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Initial Development of Safflower Submitted to Irrigation Water Salinity Levels

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Abstract

Safflower cultivation is an alternative to tropical cropping systems, with a good rusticity and some tolerance to saline stress in some cultivars. With the increase of irrigated areas around the world, salinization of the soil is an inherent concern, being the management of irrigation and cultivated species fundamental. The objective of this study was to evaluate the growth and initial development of safflower culture submitted to irrigation water salinity levels. The experiment was carried out in a greenhouse in a completely randomized design consisting of five irrigation water salinity levels (0, 2, 4, 6 and 8 dS m^{-1}) and six replications. The saline solution was prepared using NaCl and measured with a conductivity meter. Plant height, number of leaves and stem diameter at 26 and 41 days after emergence, and shoot dry weight were evaluated; root volume; root dry mass; total dry mass and dry root/shoot mass ratio at 41 days after plant emergence. There was no visual influence of salinity levels in the evaluations at 26 days after plant emergence. However, 41 days after plant emergence, the increase in salinity levels promoted a decrease in all analyzed variables, except for root volume. Safflower does not tolerate irrigation with saline water. The damages occur from 2 dS m^{-1}, but the largest reductions in the initial development of safflower occur from 6 to 8 dS m^{-1}.

Key words: *Carthamus tinctorius* L., electrical conductivity, NaCl, agricultural experimentation, Cerrado

1. Introduction

Brazil is a country with great expressiveness in the agricultural sector, being a worldwide highlight in food production, considered an important country for food security in the future (Hertel, 2015). Socio-climatic characteristics and their vast territory allow large-scale agriculture and livestock production, with emphasis on the production of oilseeds, cereals, and fibers exported to various regions of the world as well as horticulture, characterized by family farming (Goedert, 1989). However, it is perceived that for the maintenance of this scenario it is necessary to diversify production in the regions, aiming at the socioeconomic and environmental sustainability of the agricultural sector.

Specifically, in the Brazilian Central West, in general, soybeans, corn, and cotton are grown in the harvest and/or the second crop, and in some regions sugar cane. Thus, research on the adaptability of other species as an alternative to cultivation in the region, such as wheat (*Triticum aestivum*) (Freitas et al., 2018) in the State of Goiás, Mato Grosso and Mato Grosso do Sul, and the safflower (*Carthamus tinctorius* L.) in the State of Mato Grosso (Anicésio et al., 2018; Bonfim-Silva et al., 2018).

Safflower develops rapidly, and its seeds come to produce a high quality, high added value oil widely used in the food and cosmetic industry. In this sense, safflower cultivation can become an alternative to cultivation in the Brazilian Cerrado both in rainfed systems (first and second harvests) and irrigated (winter) systems.

According to the latest survey conducted by the National Water Agency in 2015, Brazil has an irrigated area of 6.95 million hectares, with a potential increase of 45% by the year 2030. Among all the regions, the Central West has the greatest effective potential for expansion, 32% according to the agency (ANA, 2017).

In these regions, an increase in the number of irrigated crops is possible, allowing up to three harvests per year, which perhaps can cause damages concerning soil salinization associated with the improper management of the system, depending on water quality and management (Wang et al., 2015; Gheyi et al., 2016). Researchers in China evaluated levels of irrigation water salinity in maize (*Zea mays* L.) and showed problems over the years in cases with soil drainage problems and found a reduction in productivity of 2.08 to 3.93% for each 1 dS m^{-1} increase in irrigation water (Feng et al., 2017).

Thus, the objective was to evaluate the initial growth and development of safflower submitted to irrigation water salinity levels.

2. Material and Methods

2.1 Overview and Experimental Design

The experiment was carried out in a greenhouse (16°28′ South Latitude, 50°34′ West Longitude, and 284 m altitude), from the Institute of Agrarian and Technological Sciences (ICAT), Federal University of Mato Grosso, Campus Rondonópolis, at the period between November 2017 and February 2018. Relative air humidity and average internal temperature during the growing season were 81% and 27 °C, respectively.

2.2 Soil Characterization and Preparation

The soil used was the Entisol (Soil Survey Staff, 2014), from an area under Cerrado vegetation, collected in the arable layer (0.0-0.20 m) and passed through a 4 mm mesh sieve. A soil sample was drawn for chemical and granulometric characterization (Table 1). The soil was analyzed according to EMBRAPA (1997).

