

Variation of Water Availability in Initial Development of Safflower

Nayara F. F. da S. Cruz¹, Luiz A. Zano Júnior¹, Reginaldo F. Santos¹, Luciene K. Tokura¹,
Lais F. J. do Nascimento¹, Jair A. C. Siqueira¹, Alessandra M. T. Alovizi², Luzia A. da S. Cruz³,
Lorenzo C. M. Castanhari¹, Maisa Y. F. Otake⁴, Marcos A. Polinarski¹, Pablo Chang¹,
Vander F. Silveira¹ & Bruna S. Schuster⁵

¹ Graduation Program, Master's in Engineering of Energy in Agriculture, State University of West Paraná, Cascavel, Paraná, Brazil

² Post-Graduation Program in Agronomy, Federal University of Grande Dourados, Dourados, Mato Grosso do Sul, Brazil

³ Graduation in Science with a degree in Mathematics, University of Parana, Umuarama, Paraná, Brazil

⁴ Post-Graduation Program in Tropical Biodiversity, Federal University of Amapá, Macapá, Amapá, Brazil

⁵ Graduation in Civil Engineering, State University of West Paraná, Cascavel, Paraná, Brazil

Correspondence: Lais F. J. do Nascimento, Graduation Program, Master's in Engineering of Energy in Agriculture, State University of West Paraná, Rua Universitária, 2069-Jardim Universitário, CEP: 85819-110, Cascavel, Paraná, Brazil. Tel: 55-(45)-3220-3151. E-mail: laisfjuchem@gmail.com

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Abstract

The availability of water is one of the most important factors for the development of the seeds. Thus, studies related to adequate humidity for germination, emergence and early development of safflowers, is necessary for the productive use of this culture. Thus, the objective of study was to evaluate the initial development of two varieties of seeds of Safflowers (IAPAR and IMA2103) in six levels of water availability in substrate: 0, 10, 20, 30, 40 and 50%. At 15 days the seedling emergence were evaluate. At 30 days were evaluate plant height, root length, stem diameter, number of leaves, fresh weight of the aerial part and root, dry weight of shoot and root. The treatment without irrigation, there was decrease the emergence, emergence speed for both genotypes. Treatments above 30% of water availability in the two varieties presented emergency superior to 50%. Lower irrigation rates favored root length and dry mass.

Keywords: humidity, emergence, seedlings, *Carthamus tinctorius* L.

1. Introduction

Carthamus tinctorius L. is an annual oilseed of great commercial importance in Mexico and India, although it is grown in the USA, Australia, Argentina, USA and other countries. It is a crop resistant to needs of low availability of water (Emerson et al., 2009), and seed oil can be used in food, in industrial and as raw materials to produce biofuels (Emongor, 2010).

In Brazil, the study of conditions for the germination and emergence of safflower seeds contributes to the commercial exploitation of the species, which is relatively new in the national market. According to Abud et al. (2010b), several environmental factors contribute to the development of differentiated seed components and can vary the morphological characteristics of the plant through color, seed format and size.

Among the environmental factors that stimulate seed development are the oxygen, temperature and water availability that must be in favorable conditions for their germination (Carvalho & Nakagawa, 2000). Among the factors, the ideal water supply is essential for the seed to initiate the germination process, becoming a limiting factor to the growth and development of the seedling (Beltrão, Fideles Filho, & Figueirêdo, 2002).

When the seed is exposed to situations of low water availability, its absorption is compromised, and seedling growth is affected, reflecting a decrease of the expansion and cellular elongation (Moterle et al., 2008). And when cultivated under conditions of water excess, the productivity of the safflower is reduced, and when this excess is greater than five days there is no grain production (Neto et al., 2012).

According to Guo et al. (2014), the drought influences the productivity of crops around the world. Stress on drought and genetic history of drought are important factors for the development of safflower (Singh, 2006).

When safflower crops are sown only in soil moisture nutrients can be maintained up to 60 days after flowering of the branches and chapters, with flowering being initiated in few sampled cultivars. Thus, the study is generally necessary because the safflower is not a priority culture but rather a rotation crop, with few studies on moisture of the crop without residual requirements of other cultivars (Singh & Nimbkar, 2016).

