academicJournals

Vol. 10(50), pp. 4599-4605, 10 December, 2015
DOI: 10.5897/AJAR2015.10348
Article Number: C11807756316
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Cultivation of golden flax with application of nitrogen and irrigation

Wellington Lucas Tondo*, Flavio Gurgacz, Reginaldo Ferreira Santos and Eduardo De Rossi

UNIOESTE - State University of the West of Parana - Brazil.

Received 25 August, 2015; Accepted 9 October, 2015

Flaxseed is the seed of the linen (*Linum usitatissimum* L.) and the most produced varieties are brown and golden flaxseed. The objective of this study was to investigate the influence of irrigation and nitrogen application in cultivation of the golden flax cultivation. The irrigation it was made by dripping, daily, except for days of rain occurrences, according to evapotranspiration. The treatments were separated by 0, 50, 100, 150, 200 and 250% of the daily irrigation, and the control value of 100% of the amount of evaporation by area. The seeds were planted on April 22, 2013. After flowering, data were analyzed as: Plant height, number of branches and siliques and the fresh and dry mass of silica and twigs on August 8, 2013. The crop occurred on October 10, 2013 and they were analyzed: amount of silica, number of seeds, total weight of seeds per plant, weight of 100 seeds, the production per meter and the proportion by hectare. Urea application resulted in an improvement in the production of two varieties. The combined irrigation also increases the production; however, in quantities exceeding 150% of irrigation, there was a decrease.

Key words: *Linum Usitatissimum* L., evapotranspiration, production.

INTRODUCTION

Flaxseed is the seed produced by flax (*Linum usitatissimum* L.) belonging to the Flax family, probably originated in Asia (Vieira et al., 2012). It is a herbaceous variable height of between 40 cm and 1 m erect stems, branches to the top of the plant. Varieties for food consumption are brown and golden (Lima, 2007; Morris, 2007).

Flaxseed was introduced in Brazil early XVII century in the state of Santa Catarina and later spread to the states of Rio Grande do Sul, Paraná and São Paulo, these regions which present climate necessary for flowering flax (0 to 2°C) and has a 150-day cycle (Marques, 2008).

Flaxseed presents in its composition omega 3, omega 6 and omega 9, as well as other basic nutritional components and antioxidant compounds. The seeds are between 39 and 45% oil. (Oliveira et al., 2012).

In South America, the largest producer is Argentina, with about 80 tons per year, while Brazil produces only 21 tons. According to the IBGE (2010), the planted area was 16.584 ha and the average yield per hectare was 974 kg, but the production can reach up to 1.5 tons (Oliveira et al., 2012).

The determination of the amount of water lost by evapotranspiration is essential to establish the water

*Corresponding author. E-mail: wltparana@yahoo.com.br

balance in the region. Thus, one can determine if this region is suitable for the cultivation of certain plant species and quantity irrigation, using efficiently water and energy (Kobiyama and Vestena, 2006).

The potential evapotranspiration (ETp), which is needed rain, is the water loss is the process into the atmosphere through a natural grassy surface, standard, without water restriction to meet the needs of soil evaporation and transpiration. The real evapotranspiration (ETr) is the water loss from a natural surface, in any condition humidity and vegetation cover and the reference evapotranspiration is a parameter that relates the ETp with a reference culture the reference. Rain and ETp are meteorological elements of opposite directions, expressed in millimeters rainfall per day (Thornthwaite, 1944; Ponce, 1989).

In irrigation management driven through evapotranspiration estimation, the most commonly used devices are the Class A tank and automatic meteorological station. The Class A tank is further used to estimate ETp when the irrigation management relies on measurement of water evaporation, where the amount of evaporation is converted into reference evapotranspiration by specific coefficients (Doorenbos and Pruitt, 1977; Allen et al., 1998).

