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Canola response to nitrogen sources and split application

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A B S T R A C T

The aim of this study was to evaluate the response of the canola crop to nitrogen (N) sources and split application. The experiment was carried out in two agricultural years (2009 and 2010), at the experimental unit of the Pontifical Catholic University of Paraná - PUCPR, Campus of Toledo. A completely randomized design in 5 x 2 factorial scheme was adopted in the experiment. The treatments consisted of five split applications of N at sowing and/or as top dressing (0 and 0, 120 and 0, 0 and 120, 40 and 80, 80 and 40 kg of N ha^{-1}) and two N sources (ammonium sulfate and urea), with four replicates. The canola genotype Hyola 61 was used in the experiment, which was evaluated for plant height, number of plants m^{-2}, shoot dry matter, leaf area, mass of seedpods plant^{-1}, thousand-grain weight, yield and the contents of protein and oil in the grains. The results show that the variables were not influenced by the evaluated sources of N fertilization, but were significantly influenced by the split application of N, with the highest results obtained for the application of 1/3 at sowing and 2/3 as top-dressing (40 and 80 kg ha^{-1} of N).

Palavras-chave:
ureia
sulfato de amônio
teor de proteína
teor de óleo
Brassica napus L.

Resposta da canola a fontes e parcelamento de nitrogênio

R E S U M O

Objetiva-se, no presente trabalho, avaliar a resposta da cultura da canola a fontes e ao parcelamento do nitrogênio (N). O experimento foi conduzido em dois anos agrícolas (2009 e 2010) na unidade experimental da Pontifícia Universidade Católica do Paraná – PUCPR, campus Toledo. O delineamento experimental adotado foi o de blocos casualizados, em esquema fatorial 5 x 2, constando de cinco parcelamentos de N aplicados na semeadura e/ou em cobertura, respectivamente (0 e 0; 120 e 0; 0 e 120; 40 e 80; 80 e 40 kg ha^{-1} de N) e duas fontes de N (sulfato de amônio e ureia), com quatro repetições. Para a condução dos trabalhos foi utilizado o genótipo Hyola 61 avaliando-se altura de planta, número de plantas m^{-2}, massa seca da parte aérea, área foliar, massa de síliquas planta^{-1}, massa de mil grãos, produtividade, o teor de proteína e óleo nos grãos de canola. Os resultados obtidos mostram que as variáveis não foram influenciadas pelas fontes de adubação nitrogenadas utilizadas, porém as variáveis foram influenciadas significativamente pelo parcelamento do N cujos maiores resultados foram alcançados pelo parcelamento aplicando-se um terço na semeadura e dois terços em cobertura (40 e 80 kg ha^{-1} de N).

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Introduction

Canola (*Brassica napus* L. var. oleifera) is a winter oilseed plant in full expansion in south Brazil, recognized as an important alternative to second-crop maize and wheat, because of its high response to N application. However, an external source is necessary to supply its requirements, since tropical soils normally show low N availability due to low contents of organic matter.

In the canola crop, N influences the number of branches per plant, number and mass of seedpods per plant, shoot dry matter, leaf area, mass of grains per plant and oil content in the seeds (Rathke et al., 2006; Cheema et al., 2010; Chavarria et al., 2011; Sanches et al., 2014). In addition, the supply of N at the adequate moment increases the maintenance of photosynthetically active leaves, also improving the production of flowers and seedpods (Ahmad et al., 2006; Gunasekera et al., 2006).

The development of canola can be hampered in case of deficiency and when N is not available at the adequate moment as well. Under low soil fertility conditions, there is a greater response to the application of higher N doses at sowing or in the initial development stage of the crop. Under conditions of good soil fertility, the application of N as top-dressing must be performed, preferentially, in the stage of four true leaves, improving N use efficiency during the vegetative and reproductive stages (Chavarria et al., 2011; Malmir et al., 2013).

Among the main sources used to supply N requirements in canola, are the fertilizers urea ($CO(NH_2)_2$) and ammonium sulfate ($(NH_4)_2SO_4$). Urea contains 45% of N and ammonium sulfate contains 21% of N and 23% of S (Bono et al., 2008).

