

## Yield and postharvest quality of winter growing crisphead lettuce as affected by doses of nitrogen and molybdenum

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### ABSTRACT

The trial was carried out at Três Pontas, Minas Gerais State, Brazil, from April to July 2003, to evaluate the influence of nitrogen and molybdenum rates on productive characteristics and postharvest quality of crisphead lettuce (*Lactuca sativa* L.). A randomized complete block design with three replications was used. Treatments were a factorial combination of four nitrogen rates (0.0; 60.0; 120.0 and 180.0 kg ha<sup>-1</sup>) applied in addition the dose commonly used by growers (60 kg ha<sup>-1</sup> of N) and five foliar molybdenum rates (0.0; 35.1; 70.2; 105.3 and 140.4 g ha<sup>-1</sup>). The total and commercial fresh weight and head circumference showed significant effects for doses of nitrogen and of molybdenum, as well as for their interaction. No significant effects of the treatments for stem length were observed. There was a linear effect of N and Mo doses for postharvest conservation at 28 days, and the rate of 150.0 kg ha<sup>-1</sup> of N showed the best conservation at 35 days after the harvest. The percentage of dry matter showed quadratic effects, and the doses of 95.9 kg ha<sup>-1</sup> of N and 75.3 kg ha<sup>-1</sup> of Mo showed the highest return.

**Keywords:** *Lactuca sativa* L., fresh weight, nutrition, storage.

### RESUMO

#### Rendimento e qualidade pós-colheita de alface americana em função de doses de nitrogênio e molibdênio

O trabalho foi conduzido no município de Três Pontas, Sul de Minas Gerais, de abril a julho de 2003, com o objetivo de avaliar a influência de doses de nitrogênio e molibdênio nas características produtivas e qualidade pós-colheita da alface tipo americana (*Lactuca sativa* L.). Utilizou-se o delineamento de blocos ao acaso em arranjo fatorial 4x5, compreendendo quatro doses de nitrogênio em cobertura adicionais à dose aplicada pelo produtor de 60 kg/ha de N (0; 60; 120 e 180 kg ha<sup>-1</sup>) e cinco doses de molibdênio via foliar (0,0; 35,1; 70,2; 105,3 e 140,4 g ha<sup>-1</sup>) com três repetições. As massas fresca total e comercial e a circunferência da cabeça evidenciaram efeitos significativos para doses de nitrogênio em cobertura e de molibdênio, assim como para sua interação. Não se observou efeito significativo dos tratamentos para comprimento do caule. Houve uma resposta linear para doses de N e Mo para conservação pós-colheita aos 28 dias, sendo que a dose de 150,0 kg ha<sup>-1</sup> de N em cobertura promoveu a melhor conservação aos 35 dias após a colheita. A dose de 95,9 kg ha<sup>-1</sup> de N em cobertura e a dose 75,3 kg ha<sup>-1</sup> de Mo propiciaram o maior retorno em termos de percentagem de massa seca.

**Palavras-chave:** *Lactuca sativa* L., massa fresca, nutrição, armazenamento.

(Recebido para publicação em 7 de outubro de 2009; aceito em 18 de agosto de 2010)

(Received on October 7, 2009; accepted on August 18, 2010)

Crisphead lettuce has grown in importance in Brazil. This type of lettuce is planted to attend the needs of the fast food market, and currently, there is an increase in the demand for this vegetable also for salads (Resende *et al.*, 2007).

As lettuce is a crop composed mostly of leaves, it responds well to nitrogen fertilization. A deficiency of nitrogen retards the growth of the plant and induces the absence or malformation of the head, the older leaves turn yellow and come off with ease. However, when applied in excess, in side dressing in the last third of the cycle, the cultivars that form a head show less firmness, which could be detrimental in marketing (Garcia *et al.*, 1982). Broadley *et al.* (2000) reported a negative relation

between plants under normal conditions of available nitrogen and deficient plants, where there was a reduction in fresh weight of the leaves, under limitations of this nutrient.