The equation to estimate the potential evapotranspiration is presented in Equation 1, using the analytical method and based on results the estimated ETp for more than a hundred locations (Camargo, 1971).

$$ETp = Qo.\ T.\ K.\ D \quad (1)$$

ETp = potential evapotranspiration in mm.dia^{-1}; Qo = extraterrestrial solar radiation above the atmosphere, on the 15th of Each month, in mm.dia^{-1}, equivalent evaporation (get it in special tables); T = period of the average daily temperature, in °C; K = adjustment factor: 0.01 for Ta (temperature annual average) to 23.5°C; 0.0105 for Ta 23.6 24.5°C; 0.011 for Ta 24.6 to 25.5°C; 0.0115 for Ta 25.6 to 26.5°C; 0.012 for Ta 26.6 to 27.5; 0.013 Ta for more than 27.5°C, and D = number of days in the period.

There are other methods for determination of evapotranspiration, among them we can mention the Thornthwaite, Jensen and Haise, Blaney-Criddle, Ivanov, Penmann-Montheith and for each evaporímeter model, different parameters apply to determine the evapotranspiration (Souza et al., 2009).

Although the Penman (1948) is based on principles right physical, it is not operationally perfect, but it can be used as a standard model to estimate the ETP. The success of this method is due to the strong influence of solar radiation in the process of evapotranspiration. The limitation of its use is the difficulty of the necessary meteorological data. This has led some researchers to suggest changes aiming to improve and simplify the Penman method (Tucci and Beltrame, 2000; Vanzela et al., 2007).

Fernandes et al. (2004), showed a correlation 0.76 and concordance of 0.94, using a mini tank to determine the evapotranspiration in melon culture compared to that obtained with an automatic weather station, through the Penman-Monteith-FAO equation, showing to be feasible use of the methodology by small producers.

The use of alternative evaporimeters is considered feasible in small irrigation systems, and the variation between the Class A tank and the evaporimeter alternative is acceptable, being approximately 18%. The over estimation provided by mini-tank was 6.6%. The lower surface of the tank, leading to a higher evaporation is compensated due to the lower thermal energy storage to be transferred to the body of water in the plastic walls (Cruz and Barreto, 2002; Lopes Filho, 2000).

The fertilization with urea and ammonium sulfate provided a significant increase in phenotypic characteristics of flaxseed. Fluid replacement resulted in a significant increase in height, fresh and dry weight of sunflower plants. (Werner et al., 2012; Bassegio et al., 2012).

Assuming the report, the goal to achieve the current study was to evaluate the characteristics of golden flax cultivation, after flowering and producing, with nitrogen application influence and different amounts of irrigation.

MATERIALS AND METHODS

The work was conducted in the experimental field of the State University of Western Paraná, in an area of 2.5 and 2.5 m, located in Cascavel, Paraná, Brazil, located at latitude 24º53'47 "S and longitude 53º32'09 "W, altitude of 781 m, with the average annual rainfall of 1640 mm and average temperature of 19°C. The climate is temperate mesothermal and super humid (IAPAR, 2011).

Golden flax seeds were planted on 04/22/2013, with and without the influence of nitrogen on the lines and applying different amounts of treatment daily irrigation, according to evapotranspiration. The soil of the region is classified as Typical Red Hapludox (EMBRAPA, 2006).

The germination of the crop came four days after planting, then immediately was made a thinning, leaving a plant spacing of about 2 cm. The spacing between the planting rows was 40 cm and the size of 1.25 m treatment line, totaling for each irrigation hose an area of 1 m^2. The flow in each hose was 75 l.h^{-1} thus representing the time required in each irrigation line treatment.

The treatments were separated into 0 (T1), 0.5 (T2), 1.0 (T3), 1.5 (T4), 2.0 (T5) and 2.5 (T6), the multiplication factor amount evaporated daily in culture, using the value of treatment T0 as witness measured daily in a mini-tank evaporimeter (EVM) installed on the site of cultivation, which has been inserted a graduated ruler and with a diameter and height of 20 cm × 20 cm, converted in proportion to the area under cultivation.

After flowering, six plants were taken for each treatment and evaluated the following characteristics: plant height, number of siliques, fresh and dry weight of silica, fresh and dry weight of the branches and the number of branches. Analyses were made on 08/20/2013.

On 10/14/13 cultivars were susceptible to harvest. Six plants from each treatment were taken and analyzed the following data: number of siliques, seed number per plant, total weight of seeds, weight of 100 seeds, after drying in an oven at 60°C for 48 h.

Until the beginning of drip irrigation, irrigation was done manually, of 15 min per day in the whole area (2.5 x 2.5 m). Drip irrigation started from May 1.