A more detailed review in the literature shows that, in Brazil, there is little information on the management of N in the cultivation of canola. As to split application, studies conducted especially in Europe indicate that adjusting the moment of N application to the period of highest crop demand tends to increase production efficiency (Sieling & Kage, 2010).

In countries with temperate climate, canola is planted in the autumn, with the phase of seedlings occurring in the winter and the end of the cycle in the spring. Large amounts of N applied during the autumn normally reduce plant survival rate in the winter, because high N doses increase the sensitivity of canola plants to low temperatures. In these conditions, N fertilization is applied as top-dressing in the spring, when the crop shows high N demand (Rathke et al., 2006). As to tropical climate countries, such as Australia, Iran, Pakistan and even Brazil, where the winter is not that severe, canola is cultivated during the spring, with higher response to N fertilization applied at sowing and/or at the beginning of crop development (Rathke et al., 2006; Chavarria et al., 2011; Sanches et al., 2014).

In Brazil, for an expected grain yield of 1,500 kg ha^{-1}, the application of 30 kg ha^{-1} of N is recommended at sowing and 30 kg ha^{-1} as top dressing. For higher yields, 20 kg ha^{-1} of N per additional ton of grains must be added (Chavarria et al., 2011; Sanches et al., 2014). However, specifically for western Paraná, there is no information in the literature on the response of canola to N splitting.

Determining the source and the most adequate moment for N application is extremely important in the production of canola. In this context, this study aimed to quantify the response of canola to N sources and split application.

Material and Methods

The experiment was carried out at the experimental unit of the Pontifical Catholic University of Paraná – PUCPR, Campus of Toledo, Western Paraná (24º 42' 49'' S; 53º 44' 35'' W; 574 m). According to Köppen's classification, the climate in the area is mesothermal humid subtropical, with hot summers, no dry seasons and with a few frosts. The mean temperature is 22 °C and the mean rainfall in the region is 1600 mm (Caviglione et al., 2000). Means of temperature and rainfall during the experiment are shown in Figure 1.

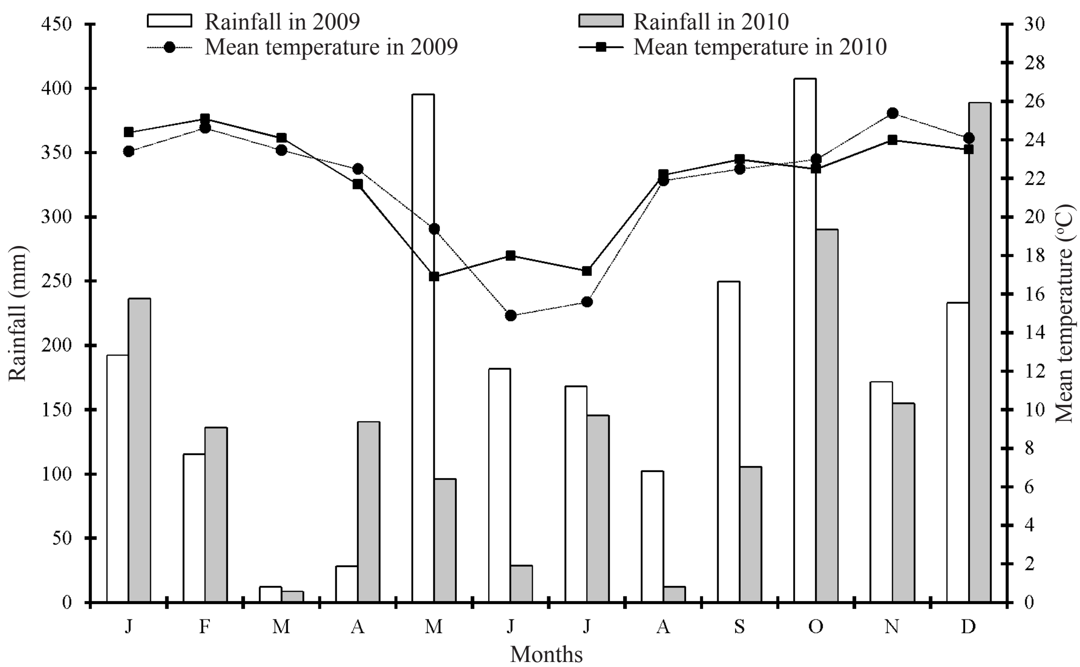

Figure 1. Monthly means of rainfall and temperature in the experimental area in the years of 2009 and 2010

