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Artigo Científico

Irrigation management in the culture of linseed

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Abstract

The study aimed to evaluate the effect of irrigation, based on fractions of evaporation on the variables phenometric of two cultivars of linseed. The crops were grown in pots in a greenhouse during the months from April to July 2012 at the State University of West Paraná - UNIOESTE, Cascavel - PR, using a factorial design (2x5), completely randomized, being two cultivars (brown and golden) and five treatments of evaporation corresponding to (0.5, 1.0, 1.5, 2.0, 2.5 Evm (blade evaporated), with four replications. The vegetal behavior was evaluated by phenometric variables: height plant, number of stems and capsules per plant, fresh and dry weight of capsules and fresh and dry weight of the plant. The results allowed the conclusion that the production components with quadratic polynomial responses were significant to the treatments, as well as the interaction between cultivars and irrigation levels. The Brown Linseed presented increase of the morphologic characteristics, while the golden cultivar presented greater number of capsules per plant.

Keywords: *Linum usitatissimum*, evapotranspiration, water deficit

Manejo da irrigação para a cultura da linhaça

Resumo

O estudo teve como objetivo avaliar o efeito de lâminas de irrigação, com base nas frações da evaporação do sobre as variáveis fenométricas de duas cultivares de linhaça. O cultivo foi realizado em vasos em ambiente protegido nos meses de abril a julho de 2012 na Universidade Estadual de Oeste do Paraná – UNIOESTE, Cascavel - PR, empregando-se o delineamento fatorial (2x5) inteiramente casualizado, sendo duas cultivares (marrom e dourada) e cinco tratamentos de evaporação correspondentes a (0,5; 1,0; 1,5; 2,0; 2,5 EVm (lâmina evaporada), com quatro repetições. O comportamento vegetativo foi avaliado através das variáveis fenométricas: altura da planta, número de hastes e cápsulas por planta, massa fresca e seca das cápsulas e massa fresca e seca da planta. Os resultados permitiram concluir que os componentes de produção foram significativos aos tratamentos com respostas polinomiais quadráticas, assim como existiu interação entre cultivares e lâminas de irrigação. A linhaça marrom apresentou acréscimo das características morfológicas, enquanto que a cultivar dourada apresentou maior número de cápsulas por planta.

Palavras chave: *Linum usitatissimum*, evapotranspiração, déficit hídrico

Gestión del riego en el cultivo de la linaza

Resumen

El objetivo del estudio fue evaluar el efecto del riego, a partir de las fracciones de la evaporación en variables fenométricas de dos cultivares de linaza. Los cultivos fueran conducidos en contenedores en un invernadero durante los meses de abril a julio de 2012 en la Universidad Estadual del Oeste del Paraná - UNIOESTE, Cascavel - PR, utilizando un diseño factorial (2x5), aleatorizado, con dos cultivares (marrón y dorado) y cinco tratamientos de evaporación correspondientes a (0.5,

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1.0, 1.5, 2.0, 2.5 EVM (lámina evaporada), con cuatro repeticiones. Se evaluó el comportamiento vegetativo por variables fenométricas: altura de la planta, número de tallos y cápsulas por planta, peso fresco y seco de cápsulas y el peso fresco y seco de la planta. Los resultados mostraron que los componentes de rendimiento se presentaran significativos a los tratamientos con respuestas de polinomios cuadrático, así como hubo interacción entre cultivares y láminas de riego. Linaza marrón mostró un aumento de las características morfológicas, mientras que la linaza dorada mayor número de cápsulas por planta.

Palabras clave: *Linum usitatissimum*, evapotranspiración, déficit de agua

Introduction

The linseed (*Linum usitatissimum* L.) is characterized as a straight growth plant, medium height of 0,7m and its seeds have many applications, having use as raw material for the production of oil and bran (GALVÃO, 2008). Since its seeds are rich in oil (38%), fibers 20-25% and proteins 20-25%, the crop has a promising future in energy use in the production of biofuels (RABETAFIKA, 2011).

This crop has been cultivated in Brazil by Polish and German immigrants in the south region, because it needs low temperatures for its flowering, finding favorable conditions around 0° C to -2º C. It is a crop of small dimension, turned only to the textile industry and for human consumption, however management practices and crop traits can lead the crop to be used in the rotation process, in order to recover physical, chemical and biological wear of the soil.

Its sowing occurs in the months of May to July and the harvest in November, December and January (SOARES, 2009). DUTTA et al. (1995); MOHAMMAD et al. (2012); LISSON and MENDHAM (2000) verified positive effect of supplemental irrigation in the cultivation of linseed, and highlighted the sensibility to water stress, particularly in critical stages of flowering and filling of grains.