Soil humidity content for germination and early stages of seedling development are useful information for evaluating the best sowing season and seedling production, increasing the chances of population survival and productivity. Therefore, information about the adaptation and the limiting factors caused by lack or excess humidity in the soil are essential for the economic use of this crop. Based on the hypothesis that the safflower presents different development according to substrate humidity, this study has the objective of submitting seeds of two strains of IAPAR and IMA2103, in different levels of wetting for the evaluation of the emergence and the morphology of the seedlings.

2. Material and Method

The work was carried out in a protected environment of high-density polyethylene high tunnel plastic greenhouse in the experimental area of the State University of the West of Paraná, Cascavel campus with geographic coordinates of 24°59'21" S and 53°26'59" W and altitude of approximately 755 m, in the period between May and June 2017, totaling 45 days. The climate of the region, according to Koppen's classification, is Cfa type, hot temperate (mesothermic), humid and the average temperature of the hottest month is above 22 °C.

The evaluation was carried out in two strains of *Carthamus tinctorius* L. (*Compositae* or also known as *Asteraceae*), one from the Matogrossense Institute of Cotton (IMA2103) and another from the Agronomic Institute of Paraná (IAPAR). These were assigned to the Postgraduate Program in Energy Engineering in Agriculture of the State University of the Western Paraná of Cascavel for scientific research.

The experimental design was a randomized block design with four replications in a 4 × 6 factorial scheme. The first factor was composed of two strains of safflower, and the second factor consisted of six water retention of 0 (control), 10, 20, 30, 40 and 50% of water in substrate. Each experimental unit was constituted by plastic cups with capacity of 0.5 L, with surface of approximately 56.74 cm². The plastic cups were punched at their base with four circumferences of approximately 0.0025 m in diameter for the flow of water and added approximately 0.5 L of substrate. The Figure 1 represents the culture of the safflower.



Figure 1. Safflower seedlings

To obtain the seedlings, five seeds of safflowers of each lineage were placed separately per cup, at a depth of 0.02 m. The substrate used was the Humusfertil® Seed Germination with *Pinus* bark composition, substrate sand, vermicompost and vermiculite with the characteristics presented in Table 1.

Table 1. Characteristics of the substrate used for the sowing of safflower

Electrical conductivity	Density (kg/m ³)	Hydrogen potential	Maximum humidity (%) w/w	Water retention capacity (% by weight/weight)
1.5±0.3	480	6±0.5	60	60

Immediately after sowing, the substrate was added distilled water in the percentages of 0, 10, 20, 30, 40 and 50%, and the water availability was restored every five days. After 15 days of sowing, daily recording the number of emerged seedlings the following indices were determined:

Percentage of Emergence (E), expressed as a percentage (%):

$$E = \frac{\text{Number of emerged seeds}}{\text{Total seed}} \times 100 \quad (1)$$

Emergency Velocity Index (EVI), which was proposed by Maguire (1962), expressed in seeds/day:

$$EVI = \frac{E_1}{N_1} + \frac{E_2}{N_2} + \dots + \frac{E_n}{N_n} \quad (2)$$

where,

$E_1, E_2 \dots E_n$: number of normal seedlings counted, in the first, second and last count; $N_1, N_2 \dots N_n$: number of days of sowing, in the first, second and last.

Average Time of Emergence (ATE): according to Laboriau and Valadares (1976), expressed in days:

$$ATE = \frac{\sum n_i t_i}{\sum n_i} \quad (3)$$

where,

n_i = number of seeds germinated in the interval between each count; t_i = time elapsed between the beginning of the emergency and the i th count.

Average Velocity of Emergence (AVE): expressed in days⁻¹:

$$AVE = \frac{1}{t} \quad (4)$$

where,

t = mean time of emergency.

After 15 days of this, the sowing was done again, duplicating the experiment. All experimental units were maintained until 30 days after sowing, after which the plants were extracted for the characterization of the plant height (PH), root length (RL), stem diameter (SD), green weight (GW), Green Root Weight (GRW), Dry Air Weight (DAW), Dry Root Weight (DRW) and Number of Leaves (NL).