Molybdenum is a constituent of at least five enzymes and its most important function in plants is related to nitrogen metabolism (Chairidchai, 2000), linked to the action or enzymatic activation, mainly of the enzymes nitrogenase and nitrate reductase (Dechen *et al.*, 1991). These enzymes together with sulfite oxidase are found in plants (Gupta & Lipsett, 1981).

The application of nitrogen on the soil together with the application of molybdenum on the leaves, could be a way to improve the fertilization of this crop, with the more rational use of

nitrogen, and for a greater activity of the enzyme nitrate reductase by means of molybdenum fertilization.

The objective of this work was to evaluate the effects of nitrogen rates as side dressing and molybdenum by foliar fertilization, on production characteristics, post-harvest quality, and the performance of crisphead lettuce grown in winter.

### MATERIAL AND METHODS

The experiment was conducted from April to July of 2003, in Três Pontas, south of Minas Gerais State (21°22'00"S and 45°30'45"W, altitude of 870 m), using a soil classified as dystroferic red latosol with clayey texture (Santos *et al.*, 2006). An analysis of the soil in which

the experiment was carried out showed the following chemical characteristics: K= 73.0 mg dm<sup>-3</sup>, P= 72.7 mg dm<sup>-3</sup>, Ca= 4.5 cmol<sub>c</sub> dm<sup>-3</sup>, Mg= 0.7 cmol<sub>c</sub> dm<sup>-3</sup>, Al= 0.0 cmol<sub>c</sub> dm<sup>-3</sup>, H + Al= 2.3 cmol<sub>c</sub> dm<sup>-3</sup>, pH in H<sub>2</sub>O= 6.3 and O.M.= 2.9 dag kg<sup>-1</sup>.

The experiments were carried out using a randomized block design with a 4 x 5 factorial scheme. We studied four rates of nitrogen as side dressing (0, 60, 120 and 180 kg ha<sup>-1</sup>), in addition to the level applied by the grower (60 kg ha<sup>-1</sup> nitrogen), and five rates of foliar molybdenum (0.0, 35.1, 70.2, 105.3 and 140.4 g ha<sup>-1</sup>), with three repetitions, giving a total of 20 treatments. Urea was used as nitrogen fertilizer and sodium molybdate was the source of molybdenum. Urea was applied as side dressing at 10, 20 and 30 days after transplanting at 40%, 30% and 30%, respectively, of the rate evaluated. The rates of urea per plot per plant were applied as a 10-mL solution, previously diluted in pure water, to the side of each plant. Sodium molybdate was applied at 21 days after transplanting using a manual backpack sprayer with a 4-L capacity at maximal pressure, producing 300 L ha<sup>-1</sup> of spray.

The preparation of the soil consisted of plowing, harrowing and raising the seedbeds to 0.20 m in height. The seedlings were prepared in 288-cell trays, with each cell filled with commercial substrate (Plantmax). Transplanting was at 25 days after sowing, utilizing the cultivar Raider.

The experimental plots consisted of seedbeds with four rows 2.1 m long, spaced 0.30 m apart with plants being 0.35 m apart. The central rows formed the area to be studied, where two plants at each end were excluded. A protective structure was installed in the whole area; it consisted of high tunnels 2.0 m high, covering two seedbeds per tunnel, and was made of galvanized iron tubes, covered with a low-density, transparent plastic sheet, which was 100 µm thick and with added anti-UV. The seedbeds were covered with a black plastic sheet (mulching), 4 m wide and 35 µm thick.

The basic fertilization at planting carried out by the grower consisted of

1500 kg ha<sup>-1</sup> formulation 02-16-08 and 1000 kg ha<sup>-1</sup> simple superphosphate. After incorporating the fertilizers into the soil, two lines of drip piping were installed in each seedbed, with nozzles spaced every 30 cm and with a flow rate of 1.5 L h<sup>-1</sup>. The side dressing were carried out by means of daily fertigations, totaling 30 kg ha<sup>-1</sup> N and 60 kg ha<sup>-1</sup> K, utilizing urea and potassium chloride as sources.

