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Soil Water Availabilities in the Content and Accumulation of Nitrogen and Chlorophyll Index in the Safflower

Edna Maria Bonfim-Silva*, Ellen Cristina Alves de Anicésio, Jakeline Rosa de Oliveira, Helon Hébano de Freitas Sousa, Tonny José Araújo da Silva

Department of Agricultural and Environmental Engineering, Institute of Agricultural Sciences and Technology, Federal University of Mato Grosso, Rondonópolis, Brazil
Email: *embonfim@hotmail.com

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Abstract

The safflower (*Carthamus tinctorius* L.) is adapted to grow in adverse conditions, is tolerant to salinity and water deficit, however, its productivity increases when grown in areas with greater availability of water and in fertilized conditions, showing that the knowledge of crop management can bring income gains for producers. It is known that extreme conditions of soil moisture damage the crop development. Given this context, the objective was to evaluate the influence of water availability on the nutritional characteristics of the safflower. The experiment was conducted in a greenhouse in a completely randomized design with five water availabilities (25%, 50%, 75%, 100% and 125% of the maximum water holding capacity of the soil) in four replications. Maintaining soil moisture was performed by gravimetric method with daily weighing of experimental units. The variables analyzed were SPAD reading (chlorophyll content), concentration and accumulation of nitrogen in the shoot and in the sections. The results were submitted to analysis of variance and regression test at 5% probability by Sisvar program. There was adjusting of variables to linear and quadratic regression models. Water availabilities between 65% and 75% have greater potential to promote better nutrition for safflower plants. Both deficit and excess of water in the soil are detrimental to the absorption of nitrogen and reduce the chlorophyll content. Safflower is less tolerant to excess than to deficit of water.

Keywords

***Carthamus tinctorius* L., Nutrition, SPAD, Irrigation**

*Corresponding author.

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1. Introduction

The safflower (*Carthamus tinctorius* L.) crop is able to be economically exploited in various ways. Its cultivation is dominated since ancient times in Egypt, Morocco and China [1], its use extends from the manufacture of dyes [2] [3], passing through medicine [4] to the industrial use. The oil content in its seed can reach up to 50% [5], with great quality even for human consumption [6].

It is a plant adapted to adverse conditions, tolerant to salinity and water deficit [7] [8]. Its root system is deep, thus facilitating the extraction of water and nutrients from deep soil layers [9]. The areas for culture are generally of low agricultural potential and in areas with no inputs [10].

Despite its hardiness, its productivity has significant increase when grown in irrigated areas or with good levels of rainfall and with supply of nutrients from fertilizers [11], showing that improvements in crop management can bring income gains for producers.

The water, beyond the formation of tissues and participation in the vital processes in plants, is responsible for the carrying of some minerals from the soil to the rhizosphere, thereby the absorption of some nutrients appears to be strongly impaired in situations of water scarcity, especially the nitrogen that is available to the plant in the soil solution via mass flow.

On the other hand, the excess of water in the soil also affects the growth of plants, slowing the growth of roots and shoots, besides providing losses of nutrients such as nitrogen, by leaching and denitrification, in addition, safflower is sensitive to the excess of water [12] [13].

Considering that among the factors of production, water is the one which, usually, more limits the yields of cultivated plants; it becomes important to determine the ideal humidity of the soil for safflower cultivation in basic research carried out in a protected environment. With the ideal humidity defined, it is possible to perform studies in greenhouses in order to investigate several factors that interfere in the production of safflower, preventing the results from being masked by the amount of water in the soil.

Given this context, it aimed to evaluate the influence of water availability on the nutritional characteristics of the safflower.

2. Materials and Methods

The study was conducted in a greenhouse located in the geographic coordinates 16˚27'52"S and 54˚34'46"W at 284 m of altitude, with an Aw climate type, Koppen classification, at the Federal University of Mato Grosso, Campus Rondonópolis-MT, Brazil.

The experiment was conducted during the winter, the average maximum and minimum temperatures inside the greenhouse during this period was 37.3˚C and 22.6˚C, respectively, mean maximum and minimum relative humidity was 88.2% and 31.7%, respectively.

The soil used in the experiment was collected in the layer from 0.0 to 0.20 m of a Oxisol in an area under Cerrado vegetation, in which it were performed, according to the reference [14], chemical and granulometric analyzes for its characterization (**Table 1**).

Calcium Chloride ($CaCl_2$), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Hydrogen (H), Aluminum (Al), Sum of Bases (SB), Cation Exchange Capacity (CEC), Base Saturation (V) and Organic Matter (O.M.).

