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EFFICIENT MANAGEMENT OF THE TIME AND DOSE OF NITROGEN APPLICATION IN LINSEED

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ABSTRACT

The objective of this work was to identify the agronomic response of the linseed crop subjected to different doses of nitrogen applied at different times throughout the development of the crop. The experimental design used was randomized blocks, organized in a factorial scheme with five nitrogen application times (0, 10, 30, 60 and 90 days after sowing) x five nitrogen doses (0, 30, 60, 90 and 120 kg ha^{-1}) in three replications, totaling 75 experimental units. Nitrogen applications between 23 and 39 days potentiate the height of the first capsule, number of capsules and grain yield. Doses of 45 kg ha^{-1} to 83 kg ha^{-1} of nitrogen maximize the number of capsules, stem diameter, number of capsules that formed grains and grain yield. The correlation indicates that the grain yield was determined by the final plant population and weight of grains per plant.

Keywords: *Linum usitatissimum* L., correlation, dissimilarity

MANEJO EFICIENTE DO MOMENTO E DOSE DE APLICAÇÃO DE NITROGÊNIO EM LINHAÇA

RESUMO

O objetivo deste trabalho foi identificar a resposta agronômica da cultura da linhaça submetida a diferentes doses de nitrogênio aplicadas em diferentes épocas ao longo do desenvolvimento da cultura. O delineamento experimental utilizado foi blocos casualizados, organizados em esquema fatorial com cinco épocas de aplicação de nitrogênio (0, 10, 30, 60 e 90 dias após a semeadura) x cinco doses de nitrogênio (0, 30, 60, 90 e 120 kg ha^{-1}) em três repetições, totalizando 75 unidades experimentais. As aplicações de nitrogênio entre 23 e 39 dias potencializam a altura da primeira cápsula, número de cápsulas e rendimento de grãos. Doses de 45 kg ha^{-1} a 83 kg ha^{-1} de nitrogênio maximizam o número de cápsulas, diâmetro do caule, número de cápsulas que formaram grãos e produtividade de grãos. A correlação indica que o rendimento de grãos foi determinado pela população final de plantas e peso de grãos por planta.

Palavras-chave: *Linum usitatissimum* L., correlação, dissimilaridade

INTRODUCTION

Linseed (*Linum usitatissimum* L.) is an autogamous species belonging to the Linaceae family, food of plant origin rich in fatty acids (ω-3), fibers, proteins and phenolic compounds (THOMPSON & CUNNANE, 2003). The world's largest producer of linseed is Canada, with approximately 950 thousand tons of grains in 2015, equivalent to 40% of all production and a sown area of 380 thousand hectares (STATISTICS CANADA, 2016).

There is a growing interest in the use of linseed grains in food, feed and industrial products, thus the demand for the product is higher than production. In order to have an economically viable production, producers have employed practices in order to maximize production. Therefore, one of the most important agronomic managements is nitrogen fertilization, and linseed responds positively to this fertilization, however, the general response is lower than that observed in crops such as wheat, however, the application of nitrogen fertilizer is necessary to optimize grain yield (DORDAS, 2012).

Among the studies carried out with linseed and nitrogen, Bilalis et al. (2010), state that nitrogen is the main contributor to the variation in oil content in the oilseed. Santos (2013) states that with two applications of nitrogen, 40 kg ha^{-1} and 80 kg ha^{-1}, regardless of the location, found that the highest dose presented higher yield, according to the authors, the increase in nitrogen supply somehow leads to an increase in the level of linear growth of the leaves, in the rate of duration of linear growth and in the maximum rate of growth. According to Antonelli et al. (2015), the linseed crop responds well to nitrogen fertilization at doses between 30 to 40 kg ha^{-1}.

Due to the lack of scientific works that bring us more specific information about the dose and moment of nitrogen application, in order to identify a management that can maximize the grain yield for the linseed crop, the need for further studies arises. Thus, the objective of this work was to identify the agronomic response of the linseed crop subjected to different doses of nitrogen applied at different times throughout the development of the crop.

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MATERIAL AND METHODS

The experiment was carried out in the experimental area of Instituto Regional de Desenvolvimento Rural, belonging to Universidade Regional do Noroeste do Estado do Rio Grande do Sul, geographically located in the municipality of Augusto Pestana, Rio Grande do Sul State, at 28° 26' 20" S and 54° 00' 23" W, at an altitude of 301 meters. The soil of the experimental area is classified as a typical dystroferric red latosol, which according to Embrapa (2020) is characterized as a deep soil with excellent porosity, allowing good root development. According to Köppen, the climate is characterized as *Cfa* (humid subtropical).

The experimental design used was randomized blocks, organized in a factorial scheme with five nitrogen application times (0, 10, 30, 60 and 90 days after sowing) x five nitrogen doses (0, 30, 60, 90 and 120 kg ha^{-1}) in three replications, totaling 75 experimental units. Nitrogen applications between 23 and 39 days potentiate the height of the first capsule, number of capsules and grain yield.

The linseed genotype used to conduct the experiment was the registered cultivar IJUI001, which is characterized by the color of brown seeds and a cycle of approximately 160 days. Sowing took place on May 15, 2020 with a seeder, using a spacing of 0.18 meters between rows and a density of 50 kg ha^{-1}, equivalent to approximately 150 seeds per linear meter. Sowing was carried out in an area prepared in the direct sowing system, where silage corn was used as the predecessor crop.

The experimental units consisted of 17 sowing lines with 6 meters in length, totaling an area of approximately 18 m^2, for the evaluations, a useful area of 10 m^2 was considered. The other cultural treatments, as well as the control of weeds, insect pests and diseases were standardized for all treatments. Thus, weed management was carried out through two applications of the herbicide Iodosulfuron-methyl at a dose of 100 g ha^{-1}. For the management of insect pests, two applications of the insecticide Diflubenzuron at a dose of 100 ml ha^{-1} and two applications of Zeta-Cypermethrin at a dose of 50 ml ha^{-1} were used.