The crop was kept clean by manual weeding, when necessary, and the pest control used was the standard method of the grower, with weekly spraying with pesticides containing copper oxychloride, iprodione, procymidone and pyrethroids.

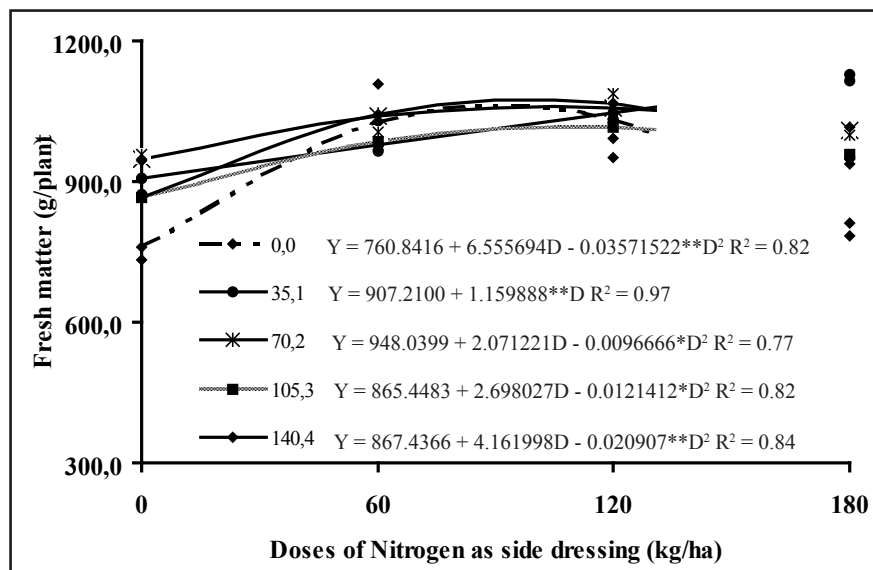
Transplanting of the seedling was done on May 13, 2003. Harvest was 36 days after transplanting, when the plants appeared to be completely developed, at which time the following parameters were assessed: total fresh weight and commercial fresh weight (head) (g plant<sup>-1</sup>); circumference and length of the stem of the commercial part in cm (head), percentage of dry weight of the commercial part (sample of ± 300 g). The samples were washed in running water and in distilled water and dried in convection oven, at 65-70°C, until reaching constant weight. The data of percentage of dry weight were transformed to arcsine  $\sqrt{P/100}$ . Post-harvest conservation was determined with a sample of two commercial heads of lettuce, evaluated at 7, 14, 21, 28 and 35 days, in a cold room at 5 ± 2°C and relative humidity of 90 ± 2%, according to grades (grade 1: commercial heads extremely deteriorated; grade 2: commercial heads deteriorated; grade 3: commercial heads moderately deteriorated; grade 4: commercial heads slightly deteriorated and grade 5: commercial heads without deterioration), where three evaluators were utilized to determine the mean grade.

The collected data were submitted to analysis of variance and regression based on the polynomial model at the 5% level of significance.