Liming was performed with dolomitic limestone (PRNT = 80.3%) to correct the pH and raise the base saturation to 60%. Soil moisture was maintained at 60% of its maximum holding capacity, remaining incubated for 30 days.

After the incubation period of the soil with limestone, basic fertilization was carried out with nitrogen, phosphorus (P_2O_5) and potassium (K_2O) with 50, 150 and 100 mg·dm^{-3}, respectively, having as source urea, simple superphosphate and potassium chloride.

Each plot consisted of a pot with a capacity of 3.5 dm^3 containing four plants. The experimental design was

Table 1. Chemical and granulometric analyzes in the layer of 0 - 0.20 m, of the Oxisol.

H	P	K	Ca	Mg	H	Al	SB	CEC	V	O.M.	Sand	Silt	Clay
$CaCl_2$	mg·dm^{-3}				cmol$_c$·dm^{-3}				%	g·dm^{-3}		g·kg^{-1}	
4.1	2.4	28	0.3	0.2	4.2	1.1	0.6	5.9	9.8	22.7	549	84	367

completely randomized, with five water availability treatments (25%, 50%, 75%, 100% and 125% of the maximum water holding capacity of the soil) in four replications. The maximum soil water holding capacity in the pots was maintained by the gravimetric method with daily weighing of experimental units, as described in the reference [15].

Five safflower seeds per pot were sown and the thinning was carried out at ten days after sowing, leaving four plants per pot.

In the first ten days after planting, soil moisture was maintained at 60% of the maximum soil water holding capacity, by the gravimetric method with daily weighing of experimental units, to ensure good plant growth in the establishment phase. After this time, each plot was irrigated with the purpose of maintaining the soil with water availability corresponding to treatments.

At 40 days after germination, a SPAD reading was performed (chlorophyll index) and at the end of the safflower cultivation period (60 days) this reading was repeated, then, by cutting the plants it were determined the total shoot dry mass (TDM), head dry mass (HDM), shoots dry mass without head (SDM), concentration and accumulation of nitrogen in the shoots and in the sections.

The chlorophyll content was determined in the second and third leaves from the apex to the base of the plant through the electronic chlorophyll meter Minolta SPAD-502. This equipment uses a non-destructive and convenient method that provides readings that correlate with the chlorophyll content present in the leaf. Thereafter, took place the cutting of the shoot, which was packed in paper bags and dried in a forced-air oven at 65˚C until constant weight. The shoot and the sections were milled separately to determine the nitrogen concentration, following the methodology described in the reference [16].

For results related to dry mass, concentration and accumulation of nitrogen in safflower sections were considered to the water availability of 100% of the soil water holding capacity, for statistical analyzes, regarding the non-production in this condition.

The results were submitted to analysis of variance by F test and, when significant, it was applied regression test at 5% probability, using the statistical program SISVAR [17].

3. Results and Discussion

There was significant effect on chlorophyll index (SPAD index) depending on the soil water availabilities, with adjustment to the quadratic regression model in the observations at 40 and 60 DAS (**Figure 1(a)** and **Figure 1(b)**). At 40 days, the highest value of the SPAD index (53.51) was obtained in the water availability of 62.42% and, at 60 days, the highest value of the SPAD index (52.79) was obtained in the availability of 35.52%. The indirect chlorophyll meter SPAD has been used for determining the nutritional status of the plants in relation to nitrogen [18]-[20], since it provides readings that correlate with chlorophyll content in the leaf.

The maximum values found in the readings are similar to those found in the reference [21], in which the authors found the maximum value for the SPAD index of about 60 to the safflower cultivation in a work with nitrogen levels. In the reference [22], the maximum value of the SPAD index (60.5) in safflower was in the nitrogen rate of 168.0 mg dm^{-3}.