To analyze the flow of water, measurements were made in each dripper, containing in each irrigation line 25 drippers. The flow rate was nearly constant in each dripper, with a value of 2.083×10^{-6} m^3 s^{-1}. Only in rainfall days were not performed irrigations.

The application of nitrogen (N) in the form of urea $(NH_2)_2CO$ in the growing area have been made in the proportion of 50 kilograms per hectare. Two applications were made during the experiment, the 1st on 06/05/2013 and the 2nd on 20/06/2013.

The experimental arrangement was completely randomized design, using five treatments and the witness, and removing the six most representative samples. The results were submitted to analysis of variance (ANOVA) and means compared by Tukey test, adopting the level 1-5% significance, with degree of freedom of the residue (GLR = 30) and using the statistical package version Assistat® 7.7 beta (Silva, 2014).

The equation that best characterized the production was polynomial regression 2nd degree, removing 1 m in treatments and adding to the 6 samples that had previously been taken for analysis, estimating through this, output per hectare.

RESULTS AND DISCUSSION

During the development of the golden flaxseed culture data were observed daily evaporation, the amount of rainfall and irrigation performed in different treatments in different months is represented in Table 1. The increase in rainfall results in a lower evapotranspiration and irrigation needs. Kobiyama and Vestena (2006) report that the potential evapotranspiration (ETP) annual average in Cascavel - PR was 1271 mm, with lower rates in the months of May, June and July, which differs from the results obtained due to the reduced number rains.

Abumanssur (2006) using data obtained by IAPAR in 25 meteorological stations located in the state of Parana for more than 17 years determined an average evapotranspiration in the region of 87 mm.mês, with 0.05 significance level, representing 57.85% below that obtained during the experiment.

After flowering, 6 samples of golden flaxseed were collected, treatments with (DCN) and without application of nitrogen (DSN) for analysis and are shown in Tables 2 and 3.

The difference of plant height (AP) between T1 and T5 treatments, where there was the highest rate, no nitrogen was 16.67%, which corroborates the results obtained by Bassegio et al. (2012), which found a water replacement value of 1.81 Evm and plant height 78 cm, this value increased to 6.37% obtained in the experiment.

Carvalho et al. (2006) reported increases in plant height with the increase in water availability. Santos et al. (2010) obtained maximum values for cultivation of *Jatropha curcas*, with replacement of 2.9 times. Taiz and Zager (2006) point out that fluid restriction can affect the metabolic processes of growth.

Werner et al. (2012) had greater plant height, in his experiments with linseed and different amounts of urea application of the rate of 50 kg.ha^{-1}, an amount used in the experiment. It was found that urea application resulted in an increase in height of only 2.92% of the plant, however, is combined with 1.5 Evm results in an increase of 36.95%.

The number of branches (NR) increased 23.04% with fluid replacement without nitrogen, between T1 and T3-T4. When added to fertilization, increased 215.21% in T3, which matches Biscaro et al. (2012), who found 1.5 ET in the cultivation of castor and Werner et al. (2012), which were obtained by culturing 50% flax increased by applying the urea 50 kg ha^{-1}.

The number of siliques (NS) is directly influenced by irrigation, an increase of 225.42% between T1 and T5, but if added to application of nitrogen, this percentage reaches 488.58% in T4, which is confirmed by Bassegio et al. (2012) and Werner et al. (2012).

Fresh mass of siliques (MFS) in the treatments without nitrogen increased from 1.38 to 3.92 g in T1 at T5, and applying nitrogen increased from 3.94 to 8.45g in T1 at T4, which is similar to the trend obtained on the siliques dry mass (MSS), consistent to Werner et al. (2012) and Bassegio et al. (2012), however, larger when treatments are combined.

An increase of 488.77% occurred between T4 and T1 with nitrogen and without nitrogen, to fresh mass of the plant (MFP). The same tendency occurred for the dry mass of the plant (MSP), which went from 1.2 g to 6.05 g, corroborating Bassegio et al. (2012) that by applying a polynomial model, achieved the highest response in 1.8 Evm to golden flaxseed.

