



Adequate use of nitrogen associated with molybdenum in crambe crop

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ABSTRACT: Crambe is serving as alternative oilseed for biodiesel production, however, there are still impediments to commercial expansion because need more information about adequate fertilization. The study aimed evaluating adequate nitrogen rate applied in topdressing, associated with leaf molybdenum in crambe crop under field conditions. Treatments were four nitrogen rates (0, 40, 80 and 120 kg N ha⁻¹) and two rates of leaf molybdenum (0, 80 g ha⁻¹) in a 4 x 2 factorial under randomized complete block design experiment with four replications. Parameters evaluated were shoot dry matter, thousand grains weight, grain yield and oil content in the seed. There was no significant influence of treatments on thousand grains mass. Nitrogen rates linearly increased dry matter shoots and oil content. Grain yield growth as nitrogen increased. When molybdenum was used, grain yield increased significantly when compared to the absence of nutrient application.

Keywords: Nitrogen fertilizer; leaf molybdenum; oilseed.

Uso adequado do nitrogênio associado ao molibdênio no cultivo de crambe

RESUMO: O Crambe é uma oleaginosa que serve como alternativa para a produção de biodiesel, porém, ainda existem impedimentos à expansão comercial, pois são necessárias mais informações sobre a fertilização adequada. O estudo teve como objetivo avaliar a dose adequada de nitrogênio aplicada em cobertura, associada ao molibdênio foliar na cultura do crambe em condições de campo. Os tratamentos foram quatro doses de nitrogênio (0, 40, 80 e 120 kg N ha⁻¹) e duas doses de molibdênio foliar (0, 80 g ha⁻¹) em esquema fatorial 4 x 2 em delineamento de blocos ao acaso com quatro repetições. Os parâmetros avaliados foram matéria seca da parte aérea, massa de mil grãos, rendimento de grãos e teor de óleo na semente. Não houve influência significativa dos tratamentos na massa de mil grãos. As doses de nitrogênio aumentaram linearmente a matéria seca da parte aérea e o teor de óleo. Houve incremento da produtividade de grãos com o aumento do nitrogênio. Quando o molibdênio foi utilizado, a produtividade de grãos aumentou significativamente em relação à ausência de aplicação desse nutriente.

Palavras-chave: Adubação nitrogenada; molibdênio via foliar; oleaginosa.

1. INTRODUCTION

Crambe (*Crambe abyssinica*) is important crop and its oil has high erucic acid content which can be used as an industrial lubricant and corrosion inhibitor (LARA-FIOREZE et al., 2013).

This plant species is cultivated in winter, with high oil content in grains, serving as raw material to make biodiesel (SILVA et al., 2012), biofuel production from vegetable oils is a global reality (LARA-FIOREZE et al., 2013).

It is interesting to expand and search for alternative raw materials, to evaluate the attributes such as oil content, grain yield, production system and crop cycle, as well as grains that are not used as food source, ensuring the system sustainability. Therefore, the species in question becomes alternative because it is a winter crop (SILVA et al., 2012), however, there are still impediments to its commercial expansion in the country, since information such as evaluation appropriate sowing season in different States,

fertilization, density and the loss of crop yields, as well as market structuring are not well understood (PITOL et al., 2010; LARA-FIOREZE et al., 2013).

To most cultivated species, fertilizers are the costliest inputs, and their efficient use is key to optimal ensuring grain yield. However, studies regarding the response to crambe fertilization are still scarce. It is known that the plant absorbs high amount of nitrogen (N), which is due to the need of grain, to its high protein content (SOUZA et al., 2009), however, we did not observe in the literature, recommendations of nitrogen fertilization to crambe.

To increase nitrogen application efficiency, molybdenum use becomes important. Among molybdenum functions is the nitrate reductase enzyme constitution (DECHEN et al., 2018). This enzyme has three prosthetic groups, one of which is molybdenum cofactor, which associated with pterine, originates the molybdopterin complex (SOUZA;

FERNANDES, 2018). As stated by Dechen et al. (2018) plants that have molybdenum deficiency present nitrate accumulation, causing symptoms similar to nitrogen lack.

