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Sources and rates of nitrogen in the cultivation of flax

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This study aimed to evaluate the potential development of golden flaxseed (*Linum usitatissimum* L.) under the influence of the application of sources and rates of nitrogen. The experiment was conducted in the field Unioeste, Campus Cascavel, State of Paraná, using the factorial design (2×5) randomized, two nitrogen sources (urea and ammonium sulphate) and five rates of nitrogen (0, 50 , 100, 150 and 200 kg ha^{-1}). We evaluated the following characteristics: plant height, fresh (FWP) and dry weight (DWP) of plants, number of stems, number of capsules (NC), fresh and dry weight of capsules (FWC; DWC), 100-grain weight and yield (kg ha^{-1}). The urea as nitrogen source had a positive influence on the productivity of flax, which was only influenced depending on the nitrogen source. Nitrogen rates influenced some production components, but not the crop.

Key words: *Linum usitatissimum*, nitrogen, fertilization, nutrition.

INTRODUCTION

Flaxseed (*Linum usitatissimum* L.) is characterized as growth upright plant, average height of 0.7 m and its seeds have many applications, that may be used as raw material for production of oil and bran (Galvão et al., 2008) . It is a source of essential fatty acids for human diet with benefits for human health (Millis, 2002). Once your seeds are rich in oil (38%), fibers (20 to 25%) and protein (20 to 25%); the crop has a promising future in biofuel production (Rabetafika et al., 2011).

To increase crop yields are needed agricultural practices aimed at maximizing yield per unit area, which features the soil tillage and fertilization (Hussein, 2007). Nitrogen is the nutrient responsible for influencing and limiting the growth of Malavolta plant (1980), because of that, the nitrogen fertilization management in the crop flaxseed becomes necessary (Dordas, 2010; Lafond et al., 2008; Zimmermann et al., 2006). Ammonium sulphate and urea are the two most nitrogen sources used in Brazilian agriculture, possibly because they are less expensive and more readily available in the market (Barbosa Filho et al., 2005). The volatilization losses when using ammonium sulphate are not large; however, this source typically has a cost per unit of nitrogen far superior to urea (Lara Cabezas et al., 2008).

Rahimi et al. (2011) in a fulfilled study of eight varieties of flaxseed, five planting dates and rates of 0 to 150 kg ha^{-1}, found that the first sowing date March 14, along with 100 and 150 kg ha^{-1} of nitrogen produced the highest yield and production components.

Given the aforementioned, the purpose of this Experiment is to investigate the potential development of golden flaxseed (*L. usitatissimum* L.) subjected to

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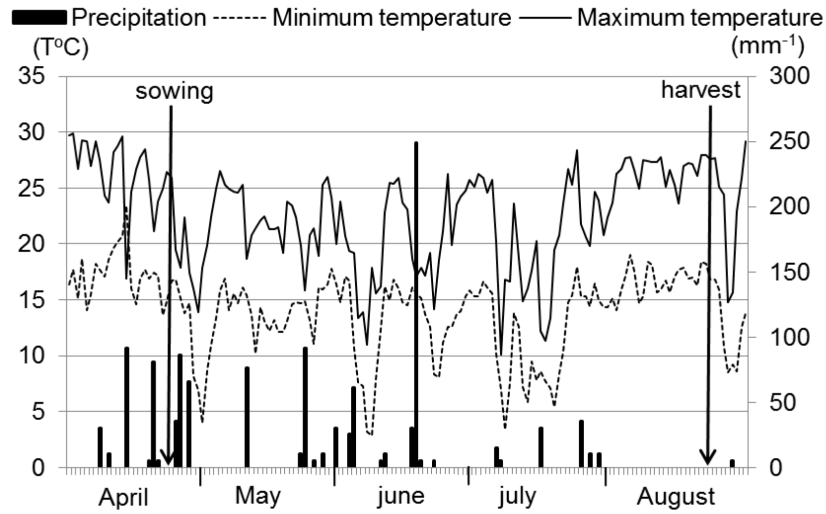

Figure 1. Precipitation (mm^{-1}) and temperature (T°C) recorded during the experiment with the culture of flaxseed.

sources and rates of nitrogen.

MATERIALS AND METHODS

The experiment was conducted under field conditions in the growing season of 2012, during the period from April to August of 2012 at the State University of West of Paraná - UNIOESTE, located in the town of Cascavel, Paraná, Brazil, latitude 24° 53'47 "S and longitude 53° 32'09 "W, presenting a mesothermal and super humid temperate climate, Cfa climate type (Koeppen) (Caviglione et al., 2000), with average annual rainfall of 1971 mm and an average temperature of 19.6°C and insolation 2462 h per year (IAPAR, 2011). The average monthly temperature and precipitation are shown in Figure 1.

