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Full Length Research Paper

Brown flax grown under different planting densities

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This study aimed to evaluate the influence of the planting system and population densities in the culture of flax. The experiment was conducted on the campus of the State University of Paraná, in the year 2012, using the split-plot design, where the main plots were the planting systems (line and haul) and plots the densities (100, 150, 200 and 250 plants/m²). The characteristics evaluated were: plant height, fresh weight and dry weight of plant, number of capsules, fresh and dry mass of the capsules. Yield components of linseed showed a positive increase in the planting line, but did not fit the regressions tested. The increased density of plants/m² was detrimental when the crop was sown by broadcasting.

Key words: *Linum usitatissimum* L., competition, population increase.

INTRODUCTION

Originally from West Asia, flaxseed (*Linum usitatissimum* L.) had its benefits spread across continents and is commonly consumed in North America and in European countries (Bombo, 2006). Its seeds are rich in oil (about 40%), fiber (20 to 25%) and protein (20 to 25%), with a promising future in energy use in the production of biofuels (Rabetafika et al., 2011). It does not require great cultivation efforts; its cultivation is done many times in the process of crop rotation (Soares et al., 2009). According to Sattle (2000), several factors interact and influence the expression of the productive potential of flaxseed, among which stand out the process of sowing, planting density and population.

These planting processes can lead to intraspecific competition (between plants) and interspecific competition (with other plants) for environmental resources such as light, water, nutrients, CO_2, among others, causing damages in growth, development, and consequently the production of crops (Zanine and Santos, 2004). These competitions happen due to elevated seedling vigor, leaf expansion, formation of dense canopy, plant height, long development cycle and rapid growth of the root system (Sanderson and Elwinger, 2002).

Brendolan et al. (2000) evaluated the effect of mineral

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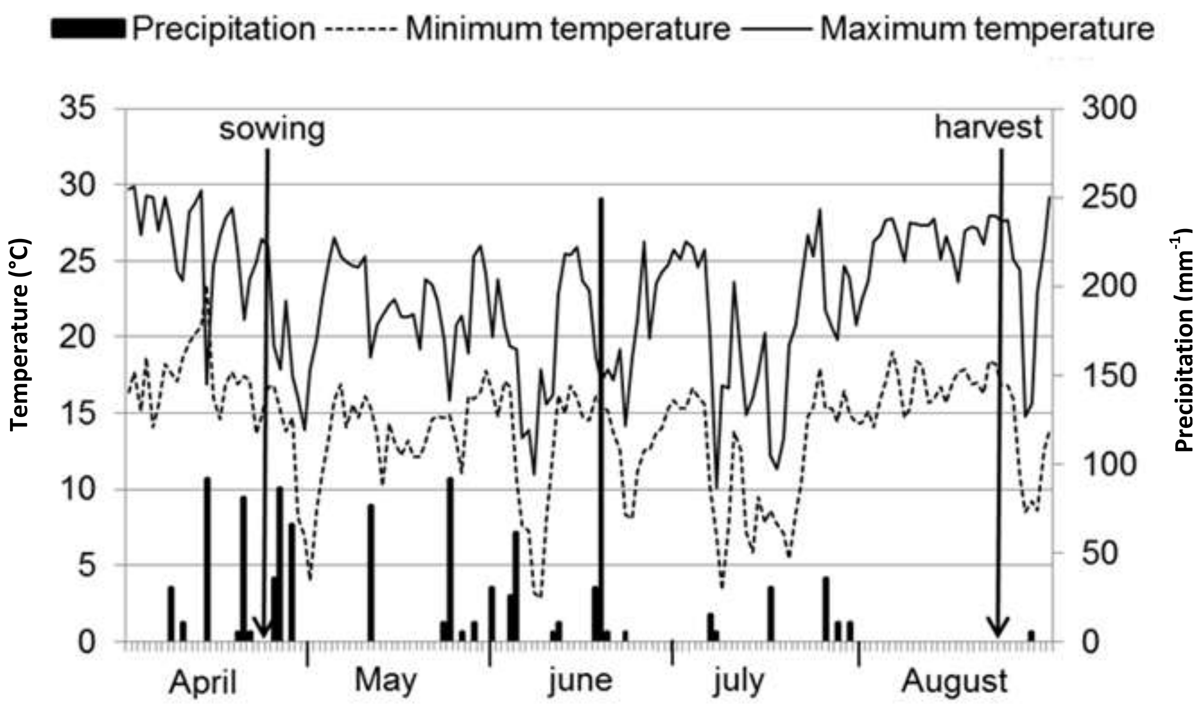