The soil in the experimental area was classified as typic dystroferric Red Latosol, with very clayey texture (EMBRAPA, 2006). Before the experiment was installed, soil samples were collected from the layer of 0-0.20 m for chemical analysis, according to the methodology proposed by Miyazawa et al. (1992). The results of chemical and physical analysis are shown in Table 1.

The experiment was set in a randomized block design, in a 5 x 2 factorial scheme, which consisted of five combinations of split applications of N at sowing and/or as top dressing (0 and 0; 120 and 0; 0 and 120; 40 and 80; 80 and 40 kg ha^{-1} of N) and two N sources (ammonium sulfate and urea), with four replicates. Top dressing fertilization was performed in the B_4 stage (canola plants with four true leaves).

The experiment was performed in two agricultural years, with sowings on May 12, 2009 and April 23, 2010. Each plot consisted of 15 plant rows, with spacing of 0.17 m and 6 m of length, totaling an area of 15.3 m^2 (2.55 m x 6 m). At sowing, 300 kg ha^{-1} of NPK fertilizer (0-25-25) were applied using a seeder/fertilizer machine (Kuhn – SDM Select), which is the dose recommend for a yield of 2,500 kg ha^{-1} (Chavarria et al., 2011). Ammonium sulfate or urea was used as the N source, which was applied according to the amounts established for each treatment.

Seeding was performed using the same seeder machine previously mentioned, by planting eight to ten seeds per linear meter in order to obtain a population of 40 to 50 plants m^{-2}. The canola genotype used was the medium-cycle hybrid Hyola 61.

Biometric characteristics and production components of canola were determined and the data were collected in the evaluation area (5 m^2) of each plot, which consisted of the seven central rows, disregarding 1 m on each side.

The following biometric variables were evaluated: plant height, considered at five points of the canopy and measured from the base to the tip of branches with seedpods; number of plants m^2, by counting all the plants inside the evaluation area of each plot after harvest; shoot dry matter, determined in the pre-flowering stage using five plants per plot, which were placed in paper bags and dried in a forced-air oven at 65 °C until constant weight; and leaf area, determined according to the methodology of Benincasa (1988), with modifications. After separating the leaves of five plants, 40 leaf disks with a known area (1.77 cm^2) were sampled in each experimental plot, which was considered as the leaf area of the sample (LA_{sample}). Then, after drying in a forced-air oven at 65 °C until constant weight (≅ 24 h), sample dry mass (DM_{sample}) and leaf dry mass (LDM) were determined. Leaf area (LA) was obtained through the equation:

$$LA = \frac{LA_{sample} \times LDM}{DM_{sample}}$$

From the collection of seedpods of five plants in each plot, the following production components were determined: mass of seedpods plant^{-1}, by drying in a forced-air oven at 65 °C until constant weight; thousand-grain weight, by weighing 10 subsamples of 100 grains; yield, by threshing the plants of each plot in a mechanical threshing machine (Triton – TR 385) and drying the grains in a forced-air oven at 65 °C until constant weight, which were then weighed. For all the production and yield components, the masses were corrected to 10% of humidity. The content of crude protein in the collected grains was determined through the method of sulfuric acid digestion for N quantification, using a micro Kjeldahl distillation apparatus, as described by Tedesco et al. (1995), and the value was multiplied by 6.25, a factor that converts N into crude protein, according to the methodology described by Jones (1931). In addition, the oil content in the grains was determined using the ether-extract method, according to the methodology proposed by Silva (1990).

