ECHER MM; ZOZ T; ROSSOL CD; STEINER F; CASTAGNARA DD; LANA MC. 2012. Plant density and nitrogen fertilization in Swiss chard. *Horticultura Brasileira* 30: 703-707.

Plant density and nitrogen fertilization in Swiss chard

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ABSTRACT

An experiment was conducted to evaluate the effect of plant spacing and nitrogen fertilization on Swiss chard's yield, from September to November 2009. The experimental design was of randomized blocks in split plot with four replications. In the plots were allocated the two plant spacings (0.30 and 0.50 m) and in the subplots the five doses of nitrogen (0, 40, 80, 120 and 160 kg ha^{-1}). The crop was harvested 90 days after transplanting. The plant spacing of 0.50 m provided increased production of total fresh weight of shoot (961.7 g plant^{-1}) and marketable (873.1 g plant^{-1}). However, the highest total yield (77.8 t ha^{-1}) and marketable (64.5 t ha^{-1}) was achieved with the smaller spacing between plants (0.30 m). The N rates applied in coverage until 160 kg ha^{-1} increased in a linear form the total and marketable production of fresh mass of shoots, the total and marketable yield, the N content and the N accumulation in the shoots of Swiss chard plants on the evaluated plant spacings.

Keywords: *Beta vulgaris* var. *cycla*, nitrogen, yield.

RESUMO

Densidade de plantio e adubação nitrogenada em acelga

Avaliou-se o efeito do espaçamento entre plantas e da adubação nitrogenada na produtividade de acelga, de setembro a novembro de 2009. O delineamento experimental adotado foi de blocos ao acaso em parcelas subdivididas com quatro repetições. Nas parcelas foram alocados dois espaçamentos entre plantas (0,30 e 0,50 m) e nas subparcelas cinco doses de nitrogênio em cobertura (0; 40, 80, 120 e 160 kg ha^{-1}). A colheita foi realizada 90 dias após o transplante das mudas. O espaçamento entre plantas de 0,50 m proporciona maior produção de massa fresca da parte aérea total (961,7 g planta^{-1}) e comercial (873,1 g planta^{-1}) por planta. Porém, a maior produtividade total (77,8 t ha^{-1}) e comercial (64,5 t ha^{-1}) foi obtida com o menor espaçamento entre plantas (0,30 m). As doses de N aplicadas em cobertura até 160 kg ha^{-1} incrementam de forma linear a produção de massa fresca da parte aérea total e comercial, a produtividade total e comercial, o teor de N e o N acumulado na parte aérea das plantas de acelga nos espaçamentos avaliados.

Palavras-chave: *Beta vulgaris* var. *cycla*, nitrogênio, produtividade.

(Recebido para publicação em 31 de agosto de 2011; aceito em 30 de agosto de 2012)
(*Received on August 31, 2011; accepted on August 30, 2012*)

The Swiss chard (*Beta vulgaris* var. *cycla*) is a leafy vegetable, biennial, of long cycle from Europe belonging to the Chenopodiaceae family. This vegetable is characterized by having large ovate leaves with armored edges, the color varies according to the cultivar from dark green to light green, and has creamy or white colored petiolates (Filgueira, 2008). It is a temperate climate plant, which grows best in warm weather, with temperatures ranging between 18 and 25°C (Costa *et al*., 2003). Currently, the Swiss chard cultivation has been gaining ground and economic importance among leafy vegetables. However, there is little technical information about their culture, mainly in concerning to mineral nutrition and planting density.

Planting density is one of the main factors influencing crop yield (López-Bellido *et al*., 2005). The increase in the number of plants per area reduces the production of fresh weight per plant and increases yield to some extent. The Swiss chard is normally planted in the field with 0.45 to 0.6 m between rows and 0.25 to 0.30 m spacing between plants (Daeard, 2011). The adjustment of spacing is necessary for each cultivar, to prevent the leaf area, important in photoassimilates supply, to be affected in any way prejudicing the productivity (Castro *et al*., 1987).

In addition to planting density, fertilization also alters crop yields, being one of the farming practices with higher cost and economic return, resulting in higher yields, more uniform products and higher marketable value (Ricci *et al*., 1995). In leafy vegetables such as Swiss chard, nitrogen (N) plays a fundamental role in vegetative growth and hence yield and product quality. This crop presents nutrient extraction efficiency, providing high short-term yield (Filgueira, 2008). However, it is possible that excessive N can accumulate in plants as nitrate (NO^{-3}) being detrimental to health.

Studies aiming to evaluate the distribution of plants and Swiss chard fertilization with N are scarce in Brazil. This study aimed to evaluate the effect of plant spacing and N fertilization on Swiss chard's yield.

