PRODUCTION OF CACTUS PEAR IRRIGATED WITH BRACKISH WATER AND ORGANIC MATTER

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ABSTRACT: Due to the lack of food to offer the animals during the dry season, the irrigated cultivation of cactus pear is justified to accelerate the harvest. Given this, the supply of saline water as a water source to meet the needs of plants becomes an important alternative for the development of irrigated agriculture. However, irrigation with saline water when poorly managed, can compromise the production system. Animal manure can be used to minimize the harmful effects of irrigation water salinity on plants. For higher productivity of cactus pear crops, the implementation of a production system with water supplementation using irrigation with brackish water from underground wells in the region and the adequate incorporation of organic fertilizer is an alternative for farmers. Therefore, this review aimed to gather information about the cultivation of cactus pear irrigated with saline water and fertilized with doses of of organic matter.

KEYWORDS: Brackish water, Manure, *Opuntia stricta* Haw, Semiarid.

PRODUÇÃO DE PALMA FORRAGEIRA IRRIGADA COM ÁGUA SALOBRA E DOSES DE MATÉRIA ORGÂNICA

RESUMO: Devido à falta de alimentos para oferecer aos animais durante a estação seca, justifica-se o cultivo irrigado da palma forrageira para acelerar a colheita. Diante disso, o fornecimento de água salina como fonte hídrica para suprir as necessidades das plantas torna-se uma importante alternativa para o desenvolvimento da agricultura irrigada. No entanto, a irrigação com água salina, quando mal manejada, pode comprometer o sistema de produção. O esterco animal pode ser usado para minimizar os efeitos nocivos da salinidade da água de irrigação nas plantas. Para maior produtividade da cultura da palma forrageira, a implantação de um sistema de produção com suplementação hídrica utilizando irrigação com água salobra de poços subterrâneos da região e a incorporação adequada de adubo orgânico é uma alternativa para os agricultores. Portanto, esta revisão teve como objetivo reunir informações sobre o cultivo da palma forrageira irrigada com água salina e adubada com doses de matéria orgânica.

PALAVRAS-CHAVE: Água salobra, Esterco, *Opuntia stricta* Haw, Semiárido.

INTRODUCTION

In arid and semiarid regions, the uneven distribution of rainfall and the limited availability of freshwater can limit the development of competitive and economically viable livestock production (Silva, 2017). In this context, the use of water from underground wells, which mostly have high levels of salinity, appears as an alternative. When well managed, the use of this water in a rational and controlled way can represent an alternative for irrigation of some crops. According to Lima et al. (2018), irrigation in a production system depends on agroeconomic performance, which is based on the productive response, net income, and economic viability.

Cactus pear responds positively to irrigation. According to Araújo Júnior et al. (2021), the Orelha de Elefante Mexicana (OEM) variety, when irrigated, provides an economic return 18 months after planting. However, caution is required in the irrigation of this plant with saline water, since when in excess in the soil, the salts can compromise the rational agricultural exploration because of the osmotic effects, ionic toxicity, and nutritional imbalance, causing a reduction in growth and development of the crops, consequently serious damage to agricultural activity (Andrade et al., 2019). In addition to promoting variations in the chemical and physical structures of the soil, culminating in the loss of fertility and susceptibility to erosion (Schossler et al., 2012).

Considering the damage that saline water can cause, salt toxicity has to be minimized and soil properties have to be improved by using economic approaches such as the application of organic fertilizer (Shaaban et al., 2013). The benefits of adding organic materials are due to their role in minimizing the deleterious effects of salts in the soil through improvement, and alteration of the chemical and physical properties of the soil, as well as its role as a fertilizer (Murtaza et al., 2020).

For greater productivity of cactus pear crops, the implementation of a production system with water supplementation using irrigation with brackish water from underground wells in the region and the adequate incorporation of organic fertilizer is an alternative for farmers in this region, mainly due to freshwater restriction. In this sense, this review aimed to gather information about the cultivation of cactus pear irrigated with saline water and fertilized with doses of organic matter.