Since the experiments were conducted in two agricultural years, the data were subjected to joint analysis of variance by F test ($p \leq 0.05$) and, when significant, the means of the treatments were compared by orthogonal contrasts ($p \leq 0.05$) using the program "SISVAR" (Ferreira, 2009). The orthogonal contrasts were arranged as follows: (1) control (without N) versus the other N application forms, (2) single N application at sowing versus single N application as top dressing, (3) 1/3 of N at sowing + 2/3 as top dressing versus 2/3 at sowing + 1/3 as top dressing, and (4) single N application at sowing and single N application as top dressing versus 1/3 at sowing + 2/3 as top dressing and 2/3 at sowing + 1/3 as top-dressing.

Results and Discussion

According to the means of the contrasts, there were significant by F test in both experiments and for all the evaluated variables. Canola plants responded positively to the evaluated management of N fertilization (Table 2), according to the comparison between the control (without N) and the different combinations of N splitting.

In the comparison between single N applications at sowing (120 kg ha^{-1}) and as top dressing (120 kg ha^{-1} applied in plants with four true leaves), no significant differences ($p > 0.05$) were observed for plant height (PH) in both experiments (sowings on May 12, 2009 and April 23, 2010). However, there were significant differences ($p \leq 0.05$) for the other studied variables, in both experiments (Table 2). According to the means of this contrast, when a single N dose was applied at sowing, the result was superior to that of for the single N application as top dressing. A single N application at sowing, besides not affecting seedlings emergence due to a possible increase in salinity around the seeds, can positively influence the initial development of canola by supplying N in its initial physiological stages, which provides adequate conditions for the development of physiological processes.

For the contrast between 1/3 of N at sowing + 2/3 as top dressing (40 and 80 kg ha^{-1} of N, respectively) and 2/3 at sowing + 1/3 as top dressing (80 and 40 kg ha^{-1} of N, respectively),

Table 1. Soil chemical and physical analysis for the layer of 0-0.20 m, before experiment installation

Year	pH ($CaCl_2$)	OM (g dm^{-3})	P (mg dm^{-3})	SO_4	$H^+ + Al^{3+}$ (cmol$_c$ dm^{-3})	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	Sand (g kg^{-1})	Silt	Clay
2009	5.0	48.90	15.6	12.4	6.21	0	6.34	2.47	0.26	110	140	750
2010	4.7	36.90	13.0	13.3	7.20	0	5.04	2.30	0.18	90	130	780

Table 2. Summary of the analysis of variance and means of the contrasts for plant height (PH), number of plants m^{-2} (NPM2), shoot dry matter (SDM) and leaf area (LA) of the canola hybrid Hyola 61, as a function of two experiments and different split applications of nitrogen (N)

Contrasts			ZN versus TNS+TNT+$^{1/3}$NS$^{2/3}$NT+ $^{2/3}$NS$^{1/3}$NT	TNS versus TNT	$^{1/3}$NS$^{2/3}$NT versus $^{2/3}$NS$^{1/3}$NT	TNS + TNT versus $^{1/3}$NS$^{2/3}$NT+$^{2/3}$NS$^{1/3}$NT
Degrees of Freedom			1	1	1	1
PH	May 12[1]	MS[2]	1.402.33*	34.02 ns	75.21 ns	3.63 ns
		Means	86.2 x 101.0	99.1 x 99.2	103.5 x 102.1	99.1 x 102.8
	April 23[1]	MS	2.146.22*	169.00 ns	4.00 ns	6.12 ns
		Means	83.6 x 101.9	101.9 x 98.2	102.9 x 104.7	100.1 x 103.8
NPM2	May 12	MS	24.43 *	18.42 *	0.40 ns	5.86 ns
		Means	17.9 x 19.8	20.1 x 18.3	20.4 x 20.4	19.2 x 20.4
	April 23	MS	55.02**	41.47**	0.88 ns	13.25*
		Means	26.8 x 29.7	30.1 x 27.5	30.6 x 30.7	28.8 x 30.6
SDM	May 12	MS	2.246.10**	255.60**	754.85**	748.16**
		Means	12.3 x 31.0	29.0 x 22.1	42.7 x 30.1	25.5 x 36.4
	April 23	MS	1.225.34**	226.65**	219.56**	608.11**
		Means	8.7 x 22.5	19.0 x 16.2	31.3 x 23.7	17.6 x 27.5
LA	May 12	MS	13.726.47**	854.39*	5.099.74**	2.639.13**
		Means	91.7 x 138.0	137.8 x 118.1	163.5 x 132.7	127.9 x 148.1
	April 23	MS	3.720.27**	728.05*	171.96 ns	1.183.19*
		Means	72.4 x 96.5	90.24 x 87.5	107.4 x 100.9	88.8 x 104.2