Figure 1. Precipitation (mm^{-1}) and temperature (T°C) recorded during the experiment with the culture of flaxseed.

nutrition on the competition between *Eucalyptus gandis* and *Brachiaria decumbens,* and observed that the intraspecific competition for environment resources decreased on average 23% in root length, leaf area and both shoot and root dry matter of eucalyptus. Some species have greater competitive ability, quickly developing architecture to intercept light: rapid expansion of leaf area and rapid colonization of the upper layer of the canopy, favoring the growth and production of photosynthesis (Lemaire, 2001).

Studies have shown that flaxseed may respond differently to the density and spacing of plants. Several experiments demonstrated that the variation in plant population resulted in significant differences in yield. According to Khan and Bradshaw (1976), plasticity, which is the ability to respond to altered spacing, ensures the success of plant development, directly influencing the density.

An experiment was conducted at the campus of the State University of Western Paraná, in 2012, using the design of split plot, in which the main plots consisted planting systems (line and haul), and the subplots by densities (100, 150, 200 and 250 plants / m²), Tomassoni et al. (2013) found the plant height behavior, fresh and dry mass of the plant, number of capsules, fresh and dry mass of the capsules. According to the authors, linseed production components showed positive growth in the sowing haul, but did not fit tested regression and increased plant density / m² was detrimental when the crop was sown in the line.

Diepenbrock and Pörksen (1992) found maximum seed yields with lower population densities, 200 and 400 plants/m², respectively. Lisson and Mendham (2000) observed that the increase in population from 390 to 530 seeds / m² provides increased performance. Turner (1991) noted that the number of capsules doubled when the population went from from 400 to 900 seeds/m².

However, with the enormous edaphoclimatic diversity and lack of studies on flaxseed, as well as the population density of the crop, the present study aimed to evaluate different population rates on plant development.

MATERIALS AND METHODS

The work was conducted in the experimental field of Western Paraná State University (UNIOESTE), located in Cascavel, Paraná, Brazil, at latitude 24°53'47" S and longitude 53°32'09" W. The average annual rainfall is 1,640 mm and the average temperature is 19°C. The soil is classified as typical Haplorthox, with clayey to very clayey texture, undulated relief and basalt substrate (EMBRAPA, 2006). The climate is temperate mesothermal and super humid, climate type: Cfa (Koeppen) (IAPAR, 2011). The average monthly temperature and precipitation are shown in Figure 1.

The experimental design consisted of a split-plot arrange. The main plots were composed of two planting systems (line and broadcast), and subplots consisted of four densities: 100, 150, 200 and 250 plants/m², with four replications.

The sowing of brown flaxseed was held manually on 10 April, 2012, in conventional tillage system. Halfway through the main plot, a spacing of 0.36 m was used for line planting. Base fertilization and crop processing was not performed throughout the experiment. Each plot measured 5 m wide and 5 m long, constituting 25 m².

Table 1. Analysis of variance for height, number of capsules (N/C), fresh weight of plant (FWP), dry weight oh plant (DWP), fresh weight of capsules (FWC) and dry weight of capsules (DWC).