PRODUCTIVE AND NUTRITIONAL POTENTIAL OF CACTUS PEAR

Cactus pear represents most of the food offered to animals during the dry season in the northeastern semiarid regions, which is justified by the following characteristics: rich in water, mucilage, and mineral residue, high coefficient of dry matter digestibility, and high productivity per unit area (Lopes et al., 2013). Which makes it a viable alternative to maintaining adequate levels of animal productivity in the semiarid region (Dubeux Júnior et al., 2010).

According to Abidi et al. (2009), cactus pear contains an average of 90% water in its composition. This high-water content tends to reduce water intake by animals (Magalhães et al., 2019), which favors animal production in periods of water deficit, common in the semiarid region. Some authors observed that water intake via a drinking fountain linearly decreased as the levels of cactus in the diet increased (Abidi et al., 2009; Soares, 2017). According to the NRC (2001), the requirement for water can be met through three different sources: voluntary intake of water; water intake from food; and water from the metabolism of nutrients in the body.

Among the cactus pear varieties, the Orelha de Elefante Mexicana (OEM) presents good agronomic responses, is less demanding in terms of nutrients, more tolerant to water stress conditions, and shows a higher production of dry matter per unit area compared to the Miúda cactus (Lopes et al., 2019). However, it presents variations in chemical composition (Table 1) according to plant age, harvest time, climate, fertilization management, and planting spacing.

References	DM[1]	OM[2]	MM[2]	CP[2]	EE[2]	NFC[2]	NDF[2]	ADF[2]
				g.kg^{-1}				
Araújo Júnior et al. (2021)	86,5	840,2	159,7	35,8	8,0	-	161,6	-
Conceição et al. (2018)	105,5	802,5	198	55,5	12,1	406,7	291,6	
Góes Neto et al. (2021)	103,4	811,4	-	74,1	16,2	342,8	421,2	281,0
Pessoa et al. (2020)	96,86	889,9	112,8	53,1	15,4	616,7	210	141,1
Monteiro et al. (2019)	123	914	86	55	-	550	259	-
Morais et al. (2019)	107,7	893,2	-	63,6		545,1	272,4	-
Silva et al. (2018)	94,0	881,2	-	60,0	12,7	547,3	262	-

DM= Dry matter, OM= Organic matter, MM= Mineral matter, CP= Crude protein, NFC= Non-fibrous carbohydrates, NDF= Neutral detergent fiber, ADF= Acid detergent fiber. [1]g.kg^{-1} Natural matter. [2]g.kg^{-1} Dry matter.

Table 1. Chemical composition of cactus pear Orelha de elefante mexicana

The high productivity of cactus pear in the semiarid region is due to their adaptation to the climate of this region, which can be partially explained by the opening of the stomata essentially at night, when ambient temperatures are mild, which reduces water losses by evapotranspiration, thus showing a high water use efficiency (WUE) (Taiz & Zaiger, 2016).

Water use efficiency (WUE) for cactus pear is 50:1, that is, 50 kg water for each 1 kg dry matter produced, while C3 and C4 plants have efficiencies of 1000:1 and 500:1, respectively (Pereira et al., 2012). Water use efficiency can be different between cultivars, as demonstrated by Silva et al. (2014a, 2014b), who found that the Orelha de elefante mexicana cultivar presented a superior WUE than the other cultivars studied, considering the green matter production.

The cactus pear production system in the semiarid region is marked by the low adoption of technologies, which directly leads to productivity lower than the capacity of the crop given its multiple options for use that are not explored. Traditionally, under non-irrigated cultivation conditions, cactus pear is harvested every two years (Silva et al., 2015), however, the beginning and length of each vegetative stage may vary depending on the adopted management practices, postponing or anticipating the time of crop harvest (Araújo Júnior et al., 2021). Among these technologies, the use of irrigation, fertilization, denser planting with techniques that increase crop yield, and the combination of these can be highlighted.