For the development of plants and the rationalization of water resources is necessary the knowledge of how much and when to irrigate. The dimensioning of system and water management for irrigation requires the adoption of studies, assessments, and adjusts for its correct utilization (MENDONÇA and DANTAS, 2010). In a protected environment the evapotranspiration is in average lower than the verified externally, due to reduction of solar radiation and wind action affecting the growth and the production indirectly, through the influence on the leaf temperature and stomatal conductance (COCKSHULL, 1998).

Among the indirect methods of determination of water quantity to be provided for the crops, the methods of Class A Evaporation Pan has been commonly employed, due to its low cost and easy handling, BERNARDO et al. (2005), however the utilization of a Class A Evaporation Pan compromises a productive area of approximately 10 m² for the installation of equipments in a greenhouse, making it impracticable in small scale (FERNANDES et al., 2004). Therefore the utilization of the reduced tank is an alternative in small systems of irrigation, being a variation between the system Class A and the evaporimeter considered acceptable, with variation of approximately 18% (CRUZ and BARRETO, 2002).

FERNANDES et al. (2001) working with a reduced tank in the melon crop observed a good correlation comparing with the obtained by an automatic agrometeorological station, through the equation of Penman-Monteith, with correlation of 0,76 and concordance of 0,94, showing to be feasible the use of the method by small producers.

SANTOS et al. (2011) working in the irrigation management with a minitank in seedlings of Jatropha, verified that 2.5 Evm provided greater averages of phenometric characteristics. BUTRINOWSKI et al. (2011) also highlighted the importance of irrigation, obtaining similar results in their study with irrigation of 2.5 Evm, for the phenomotric variables assessed. LIMA JUNIOR et al. (2010) verified for the crop of lettuce with utilization of a minitank, a reposition factor of 1.01 provided maximum commercial productivity 35308 kg ha^{-1}.

However, with the huge Brazilian edaphoclimatic diversity and, practically nonexistence of studies about the irrigation influence on the linseed development, this study aims to assess the behavior and performance of linseed, submitted to the management of water reposition, using an evaporimeter minitank.

Material and Methods

The experiment was done during the period of April to August of 2012, in a greenhouse in the Universidade Estadual do Oeste do Paraná –

UNIOESTE, located at the city of Cascavel, Paraná, Brazil, latitude 24º53'47"S and longitude 53º32'09" W, with average annual rainfall of 1640 mm and average temperature of 19 ºC. The region presents mesothermal temperate and super humid weather, climate type Cfa (koeppen) (CAVIGLIONE et al., 2000). The average annual temperature in the regions is of 19.6 ºC, and the annual rainfall of 1971 mm and 2462 sunshine hours per year (IAPAR, 2011).

The experiment was done in a greenhouse of low density polyethylene, due to the nonexistence of study on the cultivation of the specie in the region. The data relative to the evapotranspiration, which served as basis for the irrigation levels were obtained from a evaporimeter minitank of 200 mm, installed on an one iron bedstead at 80 cm above the ground of white color, put in the interior of the greenhouse, being done as recommend VOLPE and CHURATA-MASCA (1988) and BERNARDO (1989). The reading was done with variation of 2 to 3 days through the complement of the evaporated water with a 1000 ml measuring cylinder.

The used experimental design was the factorial scheme (2x5), with two cultivar of linseed (brown and the golden) and five treatments of evaporation corresponding to (0.5; 1.0; 1.5; 2.0; 2.5 Evm (evaporated), with four repetitions. The sowing was done in April 15th of 2012 in pots of 28 cm of diameter with 10 liters of soil of the layer between 0-20 cm in a Eutroferric Red Latossol, of clayey texture (EMBRAPA, 2006), without basic fertilization. The control of invasive plants in the pots was done manually.

After completion of the crop cycle (about 128 days), in the day of July 20th of 2012, was determined the plant height (PH), number of stems per plant (Stems number), number of capsules per plant (Capsules number), fresh mass (FM) and dry mass (DM) of the capsules, fresh mass (FMP) and dry mass (DMP) of the plants' shoots. The plants and the capsules were dried in a greenhouse with forced ventilation at a temperature of 65 °C for a period of 72 hours.

The results obtained were submitted to variance analysis and the interaction between the factors, as well as its measures were compared through the Tukey test at 5% of error probability, with the utilization of the statistical package Assistat® version 7.5 beta (SILVA and AZEVEDO, 2002). When observed significance by analysis of variance The doses were compared using regression analysis.