MATERIAL AND METHODS

The experiment was conducted in the UNIOESTE University (24º33'S, 54º04'W, altitude 420 m) between September and November 2009. According to Köppen's classification, the climate is Cfa, mesothermal humid subtropical with hot summers, winters with infrequent frosts, no dry season, with 21.4°C average annual temperature and 1,500 mm precipitation.

The soil is classified as typical Oxisol, deep, well drained and with loamy texture (640 g kg^{-1} clay) (Embrapa, 2006). The chemical analysis of the soil, performed at 0-20 cm prior to the experiment, showed the following results: 5.2 pH in $CaCl_2$, 16 g dm^{-3} organic matter, 85 t dm^{-3} P (Mehlich-1), 48 $mmol_c$ dm^{-3} H + Al, 3.1 $mmol_c$ dm^{-3} K^+, 54 $mmol_c$ dm^{-3} Ca^{2+}, 14 $mmol_c$ dm^{-3} T^{2+}, 118 $mmol_c$ dm^{-3} CTC and 60% saturation.

The experimental design was of randomized blocks in a split plot design with four replications. Two plant spacings were allocated in plots (0.30 and 0.50 m between rows) and five nitrogen doses in the subplots (0, 40, 80, 120 and 160 kg ha^{-1}). The subplot consisted of three rows spaced by 0.40 m and five plants per row, totaling 15 plants. Side dressing nitrogen doses were divided in three applications at 14, 21 and 28 days after transplanting. Urea Super N® (45% N) was used as the nitrogen source. Seedlings of Swiss chard (Blonde cultivar) were grown in a greenhouse, in expanded polystyrene trays with 128 cells, supplied with marketable substrate Plantmax HA composed of expanded vermiculite and organic matter of vegetable origin. At 45 days after sowing, seedlings were transplanted to beds with 1.20 m wide and 0.20 m elevation. The basic fertilization at transplantation was performed by applying 40 kg ha^{-1} N, 180 kg ha^{-1} P_2O_5 and 100 kg ha^{-1} K_2O. Fertilizers were distributed manually on the soil surface and incorporated until the 0-15 cm layer. Irrigation was performed by spraying twice a day: the first in the morning and second in the afternoon. Weed control was carried out with hand weeding.

The crop was harvested 90 days after seedlings transplantation. Three central plants of each subplot were cut close to the soil surface and taken to the laboratory. Plant height and fresh weight production in the total and marketable shoot were measured. The production of marketable fresh weight was obtained after removal of damaged leaves or those unfit for marketing. Total (t ha^{-1}) and marketable yield (t ha^{-1}) were extrapolated from production data per plant. Subsequently, plants were packed in paper bags and dried in forced-air oven at 55±3°C until constant weight. Afterwards, the material was ground and N content determined by Kjeldahl distillation (Tedesco *et al*., 1995).

Data were subjected to analysis of variance by F test ($p \leq 0.05$). Means related to spacing among plants were compared by the Tukey test ($p \leq 0.05$). Means referring to nitrogen levels were adjusted through regression equations, choosing the significant model with greater coefficient of determination (R^2). For data processing we used the statistical software version 4.0 SISVAR.

RESULTS AND DISCUSSION

There occurred a significant effect of the interaction ($p<0.05$) between plant spacing and nitrogen top dressing on fresh weight production of total shoots, marketable shoots and total yield.

The plant spacing significantly affected only the fresh weight production of shoots using 160 kg ha^{-1} nitrogen in side dressing (Figure 1a). The 0.50 m plant spacing promoted higher fresh weight production of shoots per plant only with application of 160 kg ha^{-1} N. For fresh weight production of marketable shoots, 0.50 m plant spacing was superior to 0.30 m spacing using 120 and 160 kg ha^{-1} nitrogen (Figure 1b). The highest fresh weight production of Swiss chard shoots at