ns, *, **Not significant, significant at 0.05 and 0.01 probability levels by F test, respectively. ZN: zero nitrogen; TNS = 120 and 0 kg ha^{-1} of N applied at sowing and as top dressing; TNT = 0 and 120 kg ha^{-1} of N applied at sowing and as top dressing; $^{1/3}$NS$^{2/3}$NT = 40 and 80 kg ha^{-1} of N applied at sowing and as top dressing; $^{2/3}$NS$^{1/3}$NT = 80 and 40 kg ha^{-1} of N applied at sowing and as top dressing; [1]Corresponding to two experiments planted respectively on May 12, 2009 and April 23, 2010; [2]MS – mean square

there were no significant differences (p > 0.05) for PH and NPM2 in both experiments, and for LA in the experiment planted on April 23, 2010 (Table 2), despite the significant difference by F test (p ≤ 0.05) for SDM in both experiments. In general, the mean values indicate a higher response of the evaluated variables to the application of 1/3 at sowing + 2/3 as top-dressing, which suggests that canola plants need a lower amount of N initially and that this demand increases along the crop cycle.

For the contrast between single N application at sowing + single N application as top dressing versus 1/3 at sowing + 2/3 as top dressing and 2/3 at sowing + 1/3 as top dressing (Table 2), there were no significant differences by F test (p > 0.05) for PH in both experiments, and NPM2 in the experiment planted on April 23, 2010 (Table 2), but there was significant difference by F test (p ≤ 0.05) for SDM and LA in both experiments. The means for this contrast indicate a higher response of the variables to the split application of N, compared with its single applications, at sowing and as top dressing.

Better results caused by the split application of N, compared with single application, were also reported by Cheema et al. (2010), who observed higher accumulation of shoot dry matter when using 1/3 at sowing and 2/3 at pre-flowering. Al-Solaimani et al. (2015) observed increase of 59% in PH with the application of 180 kg ha^{-1} of N two, four and eight weeks after sowing. Yasari et al. (2008) observed higher LA in canola for the application of 250 kg ha^{-1} of N, 1/3 at sowing, 1/3 after rosette formation and 1/3 during stem elongation.

Better results in canola for the split application of N are possibly related to a better N use by plants. N is an essential nutrient for plant metabolism, because it is directly related to the synthesis of proteins, amino acids and nucleic acids. Its absence limits plant growth and its availability has been associated with the increase in cell division and expansion, leaf area and photosynthesis (Bybordi, 2012). It is important to mention that higher LA is a desirable aspect in plants, because it allows the interception of greater amount of solar energy and, combined with adequate N supply, provides better conditions for converting this energy into photoassimilates (Rathke, et al., 2006; Chavarria et al., 2011; Kaefer et al., 2014).

According to the means of the contrasts for the control (without N) and the different combinations of split application of N, there was significant difference by F test (p ≤ 0.05) in both experiments and for all the evaluated variables, which indicates that canola responds positively to N application (Table 3).

For the contrast TNS versus TNT, which compares the single applications of N at sowing and as top dressing, in the stage of four true leaves, there were no significant differences by F test (p > 0.05) for MSP in both experiments and also for TGW in the first experiment, despite the significant differences by F test (p > 0.05) for PROD, PROT and OIL in both experiments (Table 3).

