Araújo Primo, J. T. de; Silva, S. M. S. e; Moura, M. S. B. de; Santos, D. C. dos; Silva, M. da C.; Araújo, J. E. M. Indicadores de eficiência do uso da água e de nutrientes de clones de palma forrageira em condições de sequeiro no semiárido brasileiro. Bragantia, v.73, p.184-191, 2014a. https://doi.org/10.1590/brag.2014.017

Silva, T. G. F. da; Miranda, K. R. de; Santos, D. C. dos; Queiroz, M. G. de; Silva, M. da C.; Cruz Neto, J. F. da; Araújo, J. E. M. Área do cladódio de clones de palma forrageira: Modelagem, análise e aplicabilidade. Revista Brasileira de Ciências Agrárias, v.9, p.633-641, 2014b. https://doi.org/10.5039/agraria.v9i4a4553

Stoltz, E.; Nadeau, E. Effects of intercropping on yield, weed incidence, forage quality and soil residual N in organically grown forage maize (*Zea mays* L.) and faba bean (*Vicia faba* L.). Field Crops Research, v.169, p.21-29, 2014. https://doi.org/10.1016/j.fcr.2014.09.004

Wang, Z.; Zhao, X.; Wu, P.; Chen, Z. Effects of water limitation on yield advantage and water use in wheat (*Triticum aestivum* L.) / maize (*Zea mays* L.) strip intercropping. European Journal of Agronomy, v.71, p.149-159, 2015. https://doi.org/10.1016/j.eja.2015.09.007

Yang, C.; Huang, G.; Chai, Q.; Luo, Z. Water use and yield of wheat/maize intercropping under alternate irrigation in the oasis field of northwest China. Field Crops Research, v.124, p.426-432, 2011. https://doi.org/10.1016/j.fcr.2011.07.013