It is worth mentioning that the use without fertilizer criteria can lead to serious environmental problems. Excessively applied fertilizer was lost through leaching, resulting in problems, such as soil acidification and nitrate leaching (ENEJI et al., 2013). There are several reports on nitrate occurrence in drinking water sources, especially in groundwater (SHAKYA; GOSH, 2018). Eneji et al. (2013) affirmed the underground water pollution associated with nitrate leaching has become major concern in areas with intensive cereal production. Besides all this, nitrogen is expensive agricultural input. Therefore, nitrogen rational use becomes essential for agricultural system that the sustainability and reduction of drinking water contamination. Yin et al. (2018) highlighted sustainable utilization of agricultural wastes is an effective approach to alleviate problem with residues.

In view of on this regard, the study aimed to determine adequate nitrogen rate applied in topdressing, with its association the leaf molybdenum in crop crambe.

2. MATERIAL AND METHODS

The experiment was conducted under field conditions, at Universidade Estadual de Maringá, Regional Campus of Umuarama, Parana State, Brazil, at 23°47' south latitude and 53°14' west longitude. The region presents subhumid climate with annual average temperature of 24 °C and precipitation of 1,600 mm. The soil is Oxisol Dystrophic with a sandy texture (USDA, 1998).

Soil samples were collected approximately 50 days before the experiment and presented the following results in the 0-20 cm layer: 4.8 mg dm⁻³ phosphorus (Mehlich 1); 10.25 g kg⁻¹ of Organic Matter; 5.28 pH in CaCl₂; 0.19; 0.25; 0.14 and 7.47 cmolc dm⁻³ of K, Ca, Mg and capacity of cation change, respectively, bases saturation of 58%.

Treatments were four nitrogen application rates on topdressing (0, 40, 80 and 120 kg N ha⁻¹) and two rates of leaf molybdenum application (0, 80 g ha⁻¹) in a 4 x 2 factorial in a randomized complete block design experiment with four replications of each treatment combination. The nitrogen source was urea (45% N) and molybdenum was sodium molybdate (39% Mo). Nitrogen rates were chosen according to the concentrations adopted in other experiments with crambe (SILVA et al., 2012; SILVA et al., 2013). As there is no recommendation of molybdenum dose for crambe, the rate used in other plant species, such as common bean (SILVA et al., 2006), was adopted.

Experimental area was desiccated whit glyphosate three days before sowing and fertilized with 360 kg ha⁻¹ of the formulated 10-17-17, using soil analysis and recommendations to crop (PITOL et al., 2010). The nitrogen rate applied at sowing was not taken into account for the calculation of the top-dressing rates. Thus, sowing was performed manually on May 30, 2014, with the cultivar of Crambe FMS-Brilhante. The plots consisted of 4 lines with 4 meters in length and row spacing of 0.35 m, totaling 32 plots. In 30 days after sowing, the nitrogen fertilization was applied in a single rate in topdressing on the same day with foliar fertilization with molybdenum according to the proposed treatments. Nitrogen fertilization was carried out beside the plants row, with subsequent incorporation, in order to minimize losses by volatilization. Nitrogen was applied first,

and then molybdenum was applied.

In order to control weeds, manual weeding was performed whenever necessary and in relation to pest and disease control during crop growth, this was not necessary.

Approximately 90 days after the emergence of plants, the final population of plants was counted, observing about 800,000 plants ha⁻¹ in all plots. The harvest was done manually, collecting two meters of the two central lines, which were considered as useful area of each plot. The cleaning of harvested grains was carried out with the aid of sieves, removing impurities from harvest and thus leaving grains clean. Evaluated parameters were shoot dry matter, mass of thousand grains, grain yield, standardized to 13% moisture, following the adopted methodologies of Silva et al. (2013) and oil content in the seeds.

Oil content determination was performed after removing water from the grains by the method of extraction through the muffle and use of linear regression equation for converting weight to oil data (SILVA et al., 2015)

Statistical analysis was carried out by subjecting the data to analysis of variance, the means from application or not of molybdenum were compared by the Tukey test. The averages adjustment originated to application of nitrogen rates by linear regression was verified. All the evaluations were performed by the Sisvar computer program (FERREIRA, 2011), with a 5% probability of error.

3. RESULTS

It is observed that nitrogen application in topdressing significantly increased the shoot dry matter regardless of leaf molybdenum application (Table 1). Note that there was significant adjustment in positive linear regression for this parameter (Figure 1A).

It can be seen that the treatments did not significantly influence thousand grain mass (Table 1), demonstrating that these nutrients did not influence grain density and size.