Treatment	Height	N/C	FWP (g)	DWP (g)	FWC (g)	DWC (g)
Line	67.50	25.18[a]	4.50[a]	1.88[a]	2.06[a]	0.80[a]
Haul	64.56	9.50[b]	1.73[b]	0.81[b]	0.81[b]	0.25[b]
CV(%)	6.32	25.54	22.56	22.22	23.27	17.23
Test values F						
S.P.	3.96[n.s]	100.37**	124.00**	102.57**	112.60**	289.05**
Density						
CV(%)	8.60	35.58	38.74	35.01	33.26	44.46
I (S×D)	1.60[n.s]	0.48[n.s]	0.62[n.s]	0.59[n.s]	1.29[n.s]	0.09[n.s]

Means with different small letters in the columns are statistically different at (**) 1% and (*) 5% of probability or no significant ([n.s]) Tukey test.

During harvest, at 140 days after sowing, the following characteristics were evaluated: plant height (with the aid of a measuring tape), number of capsules per plant, capsule fresh and dry matter, plant fresh and dry matter (measured on a precision scale). Dry matter was determined after the samples were kept in a greenhouse at 60°C + -5°C, within 7 days, when there was no difference in dry matter in the period of 24 h.

The results were submitted to analysis of variance and their means were compared by Tukey's test at 5% of probability, using the statistical package Assistat® version 7.5 beta (Silva and Azevedo, 2002). Doses were compared by means of regression analysis when significance was observed by the analysis of variance.

RESULTS AND DISCUSSION

The crops that we grow for food need specific climatic conditions to show better performance in view of economic yield. Yield is dependent on edaphic and climatic factors. The response to population density is highly dependent on limiting factor(s) (Amin et al., 2015). One can observe in Table 1 that plant height was not influenced by the tillage system, as well as the arrangement, regardless of the tillage system. The sowing of flaxseed in lines did not adapt to the regressions tested, but showed higher means for yield components. The planting system and population density did not affect plant height (Figure 2A). Gabiana (2005) found contradictory results, by observing negative effect of population growth on plant height, with 52.3, 49.7, 48.9 and 47.5 cm for 238, 379, 583 and 769 plants\m², respectively.

One may observe in Figure 2B that the number of capsules, and component which is responsible for crop productivity was significantly higher in the line planting system, but the increase in plants \ m² influenced only the broadcast sowing system. Similar results were found by Gabiana (2005), who obtained 24.3 capsules/plant for 238 plants/m².

In the broadcast sowing system, the number of capsules per plant was adjusted in a negative linear way, showing the detrimental effect of plant density, corroborating partially with Gabiana (2005), who also observed a negative effect of population density increase in the variable, but for line sowing. Ceccon et al. (2004) observed that the lowest densities (60 and 120 plants / m²) provided higher number of panicles at the end of the oat crop. Fontoura and Moraes (2002) also studying an oat crop, observed effect of planting density, with higher grain yield for densities 200, 300 and 400 plants / m².

Both fresh and dry matters of the plant (Figure 2C and E) were better explained according to the linear regression for the broadcast sowing system, however, the line sowing provided the best averages. Following the same trend of fresh and dry matter of the plant, the variable fresh and dry matter of capsules was higher in the line sowing system, even not being significantly adjusted. In the broadcast system, increased plant density\m² was detrimental to the accumulation of fresh and dry capsules. Casa et al. (1999) observed that flaxseed at low density had higher leaf area unity.

Bellé et al. (2012) in a work with the culture of safflower, found that the fresh matter of the stem was reduced when the culture was subjected to population growth. Gabiana (2005) observed no effect of the variation of plants per hectare for fresh matter of the flaxssed plant. Tomassoni et al. (2013) found that the golden flaxseed production components showed positive growth in online seeding adjusting to the tested regressions, and that increasing plant density / m² was detrimental when the crop was sown by broadcasting.