In the useful area of each experimental unit, the following were measured: number of plants per unit of area (PPUA, units), by counting a linear meter, which was used to determine productivity; plant height (PH, cm) and height insertion of the first capsules (HIFC, cm). Subsequently, ten representative plants of the experimental unit were removed, which were submitted to the evaluations. Therefore, the variables analyzed were: the number of basal branches (NBB, units), stem diameter (SD, mm), number of stem branches (NSB, units), number of productive branches (NPB, units), number of capsules (NCAP, pcs), mass of capsules (MCAP, g), number of capsules that formed grains (NCFG, pcs), number of capsules that did not form grains (NCNFG, pcs), number of seeds per plant (NSPP, units), weight of grains per plant (WGPP, g), thousand grain weight (TGW, g) and grain yield (GY, kg ha^{-1}). Meteorological data for characterizing each application moment, such as temperature and precipitation conditions, were obtained through the IRDeR meteorological station.

The data obtained were submitted to the assumptions of the statistical model, normality and homogeneity of residual variances, model additivity. Subsequently, descriptive analysis and analysis of variance at 5% probability were performed using the F test. The interaction between nitrogen application times x nitrogen doses was tested. The variables that showed significant interaction were broken down to simple effects through polynomial linear regression with a significant degree based on the t test at 5% probability. The significant quadratic phenomena were submitted to the estimation of the maximum technical efficiency through the ratio between the linear and quadratic coefficients. In order to identify the tendency of association between the characters, the linear correlation at 5% probability was determined. All statistical analyzes were performed using the R software, using the packages *ggplot2, metan, agricolae and Exp. Des.Pt.*

RESULTS AND DISCUSSION

The temperature and relative humidity of the air are climatic factors that exert great influence on the physiology of the linseed crop, causing effects on the productive capacity, quality and oil content in the grains. Figure 1 shows the manifestation of meteorological phenomena during the linseed crop development cycle in the 2020 crop in Augusto Pestana, Rio Grande do Sul State.

Linseed in its vegetative phase develops well in mild temperatures between 15 ºC and 20ºC. The occurrence of cold is a determining climatic factor, because when it does not occur, it causes delays in flowering, even if there are ideal photoperiod conditions (STANCK et al., 2018). However, the culture is sensitive to the occurrence of frost, and the greatest effect of this phenomenon occurs during the seedling and flowering phase (TOMM et al., 2006). High temperatures, around 32ºC, are usually harmful during flowering and grain filling, causing

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reductions in the differentiation processes of components, size and oil content in the grains, as well as the quality of the oil (STANCK et al., 2018).

Linseed has a need between 400 mm and 750 mm of water for the normal growth and development of plants (BOSCO et al., 2020). During the experiment, there was an accumulated total of 887.4 mm, which is represented by 36 days of rain.

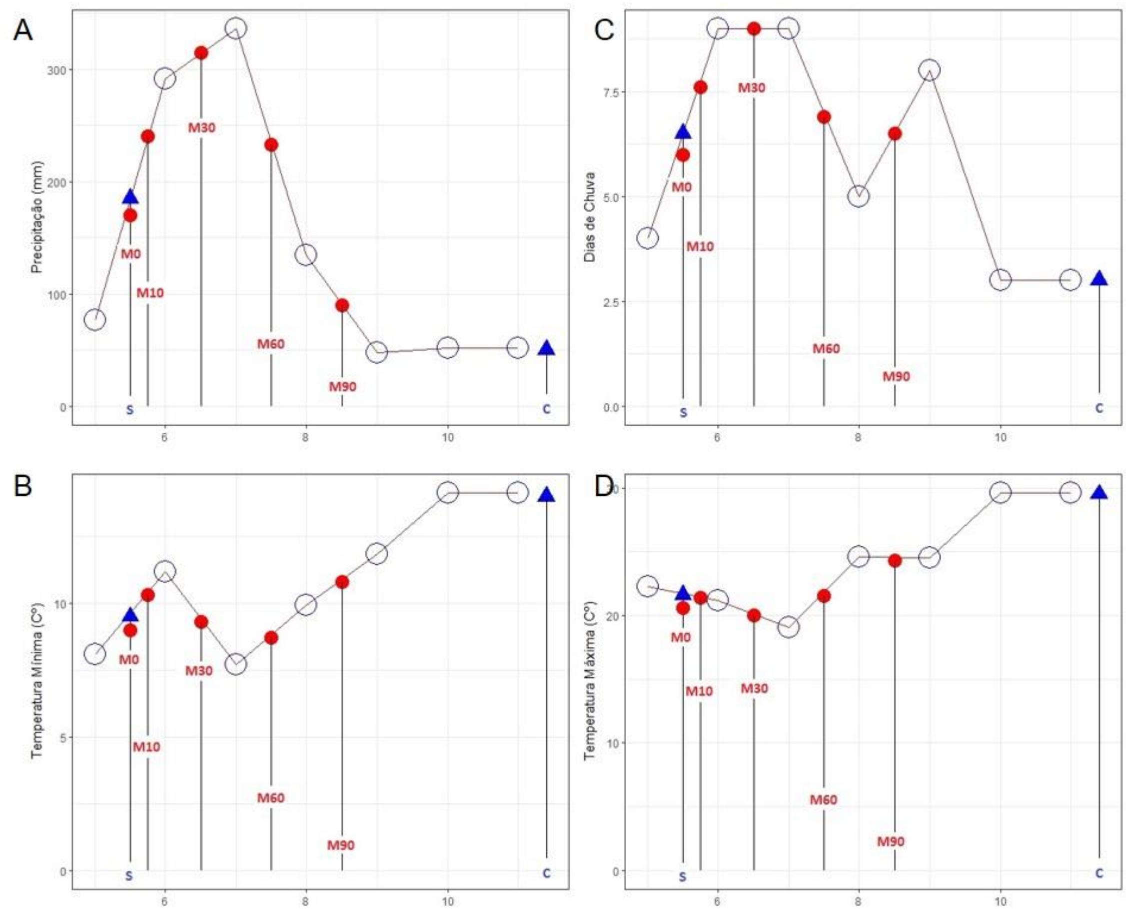

Figure 1. Climatic data from the meteorological station of Instituto Regional de Desenvolvimento Rural (IRDeR) during the development cycles of the linseed crop. A: Precipitation (mm), Rainy days (units), B: Minimum temperature (ºC), C: Rainy days (units); D: maximum temperature (ºC). Points expressed in red color indicate the times of nitrogen application in days after sowing (DAS); Triangles expressed in blue color indicate sowing and harvesting periods; Circles indicate the outliers of precipitation, temperature, and rainy days.