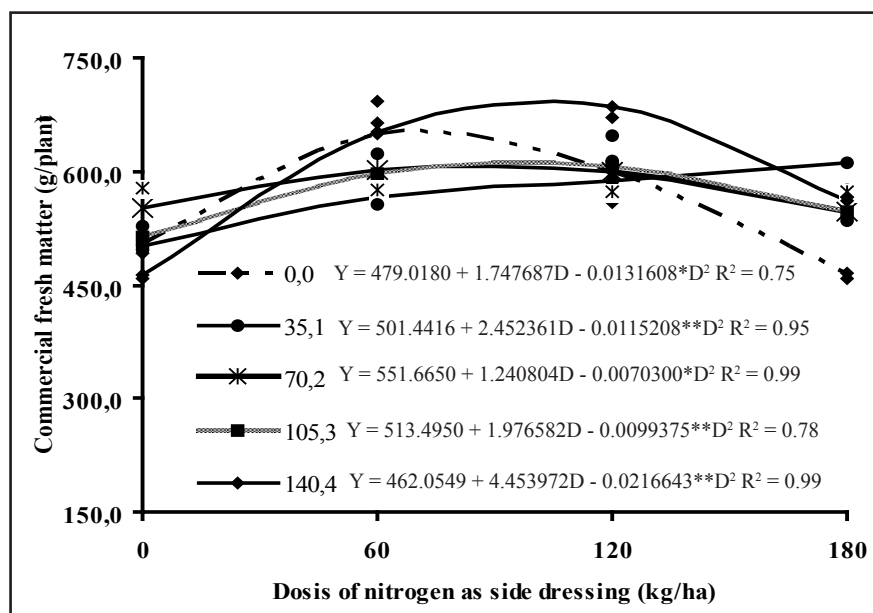
## RESULTS AND DISCUSSION

The total fresh weight of the aerial part showed significant effects for rates of nitrogen and molybdenum, as well as for the interaction between these nutrients. Except for the rate of 35.1 g ha<sup>-1</sup> molybdenum which fit a linear model, the other rates were fitted to quadratic models with points of maximal productivity of total fresh weight varying with the rate of nitrogen applied (Figure 1).

In the absence of fertilization with molybdenum, the rate of nitrogen of 91.8 kg ha<sup>-1</sup> as dressing gave the highest return in terms total fresh weight of lettuce. When rates of 70.2, 105.2 and 140.4 g ha<sup>-1</sup> molybdenum were applied, respective rates of 107.1, 111.1 and 99.5 kg ha<sup>-1</sup> nitrogen as dressing provided the greatest weights. Taking into consideration that the grower utilized 30.0 and 30.0 kg ha<sup>-1</sup> N, respectively, at planting and as daily dressings, totaling 60.0 kg ha<sup>-1</sup>, during the crop cycle, it can be inferred that these rates, based on the results obtained, are insufficient for achieving the maximal productivity of total fresh weight per plant, which in the absence of fertilization with molybdenum was achieved completely with 151.8 kg ha<sup>-1</sup> nitrogen, that is, 153.0% higher than the rate utilized by the grower. Alvarenga *et al.* (2000) transplanted the same cultivar in May and observed effects of the interaction nitrogen x calcium, pointing out that better results were obtained in the absence of calcium with 1,011.0 g plant<sup>-1</sup>, declining down to 809.1 g plant<sup>-1</sup>, where these weights are within variation range found in the present work. These results are a little above those obtained by Thompson & Doerge (1996a), who found for butter lettuce, maximal productivity when utilizing 165.0 kg ha<sup>-1</sup> nitrogen, and lower than those obtained by McPharlin *et al.* (1995) in Australia, who determined a maximal production with rates of 288.0 and 344 kg ha<sup>-1</sup> N, in two years of study, utilizing the cultivar Salinas. Positive results for productivity with the sole application of molybdenum in winter cultivation of the same cultivar were reported by Resende *et al.* (2008). The difference in these results is probably due to the cultivar utilized, edaphoclimatic conditions



**Figure 1.** Total fresh weight of crisphead lettuce submitted to 0.0; 35.1; 70.2 and 105.3 g ha<sup>-1</sup> molybdenum levels in response to nitrogen levels (massa fresca total da alface tipo americana nas doses 0,0; 35,1; 70,2 e 105,3 g ha<sup>-1</sup> de molibdênio em função de doses de nitrogênio). Três Pontas, Embrapa Semi-Árido, 2003.



**Figure 2.** Commercial fresh mass of crisphead lettuce submitted to 0.0; 35.1; 70.2 and 105.3 g ha<sup>-1</sup> molybdenum levels in response to nitrogen levels (massa fresca comercial da alface tipo americana nas doses 0,0; 35,1; 70,2 e 105,3 g ha<sup>-1</sup> de molibdênio em função de doses de nitrogênio). Três Pontas, Embrapa Semi-Árido, 2003.

and irrigation management, important factors in the productivity of the crop.