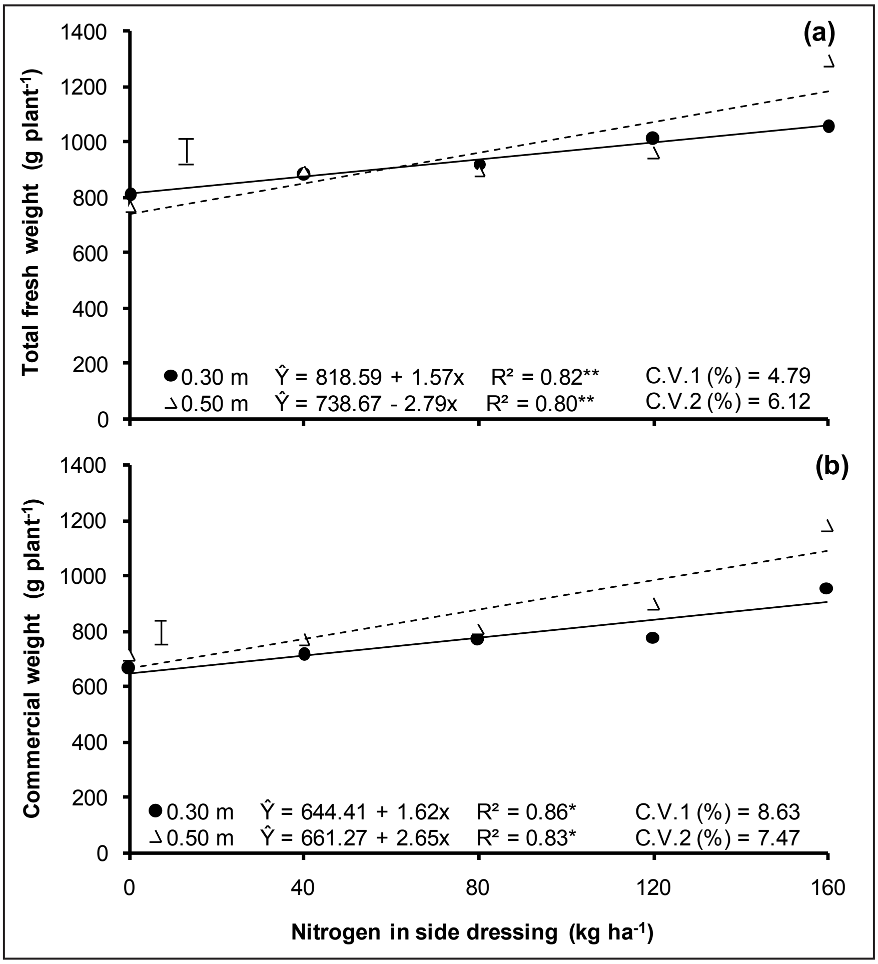

Figure 1. Total (a) and marketable weight (b) of Swiss chards grown at 0.30 (●) and 0.50 m (Δ) plant spacing with different doses of nitrogen application in side dressing (massa fresca total (a) e comercial (b) de plantas de acelga cultivadas no espaçamento entre plantas de 0,30 (●) e 0,50 m (Δ) com a aplicação de nitrogênio em cobertura).** and * significant at 1 and 5% probability respectively; vertical bars represent the LSD ($p<0.05$)). Marechal Cândido Rondon, UNIOESTE, 2009.