Therefore, when analyzing the meteorological conditions during the linseed crop cycle, it can be observed that for all the moments of nitrogen application, good conditions of humidity and temperature were established, allowing the maximum absorption of the nutrient and thus minimizing the losses. For the temperature variable, a variation of 8ºC to 25ºC was identified between applications. Therefore, the moment of 90 days after sowing (DAS) was the one that showed the greatest prominence, and for this moment there was an application condition with a temperature between 15ºC and 25ºC and precipitation of approximately 80 mm.

The analysis of variance (Table 1) revealed significance at 5% of probability for the interaction of the factors moments of application x doses of nitrogen for the characters height of insertion of the first capsule (HIFC), number of capsules (NCAP), grain yield (GY), stem diameter (SD) and number of capsules that formed grain (NCFG). The block variation factor showed significance for the variables plant height (PH), stem diameter (SD), plants per unit area (PPUA) and grain yield (GY). Regarding the treatment time of application, significant interaction was obtained for height of insertion of the first capsule (HIFC), number of capsules (NCAP) and grain yield (GY). As for the nitrogen dose factor, there is a significant interaction for stem diameter (SD), number of capsules (NCAP), number of capsules that formed grains (NCFG) and grain yield (GY).

The absence of interaction was observed in the block factor for the variables height of insertion of the first capsule (HIFC), thousand grain weight (TGW), number of productive branches (NPB), number of capsules (NCAP), number of capsules that formed grains (NCFG), number of basal branches (NBB), number of stem branches (NSB) and number of grains per plant (NGPP). For the moment factor of nitrogen application, there was no significance for the characters plant height (PH), stem diameter (SD), weight of grains per plant (WGPP), thousand grain weight (TGW), number of productive branches (NPB), number of capsules that formed grains (NCFG), number of basal branches (NBB), number of stem branches (NSB), number of grains per plant (NGPP) and plants per unit area (PPUA). There was also no significance for nitrogen dose in the variables height of insertion of the first capsule (HIFC), plant height (PH), weight of grains per plant (WGPP), thousand grain weight (TGW), number of productive branches (NPP), number of basal branches (NBB), number of stem branches (NSB), number of grains per plant (NGPP) and plants per unit area (PPUA). Furthermore, there was no interaction for the dose x moment factor in the characters height of insertion of the first capsule (HIFC), plant height (PH), stem diameter (SD), weight of grains per plant (WGPP), thousand grain weight, (TGW), number of productive branches (NPB), number of capsules (NCAP), number of capsules that formed grains (NCFG), number of basal branches (NBB), number of stem branches (NSB), number of grains per plant (NGPP), plants per unit area (PPUA) and grain yield (GY).

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Table 1. Summary of analysis of variance for five nitrogen doses x five different times during cultivation.

		HIFC	PH	SD	WGPP	TGW	NPB	NCAP	NCFG	NBB	NSB	NGPP	PPUA	GY
Variation Factor	GL	Pr>Fc												
Block	2	0.757	0.005*	0.002*	0.940	0.346	0.228	0.996	0.646	0.159	0.076	0.907	0.000*	0.024*
Moment (M)	4	0.021*	0.328	0.573	0.144	0.515	0.874	0.026*	0.242	0.287	0.468	0.086	0.227	0.000*
Dose (D)	4	0.248	0.260	0.020*	0.141	0.336	0.143	0.024*	0.006*	0.523	0.277	0.096	0.646	0.025*
M x D	16	0.636	0.593	0.364	0.378	0.770	0.481	0.257	0.112	0.588	0.291	0.361	0.284	0.098
Residue	48													
TOTAL	74													
CV (%)	8.48		8.24	16.34	21.76	2.66	17.1	16.88	15.04	26.87	11.37	20.69	12.25	17.14

DF: degrees of freedom; HIFC: Height of insertion of the first capsule; PH: Plant Height; SD: Stem diameter; WGPP: Weight of grains per plant; TGW: Thousand grain weight; NPB: Number of productive branches; NCAP: Number of capsules; NCFG: Number of capsules that formed grains; NBB: Number of basal branches; NSB: Number of stem branches; NGPP: Number of grains per plant; PPUA: Plants per unit area; GY: Grain yield. * Significant at 5% probability.

By analyzing the variable number of capsules per plant (NCAP) (Figure 2A), according to the statistical model of linear quadratic regression $y = 1.5418+0.0332x-0.0002x^2$ R^2 =0.81, it is possible to analyze the quantities of capsules per plant to be obtained in each of the applied doses of nitrogen. For 25 kg ha^{-1} of applied nitrogen, an amount of 7.1 capsules was obtained, for 50 kg ha^{-1} of applied nitrogen the plant can produce up to 8.7 capsules, with a dose of 75 kg ha^{-1} of nitrogen the plant produced up to 8.9 capsules. The maximum technical efficiency of nitrogen application was obtained at the rate of 83 kg ha^{-1}, where a production of 21.3 capsules per plant was obtained. Subsequent doses such as 100 kg ha^{-1} and 125 kg ha^{-1} of nitrogen resulted in a decrease in the number of capsules, yielding results of 8.8 and 8.5 capsules per plant respectively. It is observed that there is a decrease from the dose of 90 kg ha^{-1}. For Antonelli et al. (2015), the number of capsules can be influenced with the application of nitrogen, and the best results were obtained with the application of 25 and 50 kg ha^{-1} of nitrogen.