Table 1. Shoot dry matter (kg ha⁻¹), thousand grains mass (g), and oil content (%) of crambe seeds, as function of nitrogen topdressing fertilization and leaf molybdenum.

Tabela 1. Matéria seca da parte aérea (kg ha⁻¹), massa de 1.000 grãos (g), teor de óleo (%) de sementes de crambe, em função da adubação nitrogenada em cobertura e molibdênio via foliar.

Treatment	Shoot dry matter kg ha ⁻¹	Thousand grain mass g	Oil content %
Nitrogen kg ha ⁻¹			
0	920	8.0	28.3
40	1,690	7.6	29.8
80	1,780	7.7	30.3
120	3,952	7.9	31.2
Molybdenum g ha ⁻¹			
0	2,000	7.8	30.0
80	2,120	7.8	29.9
C.V. (%)	9.8	6.0	8.0
F Test			
Nitrogen (N)	*	n.s.	*
Molybdenum (Mo)	n.s.	n.s.	n.s.
N x Mo	n.s.	n.s.	n.s.

* = significant at 5% probability of error; Averages followed by the same letter, within the molybdenum parameter, do not differ among themselves by the Tukey test at 5% of error probability; C.V. = coefficient of variation.

It is noted that the contented oil was significantly influenced by nitrogen application, but not with molybdenum addition (Table 1). To grain yield, there was a

significant interaction between nitrogen and molybdenum factors, shown in Table 2. It can be observed that the crambe is responsive to nitrogen, regardless of the use or not of molybdenum, however, with the use of this micronutrient the yield increased even more.

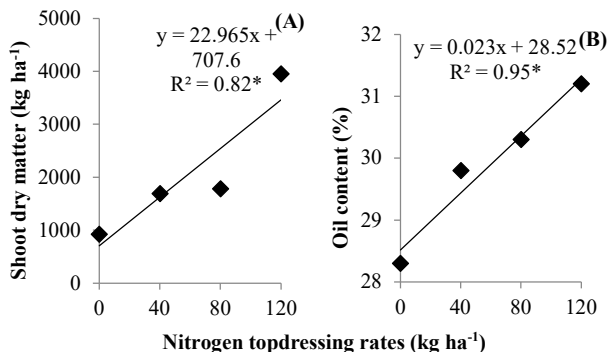


Figure 1. (A) Dry matter shoots (kg ha^{-1}) and (B) oil content (%), as function of nitrogen topdressing fertilization and leaf molybdenum. * = significant at 5% probability.

Figura 1. (A) Matéria seca da parte aérea (kg ha^{-1}) e (B) teor de óleo (%), em função da adubação nitrogenada em cobertura e molibdênio via foliar. * = significativo a 5% de probabilidade.

Table 2. Grain yield (kg ha^{-1}) unfolding as a function of nitrogen topdressing fertilization and leaf molybdenum, for crambe at Universidade Estadual de Maringá, Regional Campus of Umuarama, Paraná State, Brazil.

Table 2. Produtividade de grãos (kg ha^{-1}) em função da adubação nitrogenada em cobertura e molibdênio via foliar no crambe. Universidade Estadual de Maringá, Campus Regional de Umuarama, Paraná-Brasil.

Molybdenum g ha^{-1}	Nitrogen (kg ha^{-1})			
	0	40	80	120
0	492 a	689 a	1,047 b	1,275 b *
80	526 a	763 a	1,275 a	1,757 a **

* $Y=6.7675x + 469.7$ $R^2=0.98$ ($p<0,05$)

** $Y=10.513x + 449.5$ $R^2=0.97$ ($p<0,05$)

Means followed by the same letter in the column, do not differ by Tukey test at 5% of error probability.

Variation coefficient = 7.2%

4. DISCUSSION

Nitrogen application in topdressing significantly increased the shoot dry matter regardless of leaf molybdenum application. There was then an increasing linear increase as a function of the application of this macronutrient. This was due to the fact that nitrogen, when absorbed both in the form of nitrate and ammonium, can be incorporated into carbon chains, causing increase of vegetable mass (SOUZA; FERNANDES, 2018). This result agrees with the one obtained by Barbosa et al. (2010), that when studying nitrogen fertilization with molybdcic in common bean, found that there was a greater accumulation of dry matter, as nitrogen fertilization rate increased. When evaluating crambe development in relation to N application, at 30, 45 and 60 DAE, Vechiatto (2011) also obtained N effect on dry matter accumulation of crambe.