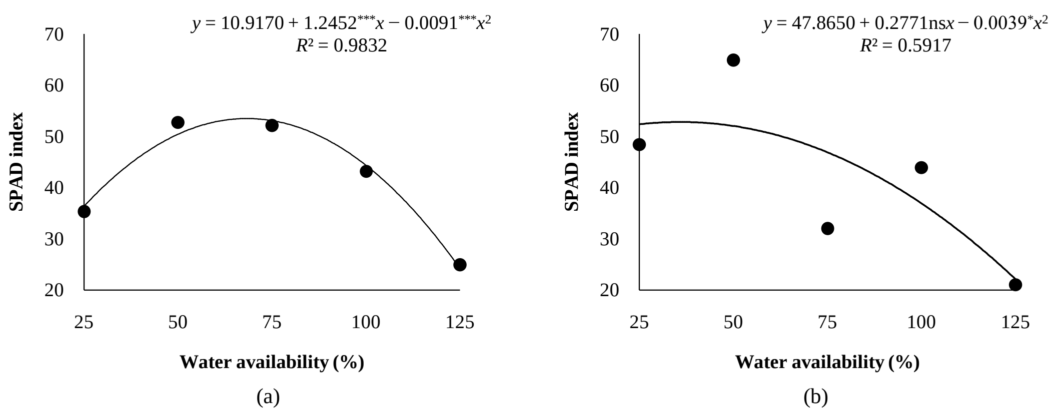

Figure 1. SPAD index (chlorophyll index) at 40 days (a) and 60 days (b) in safflower plants submitted to different soil water availabilities. ns, *, ***, Non-significant, significant at 5% and 0.1%, respectively.

The results of the SPAD index show that the safflower crop has greater tolerance to water deficit, corroborating the statement of references [7] [8], than to flooding.

There was significant effect for the variables total dry mass, dry mass of shoots and dry mass of the sections depending on the soil water availabilities. The water availabilities that promoted the highest values were 74.71% (19.35 g·pot^{-1}), 76.41% (11.58 g·pot^{-1}) and 74.56% (9.57 g·pot^{-1}), respectively, with data fitting the quadratic regression model (**Figure 2**).

Despite the safflower presenting the tolerance to water stress [7] [8] as characteristic, the results show that the dry mass yield is directly related to the water availability. Various processes are affected by the water deficit, among them stand out photosynthesis and cell growth [23] [24], being the photosynthesis influenced by low water availability, consequently it will occur decreases in dry mass contents.

The treatment that promoted the condition of hypoxia due to saturation of the soil by water (125%) led to culture stress condition causing damage to the development of the plant, to the extent of non-production of sections by the same, safflower is sensitive to water excess [12] [13].

Regarding the concentration of nitrogen in the shoot, there was a significant effect depending on the soil water availabilities with adjustment to the quadratic regression model, presenting the minimum value (10.59 g·kg^{-1}) in the water availability of 75.73% (**Figure 3(a)**). However, since in this range of water availability there was increased production of dry mass and nitrogen accumulation in the shoot (**Figure 3(b)**), the lowest concentration

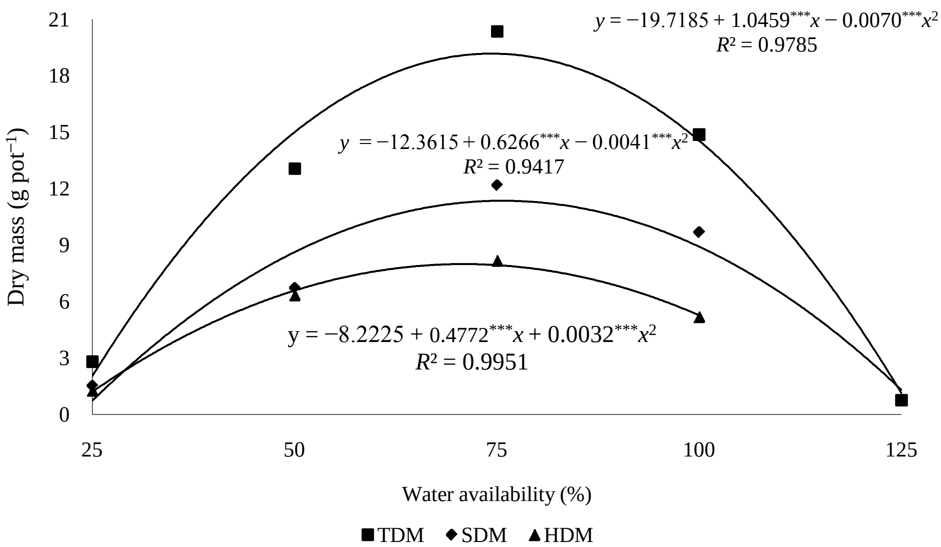

Figure 2. Total shoot dry mass (TDM), shoots dry mass without head (SDM), head dry mass (HDM), in safflower plants submitted to different soil water availabilities. *** Significant at 0.1%.