The soil is classified as Oxisol (LVEF), clayey (Embrapa, 2006), presenting the following chemical properties: 26.80 $mg.dm^{-3}$ Fe, Cu 3.06 $mg.dm^{-3}$; 8.50 $mg.dm^{-3}$ Zn, Mn 104.00 $mg.dm^{-3}$; $CaCl_2$ pH 5.37, 6.93 $cmol_c$ dm^{-3} H + Al; 50.29 g dm^{-3} organic matter; 19.00 $mg.dm^{-3}$ P; $cmol_c$ dm^{-3}0.22 dm^{-3} K^+; $cmol_c$ dm^{-3} 12.25 dm^{-3} Ca^{2+}; $cmol_c$ dm^{-3} 5.35 dm^{-3} Mg^{2+}; $cmol_c$ dm^{-3} 17.82 dm^{-3} SB; $cmol_c$ dm^{-3}; 24.75 dm^{-3}CTC; 72 V%.

The experimental arrangement/ used was a factorial (2×5), two sources of nitrogen (N ammonium sulphate and urea-22% N-46%) and five rates of nitrogen (0, 50, 100, 150 and 200 kg ha^{-1}). Each plot consisted of six rows of 5 m long, spaced by 0.40 cm.

The sowing of flaxseed was held on April 14/2012 manually. In the operation of sowing was obtained a final population of 175 plants per m^2. The soil preparation was constituted of one decompression. The basic fertilization was performed according to the analysis of soil with 200 kg ha^{-1} of 02-20-18 formula. The control of weeds was performed manually. There was no agrochemical applied during the experiment.

The following components was evaluated: Plant height, fresh and dry weight of plant, number of stems, number of capsules, fresh and dry weight of capsules, weight of 100 grains and yield kg ha^{-1}. For determination of the component's production were sampled ten plants in each plot. After harvested and weighed, they were carried into a forced ventilation oven at a temperature of 65°C, for a period of 72 h. The grain yield was obtained by manual harvesting of central lines in each experimental unit in each plot. Subsequently, were realized the track and weighing of the grains. The yield was adjusted to 13% moisture, and the results expressed as kg ha^{-1}.

The results obtained were submitted to analysis of variance and the interaction between factors and their means were compared using the Tukey test and linear regression at 1 and 5% probability of error, using the statistical package Assistat® version 7.5 beta (Silva and Azevedo, 2002).

RESULTS AND DISCUSSION

The rainfalls that occurred at the site of the experiment (Figure 1) were considered good for the development of culture, despite the uneven distribution, it can be stated that the productive performance was not influenced by soil water deficit. According to Hocking et al. (1997), factors such as low rainfall and high temperatures during an anthesis and grain filling stage has a significant effect on the yield of flaxseed.

The behavior of variance analysis is shown in Tables 1 and 2. It can be observed that there was no significant difference between sources (ammonium sulphate and urea) only for plant height and fresh weight of capsules, while the other components of culture were influenced by the nitrogen source. The rates of nitrogen did not affect significantly the weight of 100 grains and productivity.

It can also be note (Table 1) that the source of nitrogen in the form of urea (46% nitrogen) has demonstrated the highest means of production components. It can be highlighted that despite the fact that high losses of N-urea in certain situations, under the experimental conditions of this study the nitrogen source in the form of urea has developed the best feature of flaxseed. Due to the interaction between N sources × nitrogen fertilizer rates, the deployment will be analyzed (Table 2) of plant height, number of stems, number of capsules and fresh and dry weight of capsules. Plant height was adjusted linearly

Table 1. Height, number of stems, number of capsules, fresh and dry weight of capsules of flaxseed.

Treatment	Plant height	N stems	NC	FWC	DWC
Sources	**--cm--**	**-n plant-**	**-n plant-**	**-------g plant-------**	
Sulfate ammonium	71.66	1.0^b	23.85^b	2.45	0.99^b
Urea	73.75	1.5^a	33.30^a	3.19	1.56^a
Rates kg ha^{-1}					
0	68.01^b	1.0^a	18.50^b	1.71^b	0.72^b
50	72.96^{ab}	1.12^a	22.62^{ab}	2.19^{ab}	0.99^{ab}
100	72.98^{ab}	1.5^a	30.62^{ab}	3.03^{ab}	1.41^{ab}
150	73.68^{ab}	1.0^a	33.75^{ab}	3.33^{ab}	1.55^a
200	75.87^a	1.75^a	37.37^a	3.85^a	1.71^a
CV (%)	6.11	44.71	39.68	42.50	41.06
Sources (S)	n.s.	**	**	n.s.	**
Rates (R)	*	*	*	**	**
S × R	**	*	*	**	**

n.s. = Not significant, * = significant at the 5% probability level, ** = significant at 1% probability.