According to the means of the variables for this contrast, there was a higher response to the single application of N at sowing, compared with the single application as top dressing. This result corroborates the previously discussed data for the development of biometric variables (Table 2). Probably, the better results for the single application of N at sowing are related to a better N use, when it is available in the initial development stages of canola, in contrast with a possible initial deficiency of N, when it is applied as top dressing.

Similar performance of the variables was observed for the split application of N, as 1/3 at sowing + 2/3 as top-dressing, in comparison to 2/3 at sowing + 1/3 as top-dressing (Table 3).

Better results were observed when N fertilization was split as 1/3 at sowing + 2/3 as top dressing, compared with 2/3 at sowing + 1/3 as top dressing, which corroborates the result obtained in the previous contrast, which shows that canola does not tolerate N deficiency in its initial development stage; nevertheless, higher doses as top dressing are preferred. Split application allows a more adequate management of the applied N, decreasing the possibility of losses through leaching and

Table 3. Summary of the analysis of variance and means of contrasts for mass of seedpods plant^{-1} (MSP), thousand-grain weight (TGW), grain productivity (PROD), protein content (PROT) and oil content (OIL) in the mass of grains of the canola hybrid Hyola 61, as a function of two experiments and different split applications of nitrogen (N)

Contrasts			ZN versus TNS+TNT+$^{1/3}$NS$^{2/3}$NT+ $^{2/3}$NS$^{1/3}$NT	TNS versus TNT	$^{1/3}$NS$^{2/3}$NT versus $^{2/3}$NS$^{1/3}$NT	TNS + TNT versus $^{1/3}$NS$^{2/3}$NT+$^{2/3}$NS$^{1/3}$NT
Degrees of Freedom			1	1	1	1
MSP	May 12[1]	MS[2]	1.566.75**	160.97^{ns}	116.48^{ns}	402.00^{ns}
		Means	20.7 x 36.4	37.2 x 29.7	42.6 x 36.0	33.4 x 39.3
	April 23[1]	MS	418.12**	98.30^{ns}	66.38^{ns}	40.52^{ns}
		Means	13.3 x 21.4	20.5 x 17.8	19.1 x 23.6	24.5 x 22.7
TGW	May 12	MS	3.43*	0.45^{ns}	0.01^{ns}	0.94^{ns}
		Means	2.0 x 2.8	2.9 x 2.4	2.9 x 2.7	2.7 x 2.9
	April 23	MS	7.14**	3.03*	2.45*	2.73*
		Means	1.7 x 2.3	2.2 x 1.6	3.0 x 2.5	1.91 x 2.7
PROD	May 12	MS	4.977.806.94**	467.760.24**	303.807.66**	342.765.09**
		Means	558 x 1.440	1.406 x 1.166	1.682 x 1.508	1.286 x 1.595
	April 23	MS	2.189.928.79**	999.730.02**	1.527.417.91**	1.185.257.21**
		Means	779 x 1.204	1.088 x 762	1.706 x 1.262	925 x 1.484
PROT	May 12	MS	166.22**	10.81**	18.99**	2.54*
		Means	20.7 x 25.8	25.0 x 24.7	27.62 x 26.3	24.8 x 26.7
	April 23	MS	132.04**	18.34**	18.49**	5.22**
		Means	20.8 x 25.3	24.6 x 23.8	26.8 x 26.0	24.2 x 26.4
OIL	May 12[1]	MS	175.02**	4.08**	2.31*	10.28**
		Means	29.6 x 24.4	24.6 x 23.3	25.3 x 24.3	23.9 x 24.8
	April 23[1]	MS	169.85**	17.81**	23.64**	2.57**
		Means	30.3 x 25.1	24.2 x 23.8	26.6 x 25.9	24.0 x 26.2

^{ns}, *, **Not significant, significant at 0.05 and 0.01 probability levels by F test, respectively. ZN: zero nitrogen; TNS = 120 and 0 kg ha^{-1} of N applied at sowing and as top dressing; TNT = 0 and 120 kg ha^{-1} of N applied at sowing and as top dressing; $^{1/3}$NS$^{2/3}$NT = 40 and 80 kg ha^{-1} of N applied at sowing and as top dressing; $^{2/3}$NS$^{1/3}$NT = 80 and 40 kg ha^{-1} of N applied at sowing and as top dressing; [1]Corresponding to two experiments planted respectively on May 12, 2009 and April 23, 2010; [2]MS – mean square

immobilization of N when applied in higher amounts at sowing (Ibrahim et al., 2008; Cheema et al., 2010; Narits, 2010).