Colodetti et al. (2013), when analyzing plants grown under conditions of N deficiency, noticed a drastic reduction in size, reduced leaf area (small leaves) and shortening of phenological cycle, reaching the flowering stage in a short time period. Same authors concluded that all deficiencies of macronutrients promote limitation in the crambe plants biomass production and N deficiency generates loss of

biomass accumulation 94.82%, thus, a linear decrease in shoot dry matter of crambe plants was observed, with N deficiency in soil.

Observed the nitrogen did not influence grain density and size, available by thousand grains mass. A result similar to that found by Silva et al. (2013), that when evaluating crambe plants in several growth periods, found that nitrogen did not influence in this parameter. Similar results were found by Nascimento et al. (2009), that when studying nitrogen and molybdcic fertilizer rates in common bean, also did not obtain significant differences in relation to grain mass.

These results also agree with those found by Chaves; Ledur (2014), when evaluating increasing nitrogen rates and phosphate fertilization in crambe, found that the mass of 1,000 grains was not influenced by fertilization. According to Silva et al. (2013), nitrogen presents functions to formation of amino acids, proteins, nitrogen bases, formation of chlorophyll, vegetation and tillers increase, causing plant to grow more and produce more fruits and grains, not increasing density necessarily. This was the case in the present experiment, with increase in shoot dry mass without increasing the 1,000 grains mass. Nitrogen application caused increase in your growth, however, the energy produced by the photosynthesis enlarged by increasing N (EPSTEIN; BLOOM, 2006) causes the plant to produce more grains, but with the same density.

There was a significant adjustment in positive linear regression for oil meaning (Figure 1B), that is, the oil content in the grains increased due to nitrogen applied in soil, this was probably due to the improvement in plant photosynthetic activity, by increase of nitrogen. Epstein and Bloom (2006) report that nitrogen is essential to plant and is present in several compounds within it, without this element, plant metabolism would be compromised. This result corroborates that found by Souza et al. (2014), which observed significant effect in relation to increase of the N rate with the oil content on crambe grains.

It is observed that regardless of molybdenum application, there was increase in yield due to the increase in nitrogen on soil, with significant adjustments in positive linear regressions. This demonstrates the nitrogen importance of crambe cultivation, as this chemical element is responsible for numerous functions inside the plant, photosynthesis being one of them (EPSTEIN; BLOOM, 2006).

Wright et al. (1988) working with rape seed, found that N treatment prolongs the leaf life span, improves flowering and increases crop assimilation in general, contributing to grain yield. Pitol et al. (2010), in a field experiment to evaluate the isolated effect of N, P and K on crambe grain yield, observed gains with N and K fertilization.

It can also be seen in Table 2 that with application of high nitrogen rates (80 and 120 kg ha^{-1}) there are significant differences in grain yield when comparing the application of molybdenum with its absence. It is noted that with the addition of this micronutrient the grain yield goes from 1,047 kg ha^{-1} to 1,275 kg ha^{-1} in 80 kg ha^{-1} rate and goes from 1,275 kg ha^{-1} to 1,757 kg ha^{-1} in 120 kg ha^{-1} rate.

This is explained by the fact that nitrate is the main nitrogen source to most plant species, mainly for grain plants. Plants only assimilate nitrate if it is first reduced to ammonium (SOUZA; FERNANDES, 2018), for which several reduction steps are necessary inside the plant (DECHEN et al., 2018), with nitrate reductase being the first enzyme in the reduction path and represents the limiting step

in this process (Souza and Fernandes, 2018), one of the main molybdenum functions being the activation of this enzyme (EPSTEIN; BLOOM, 2006). Therefore, molybdenum application, especially in sandy soils in case of present experiment, which are commonly poor in this nutrient, increased the efficiency nitrogen use by crambe production process, step that requires high photosynthetic capacity of the plant. This result is in agreement with that found by Ferreira et al. (2003), which reached higher yields with higher nitrogen rates together with molybdenum leaf application.

5. CONCLUSION

Covering nitrogen rates linearly increased some vegetative and productive parameters. The use of leaf molybdenum increased grain yield at higher nitrogen rates.

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