The results show that the fluid resuscitation and fertilization improves plant response in its development. But with excess water is decreased due to the reduction in gas exchange between the plant and the environment, which reduces the supply of oxygen to the root system and limits breathing and nutrient absorption (Armstrong et al., 1994; Pardos, 2004).

To evaluate production were collected 6 plants per treatment and analyzed: number of siliques (NS), seeds (NSEM) and mass (M) and the weight of 100 seeds (M100).

These data for the different treatments applied on Golden flaxseed (DCN) and without nitrogen (DSN) are shown in Tables 4 and 5.

The number of siliques (NS) collected in production was on average for all treatments without application of nitrogen (DSN), 19.41% lower than in the samples taken after flowering, due to losses by climatic phenomena and animals that may fed. With application of nitrogen (DCN), the lost NS was even greater, with 30.66%.

Santos et al., (2013) studied the golden flaxseed, found between 40 and 80 siliques the harvest period, more responsive applying nitrogen between 200 and 300 kg ha^{-1}, while Viera et al. (2012) obtained value 53.17 most siliques applying 40 kg ha^{-1} of potassium (K).

The number of seeds (NSEM) of the treatments did not differ statistically analyzed. The T5 treatment without application of nitrogen showed an increased number of

Table 1. Evapotranspiration – ET, Precipitation - P and irrigation in treatments (mm.month^{-1}).

Date	ET	T1	T2	T3	T4	T5	T6	P
05/13	109.43	0	54.21	108.43	162.64	216.86	271.07	330.00
06/13	75.41	0	38.71	77.42	116.13	154.84	193.55	365.50
07/13	216.84	0	109.98	219.96	329.94	439.92	549.90	26.00
08/13	220.38	0	111.43	222.86	334.29	445.72	557.16	55.50
09/13	129.90	0	63.94	127.89	191.83	255.78	319.72	200.00

Table 2. Golden flaxseed after flowing without application of nitrogen (DSN).

Treatment	AP	NS	MFS	MSS	NR	MFP	MSP
T1	62.67^{b}	19^{b}	1.38^{c}	0.29^{b}	2.17^{a}	3.74^{c}	1.20^{b}
T2	63.33^{b}	22.67^{ab}	1.97^{bc}	0.54^{ab}	2.17^{a}	4.62^{bc}	1.4^{b}
T3	69.00^{ab}	36.50^{ab}	3.32^{ab}	0.84^{ab}	2.67^{a}	8.70^{a}	2.66^{a}
T4	69.17^{ab}	39.33^{ab}	2.66^{abc}	0.68^{ab}	2.67^{a}	8.01^{ab}	1.89^{ab}
T5	73.17^{a}	42.83^{a}	3.92^{a}	0.95^{a}	2.33^{a}	9.33^{a}	2.84^{a}
T6	70.33^{ab}	22.50^{ab}	1.92^{bc}	0.49^{ab}	2.33^{a}	6.12^{abc}	1.86^{ab}
F	3.28*	4.54**	5.39**	3.35*	0.62^{ns}	6.41**	6.60**
dms	9.77	20.65	1.78	0.568	1.24	3.88	1.10
CV%	8.19	38.61	40.03	51.24	29.60	32.69	31.81
GA	67.94	30.47	2.53	0.632	2.39	6.75	1.97

[a]Means followed by the same letter within each analyzed parameter (column), do not differ by Tukey test at 5% error probability. (**) = Significant at 1% probability, (*) = significant at the 5% probability, (NS) = not significant. CV% = coefficient of variation. dms = least significant difference. GA = general average. AP = plant height (cm), NS = number of siliques, MFS = fresh mass siliques (g), MSS = dry mass siliques (g) NR = number of branches, MFP = fresh mass of plants (g) MSP = dry mass of the plant (g), T1 (0%), T2 (50%), T3 (100%), T4 (150%), T5 (200%) and T6 (250%).

Table 3. Golden flaxseed after flowing with application of nitrogen (DCN).