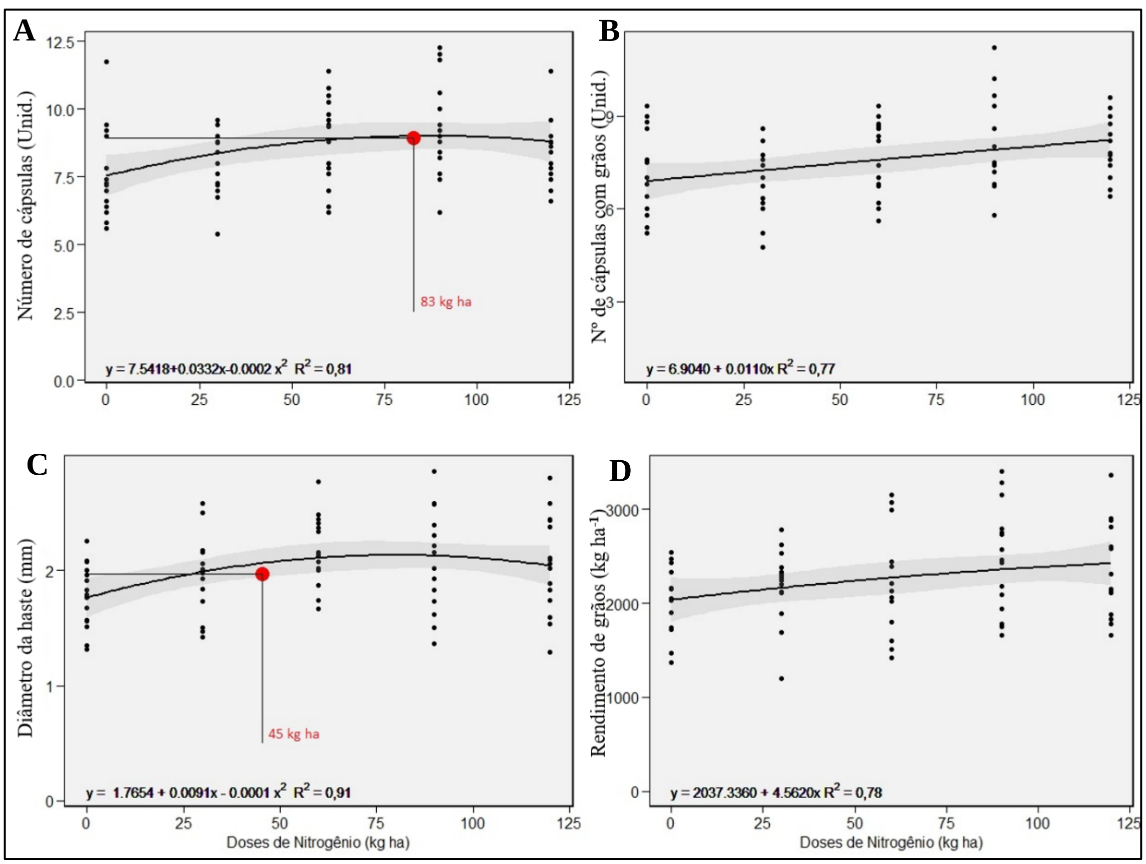

Figure 2. Linear regression with maximum technical efficiency for the effects of nitrogen doses. A: number of capsules (NCAP, pcs), B: stem diameter (SD; mm); C: number of capsules formed grains (NCFG; pcs); D: grain yield (GY; kg ha^{-1}).

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The stem diameter (SD) character (Figure 2B) showed a positive effect for nitrogen dose, where it had the highest technical efficiency at the dose of 45 kg ha^{-1} of nitrogen, with no decrease in the stem diameter after this dose. For the variable number of capsules that formed grains (NCFG) (Figure 2C), it is observed that the maximum technical efficiency was not obtained in any of the doses of nitrogen applied, it is concluded that the number of capsules with grains increases according to with increasing nitrogen doses. Grain yield (GY) (Figure 2D) did not show the maximum technical efficiency for any of the doses. It is observed that the increase in the nitrogen dose has a linear effect with an increase in grain yield up to the dose of 120 kg ha^{-1}. However, Kariuki et al. (2014) showed that nitrogen fertilization with up to 150 kg ha-^{1} does not result in differences in linseed growth. Lafond et al. (2008) identified that grain production followed the increase of nitrogen fertilizer up to 80 kg ha^{-1}, showing a limitation in production with fertilization, due to high levels of NO_3 in the soil.

Thus, the increase in grain yield may be related to the increase in weight of grains per plant (WGPP), number of capsules (NCAP) and the effect of nitrogen on growth rate (DORDAS, 2012). In the application of nitrogen at 39 days after sowing (DAS), a maximum technical efficiency can be obtained for the height of insertion of the first capsule (HIFC) around 72 centimeters (Figure 3A). In the mathematical equation of Figure 3B it is possible to analyze that the maximum technical efficiency of the number of capsules (NCAP) can be obtained when the application of nitrogen is carried out after 23 days after sowing (DAS), where up to 8 capsules per plant. When nitrogen application was extended to 50 days, it is possible to add 9 capsules per plant. The effects of the time of application of nitrogen in relation to the variable grain yield (GY) (Figure 3C), shows that the maximum technical efficiency can be obtained with application of nitrogen at 38 days after sowing, thus, it allows an increase in the yield of grains (GY).