Table 1. Chemical characterization and granulometric characterization of an Entisol, collected in the layer of 0.0 to 0.2 m depth

pH ($CaCl_2$)	P	K	Ca	Mg	Al+H	CEC	V	m	O.M.	sand	silt	clay
	--- mg dm^{-3} ---		------------- cmolc dm^{-3} ------------				------- % -------		---------------- g kg^{-1} ----------------			
4.9	1.1	12	0.2	0.2	3.8	4.2	10.4	65.04	12.3	773	36	191

Note. CEC: cation exchange capacity; V: base saturation; m: aluminum saturation; O.M.: organic matter.

The treatments consisted of five levels of saline water (0, 2, 4, 6 and 8 dS m^{-1}) arranged in a completely randomized design with six replicates, which were composed of plastic pots with a capacity of 1.5 dm^{-3}.

The saline solution was prepared in the laboratory using NaCl, weighed in an analytical balance to establish the relationship between the electrical conductivity (EC dS m^{-1}) as a function of NaCl concentration (g L^{-1}) using a 50 mL volumetric flask and calibration with a conductivity meter (Figure 1). Forcing the line to cross the origin, it is observed that the model overestimated the salinity levels of the soil, with a determination coefficient of 98%.

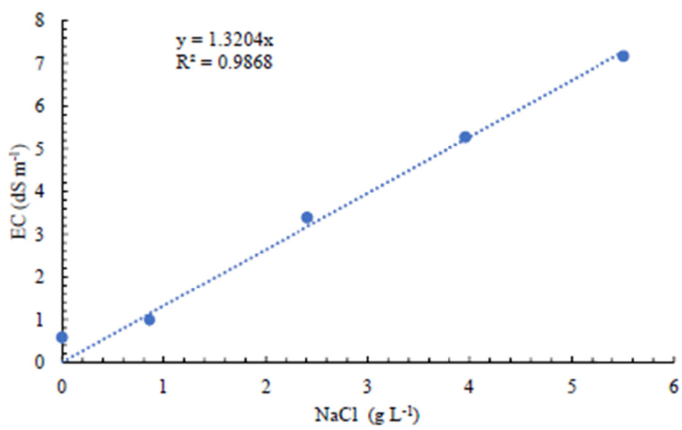

Figure 1. Electrical conductivity (EC) of the solution as a function of NaCl concentration

After the calibration, the model was used to prepare the solutions to be applied, using 2 L volumetric flasks. The control treatment was irrigated with the same water used to prepare the solutions.

The soil liming and incubation were performed for 21 days, for which purpose, the experimental units were filled. Dolomitic limestone (PRNT of 80%) was used and the level of base saturation was 60%. The fertilization with the primary macronutrients consisted of the application of 200 mg dm^{-3} phosphorus (P_2O_5) of 150 mg dm^{-3}, potassium (K_2O) of 200 mg dm^{-3} from urea, single superphosphate and respectively. Micronutrient fertilization consisted of the application of 15 mg dm^{-3} of FTE BR 12 (9%-Zn, 1.8%-B, 0.8%-Cu, 2%-Mn, 3.5%-Fe; 1%-Mo), applied at the time of plant transplanting (Paludo et al., 2017).

Due to the difficulty of germination and emergence of the seeds directly in the soil, they were first sown in a styrofoam tray for later transplanting to the soil (Figure 2). The cultivar used was IMA 0213, adapted to the edaphoclimatic conditions of the region.

Figure 2. Safflower plants (*Carthamus tinctorius* L.) emerging and emerged on a tray, prior to transplanting

After transplanting, a period of 11 days could acclimate the seedlings, and then, to begin the irrigation application with saline water. Two seedlings were transplanted per experimental unit (Figure 3). On the soil, a layer of wood sawing was applied to reduce the thermal amplitude in the soil, so that the volume used was 0.2 dm^{-3} for each experimental unit.