Similar results were obtained for commercial fresh weight where, in elucidating the interaction of molybdenum rates within the nitrogen rates studied, quadratic models were established with points of maximal production of fresh weight with or without the application of molybdenum

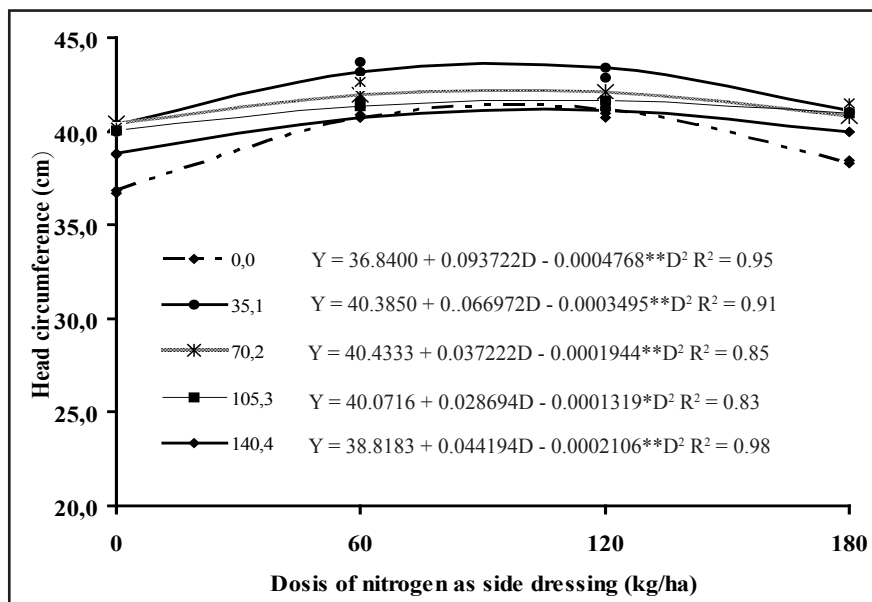
(Figure 2). In the absence of fertilization with molybdenum, a rate of 74.8 kg ha<sup>-1</sup> nitrogen as dressing provided the highest response. Considering that the grower utilized a total of 60.0 kg ha<sup>-1</sup> N, maximal commercial productivity in the absence of molybdenum fertilization required a rate nitrogen of 134.8 kg ha<sup>-1</sup>. With the application of 35.1, 70.2, 105.3 and 140.4 g ha<sup>-1</sup> molybdenum,

rates of 106.4, 88.2, 99.4 and 102.8 kg ha<sup>-1</sup> nitrogen as dressing were needed to provide the highest returns. Adding to the 60.0 kg ha<sup>-1</sup> nitrogen employed by the grower, it is seen that rates varying from 148.2 to 166.4 kg ha<sup>-1</sup> resulted in the highest productions with regard to commercial fresh weight, fluctuating with the application of molybdenum.

In the absence of the molybdenum fertilization a yield of 509.5 g plant<sup>-1</sup> (head) was obtained. When the highest rates of nitrogen and molybdenum were employed the yield of heads was of 690.9 g plant<sup>-1</sup>. These results are much better than those found by Bueno (1998), with the highest rate of nitrogen used (105.6 kg ha<sup>-1</sup>), producing the equivalent of 461.1 g plant<sup>-1</sup> as also the results obtained by Alvarenga *et al.* (2000), who did not find significant differences between rates of 120 and 240 kg ha<sup>-1</sup> N, but did observe a maximal fresh weight at 609.2 g plant<sup>-1</sup>. The importance of nitrogen fertilization was reported by Broadley *et al.* (2000) who noted a negative relation between plants under normal conditions of available nitrogen and deficient plants, where a reduction in leaf weight occurred under conditions limiting this nutrient. The results obtained, however, are still a level lower than the recommended rates of nitrogen utilized in the United States, which according to Thompson & Doerge (1996a, b), vary from 224.0 to 370.0 kg ha<sup>-1</sup>, probably due to the cultivar, type of soil, climatic conditions and management of the crop, as mentioned previously.