Pearson's linear correlation performed for the 14 variables (Figure 4) revealed 91 associations, where 30 is significant. Regarding the plant height (PH) character, a positive correlation coefficient with height of the insertion of the first capsule (HIFC) (r= 0.74), stem diameter (SD) (r= 0.35) and negative with CYCLE (r= -0.36), thus, plants with greater stature have height of the first upper capsule, thicker stems, and with a shorter cycle compared to smaller plants. From an agronomic point of view, plants that have thicker stems tend to be less susceptible to the occurrence of toppling caused by weather conditions, such as the occurrence of winds (REDDY et al., 2013). The same occurred with the character height of insertion of the first capsule (HIFC), which showed a weak correlation with the stem diameter (SD) (r= 0.26).

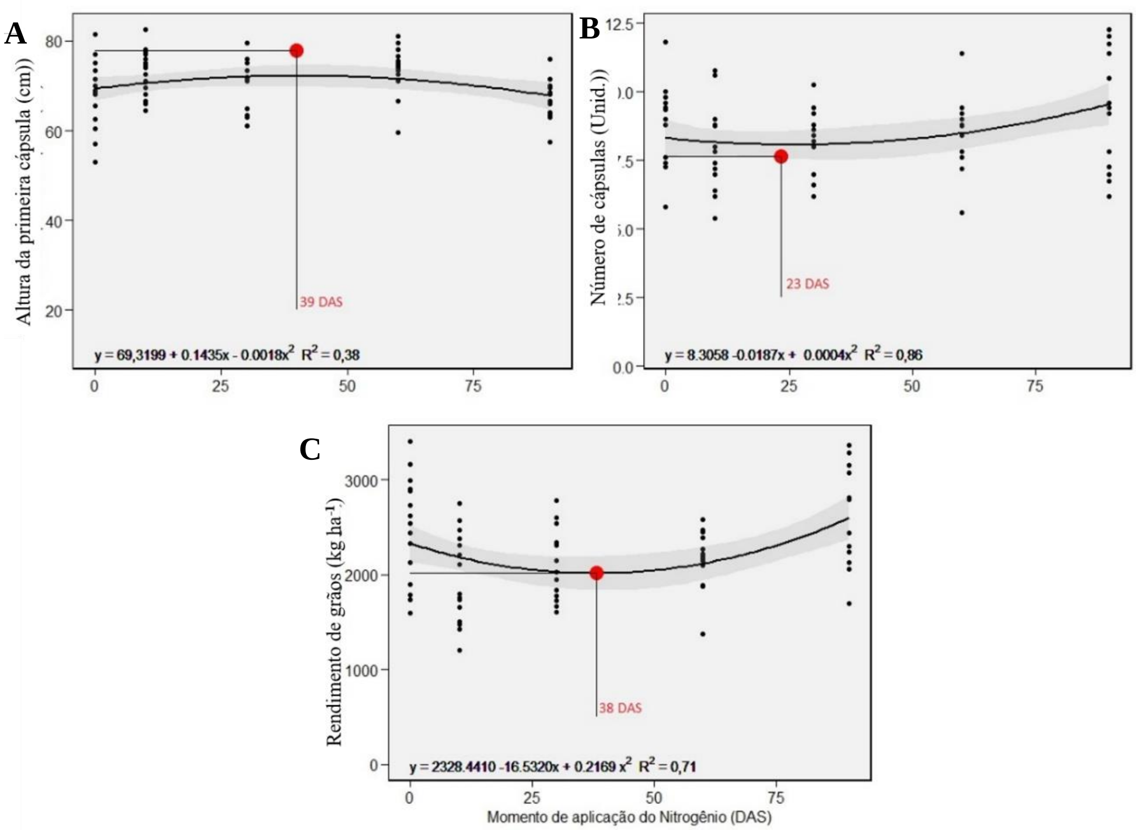

Figure 3. Linear regression with maximum technical efficiency for the effects of nitrogen application moments. A: height of insertion of the first capsule (HIFC, cm), B: number of capsules (NCAP, pcs); C: grain yield (GY, unit), obtained as a function.

Regarding the character stem diameter (DHAS) there was a positive correlation with the number of productive branches (NPB) (r= 0.56), number of capsules (NCAP) (r= 0.52), number of capsules that formed grains (NCFG) (r= 0.42), grain yield (GY) (r= 0.28), weight of grains per plant (WGPP) (r= 0.5), and negative for the CYCLE variable (r= - 0.3), reveals that plants with thicker stems tend to have a greater number of productive branches (NPB), a greater number of capsules (NCAP) and consequently express greater grain yield (GY).

For the character number of stem branches (NSB) there is a weak positive correlation with the number of productive branches (NPB) (r= 0.26) and a negative correlation with CYCLE (r= - 0.28). As for the number of productive branches (NPB) there was a positive correlation with the characters number of capsules (NCAP) (r= 0.71), number of capsules that formed grains (NCFG)

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(r= 0.64), number of grains per plant (NGPP) (r= 0.55), weight of grains per plant (WGPP) (r= 0.54) and grain yield (GY) (r= 0.41), so more branched plants have a greater effect compensatory insofar as they have structures to hold a greater number of capsules per plant, and thus maximize two components of crop productivity, number and weight of grains per plant, essential to enhance the grain yield per hectare.