The superior performance of canola with the split application of N is evident when compared with its single application, whether at sowing or as top-dressing (Table 3). According to the means of TGW, PROD, PROT and OIL for the single N applications at sowing and as top dressing, compared with the split application, canola plants are positively influenced by the split application. Rathke et al. (2006) observed that high N doses applied at once are susceptible to greater losses through immobilization, denitrification, leaching and ammonia losses through volatilization. In addition, for the single application, there can be a luxury consumption of N by plants and inhibition of the absorption of other nutrients, caused by the presence of N in excess.

Positive results with respect to N application, especially when split, were reported by many authors. Yasari et al. (2008) observed an increase in mass of seedpods per plant for the application of 250 kg ha^{-1} of N, 1/3 at sowing, 1/3 after rosette formation and 1/3 during stem elongation. Al-Solaimani et al. (2015) reported an increment of 112% in the number of branches per plant for the application of 180 kg ha^{-1} of N two, four and eight weeks after sowing. Puhl & Rasche-Alvarez (2015) obtained higher number of seedpods plant^{-1} of canola for the applications of 15, 23 and 23 kg ha^{-1} of N, respectively at sowing and in the stages of rosette and flowering. Narits (2010) observed that the highest yields were obtained with 120 kg ha^{-1} of N divided into three applications, 40 kg at sowing, 40 kg when the main stem length was 10 cm and 40 kg in the beginning of flowering. This result was superior to that for the application of 140 kg ha^{-1} in a single dose at sowing, which indicates that the quality achieved by the split application of N has a greater impact on yield compared with the amount of N applied in a single dose.

Compared with single N applications at sowing and as top dressing, the split application promotes a better performance of the variables evaluated in this study. As previously mentioned, this result probably points to a better N use for the split application, possibly due to lower N losses. On the other hand, when entirely applied as top dressing, the excess of N can reduce plant production, because it extends the cycle, delays harvest, increase the size of leaves and, consequently, of shoots and creates a microclimate that can increase the incidence of diseases (Rathke et al., 2006; Ghatei et al., 2013).

Canola is mainly cultivated for the oil production. Although the oil content in canola grains is inversely influenced by N fertilization, its adequate management has a positive effect on grain yield (Karaaslan, 2008; El-Habbasha & El-Salam, 2010; Ghanbari-Malidarreh, 2010; Narits, 2010). This explains the higher oil contents observed in the control (without N), in comparison to the other treatments (Mousavian et al., 2013). However, a higher oil production in the mass of grains was observed for the split application of N, compared with single applications at sowing or as top-dressing. Cheema et al. (2010) evaluated two split applications of N and observed that the best oil yields were obtained with 120 kg ha^{-1} of N applied 50% at sowing and 50% in the rosette stage.

In general, the results point to a better performance of the variables for the split application of N, compared with single applications, especially for 1/3 at sowing + 2/3 as top-dressing. When N was applied in a single dose, the best results were observed for the application at sowing.

Conclusions

1. The analyzed variables of canola were not influenced by N sources (ammonium sulfate and urea).

2. The studied variables tended to show higher response when N was applied in a single dose at sowing, in comparison to the total application as top-dressing.

3. Higher response of the variables, especially yield, occurred when N was applied as 1/3 at sowing + 2/3 as top-dressing, compared with the application of 2/3 at sowing and 1/3 as top dressing.

4. N split application promoted a higher response of the evaluated variables, compared with single applications, whether at sowing or as top-dressing.

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