The adoption of irrigation to increase the growth and survival of cactus pear plantations is an alternative that can be used by farmers. Lira et al. (2016) mention that when having an irrigation system, even if the amount of water is limited, that is, even in conditions where the water supply through irrigation does not meet the requirements of the crop, a small amount of water can result in positive responses in the plant, mainly in cactus pear.

Irrigation promotes and guarantees the survival of the cactus pear crop and generates a strategic green reserve of water. According to Cândido et al. (2013), the water potential of dense cultivation of the cactus pear cultivar Gigante with a production of 400 Mg of green matter per hectare is high, with water content in the plantation around 90%, in which one hectare of the crop can supply around 360,000 liters water to cattle or goats in the semiarid region of Brazil.

USE OF BIOSALINE AGRICULTURE IN FORAGE PRODUCTION

Biosaline agriculture is a broad term used to characterize the cultivation of forage plants irrigated with saline well water (Masters et al., 2007). According to Silva et al. (2023), the use of saline water sources represents an alternative that can minimize the water supply crisis, especially in the arid and semiarid zones of the planet. These waters are used for irrigation and contain varying amounts of salts, which can interfere with crop development and production at certain concentrations.

The effects of salt stress on plants vary depending on different factors, such as the level of salt concentration, duration of exposure, phenological stage, interaction with environmental conditions, and resistance of the species or cultivar to salinity conditions (Toscano et al., 2019). The ability of the plant to survive and develop under saline stress is a function of its tolerance or escape mechanisms or a combination of both (Munns & Tester, 2008). According to the degree of tolerance to salinity, plants can be classified into halophytes: Plants that have a set of morphological, anatomical, and physiological adaptations that help them to germinate, grow, reproduce, and complete their life cycle in environments with high concentrations of salts (Nikalje et al., 2018); and glycophytes: Plants that are not adapted to tolerate salinity (Cheeseman et al., 2015).

Some halophytes have developed modified epidermal cells that accumulate excessive Na^+ in their vacuoles, which allows them to adapt to high salinity (Zhao et al., 2020), and can develop in environments with salt concentrations above 200 mM (millimolar) (Cheeseman et al., 2015).

In the Northeast, as in other regions of Brazil, the use of groundwater has increased in recent years. Soil drilling to reach water is a practice that farmers in semi-arid region use in search of a water source to meet the requirements of plants, thus becoming an important alternative for the development of irrigated agriculture (Santos et al., 2020).

Biosaline agriculture, when properly used, can increase crop production, however, when combined with inadequate management can cause great losses in a productive system, due to the excessive increase in the concentration of salts in the soil. The effects of salts on soil occur through the electrochemical interaction between salts and clay (Gheyi et al., 2016).

The increase in the exchangeable sodium concentration in the soil may make it denser, compact in dry conditions, dispersed, and sticky in wet conditions (Dias & Blanco, 2010). The concentration of sodium in the soil is capable of promoting the dispersion of clay particles, making the soil pulverized, causing clogging of micropores, reduced aeration, and water infiltration (Gasparetto et al., 2009).

Melloni et al. (2000) summarize the effects of soil salinity on plants into effect caused by the reduction of osmotic potential; nutritional imbalance due to the high ionic concentration and the inhibition of the absorption of other cations by the excess and toxic effect of sodium and chloride ions. The osmotic effect is due to the presence of salts in the soil that increase water retention forces, which reduces its availability for plants (Acosta-Motos et al., 2017) and, as a result, also reduces the availability of nutrients.

The increase in osmotic pressure caused by the excess of soluble salts in the soil solution may reach a level where plants will not have enough suction force to overcome the osmotic potential and, as a result, the plant will not absorb water, and consequently nutrients and this process is also called physiological drought (Dias & Blanco, 2010).