Table 2. Deployment of interaction sources x rates for plant height, number of stems, number of capsules and fresh and dry weight of capsules.

Source	Rates (kg ha^{-1})					
	0	**50**	**100**	**150**	**200**	**Function**
Plant height						
Sulfate ammonium	74.57^{aA}	75.47^{aA}	70.25^{aAB}	67.57^{bB}	70.42^{bAB}	(1)
Urea	61.45^{bC}	70.45^{aB}	75.72^{aAB}	79.80^{aA}	81.32^{aA}	(2)
Number of stems						
Sul. Amm	1.00^{aA}	1.00^{aA}	1.00^{bA}	1.00^{aA}	1.00^{bA}	n.s.
Urea	1.00^{aB}	1.25^{aB}	2.00^{aAB}	1.00^{aB}	2.5^{aA}	(3)
Number of capsules						
Sul. Amm	24.75^{aA}	22.25^{aA}	23.75^{aA}	29.75^{aA}	18.75^{bA}	n.s.
Urea	12.25^{aC}	23.00^{aBC}	37.50^{aAB}	37.75^{aAB}	56.00^{aA}	(4)
Fresh weight capsules						
Sul. Amm	2.30^{aA}	2.36^{aA}	2.23^{aA}	3.25^{aA}	2.13^{bA}	n.s.
Urea	1.13^{aC}	2.02^{aBC}	3.84^{aAB}	3.41^{aABC}	5.5705^{aA}	(5)
Dry weight of capsules						
Sul. Amm	0.98^{aA}	1.00^{aA}	0.98^{bA}	1.23^{aA}	0.77^{bA}	n.s.
Urea	0.46^{aC}	0.99^{aBC}	1.85^{aAB}	1.87^{aAB}	2.65^{aA}	(6)

Columns = lowercase; Lines = uppercase; Means followed by the same letter do not differ statistically among themselves. ns = not significant, * = significant at the 5% probability; ** = significant at 1% probability. (1) Y = - 0,016x + 37.45 R^2 = 0,60*; (2) Y = 63.93x + 0.098 R^2 = 0.92**; (3) Y = 0,0055x + 1.00 R^2 = 0.42*; (4) Y = 0.20x + 12.95 R^2 = 0.94**; (5) Y = 0.020x + 1.143R^2 = 0.89**; (6) Y = 0.0105x + 0.516 R^2 = 0.95**.

independent of the source, but the urea promoted greater growth with 81.32 cm for the dose of 200 kg ha^{-1}. Superior results were found by El-Nagdy et al. (2010) in a study conducted in Egypt, during the harvest 2007/2008 and 2008/2009 with 25, 50 and 100% of the 100 kg N ha^{-1} in the form of urea obtained height of 66.8, 83.7 and 105. 9 cm, respectively.

A significant influence of nitrogen fertilization for the number of stems per plant, as well as on the sources and the interaction between factors was observed (Table 2). The nitrogen fertilization under urea form linearly added in a significant way as higher dose (200 kg ha^{-1}) at most

Table 3. Fresh and dry weight of the plant (FWP), (DWP), weight of 100 grains and yield Kg ha^{-1}.

Treatment	FWP	DWP	Weight of 100 grains	Yield
Fontes	**-----------g planta----------**		**Grams**	**Kg ha^{-1}**
Sulfate ammonium	3.84^{a}	1.82^{b}	0.1337^{a}	1422.35^{b}
Urea	5.97^{b}	2.55^{a}	0. 1263^{b}	2658.80^{a}
Rates (kg ha^{-1})				
0	3.07^{b}	1.48^{b}	0.1286	1590.87
50	4.12^{ab}	1.86^{ab}	0.1256	1638.87
100	5.36^{ab}	2.32^{ab}	0.1313	2861.87
150	5.58^{ab}	2.46^{ab}	0.1312	2054.50
200	6.39^{a}	2.81^{a}	0.1332	2056.75
CV (%)	41.35	37.63	6.31	56.50
Source (S)	**	**	**	*
Rates (R)	*	*	n.s.	n.s.
S × R	**	**	n.s.	n.s.

ns = Not significant, * = significant at the 5% probability level, ** = significant at 1% probability.

of stems per plant.