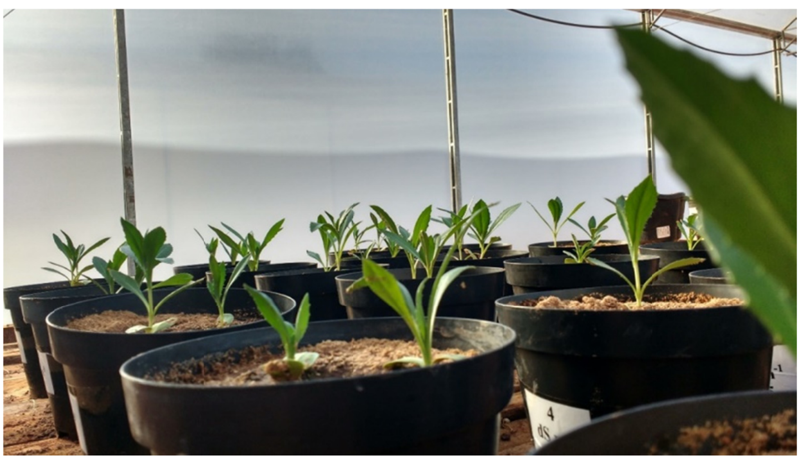

Figure 3. Safflower plants (*Carthamus tinctorius* L.) after transplanting submitted to irrigation with saline water

Irrigations with the treatments were carried out daily (for 11 days until 12/31/2018), applying 180 ml of solution in the respective treatments. On the other days, irrigations were carried out by the gravimetric method, and the amount needed to maintain soil moisture was 80% of the field capacity (Bonfim-Silva et al., 2011). The application of the treatments was interrupted at 27 days after transplanting due to the appearance of strong symptoms of salt stress toxicity in safflower plants (Figure 4).

Figure 4. Evolution of symptoms of saline toxicity (epinasty and chlorosis) in safflower plants (*Carthamus tinctorius* L.) grown in Entisol

2.3 Analyzed Variables

It was evaluated: height of plants; the number of leaves and stalk diameter at 26 and 41 days after emergence and shoot dry mass; root volume; root dry mass; total dry mass and dry root/shoot mass ratio at 41 days after emergence. After cutting, shoot and roots were weighed in a semi-analytical balance and taken to the forced circulation oven at 60-65 °C until a constant mass was reached.

Data were submitted to analysis of variance and when significant to regression test both significantly up to 5% probability by means of the statistical program SISVAR (Ferreira, 2011).

3. Results and Discussion

There was no effect for any evaluation at 26 days after emergence of safflower plants. This occurred due to the application of the treatments only beginning at 21 days after the emergence of the plants, and this period of four days was insufficient to accumulate salts at levels that affected the development of the plants.

When evaluated, plant height at 26 days after emergence did not show a difference between salinity levels with an average of 14.68 cm plant^{-1}. At 41 days, there was a difference between the treatments, adjusted to the linear regression model, with a decrease in plant height of 41.5%, in the comparison of the absence of salinity with the application of 8 dS m^{-1} (Figure 5).

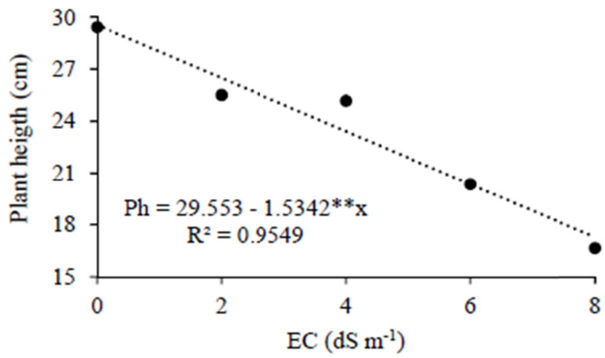

Figure 5. Safflower plant height (*Carthamus tinctorius* L.) at 41 days after emergence as a function of irrigation water salinity levels. EC: Electrical conductivity; Ph: Plant height. ** Significant at 1% probability.

As with plant height, the number of leaves of the plants was not significantly influenced by the treatments at 26 days after emergence, presenting a mean of 23.56 leaves of pot^{-1}. However, when evaluated at 41 days after emergence, leaf numbers were negatively influenced linearly by increased salinity levels of irrigation water (Figure 6). The percentage reduction was on the order of 52.4%, comparing the control at the highest saline level (8 dS m^{-1}).