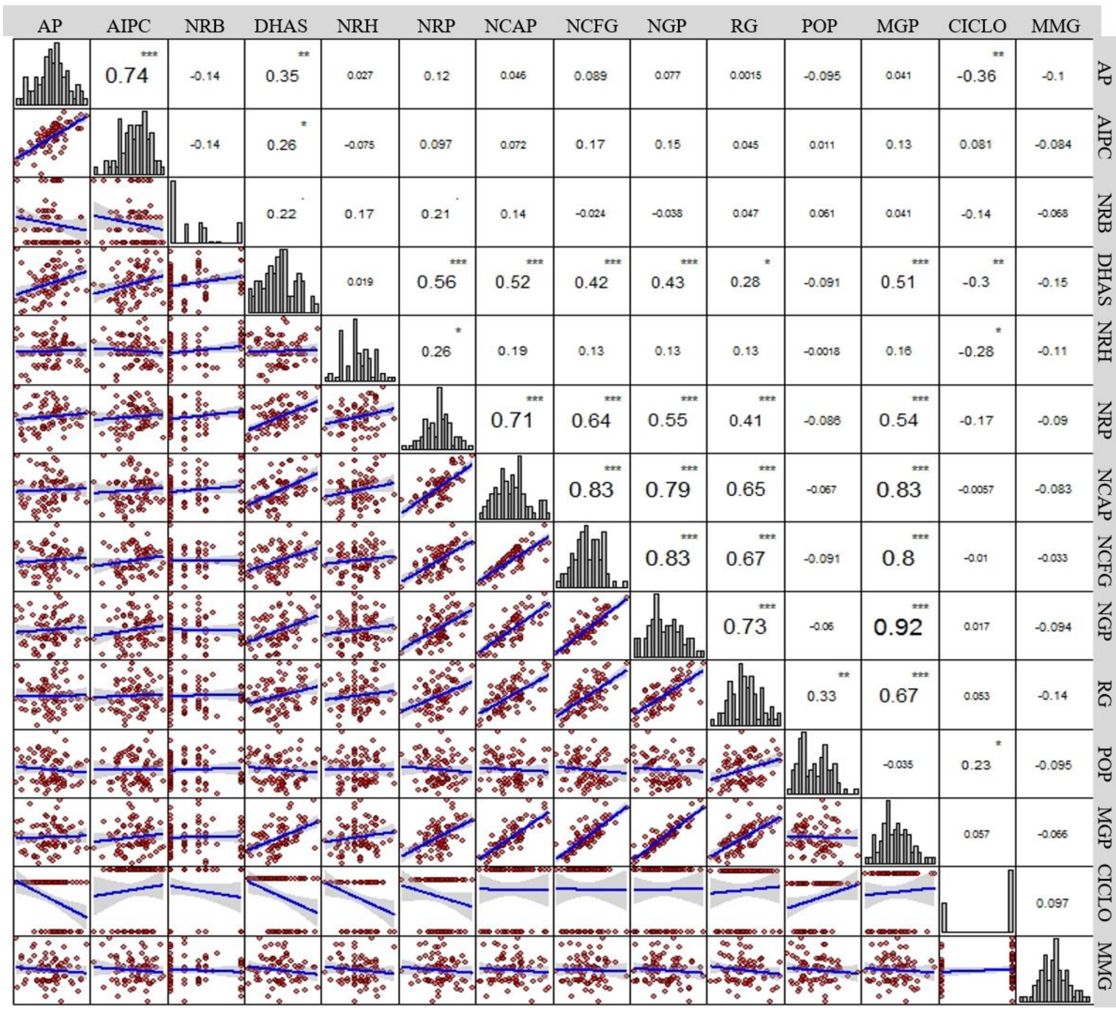

Figure 4. Linear correlation estimates for the 14 characters measured in linseed. *Significant at 0.05 probability, **Significant at 0.01 probability,*** Significant at 0.001 probability by T test. PH: plant height; HIFC: height of insertion of the first capsule; NBB: number of basal branches; SD: stem diameter; NSB: number of stem branches; NPB: number of productive branches; NCAP: number of capsules; NCFG: number of capsules that formed grains; NGPP: number of grains per plant; GY: grain yield; POP: population of plants; WGPP: weight of grains per plant; CYCLE: cycle; TGW: thousand grain weight. AP: PH; AIPC: HIFC; NRB: NBB; DHAS: SD; NRH: NSB; NRP: NPB; NCAP: NCAP NCFG: NCFC; NGP: NGPP; RG: GY; POP: POP; MGP: WGPP; CICLO: CYCLE; MMG: TGW.

A similar effect was identified for the number of capsules (NCAP) character, which showed a strong positive correlation with the number of capsules that formed grains (NCFG) (r= 0.83), number of grains per plant (NGPP) (r= 0.79), grain yield (GY) (r= 0.65) and weight grains per plant (WGPP) (r= 0.83). For the number of capsules that formed grains (NCFG) a strong positive correlation was also identified with the characters number of grains per plant (NGPP) (r= 0.83), weight of grains per plant (WGPP) (r= 0.8) and grain yield (GY) (r=0.67).

The character number of grains per plant (NGPP) presents a strong positive correlation with the weight of grains per plant (WGPP) (r= 0.92) and grain yield (GY) (r= 0.73), showing that the increase in number of grains per plant contributes to individual weight gain, consequently maximizing grain yield. In the same way, it is observed that the grain yield (GY) was positively correlated with the weight of grains per plant (WGPP) (r= 0.67) and population of plants (POP) (r= 0.33) . According to Antonelli et al. (2015), the grain yield of linseed is directly related to plant height (PH), number of capsules (NCAP) and weight of grains per plant (WGPP). Finally, it indicates that the plant population of plants (POP) character showed a weak correlation with the crop cycle, demonstrating that the increase in the plant population tends to affect the duration of the crop cycle.

The analysis of the average Euclidean distance is intended to show the dissimilarity between the evaluation of 25 managements, which include different moments of application and nitrogen doses. Therefore, when analyzing the dendrogram (Figure 5) it can be highlighted that there was the formation of two large distinct groups between the different nitrogen managements, the first large group being expressed by subgroups I, II, III, IV and V and the second large group expressed by subgroup VI.

Subgroup I is formed by the managements: moment 60 dose 0 (M60D0), moment 10 dose 0 (M10D0), moment 30 dose 90 (M30D90), moment 10 dose 60 (M10D60), moment 70 dose 120 (M70D120) that showed similarity with each other for the following variables stem diameter (SD), number of stem branches (NSB), weight of grains per plant (WGPP) and CYCLE. Subgroup II is composed of the managements moment 90 dose 60 (M90D60), moment 60 dose 60 (M60D60), moment 0 dose 0 (M0D0), moment 30 dose 0 (M30D0) and moment 10 dose 30 (M10D30) having similarity to the variables stem diameter (SD), number of stem branches (NSB), weight of grains per plant (WGPP) and CYCLE. Group III is composed only by the M10D90 management, where there was no similarity with the other managements in the variables presented.