These analyzes were carried out at the University's own Soil Laboratory with the following equipment's: analytical balance with precision of 0.002, greenhouse at 65 °C for 72 hours, Starrett digital caliper, and graduated tape in mm.

The results were submitted to analysis of variance ANOVA and the comparison of the means by the test of Tukey to 5% of probability realized by software SISVAR® (Ferreira, 2011).

3. Results and Discussion

The analysis of variance indicated that the treatment with no addition of water resulted in lower values of Emergency Score (E), Emergency Velocity Index (EVI), Mean Time of Emergence (ATE) and Average Velocity of Emergence (AVE) of seeds of the IMA2103 and IAPAR varieties (Table 2).

Table 2. Average values of Emergency Percentage (E), Emergency Velocity Index (EVI), Average Time of Emergency (ATE) and Average Velocity of Emergence (AVE) of seed of the IMA2103 and IAPAR varieties seeded and subjected to irrigation of 0, 10, 20, 30, 40 and 50% of water in substrate, in Cascavel, Paraná, during the period of May (experiment 1) and June (experiment 2) of 2017

Treatment	E (%)		EVI (seeds/day)		ATE (day)		AVE (day ⁻¹)	
	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA
<i>Experiment 1</i>								
0%	15 aA	10 aA	0.100aA	0.085aA	0.625aA	0.500aA	0.415aA	0.500aA
10%	60 aA	50 bA	0.387aA	0.410bA	2.832bA	1.082aA	0.402aA	0.937aB
20%	50 aA	20 bA	0.342aA	0.175aA	2.415bA	1.125aA	0.525aA	0.600aA
30%	65 aA	50 bA	0.465aA	0.410bA	4.125cA	2.500aA	0.252aA	0.552aA
40%	55 aA	75 cA	0.420aA	0.687cA	2.375bA	1.887aA	0.537aA	0.667aA
50%	75 aA	50 bA	0.547aA	0.435bA	2.770bA	1.900aA	0.397aA	0.692aA
Average	53.33	42.50	0.376	0.367	2.523	1.499	0.421	0.658
CV (%)	35.35	50.71	36.984	53.012	40.792	44.126	22.475	21.370
<i>Experiment 2</i>								
0%	10 aA	15 aA	0.085aA	0.142aA	0.500aA	0.625aA	0.500aA	0.417aA
10%	35 bA	30 aA	0.342bA	0.177aA	2.165bA	1.500cA	0.650aA	0.767aA
20%	55 bA	50 aA	0.505bA	0.452aA	2.500bA	3.915bA	0.550aA	0.275aA
30%	85 cA	55 aA	0.680cA	0.467aA	3.350bA	3.412bA	0.335aA	0.292aA
40%	75 cA	70 aA	0.672cA	0.635aA	2.962bA	2.470bA	0.357aA	0.512aA
50%	60 bA	70 aA	0.497bA	0.642aA	4.165cA	2.990bA	0.242aA	0.432aA
Average	53.33	48.33	0.4635	0.4192	2.607	2.4853	0.439	0.4491
CV (%)	46.77	41.66	44.146	47.187	43.599	45.252	31.797	36.506

Note. Averages followed by the same upper case letter within a line and the same lower case letter within a column do not differ significantly according to Tukey's test at $P < 0.05$.

Treatments with 30% or more of water resulted in emergency percentage (E) of more than 50 in both varieties and in both experiments, being the highest index of the IAPAR variety with 85%. However, the average of E (%) in the treatments of IAPAR seeds was 53.33%, like the study by Venturoso et al. (2015), which obtained a mean of 58.3% for the emergence of CV.

The EVI was maintained with averages close to the two lines in experiment 1 and increased in experiment 2, being the IAPAR with the highest result of 0.4635 seeds/day.

Abud et al. (2010a), obtained higher EVI values, being equal to 0.55 seeds/day in treatment with intermittent irrigation of seedlings of safflowers, being this value exceeded in this experiment in 20.83% of the treatments.

In relation to ATE, in experiment 1, both varieties showed higher averages in the 30% treatment; in the second experiment, there was no relation between treatments. The lowest MTE occurred in the 0% treatment for both periods and varieties, as fewer seedlings also decreased the initial and final counting time. In the sum of the means, the IMA2103 variety presented lower indexes, thus presenting greater uniformity in the emergency period.