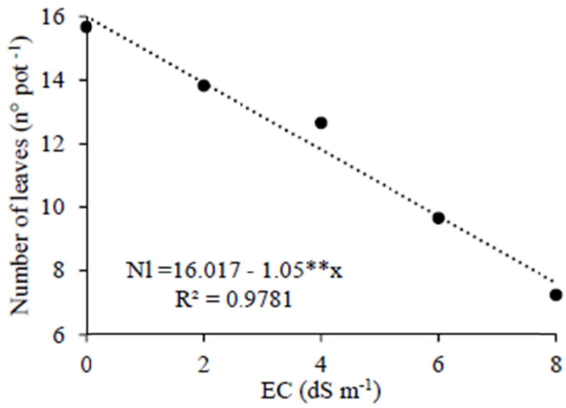

Figure 6. A number of safflower leaves (*Carthamus tinctorius* L.) at 30 days after emergence as a function of irrigation water salinity levels. EC: Electrical conductivity; Nl: Number of leaves.
** Significant at 1% probability

The accumulation of the Na^+ ion can cause serious damage to the leaves of the safflower plant so that the most characteristic symptom is "leaf burning" (Hussain et al., 2016). The reduction of the number of leaves will cause, consequently, less radiation interception, reduction of the photosynthetic rate and reduction of other productivity components, such as shoot dry mass.

The diameter of the stem was not significantly influenced by the salinity levels at 26 days after emergence, with a mean of 2.35 mm. When evaluated at 41 days, the diameter decreased linearly as the salinity levels were increased (Figure 7), resulting in a percentage reduction of 33.3%, comparing the control treatment with the highest saline irrigation water level (8 dS m^{-1}).

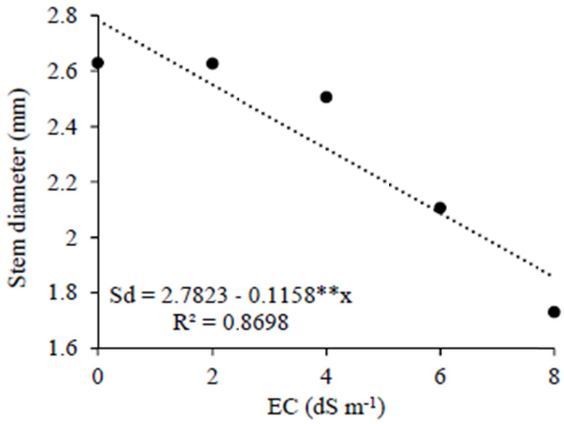

Figure 7. Stem diameter of safflower (*Carthamus tinctorius* L.) at 30 days after emergence as a function of irrigation water salinity levels. EC: Electrical conductivity; Sd: Stem diameter. ** Significant at 1.0% probability

The development of the aerial part of the plants was influenced in a linear descending manner as the salinity levels of the irrigation water increased, as well as for the previous variables. A decrease of 68% was observed when compared to the absence of salinity with maximum applied stress (8 dS m^{-1}) (Figure 8).

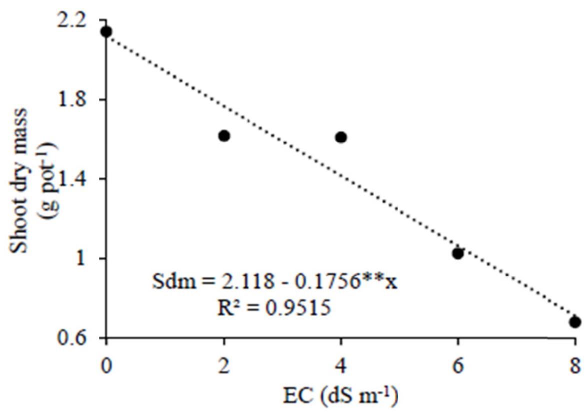

Figure 8. Shoot dry mass of the safflower (*Carthamus tinctorius* L.), as a function of irrigation water salinity levels. EC: Electrical conductivity; Sdm: Shoot dry mass. ** Significant at 1.0% probability

Regarding the root development, no difference was observed between treatments for root volume of safflower plants, presenting an average of 1.75 cm^3. However, for the dry mass of roots, it was verified the difference between the salinity levels of the soil, presenting an adjustment to the linear regression model. When comparing the absence of salt stress with the highest salinity level, there was a decrease of 72% in the root dry mass (Figure 9).

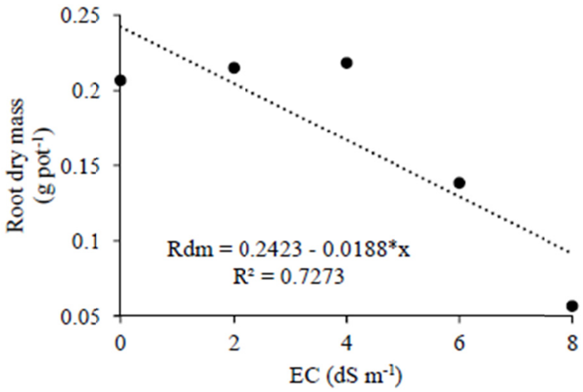

Figure 9. Root dry mass of safflower (*Carthamus tinctorius* L.) as a function of irrigation water salinity levels. EC: Electrical conductivity; Rdm: Root dry mass. * Significant at 5% probability

In a study evaluating the effects of salinity levels on germination and initial growth of safflower plants grown under greenhouse conditions in Turkey, a greater influence of salinity levels was observed in the roots than in the aerial part of safflower plants of evaluated varieties (Kaya, Ipek, & Öztürk, 2003).