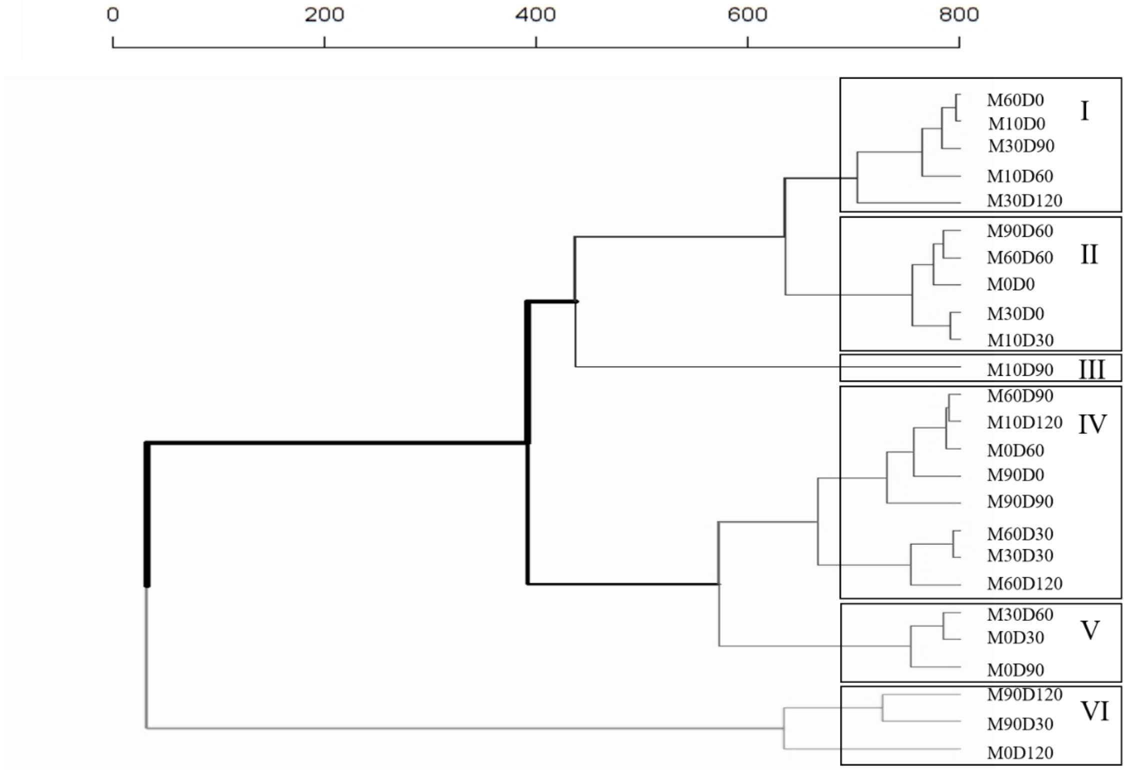

Figure 5. Dendrogram based on the dissimilarity between the different nitrogen managements (doses and application times) made through the 14 variables measured in the linseed, using the average Euclidean algorithm and UPGMA clustering method. PH: plant height; HIFC: height of insertion of the first capsule; NBB: number of basal branches; SD: stem diameter; NSB: number of stem branches; NPB: number of productive branches; NCAP: number of capsules; NCFG: number of capsules that formed grains; NGPP: number of grains per plant; GY: grain yield; POP: population of plants; WGPP: weight of grains per plant; CYCLE: cycle; TGW: thousand grain weight. Nitrogen doses used M60D0: moment 60 dose 0; M10D0: time 10 dose 0; M30D90:time 30 dose 90; M10D60: time 10 dose 60; M30D120:moment 30 dose 120; M90D60:moment 90 dose 60; M60D60: moment 60 dose 60; M0D0: moment 0 dose 0; M30D0: moment 30 dose 0; M10D30: time 10 dose 30; M10D90: time 10 dose 90; M60D90: moment 60 dose 90; M10D120: time 10 dose 120; M0D60: time 0 dose 60; M90D0: moment 90 dose 0; M90D90: moment 90 dose 90; M60D30: moment 60 dose 30; M30D30: moment 30 dose 30; M60D120: moment 60 dose 120; M30D60: moment 30 dose 60; M0D30: time 0 dose 30; M0D90: time 0 dose 90; M90D120: moment 90 dose 120; M90D30: moment 90 dose 30; M0D120: moment 0 dose 120.

Group IV consisted of the managements moment 60 dose 90 (M60D90), moment 10 dose 120 (M10D120) moment 0 dose 60 (M0D60), moment 90 dose 0 (M90D0), moment 90 dose 90 (M90D90), moment 60 dose 30 (M60D30), moment 30 dose 30 (M30D30), moment 60 dose 120

(M60D120) which showed similarity for the variables stem diameter (SD) and weight of grains per plant (WGPP). Group V was also formed, where we can identify the presence of the managements moment 30 dose 60 (M30D60), moment 0 dose 30 (M0D30) and moment 0 dose 90 (M0D90) that presented similarity for the variables numer of basal branch (NBB) , stem diameter (SD), number of stem branch (NSB), weight of grains per plant (WGPP) and CYCLE. The last group VI, which includes the managements moment 90 dose 120 (M90D120), moment 90 dose 30 (M90D30), moment 0 dose 120 (M0D120) showed similarity for the variables number of basal branch (NBB), stem diameter (SD), number of stem branch (NSB), weight of grains per plant (WGPP) and CYCLE.