The AVE in experiment 1 of treatment 10% in the variety IMA2103 presented the highest result, with 0.937 days⁻¹, being statistically different from the others.

With respect to the results of the morphological analysis of the plants at 30 days of sowing, it is possible to verify differentiation in the genotypes with significance at 5% probability only for the root length (RL) in treatments 10 and 20% water addition, higher values for IMA2103 in experiment 1 (Table 3).

Table 3. Average values of plant height (PH), root length (RL), stem diameter (SD), number of leaves (NL), fresh plant mass (FPM), fresh root mass (FRM), Plant dry mass (PDM) and Dry Root Mass (DRM) of seeds of IMA2103 and IAPAR varieties seeded on substrate and submitted to humidity of 0, 10, 20, 30, 40 and 50% in Cascavel, Paraná, Brazil. May 2017

Treatment	PH (cm)		RL (cm)		SD (mm)		NL	
	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA
0%	9.40aA	9.30aA	18.00aA	19.90aA	1.37aA	1.92aA	4.00aA	4.00aA
10%	10.85aA	12.20aA	14.72aA	30.43aB	1.81aA	1.86aA	4.00aA	4.00aA
20%	12.32aA	11.60aA	15.87aA	29.90aB	2.00aA	1.73aA	4.50aA	4.00aA
30%	12.68aA	9.00aA	14.75aA	18.92aA	1.80aA	1.84aA	4.66aA	4.00aA
40%	11.18aA	11.10aA	17.13aA	13.93aA	1.73aA	1.75aA	4.00aA	4.00aA
50%	11.28aA	11.00aA	16.21aA	8.60aA	1.71aA	1.61aA	3.66aA	4.00aA
Average	11.28	10.70	16.11	20.28	1.73	1.78	4.13	4.00
CV (%)	30.34	10.89	7.37	38.94	10.87	5.68	8.19	0.00
Treatment	FPM (g)		FRM (g)		PDM (g)		DRM (g)	
	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA
0%	0.301aA	0.340aA	0.125aA	0.089aA	0.019aA	0.031aA	0.049bA	0.031aA
10%	0.462aA	0.481aA	0.118aA	0.120aA	0.029aA	0.022aA	0.016cA	0.012aA
20%	0.474aA	0.408aA	0.262aA	0.145aA	0.026aA	0.020aA	0.010aA	0.015aA
30%	0.528aA	0.375aA	0.084aA	0.108aA	0.023aA	0.018aA	0.007aA	0.011aA
40%	0.448aA	0.383aA	0.098aA	0.066aA	0.020aA	0.015aA	0.008aA	0.010aA
50%	0.381aA	0.495aA	0.244aA	0.063aA	0.019aA	0.012aA	0.018cA	0.016aA
Average	0.432	0.413	0.155	0.098	0.022	0.019	0.018	0.015
CV (%)	16.864	13.619	45.516	29.661	16.637	30.602	80.187	44.869

Note. Averages followed by the same upper-case letter within a line and the same lower-case letter within a column do not differ significantly according to Tukey's test at $P < 0.05$.

The RL may have been influenced by the density of emerged seedlings, since in the treatments with higher E, resulted in greater root development, corroborating with Corrêa et al. (2014), which associates the reduction of fresh root mass and the reduction in root size to the increase of planting density, causing competition for light and nutrients among beet plants.

The lowest value of OS and FAM was verified at 0% (control) humidity for both genotypes in experiment 1, evidencing the necessity of irrigation for the initial development of the seedlings of safflowers, although Kizil et al. (2008) and Dantas et al. (2011) cite their resistance to water deficiency.

Regarding the genotypes, the IAPAR obtained in the treatments of 20 and 30% of humidity, the best results of PS, SD, NL and FAM. For the IMA2103 variety, treatments 10 and 20% presented higher PS, RL and FRM values. The best performance of the varieties to the treatments of smaller amount of irrigation can be related to the greater aeration of the substrate, because greater availability of water to the soil can promote reduction in the supply of oxygen to the roots, inhibiting the root development (Paiva Sobrinho, Tieppo, & Silva, 2011).