Results and Discussion

The summary of the variance analysis of respective variables analyzed is found in Table 1. The irrigation provided significant effects by the F test (P <0.01) in the plant height, number of stem per plant, number of capsules per plant, fresh and dry mass of capsules and fresh and dry mass of the plants for the two cultivars studied (brown and golden). There was no significant interaction between the cultivars and applied irrigation for the variable number of stems per plant. There were significant effects by the F test (P <0.01) between the cultivars and irrigation applied for the other analyzed variables.

It can be observed in Figure 1A that the quadratic model obtained adjust for the variable plant height of linseed in relation to the management of reposition of evapotranspirated water. The brown linseed demonstrated greater vegetative growth with maximum values of 102 cm of height with repostion of 1.73 EVm. The golden species by the local edaphoclimatic conditions obtained with reposition irrigation of 1.81 EVm an average height of 78 cm.

CARVALHO et al. (2006) observed increase in the plants height with increase in the water availability. SANTOS et al. (2010) found maximum values for the crop of *Jatropha curcas* in Cascavel-PR with reposition of 2.9 EVm. BUTRINOWSKI et al. (2011) working with levels of reposition for the crop of crambe, observed tendencies of increase in the biometry of plants with increasing application of irrigation, not finding the point of maximum technical efficiency, which according the polynomial regression would be with reposition of 2.9 EVm. AHLAWA and GANGAIAH (2009) emphasized the sensibility of the linseed to water limitation in their study, with reduction on the plant height. TAIZ and ZAGER (2006) state that lesser water availability tends to present lesser plant height, because the water restriction can affect the metabolic processes of growth.

The number of stems per plant (Figure 1B) was influenced by the management of water reposition. The brown cultivar presented higher response to the irrigation management. It was not possible to find the point of maximum efficiency of reposition for the brown linseed, however the regression equation presented tendency with maximum point of 3.36 EVm of reposition with 7.05 stems per plant. The golden linseed had quadratic polynomial behavior with 2.11 and 5.70. EVm of reposition and stem per plant, respectively.

Table 1. Variance analysis of the data referring to the plant height (AL); number of steam per plant (N ST); number of capsules per plant (N CAP); fresh and dry mass of the capsules (FMP and DMP); of Linseed in function of different irrigation

FV	GL	Average square						
		AL (cm)	N HA	N CAP	MFC	MSC	MFP	MSP
Cultivars (A)	1	1782.22**	4.22 **	5640.62**	2059.08**	75.32**	47.46**	7.12**
Irrigation (B)	4	1386.77**	14.77**	2132.71**	1886.66**	153.65**	22.17**	2.29**
Interaction A*B	4	980.52**	0.47ns	143.68**	272.65**	15.32**	2.45**	0.66**
Treatments	9	4.21**	7.24**	1638.46**	1188.48**	83.47**	16.21**	2.10**
Residues	30	88.69	0.45	19.75	25.12	1.87	47.46**	0.04
CV (%)		12.04	13.47	13.48	18.88	18.89	19.23	18.05
Overall average		78.22	5.02	32.97	26.06	7.59	3.61	1.16

*** significant at 0.01 of probability by the F test; * significant at 0.05 of probability by th F test; ns non significant; SV Source of variation.*