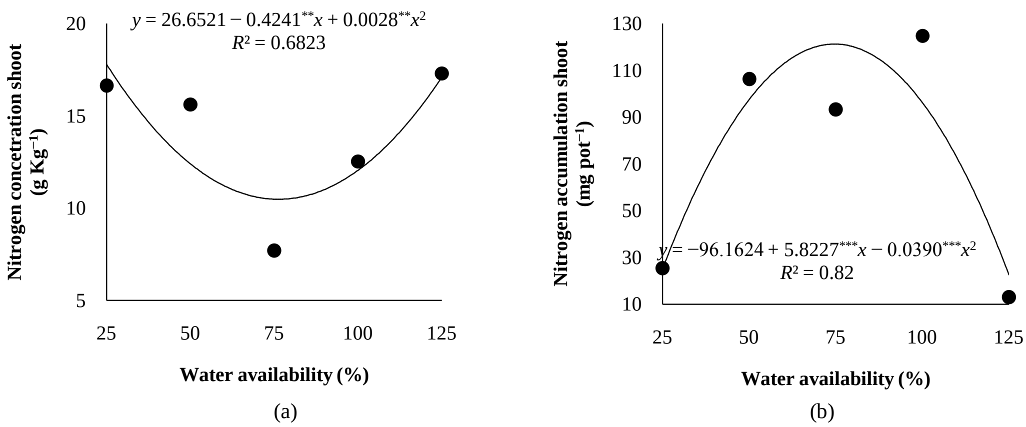

Figure 3. Concentration (a) and accumulation (b) of nitrogen in the shoot of safflower plants submitted to soil water availabilities. ** and *** significant at 1% and 0.1%, respectively.

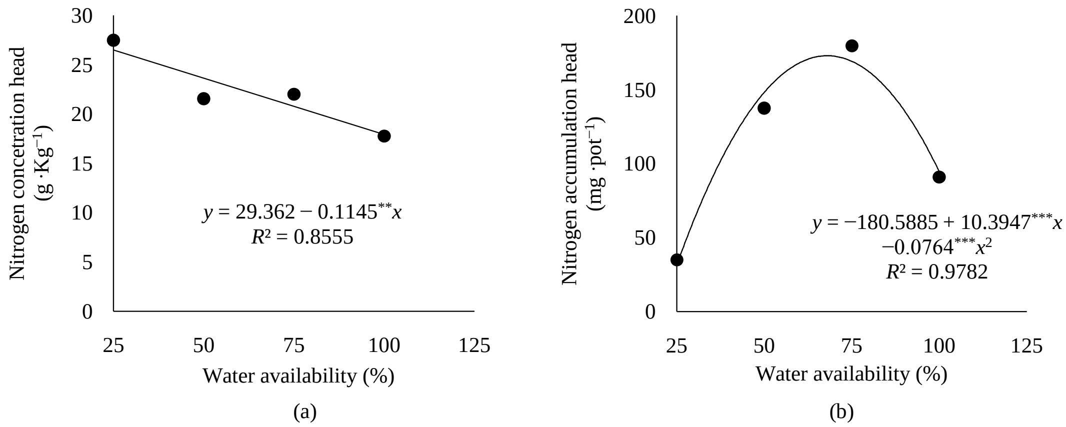

Figure 4. Concentration (a) and accumulation (b) of nitrogen in sections of safflower plants submitted to soil water availabilities. ** and *** significant at 1% and 0.1%, respectively.

of this nutrient occurred due to the dilution effect, being this moisture range responsible for the greatest phytomass production.

The nitrogen accumulation in the shoot presented maximum water availability of 74.68%, an increase of 79.35% and 81.36% when compared to the treatment of 25% (water deficit) and 125% (flooded), respectively (**Figure 3(b)**).

In the reference [21], the authors found accumulation of 125.64 kg·ha^{-1} of nitrogen in the shoot of safflower plants, at anthesis, with the soil fertilized with 100 kg·ha^{-1} of nitrogen, conditions similar to those of this study.

According to the results of this research, both the deficit and the excess of water in the soil reduced the nitrogen accumulation in safflower leaves, demonstrating that this culture, even being tolerant to water deficit, requires a level around 70% of the maximum holding capacity of the soil to reach its nutritional potential entirely.

The concentration of nitrogen in sections was inversely proportional to the increase in water availability, the results fit to the linear regression model. Nonetheless, the accumulation of nitrogen in sections fit to the quadratic regression model, the highest value (172.98 mg·pot^{-1}) was observed in plants submitted to the water availability of 68.03% (**Figure 4(a)** and **Figure 4(b)**).

The water deficit may impair nutrient absorption by the closure of stomata which reduces the water flow in plants. The absorption of some nutrients, such as nitrogen, appears to be severely hampered by the lack of water in the soil. Not with standing, excess of water causes loss of nitrogen in the soil in the form of N_2 and N_2O, due to the process of denitrification [25].

4. Conclusion

The water availabilities between 65% and 75% of the maximum soil water holding capacity have greater potential to promote better nutrition for safflower plants. Both deficit and excess of water in the soil are detrimental to the absorption of nitrogen and reduce the chlorophyll content. Safflower is less tolerant to excess than to deficit of water.

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