For both varieties FRM and DRM were found higher results for the treatments with lower water availability, which can be explained by the higher growth of the roots in search of humidity.

However, the values of SD and NL did not show large variations even for the 0% water treatment. In the experiment 2, it is possible to verify differentiation in the genotypes with significance to 5% probability only for the Diameter of the Stem (SD) with the highest values for the IAPAR variety in the treatments of 20 to 50% of humidity (Table 4).

Table 4. Mean values of plant height (PH), root length (RL), stem diameter (SD), number of leaves (NL), fresh plant mass (FPM), fresh root mass (FRM), Plant dry mass (PDM) and Dry Root Mass (DRM) of seeds of IMA2103 and IAPAR varieties seeded on substrate and submitted to moisture of 0, 10, 20, 30, 40 and 50% in Cascavel, Paraná, Brazil. June 2017

Treatment	PH (cm)		RL (cm)		SD (mm)		NL	
	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA
0%	-	10.000aA	-	14.400aA	-	0.865aA	-	3.000aA
10%	12.450aA	8.950aA	20.800aA	27.200aA	1.908aA	1.215aA	4.000aA	4.000aA
20%	12.366aA	9.740aA	19.950aA	21.500cA	2.078aB	1.212aA	3.666aA	3.600aA
30%	13.150aA	11.216aA	18.633aA	19.183cA	1.881aB	1.108aA	4.000aA	3.666aA
40%	10.780aA	11.166aA	18.400aA	21.316cA	1.838aB	1.165aA	3.600aA	3.666aA
50%	11.183aA	12.416aA	13.883aA	14.883cA	1.945aB	1.130aA	3.666aA	3.666aA
Average	11.985	10.581	18.333	19.747	1.930	1.115	3.786	3.599
CV (%)	7.286	10.787	13.044	22.039	4.239	10.646	4.649	8.280
Treatment	FPM (g)		FRM (g)		PDM (g)		DRM (g)	
	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA	IAPAR	IMA
0%	-	0.289aA	-	0.198aA	-	0.018aA	-	0.097bA
10%	0.599aA	0.379aA	0.165aA	0.166aA	0.040aA	0.020aA	0.018aA	0.035aA
20%	0.554aA	0.413aA	0.160aA	0.131aA	0.029aA	0.042aA	0.021aA	0.021aA
30%	0.610aA	0.487aA	0.171aA	0.151aA	0.028aA	0.025aA	0.020aA	0.196aA
40%	0.374aA	0.449aA	0.106aA	0.118aA	0.028aA	0.024aA	0.026aA	0.015aA
50%	0.507aA	0.546aA	0.091aA	0.101aA	0.030aA	0.026aA	0.010aA	0.014aA
Average	0.5288	0.427	0.138	0.144	0.031	0.025	0.019	0.063
CV (%)	16.178	19.063	24.001	22.194	14.711	30.019	27.449	104.685

Note. Averages followed by the same upper-case letter within a line and the same lower-case letter within a column do not differ significantly according to Tukey's test at $P < 0.05$. (-) Plants that did not emerge.

In this experiment, no seedling of the IAPAR lineage survived until 30 days of the sowing in the treatment without irrigation to perform the morphological analysis, thus, it is not possible to compare the genotypes.

The PS and FPM values were higher in the 30% treatment for the IAPAR variety and 50% for the IMA2103. And the RL was superior for the two genotypes for the treatment at 10% of humidity, emphasizing in both experiments, greater development of the same ones in water deficit.

For the other treatments there was no direct relationship between moisture and values of morphological variables. This variation of seedling behavior can be explained by the variation of seed size, since it can influence seed vigor, which according to Carvalho and Nakagawa (2000) reports the larger seed size is generally related to better formed embryos and with greater amount of reserves, presenting better vigor. However, according to Abud et al. (2010a), seed size does not influence emergence, velocity and mean time of emergence of seedlings, suggesting the mixing of sowing sizes.

4. Conclusion

The treatment without irrigation showed less emergency percentage and emergency speed index for two genotypes.

Seedling emergence was higher than 50% in treatments above 30% of water availability, in both varieties.

Lower irrigation rates favored root length and dry root mass.

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