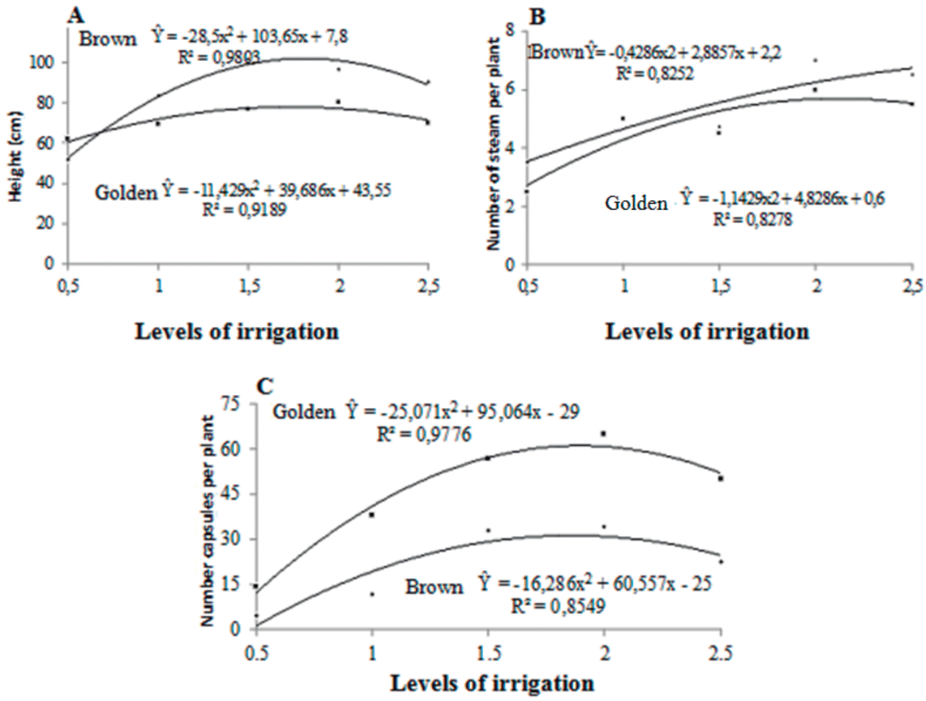

Figure 1. Height (H) A); number of steam (N ST) (B); and number of capsules (N CAP) (C) per plant in function of the different irrigation, with management based in the evaporation of the "evaporimeter minitank".

BISCARO et al. (2012) also obtained significant quadratic response (P <001) in function of the irrigation applied in the cultivars of mamona, obtaining 6,15 and 5,6 racemes per plant, with irrigation of 150% EVm. SOUZA et al. (2007) verified increase of 148% in the average number of racemes per mamona plant, comparing the irrigation of supplementation to the rainfed. According to VENDER et al. (1995), the number of main ramifications or stem is a variable that depends upon the linseed specie, however MOHAMMAD et al. (2012), observed decrease of this variable with increase of the water deficit.

The irrigation management with basis in the fractions of evaporation of the evaporimeter minitank was significant with increase in the number of capsules per plant (Figure 1C). The number of capsules, in this assessment was considered as a variable of great importance which confers the productivity to the plant and was significantly higher in the golden cultivar. The points of maximum efficiency were close to 1.89 and 1.85 EVm of reposition for the cultivars golden and brow and with 61.11 and 31.29

capsules per plant, respectively. MOHAMMAD (2012) observed maximum accumulation of capsules per plant of linseed, when the crop was submitted to irrigation in the whole cycle, without suffering water deficit, presenting 60 capsules per plant. GABIANA (2005) also stated the importance of irrigation in the development of linseed, obtaining 24 and 10.3 capsules per plant, with and without irrigation, respectively. According with TURNER et al. (2001), when the plant is submitted to water deficit, mainly the linseed which possess indeterminate cycle the plants activated the mechanism of speeding of the cycle, reducing thus the number of capsules and causing fast filling of the grains.

BISCARO et al. (2012) working with two cultivars of mamona and five irrigations (0, 25, 50, 100 and 150% of the evapotranspiration) did not verify significant differences for the number of fruits per raceme, observing averages of 25.3 fruits per raceme for the cultivar IAC 2028 and 22.8 fruits per racemes for the cultivar IAC 80. FREITAS et al. (2010) and SOUZA et al. (2007) in their studies observed that the irrigation favored the increase of the racemes length and of the number of fruits per raceme. MOHAMMAD et al. (2012) working with irrigation in the cultivation of linseed on the field, with water restriction in the stages of the elongation of stems, full flowering and cycle ending, observed that the height of the plant, number of capsules per plant and the productivity of the crop were negatively affected by the water restriction in the flowering stage.

The fresh and dry mass of the capsules (Figure 2A and B) and fresh and dry mass of the plant (2C and D), also presented significant quadratic responses ($P < 0.01$) in function of the applied irrigation, presenting significant difference between the two varieties, thus as for the interaction. The golden cultivar presented greater fresh and dry mass of capsules with the management of irrigation in relation to the brown cultivar with maximum values of 6.62 and 3.46g, respectively.

The polynomial model was observed as the most adequate to show the relation of fresh and dry mass versus irrigation. The maximum values were obtained under levels of irrigation corresponding to 1.80 and 1.79 EVm for the golden cultivar and 2.13 and 2.16 EVm for the brown cultivar. Based on these levels, the fresh and dry mass began to decrease, which considering information presented by ARMSTRONG et al., (1994) may have occurred due to the water excess in the soil, which caused immediate reduction in the gas exchange between the plant and the environment, which can reduce the oxygen supply to the root system, limiting the respiration, nutrients absorption and other functions of the roots.