Treatment	AP	NS	MFS	MSS	NR	MFP	MSP
T1	64.5^{c}	44.83^{a}	3.94^{a}	0.98^{a}	3.00^{ab}	8.50^{b}	3.02^{a}
T2	74.17^{b}	61.17^{a}	4.76^{a}	1.13^{a}	3.67^{ab}	10.94^{ab}	3.84^{a}
T3	78.17^{ab}	90.83^{a}	7.98^{a}	2.09^{a}	4.67^{a}	16.99^{ab}	5.78^{a}
T4	85.83^{a}	92.87^{a}	8.45^{a}	2.20^{ab}	3.67^{ab}	18.28^{a}	6.05^{a}
T5	82.67^{ab}	66.00^{a}	5.73^{a}	1.50^{a}	2.5^{b}	13.31^{ab}	4.37^{a}
T6	80.67^{ab}	54.67^{a}	4.85^{a}	1.18^{a}	2.83^{b}	12.02^{ab}	3.82^{a}
F	12.85**	2.55*	2.54*	1.72^{ns}	3.60*	3.23*	2.36^{ns}
dms	9.08	52.49	4.99	1.70	1.76	8.85	3.35
CV%	6.67	43.73	47.72	63.82	29.67	37.82	42.54
GA	77.67	68.39	5.95	1.51	3.39	13.34	4.48

[a]Means followed by the same letter within each analyzed parameter (column), do not differ by Tukey test at 5% error probability. (**) = Significant at 1% probability, (*) = significant at the 5% probability, (NS) = not significant. CV% = coefficient of variation. dms = least significant difference. GA = general average. AP = plant height (cm), NS = number of siliques, MFS = fresh mass siliques (g), MSS = dry mass siliques (g) NR = number of branches, MFP = fresh mass of plants (g) MSP = dry mass of the plant (g), T1 (0%), T2 (50%), T3 (100%), T4 (150%), T5 (200%) and T6 (250%)

seeds, while with application took place in T4. The average number of seeds, with and without nitrogen, was 6.03 and 7.01, respectively, and excels in 24.80% less than relates Morris (2007) maximum value.

The seed mass (M) increased 245.10 and 322.53% respectively between T1 and T5 treatments without nitrogen (DSN) and with nitrogen (DCN), which encourages an improvement 449.02% between planting

Table 4. Golden flaxseed production without application of nitrogen (DSN).

Treatment	NS	NSEM	M	M100	M1L
T1	16.33[b]	111.33[a]	0.51[a]	0.46[a]	19.49
T2	21.33[ab]	114.67[a]	0.61[bc]	0.53[a]	21.12
T3	34.5[ab]	192.67[a]	1.07[ab]	0.56[a]	25.66
T4	36.00[a]	191.00[a]	1.15[a]	0.55[a]	26.59
T5	37.67[a]	212.17[a]	1.25[a]	0.60[a]	27.47
T6	16.5[b]	123.50[a]	0.78[abc]	0.53[a]	25.61
F	5.09**	3.07*	6.32**	1.52[ns]	-
dms	19.19	112.25	0.52	0.16	-
CV%	40.40	40.59	33.10	16.69	-
GA	27.05	157.55	0.90	0.54	24.32

[a]Means followed by the same letter within each analyzed parameter (column), do not differ by Tukey test at 5% error probability. (**) = Significant at 1% probability (*) = significant at the 5% probability (NS) = not significant. CV% = coefficient of variation. dms = least significant difference. GA = general average. NS = number of siliques, NSEM = seed number, M = the mass of seeds (g) M100 = mass of 100 seeds (g) m1L= mass of 1 linear meter of planting (g). T1 (0%), T2 (50%), T3 (100%), T4 (150%), T5 (200%) and T6 (250%)

Table 5. Golden flaxseed production with nitrogen application (DCN).

Treatment	NS	NSEM	M	M100	M1L
T1	22.83[a]	146.67[a]	0.71[b]	0.49[a]	34.80
T2	39.67[a]	287.67[a]	1.49[ab]	0.54[a]	41.12
T3	44.67[a]	314.33[a]	1.67[ab]	0.55[a]	44.47
T4	61.50[a]	433.17[a]	2.22[ab]	0.35[a]	50.46
T5	61.33[a]	415.50[a]	2.29[a]	0.55[a]	48.87
T6	54.5[a]	409.83[a]	2.14[ab]	0.53[a]	47.13
F	2.16[ns]	2.55*	2.81*	0.52[ns]	-
dms	43.62	294.35	1.55	0.12	-
CV%	52.41	50.12	50.33	13.25	-
GA	47.42	334.53	1.76	0.53	44.47