The number of capsules per plant (Table 2) was influenced by the sources, rates and the interaction between these factors. Nitrogen rates yielded a significant increase when adjusted linear under urea form, with 56 capsules per plant at the highest rates of nitrogen. Rahimi et al. (2011) found inferior results with nitrogen in flaxseed, 150 to 100 kg ha^{-1} with (46.36 and 45.53) capsules per plant. El-Nagdy et al. (2010) concluded that the increase of the rates of mineral nitrogen from 25 to 100% results in the increase of seed production and the characteristics due to the number of capsules per plant, weight of 100 seeds, seed production per plant, seed oil production. Gauraha and Rao (2011) found that the variable number of capsules per plant had the highest effect on crop productivity.

Productivity and weight of 100 grains were influenced due to the nitrogen source, not increasing significantly in response of the rates and the interaction between them (Table 2). A 46.5% increase in productivity was verified when using urea as nitrogen source. Tadesse et al. (2009) also found no significant associations for oil content, number of capsules and seed production per plant with nitrogen fertilization. Rahimi and Bahrani (2011) found in studies with flaxseed response to nitrogen fertilization, as well as rates of 100 to 150 kg ha^{-1}, with 1511 and 1518 kg ha^{-1}, respectively. Grant et al. (1999) found an increase in seed production with applications up to 80 kg N ha^{-1} (Table 3).

The productivity of this experiment confirms the results found by Rahimi et al. (2011) in Iran, with seeding on March 5, the authors obtained yields of 2087 kg ha^{-1} at rates of 150 kg ha^{-1}.Dordas (2010) relates the income growth of flaxseed to the increase of major components such as the seed weight per plant, number of capsules per plant, plant m^{2}, and the effect of nitrogen on the growth rate and absorption N rate of culture. Fontana et al. (1996);, Kurt (1996) and Khan et al. (2005) with 8, 10 and 8 different varieties of flaxseed, respectively reported significant differences between cultivars of flaxseed for seed production, seed weight 1000 and oil production.

The interaction between sources and nitrogen rates influenced the fresh and dry weight, and the use of urea as nitrogen source provided positive linear increase (Table 4). Nitrogen fertilization with ammonium sulphate resulted in lower rates of fresh and dry weight, and no significant adjustment to the regression. Rates of 200 kg ha^{-1} provided 9.83 and 4.17 g, respectively, with urea and ammonium sulphate. Lafond (1993) observed limited response to nitrogen fertilization of flaxseed in soils where the rates of N were above 25 mgkg^{-1}.

Ibrahim (2009) working with nitrogen rates found that when rates of nitrogen went from 107 to 179 kg ha^{-1}, it increased the production of seeds and production components as well as oil content, while plant height decreased with the increase of nitrogen application above 143 kg ha^{-1}.

The answer to nitrogen fertilization of flaxseed is affected by soil type, cultivating, climate, humidity, time of planting, fertilizing form, seeding rate and sowing date. Dordas (2011) emphasizes that although nitrogen is not a major nutrient required by flaxseed yields, it was observed increasing returns with nitrogen addition of 35 and 34%, respectively, compared with the control. Therefore other authors also highlight the benefits of nitrogen in flaxseed (Diepenbrock and Pörksen, 1992 Dordas, 2010; Lafond et al., 2008).

Conclusion

The urea nitrogen source was the one that most

Table 4. Deployment of interaction of source rates for fresh and dry weight of the plant.

Source	Rates (kg ha^{-1})					
	0	50	100	150	200	Function
Plant fresh mass						
Sulfate ammonium	4.08^{aA}	3.88^{aA}	3.76^{bA}	4.54^{aA}	4.54^{aA}	n.s.
Urea	2.0728^{aC}	4.35^{aBC}	6.95^{aAB}	6.63^{aAB}	9.83^{aA}	(1)
Plant dry mass						
Sulfate ammonium	1.97^{aA}	1.81^{aA}	1.70^{bA}	2.18^{aA}	1.46^{bA}	n.s
Urea	0.99^{aC}	1.92^{aBC}	2.93^{aAB}	2.75^{aAB}	4.17^{aA}	(2)

Columns = lowercase; Lines = uppercase; Means followed by the same letter do not differ statistically among themselves. ns = not significant, * = significant at the 5% probability; ** = significant at 1% probability. (1) Y = 0,035x + 2.411R2 = 0.92**; (2) Y = 0.0143x + 1.116 R2 = 0.91**

increased the production components of flaxseed, as well as the dose of 200 kg N ha^{-1}. The yield was influenced only due to the nitrogen source.

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