ARAÚJO et al. (2010) studying the effect of irrigation levels with basis in the evaporation, emphasized the positive influence of irrigation in the individual fresh mass of the melon fruit, however differently of this study, the irrigation provided linear increment in the fresh mass of the melon. SILVA et al. (2007) found in a study with sunflower, increase of productivity and oil content with the increase of irrigation. In this study the greater irrigation applied was of 1.3 EVm with better yield in the oil content, plant height and productivity.

It is observed in (Figure 2A and 2B), significant quadratic response in function of the applied irrigation in the two cultivars, for the fresh and dry mass of the plants, presenting increment in the accumulated total fresh mass, with an irrigation of 2.7 and 1.65 EVm, for the brown and golden cultivars, respectively. Following the same tendency of the fresh mass, for the variable dry mass (Figure 2D) it was observed significant differences and tendency of biomass increase in function of the irrigation applied with quadratic response. GABIANA (2005) obtained in his study, increase of 59% in the total dry mass of the linseed crop, when it was submitted to normal irrigation in the whole cycle, comparing with rainfed.

ANDRADE JÚNIOR et al. (1992) analyzing the effects of four levels of irrigation based in the evaporation of the Class A Pan (ECA) (0.5; 0.75; 1.0 e 1.25), verified that the fresh mass of the lettuce presented quadratic response, having reached the maximum values of 184g and 23.68 t ha^{-1}, respectively, with the level of irrigation corresponding to 75% of ECA.

The results of the behavior of the average values of fresh mass in function of the irrigation levels, in the studies of VILAS BOAS et al. (2007), also presented quadratic responses, indicating an increase in the fresh mass, as they increased the irrigation applied until maximum values of 1.26 EVm of reposition of irrigation water. SANTOS and PEREIRA (2004) concluded that the yield of the commercial part fresh mass and the content of the commercial dry mass were greater when the soil humidity presented tensions close to field capacity.

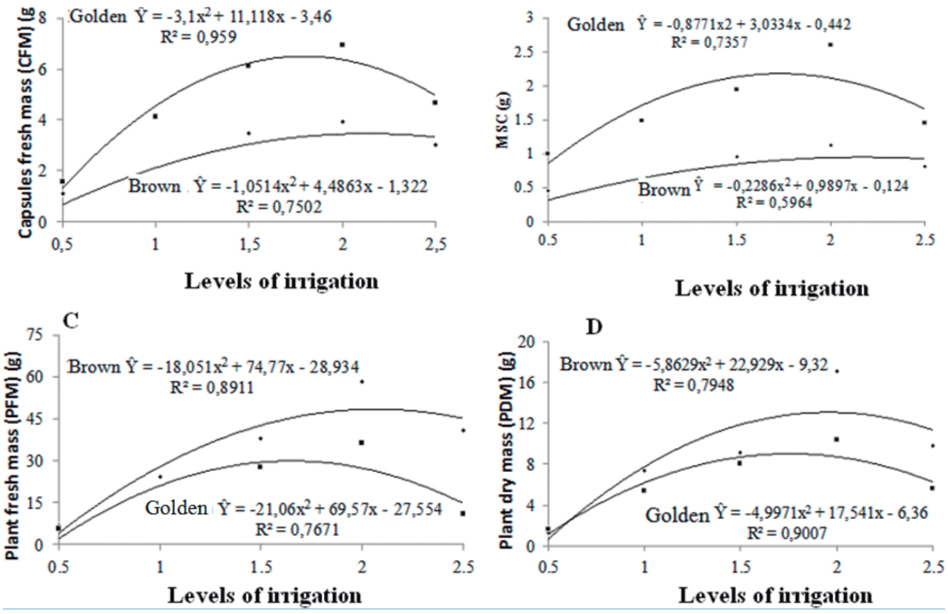

Figure 2. Fresh mass (FM) (A), dry mass (DM) (B) capsules fresh mass (FMP) (C) and plant dry mass (DMP) (D), in function of different irrigations, with the management based in the evaporation of the evaporimeter minitank.

It was observed, in the conditions of this experiment, that the linseed crop is sensible to water deficit. The quantity of water applied interfered significantly the components of linseed production, however the golden cultivar stood out as for the number of capsules per plant, variable responsible by the crop yield.

Conclusion

The components of the production had significant quadratic response to the treatments, thus as the interaction between cultivars and irrigation. The brown cultivar presented greater growth, number of stems and fresh and dry mass, while that the golden cultivar presented greater quantity of capsules, and consequently greater fresh and dry mass of the capsules.

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