[a]Means followed by the same letter within each analyzed parameter (column), do not differ by Tukey test at 5% error probability. (**) = Significant at 1% probability (*) = significant at the 5% probability (NS) = not significant. CV% = coefficient of variation. dms = least significant difference. GA = general average. NS = number of siliques, NSEM = seed number, M = the mass of seeds (g) M100 = mass of 100 seeds (g) m 1 L= mass of 1 linear meter of planting (g). T1 (0%), T2 (50%), T3 (100%), T4 (150%), T5 (200%) and T6 (250%).

without fluid replacement and application of urea (worst result) and adding the best result (T5) obtained.

Merging the results with those found by De Rossi et al. (2012) on population density in the same cultivar, which had the highest rates of fresh and dry mass of siliques with 100 plants per m^2, it leads up to a point great production.

Mass measurements of 100 seeds (M100) did not differ significantly between treatments, which are backed by Ambrosano (2012), which had the same answer. The same author states that the mass 100 flax seeds varies between 0.63 and 0.67 g, which differs from what was found, ranging between 0.35 and 0.63 g.

The mass data per hectare (Mha), with and without nitrogen, for the different treatments are shown in Figure 1, stipulated by the removal of 1 m and dried in an oven at 60°C for 48 h, using a 2nd degree polynomial regression that best relates the behavior of production.

Note that, an increase in productivity between T1 and T5 treatments at 40.94%, but in T6, there was a decrease due to water excess. The combined fertilization can raise productivity by 258.91%, between treatments with smaller and higher performance and reduces the water requirement because the summit took place in T4.

The average yield obtained flaxseed is 974 kg ha^{-1}, but can reach 1.5 tons ha^{-1}, confirming the results obtained, taking maximum values of up to 2 h^{-1} ton by optimization of resources used in cultivation. (Grant et al., 1999; IBGE, 2010; Oliveira et al, 2012.).

Santos et al. (2013) obtained from 600 to 1000 kg ha^{-1} for Golden flaxseed applying different amounts of nitrogen, but decreased slightly by applying excessive

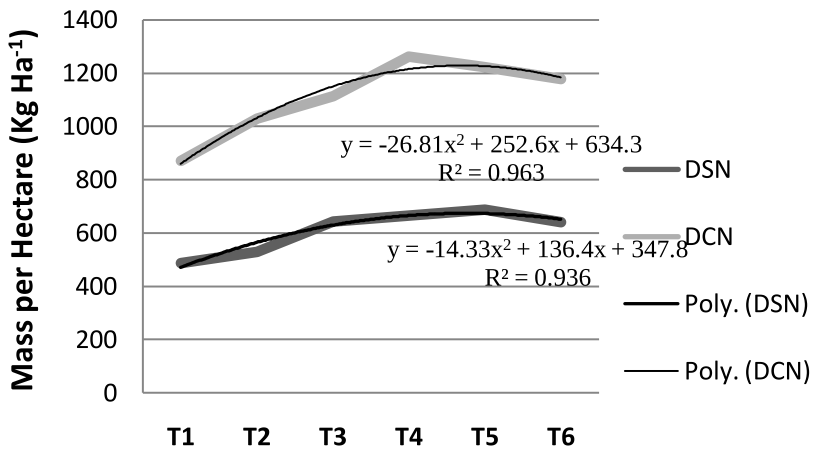

Figure 1. Mass per hectare in treatments T1 to T6, with (DCN) and without application of nitrogen (DSN), 0 (T1), 50 (T2), 100 (T3), 150 (T4), 200 (T5) and 250% (T6) of fluid replacement

amounts to 300 kg ha^{-1}, similar to the values obtained, but lower, due to the addition of irrigation.

Conclusions

By measuring the daily evapotranspiration, determined the amount of fluid replacement required for the culture of golden flax, which represented an increase of the phenotypic characteristics. However, the excess water leads to productivity losses. Allied irrigation, the application of urea $(NH_2)_2CO$ also resulted in an increase in the phenotypic characteristics.

Conflict of interest

The authors have not declared any conflict of interest.

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