The circumference of the commercial part (head) is one of the main characteristics for crisphead lettuce, considering the preference of the consumer for the acquisition of the product (Bueno, 1998). Like the preceding characteristics, for the circumference of the commercial head, the factors studied showed significant effects for rates of nitrogen and molybdenum, and for the interaction of these nutrients (Figure 3). They were fitted to quadratic models with points of maximal circumference in the absence of molybdenum as well as with its application. In the absence of molybdenum fertilization, a rate of 98.3





**Figure 3.** Head circumference of crisphead lettuce submitted to 0.0; 35.1; 70.2 and 105.3 g ha<sup>-1</sup> molybdenum levels in response to nitrogen levels (circunferência da cabeça da alface tipo americana nas doses 0,0; 35,1; 70,2 e 105,3 g ha<sup>-1</sup> de molibdênio em função de doses de nitrogênio). Três Pontas, Embrapa Semi-Árido, 2003.

**Table 1.** Dry matter (%) and postharvest conservation at 28 and 35 days in response to nitrogen and molybdenum levels (massa seca (%) e conservação pós-colheita aos 28 e 35 dias em função das doses de nitrogênio e molibdênio). Três Pontas, 2003.

Variables	Regression equations
Dry mass <sup>1</sup>	(N) $Y = 10.2236 + 0.0110626X - 0.0000554**X^2$ $R^2 = 0.99$
	(Mo) $Y = 10.2222 + 0.012291X - 0.0000816**X^2$ $R^2 = 0.96$
Post-harvest conservation (28 days)	(N) $Y = 3.5000 + 0.003611**X$ $R^2 = 0.87$
	(Mo) $Y = 3.4750 + 0.004985**X$ $R^2 = 0.67$
Post-harvest conservation (35 days)	(N) $Y = 32.0500 + 0.009722X - 0.0000324**X^2$ $R^2 = 0.98$

<sup>1</sup>Data transformed in arcsine  $\sqrt{P/100}$ ; \*\*significant at 1% level in the F test (dados transformados em arco-seno  $\sqrt{P/100}$ ; \*\*Significativo ao nível de 1% pelo teste de F).

kg ha<sup>-1</sup> N as dressing produced a larger circumference of the commercial head, reaching 41.4 cm.

For the rates of 35.1, 70.2, 105.3 and 140.4 g ha<sup>-1</sup> molybdenum (Figure 3), derivation of the regression equations gave the nitrogen rates of 95.8, 95.7, 108.8 and 104.9 kg ha<sup>-1</sup> as those providing the highest returns in head circumference, which fluctuated between 41.1 and 43.69 cm. These results are close to those obtained by Bueno (1998), who found a maximal circumference of 44.98 with an increase in nitrogen rate. These results are similar to those reported by Alves (1996), who observed a significant increase in the circumference of commercial heads

with increase in nitrogen rate. Yuri *et al.* (2004a) reported a significant effect of the application of molybdenum on increase in circumference of commercial heads.

No significant effects were observed in the treatments for stem length. Shorter stems are desirable for crisphead lettuce, mainly when destined for the processing industry, due to being very reduced, resulting in lower losses during processing. On the other hand, a very long stem leads to lower compactness of the head and makes its processing difficult, thereby affecting the final quality of the product (Resende *et al.*, 2003). In practice, stems up to 6.0 cm would be most suitable, with lengths

up to 9.0 cm being acceptable and unacceptable or less recommended for processing above this level. In this context, there was variation between 2.02 and 2.14 cm in the rates of nitrogen and for rates of molybdenum, between 2.01 and 2.13 cm, which was within the range adequate for the crop. It should be noted that there is a tendency for crisphead lettuce under conditions of winter cultivation to have shorter stems, compared to summer cultivation, probably due to its better adaptation to cultivation under conditions of amenable temperature. Similar results for the rates of molybdenum were found by Yuri *et al.* (2004a), who demonstrated significant effects for stem length. However, the results do not concur with those obtained by Bueno (1998), who found a linear increase in stem length with increase of nitrogen rates.