Another effect caused by salinization is the nutritional imbalance of the plant caused by disturbances in the absorption and/or distribution of nutrients. The reduction in Ca absorption, for example, can lead to loss of plasma membrane integrity, compromising the absorption capacity of some ions, mainly potassium (K) (Farias et al., 2009). In plants, the toxicity caused by saline water is mainly due to the presence of chlorine, sodium, and boron ions. These ions, when absorbed by plants, are accumulated in their tissues in concentrations high enough to cause damage to crops and reduce their yield (Silva et al., 2011).

One of the main determinants of livestock production in biosaline agriculture is the amount of biomass produced that can be consumed by the animals (Masters et al., 2007). The improvement in the use of brackish water has been the object of studies and, consequently, the effects of salt on the development and distribution of nutrients in plants have been better understood.

BRACKISH WATER FOR CACTUS PEAR IRRIGATION

The semiarid region has a network of very poor rivers, with low runoff volumes (Rocha & Soares, 2015). This can be explained by the temporal and spatial variability of rainfall and the dominant geological characteristics, where there is a predominance of shallow soils on crystalline rocks and, consequently, low water exchange between the river and the adjacent soil (Araújo, 2015).

In this scenario, the use of groundwater, specifically saline and brackish water, is important to increase agricultural and livestock production in the semiarid region. In addition, the availability of water for human consumption and agricultural practice has been gradually reduced both in quality and quantity, thus making the alternative use of water with higher salt contents necessary to meet the demand for agricultural irrigation in these regions (Silva et al., 2014a).

The quality of water used for irrigation is defined according to three criteria: its salinity, expressed as electrical conductivity, which assesses the risk of increasing the concentration of soluble salts in the soil; its sodicity expressed as Sodium Adsorption Ratio, SAR, which assesses the risk of raising the percentage of exchangeable sodium, causing deterioration in the soil structure, and finally its toxicity which assesses the accumulation of certain ions in plant tissues (Almeida, 2010).

Irrigation with brackish water to optimize the growth and survival of crops is a strategic alternative that can be used by farmers located in regions characterized by the uneven temporal and spatial distribution of rainfall. Nevertheless, the use of saline water must be done in a rational way, since the lack of knowledge in the use of this resource can lead to the total loss of the crop, in addition to making the use of the soil unsuitable for other crops or even accelerating a process of desertification (Silva, 2017).

For Nobel (2001), soil salinity of 100 ppm (parts per million) inhibits atmospheric CO_2 uptake and Opuntia growth by 30%. These levels are usually exceeded in soils irrigated with saline water, as well as under natural conditions, when high temperatures cause high evaporation and, consequently, accumulation of salts on the soil surface. According to Araújo Júnior et al. (2021), cactus pears are not tolerant to saline stress, with general inhibition of root development and shoots of cactus pears in saline soils, because high levels of sodium in the soil inhibit CO_2 fixation (Dubeux Júnior et al., 2010).

Freire et al. (2018) evaluated irrigation frequency (7, 14, 21, and 28 days) and salinity levels (0.3; 0.5; 1.5, and 3.6 dS m^{-1} NaCl) and noticed that the cactus pear does not tolerate the highest level of salts when irrigated with shorter intervals. In view of this, the tolerance of cactus pear and other plants to salinity for greater irrigation efficiency in each crop. When choosing to use brackish water in cactus pear irrigation, the soil must be well drained and irrigation should continue until the rainy season, since rain promotes the leaching of salts (Santos et al., 2020).

However, the use of irrigation systems with brackish water can increase the productivity of cactus pear plantations when well managed, as demonstrated by Fonseca et al. (2019), irrigating the cactus pear cultivar Gigante with 33% ETo with an interval of three days, which resulted in an increase in cactus height and the number of total cladodes in the plant.