Through the average of the productivity data in kg ha^{-1} (Figure 6A) obtained for each treatment, the net value was obtained in reais, which is the part of the gross value that will be left to remunerate the farmer after payment of production costs . For nitrogen management performed at 0, 10 and 90 days after sowing (DAS), the dose of 90 kg ha^{-1} showed the greatest response with yields of 2857 kg ha^{-1}, 2357 kg ha^{-1} and 3075 kg ha^{-1} respectively. For the application of nitrogen carried out at 30 days after sowing (DAS), the dose of 30 kg ha^{-1} showed the highest response, with a productivity of 2542 kg ha^{-1}. When nitrogen application was carried out within 60 days after sowing (DAS) the dose of 60 kg ha^{-1} influenced the best agronomic performance of linseed, obtaining a grain yield of 2351 kg ha^{-1}. Therefore, it is noted that all the evaluated managements obtained productivity above the state average, which, according to Oliveira et al. (2012), is 1500 kg ha^{-1}.

Through these results, it can be inferred that the use of nitrogen is a function of the moment of application, that is, the effects on productivity are strongly related to the ability to use nitrogen, which is influenced by two climatic factors, temperature of the air and soil moisture, but the best answer for the variable grain yield as a function of the nitrogen dose was not found, therefore, in the next researches, the nitrogen doses can be increased to identify the maximum technical efficiency of the crop.

For the net value (Figure 6B) it is identified that for the moments 0, 10 and 90 days after sowing (DAS), the dose of 90 kg ha^{-1} stood out, with a net value of R$ 10,547.00, R$8,547.00 and R$11,419.00 respectively, the latter being the treatment that presented the highest return to the farmer, despite both having a cost of R$ 880.00 per hectare. These results demonstrate that the

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grain yield proved to be decisive, resulting in increases in the farmer's income, that is, the increase in the nitrogen dose did not significantly interfere in order to make the treatment unfeasible.

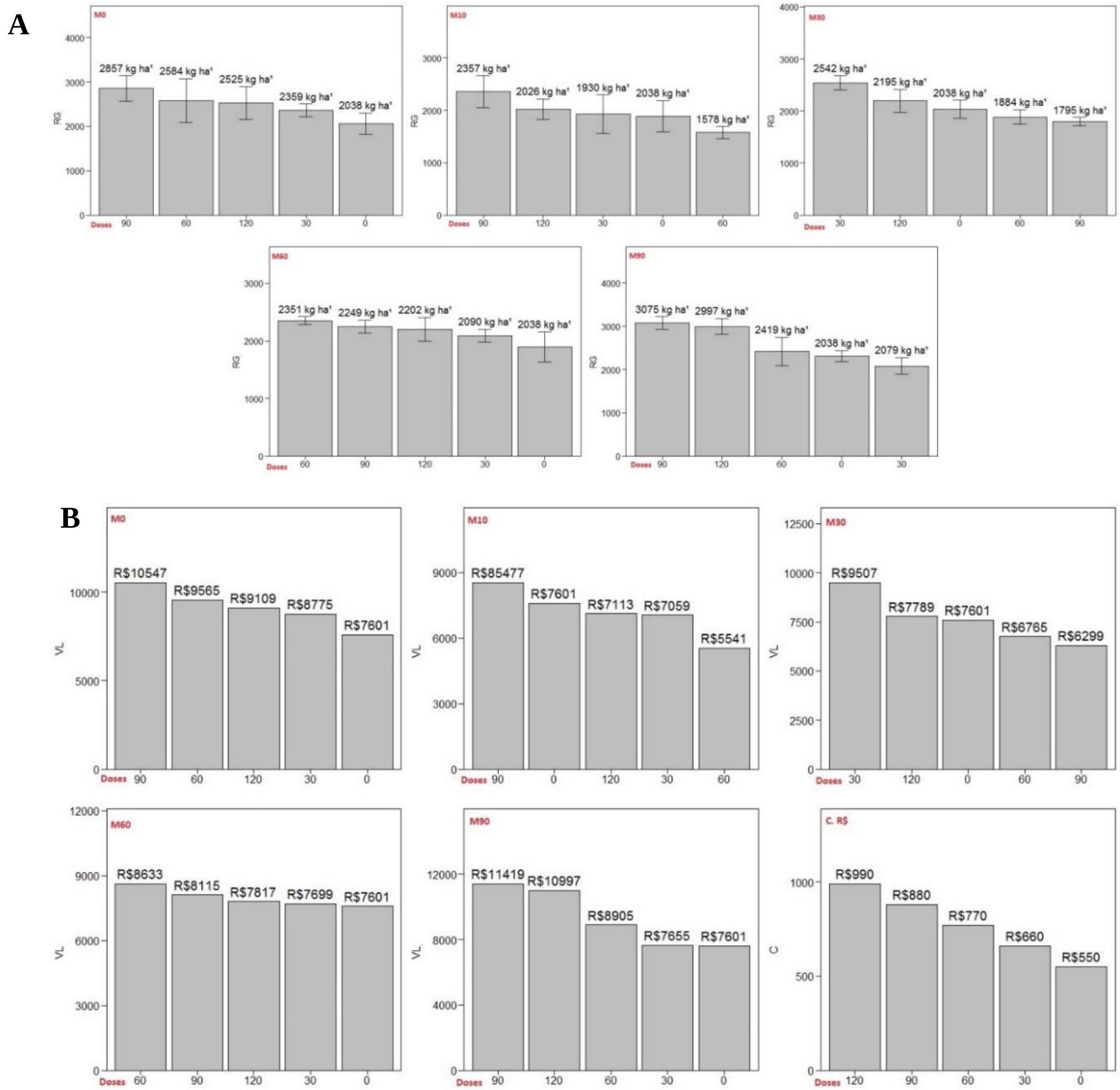

Figure 6. Average productivity data kg ha^{-1} (A) and Net value R$ (B) for the linseed crop submitted to different nitrogen managements.

CONCLUSION

Nitrogen applications between 23 and 39 days potentiate the height of the first capsule, number of capsules and grain yield. Doses of 45 to 83 kg ha^{-1} of nitrogen maximize the number of capsules, stem diameter, number of capsules that formed grains and grain yield. The correlation indicates that the grain yield was determined by the final plant population and weight of grains per plant.

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