As well as root dry mass and shoot dry mass, the total dry mass of the plant was influenced by soil salinity levels. The behavior that best described the data was the linear regression model, with a decrease of 68% when comparing the treatment without salt stress with the plants that developed in the highest saline stress (Figure 10).

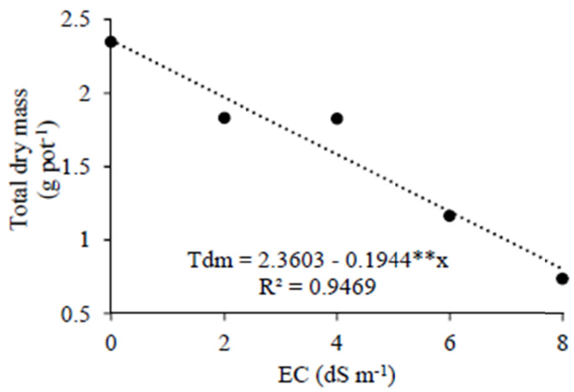

Figure 10. Total dry mass of safflower (*Carthamus tinctorius* L.) as a function of irrigation water salinity levels. EC: Electrical conductivity; Tdm: Total dry mass. ** Significant at 1% probability

In a research under protected cultivation with leek (*Allium porrum* L.) in Turkey, a significant reduction in the characteristics evaluated by the application of saline water to the electrical conductivity of the solution of 7 dS m^{-1} was also observed. Plant height, stem diameter, dry shoot, and root mass were drastically reduced as salt levels increased. Development reductions were observed from 2 dS m^{-1} (Kiremit & Arslan, 2016).

In safflower plants, salinity has negative effects at various stages of development, such as seed germination and vigor, shoot growth and roots, root-shoot ratio and root length (Hussain et al., 2016). However, the effects are less drastic in some safflower varieties, which are more tolerant to soil salinity.

In maize (*Zea mays* L.) cultivated in China in lysimeters, a significant reduction in dry mass production was also observed as a function of irrigation water salinity levels, with a reduction of up to 16.74%, higher saline level (6.25 dS m^{-1}) with the control treatment (0.78 dS m^{-1}) (Feng et al., 2017). Without an alternative soil drainage system, the researchers observed an increase in the concentration of salts in the soil in only two years of cultivation (2014 and 2015).

The ratio shoot dries mass/root dry mass dry mass, was not significantly influenced by applied saline stress, with a mean of 10.98 g pot^{-1}.

The dynamics of accumulation of salts in the soil varies between years and is dependent on the management used so that the effects can be minimized with the rainy period between two crops depending on the region. In a study evaluating the impact of irrigation with three levels of saline water on wheat cultivated in the winter in China, it was verified the return in the electrical conductivity of the soil to normal levels after a rainy season (Wang et al., 2015).

One of the main effects of salinity is osmotic stress, due to the reduction of soil water potential, reduces the absorption of water and nutrients, directly reflecting the water status of the plant. The energy expenditure for the uptake of water through biochemical adjustments is one of the initial factors for the reduction of growth due to osmotic stress (Hussain et al., 2016).

In addition, under specific conditions, salinity has an effect on photosynthesis. Research has shown a significant decrease of the photosynthetic rate under conditions of high vapor saturation deficit (high atmospheric demand) and high salinity in cucumber (*Cucumis sativus*) cultivation, thus reducing plant growth and development (Shibuya et al., 2018).

The increasing levels of salinity in the irrigation water applied in the safflower culture negatively influenced the characteristics evaluated, reducing their expression as the salinity levels were increased.

4. Conclusions

The salt level of 8 dS m^{-1} in irrigation water reduced the total dry mass of safflower plants (*Carthamus tinctorius* L.) by 68%.

The salinity of irrigation water causes reductions in the growth and development of safflower plants (*Carthamus tinctorius* L.), mainly at levels between 6 and 8 dS m^{-1}.

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