ORGANIC MATTER FOR CACTUS PEAR CULTIVATION

The selection of the ideal planting system for cactus pear is influenced by several aspects such as climatic conditions, soil quality, property size, labor supply, technical assistance, the possibility of mechanization, costs of acquisition of inputs, availability of organic fertilizer, levels and sources of fertilizers, pests, and diseases, intercropped or monoculture cultivation, spacing used and among others (Padilha Júnior et al., 2016).

The mineral and organic maintenance fertilization is an important management measure for the cactus pear crop and should be carried out at each harvest, considering the high extraction of nutrients with the removal of the paddles (Lemos, 2016). Mineral fertilizers have great efficiency in the availability of nutrients for plants, but due to their high cost, livestock farmers do not always have sufficient financial conditions to purchase in quantity and quality according to their needs (Macedo et al., 2018). Because of this, the use of organic fertilizer produced on the property is an option for farmers. The use of organic matter as a nutrient source on agricultural land improves the physical properties of the soil, in addition to being an environmentally friendly way of waste disposal (Nazli et al., 2016).

According to Finatto et al. (2013), organic fertilizer consists of residues of animal and plant origin, which, after decomposition, results in organic matter. In the past, organic sources were the only sources used in the soil, with the development of mineral sources, organic fertilization was being used less, and currently, due to the social appeal, from the conservationist and ecological point of view, this practice is gaining space in areas with agriculture or livestock (Macedo et al., 2018).

Among the various beneficial effects of organic matter in the soil in agricultural systems, the stimulation of the soil microbiota, soil physical conditioning (structure, porosity), biological and chemical buffer effect with the supply of negative charges, and increased Cation Exchange Capacity – CEC, nutrients (N, P, K, and S), thermal control and better water retention stand out (Ungera et al., 1991; Conceição et al., 2005; Boulal et al., 2011; Lemos, 2016).

Given the improvements in soil texture, organic fertilization can increase the carrying capacity capacity of the semiarid region. According to Peixoto et al. (2018), the production of green matter ($Mg.ha^{-1}$) of cactus pear cultivar Gigante fertilized with bovine manure was 33.03% higher than the treatment without fertilization.

Regarding the amount of organic matter in cactus pear crops, Dubeux Júnior et al. (2010) recommend the use of 10 to 30 $Mg.ha^{-1}$ cattle manure after each harvest, depending on the planting spacing used. In turn, Santos et al. (2002) suggest that in denser plantations 30 $Mg.ha^{-1}$ can be used. Ramos et al. (2017) evaluated the growth of cactus pear cultivar Gigante as a function of fertilization with goat manure (0, 5, 10, 15, 20 $Mg.ha^{-1}$), and observed a linear increase in the number of cladodes with the addition of organic fertilizer. Barros et al. (2016) also observed that the application of 90 $Mg.ha^{-1}$ organic fertilizer to cactus pear cultivar Miúda promoted increments from 7.17 to 20.9 cladodes.

According to Macêdo et al. (2018), factors such as temperature, pH, and soil moisture are essential for the decomposition of organic matter to be more or less efficient. Souto et al. (2005) examined the decomposition rate of manure at different depths and reported that the decomposition was strongly influenced by the rainfall during the experimental period. According to Zhou et al. (2020), soil moisture acts on the dynamics of microorganisms that are essential for nutrient cycling and the fertility of agroecosystems, which stimulates plant growth and production. This is because water contributes to the solubilization of minerals present in the organic matter and uptake by the roots of cactus pear plants (Nunes, 2018).

FINAL CONSIDERATIONS

Irrigation with saline water can be a viable alternative to increase the productivity of cactus pear plantations, but proper management is required to minimize the effects of salts on the soil. Organic matter is a low-cost alternative that minimizes the deleterious effects of salts. Because of this, further research is necessary to evaluate the morphological, productive, and nutritional parameters of cactus pear irrigated with saline water and fertilized with doses of organic matter so that the production of cactus pear in the semiarid region can be improved.

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