Conclusion

Yield components of flaxseed showed a positive increase for the line sowing system, but did not fit the regressions

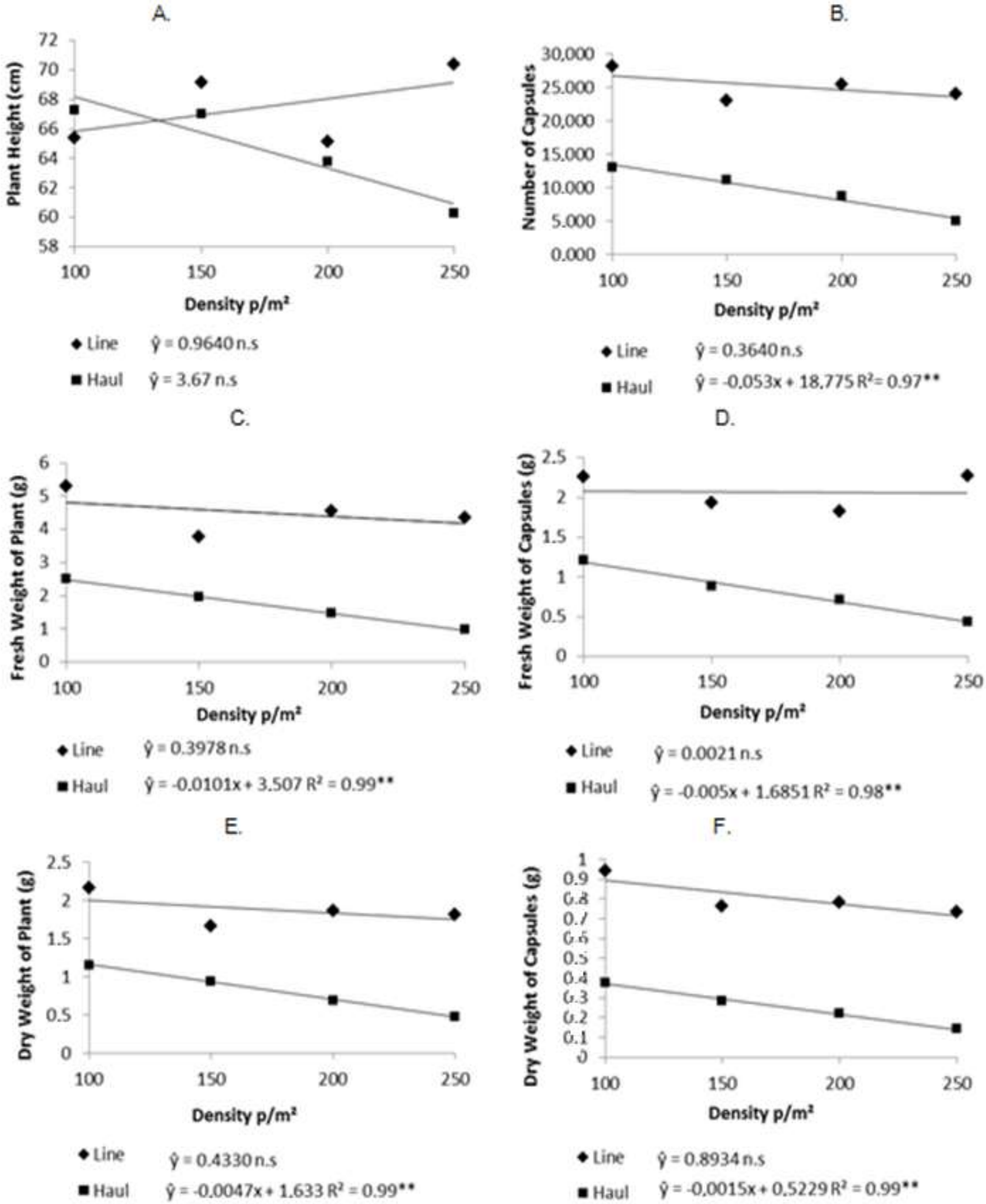

Figure 2. Plant height (A), number of capsules (B), fresh weight of plant (C), fresh weight of capsules (D), dry weight of plant (E) and dry weight of capsules (F). (**) significant at 1% probability; ($^{n.s}$) not significant.

tested. The increased density of plants/m² was detrimental when the crop was sown by broadcasting.

Conflicts of interests

The authors have not declared any conflict of interest.

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