Analysis of variance revealed significant differences for the percentage of dry weight, for rates of both nitrogen and molybdenum, in an independent way (Table 1). Quadratic models were determined for the two nutrients, in which through the derivate of the equations, it was estimated that a rate of 95.9 kg ha<sup>-1</sup> N as dressing in addition to the rate applied by the grower of 60.0 kg ha<sup>-1</sup> provided a greater return in terms of dry weight of the plant (Table 1). Similar results are observed in the works of Alves (1996) and Fontes *et al.* (1997), who obtained a positive effect for dry weight of the lettuce cultivars Regina 440 and Brasil 202, in response to the addition of nitrogen. However, Alvarenga *et al.* (2000) did not detect significant differences in the production of dry weight with fertilizations with nitrogen and calcium. In peppers, Silva (1998) and Nannetti (2001) reported a favorable effect of N in the production of dry weight of the fruits.

With regard to the rates of molybdenum, 75.3 g/ha provided the greatest response in terms of dry weight of the commercial part of crisphead lettuce (Table 1). Also in cauliflower, Novelino & Chaves (1987) found a tendency of an increase in the accumulation of dry weight in the plants, with foliar application of 24 and 48 g ha<sup>-1</sup> Mo.

Post-harvest conservation was evaluated in a cold room at 7, 14, 21, 28 and 35 days after harvest. At 7 and 14 days, the commercial heads appeared perfectly conserved. At 21 days after harvest, the heads that received nitrogen showed grades varying between 4.8 and 4.9 and those that received molybdenum showed grades of 4.8 to 5.0, noting that these indices represent heads slightly deteriorated or without deterioration. Evaluation at 28 days after harvest showed significant effects for the rates of nitrogen and molybdenum studied, where they were fitted to linear models with the increase in rates of nitrogen and molybdenum (Table 1).

With regard to post-harvest conservation at 35 days after harvest (Table 1), significant effects were found only for rates of nitrogen which were fitted to a quadratic model with the point of maximal conservation at a nitrogen rate of 150.0 kg ha<sup>-1</sup> as dressing in addition to the level of 60.0 kg ha<sup>-1</sup> utilized by the grower. This characteristic is of great importance in crisphead lettuce since the final product is processed and stored in cold rooms for later distribution. Therefore, a greater conservation of the product after its harvest is desirable and of considerable relevance.

As production is basically determined by the leaves, among all the nutrients absorbed by lettuce, nitrogen is the one that provides the greatest increase in productivity and in weight of the plant. A deficiency of nitrogen retards the growth of the plant and induces the absence or malformation of the head, where the older leaves become totally yellowish and come off with ease (Garcia *et al.*, 1982). A good vegetative development of crisphead lettuce, culminating in an optimal formation of the head and compactness, probably explains the better post-harvest conservation caused by nitrogen fertilization. In the literature, there are reports of a small effect on the loss of weight by the addition of nitrogen (Poulsen *et al.*, 1994) and of better post-harvest conservation with fertilization with other nutrients such as silicon and boron (Resende *et al.*, 2005; Yuri *et al.*, 2004b).

There was an interaction between

the rates of nitrogen as side dressing and of foliar molybdenum, which positively influenced the total commercial fresh weight, head circumference, dry weight and post-harvest conservation, where a significant effect was observed on the length of the stem of crisphead lettuce. In the absence of fertilization with molybdenum, a rate of 134.8 kg ha<sup>-1</sup> nitrogen as dressing provided a maximal productivity of commercial fresh weight, and with the application of 35.1, 70.2, 105.3 and 140.4 kg ha<sup>-1</sup> molybdenum (added to the 60.0 kg ha<sup>-1</sup> nitrogen used by the grower), rates varying from 148.2 to 166.4 kg ha<sup>-1</sup> gave the highest yields.

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