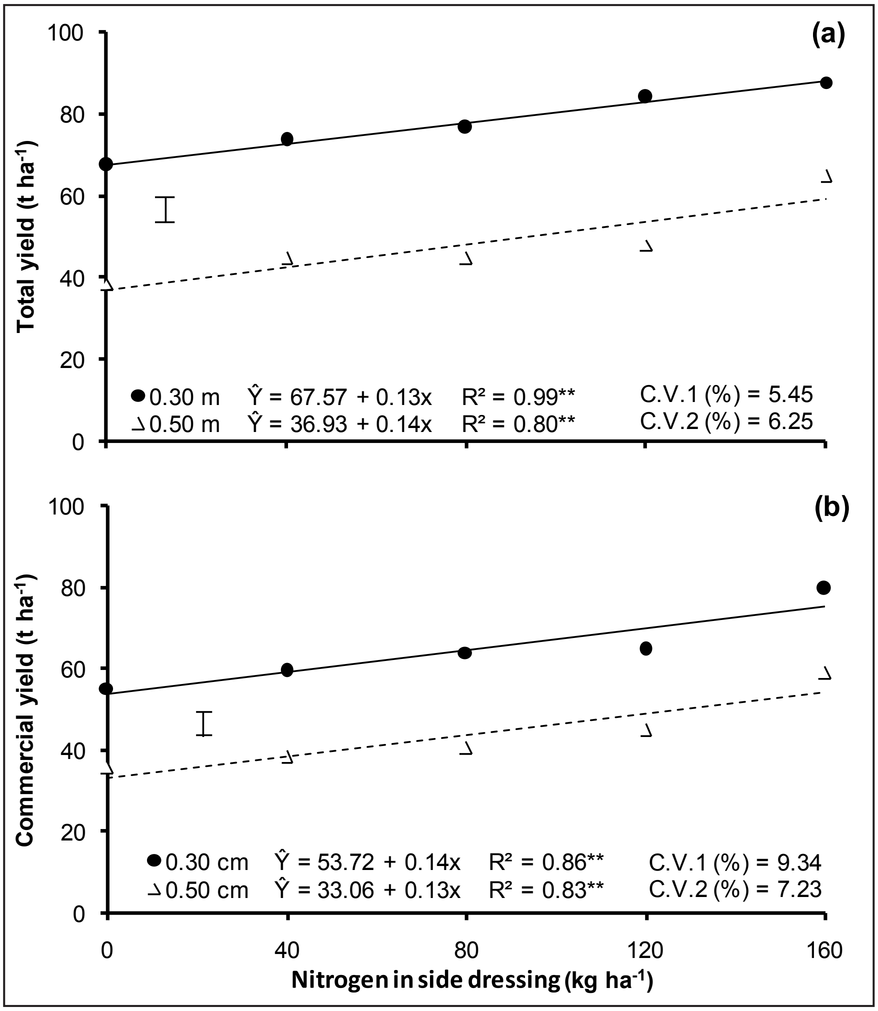

Figure 2. Total (a) and marketable yield (b) of Swiss chards grown at 0.30 (●) and 0.50 m (Δ) plant spacing with different doses of nitrogen application in side dressing (produtividade total (a) e comercial (b) de acelga cultivada no espaçamento entre plantas de 0,30 (●) e 0,50 m (Δ) com a aplicação de nitrogênio em cobertura).** and * significant at 1 and 5% probability respectively; vertical bars represent the LSD ($p<0.05$)). Marechal Cândido Rondon, UNIOESTE, 2009.

0.50 m plant spacing was due to higher N availability in the soil that can be absorbed by the plant. There was lower intraspecific competition for light, water and nutrients in the greater plant spacing favoring the further growth and development of plants.

The lower production of marketable fresh weight obtained at 0.30 m plant spacing with 120 and 160 kg ha^{-1} of N fertilization (Figure 1b) was due to increased disposal of leaves infected by diseases, making them unfit for the market. Less spacing between plants and consequently higher density, favored diseases proliferation, infecting the lower leaves of Swiss chard plants. According to Filgueira (2008), excess N increases the susceptibility of plants to disease, reducing quantity and quality of the harvested product.

Assessing the cabbage development in three row spacing with different N doses, Aquino *et al*. (2005) found that reducing the spacing resulted in reduced production of fresh weight of heads per plant. Similarly, Silva (2009) showed that reducing the spacing between cabbage plants promoted lower production of outer leaves dry weight and head dry weight. Nitrogen application promoted linear increase in the fresh weight production of total (Figure 1a) and marketable shoots (Figure 1b) in both row spacing. There was increase of 62.8 and 111.6 g fresh weight of shoots (Figure 1a) for each 40 kg ha^{-1} N applied in side dressing at 0.30 and 0.50 m of plant spacing, respectively. For marketable fresh weight production (Figure 1b) occurred an increase of 64.8 and 106.0 g per 40 kg ha^{-1} N applied in side dressing at 0.30 m and 0.50 plant spacing, respectively.

In cabbage, Aquino *et al*. (2005) observed increased head fresh weight production with N application up to 300 kg ha^{-1}. Pereira *et al*. (2003) showed linear response in the fresh weight production of lettuce to N application. Resende *et al*. (2005) found quadratic effect for the total and marketable fresh weight production of lettuce depending on the N application, with maximum production (763 g plant^{-1}) obtained by applying 147 kg ha^{-1} N. For total and marketable yield occurred the reverse of fresh weight production per plant and the plant spacing of 0.30 m promoted highest yield of Swiss chard compared to the spacing of 0.50 m at all N doses in side dressing (Figure 2a and 2b). The highest yield of Swiss chard obtained at the smallest spacing can be attributed to the greater number of plants per area. Similar results were observed by Aquino *et al*. (2005) evaluating cabbage development in three rows, who found highest yield of fresh weight of heads per area at smaller spacing. Silva (2005), evaluating cabbage cultivation at different spacing between plants and between rows, found that, by reducing the spacing, occurred an increased production per area.

Nitrogen application promoted linear increase in total (Figure 2a) and marketable yield (Figure 2b) in both row spacing studied. There was 5.2 and 5.6 t ha^{-1} increase of total yield (Figure 2a) and 5.6 and 5.2 t ha^{-1} for marketable yield (Figure 2a) of Swiss chard for each 40 kg ha^{-1} N applied in side dressing, respectively, at 0.30 and 0.50 m plant spacing. Results are consistent with those obtained by Marques *et al*. (2010) who found increase in total and marketable production of sugar beet with manure application and attributed such production increase to the N present in manure. However, Aquino *et al*. (2006), applying N rates in sugar beet obtained quadratic adjustment in

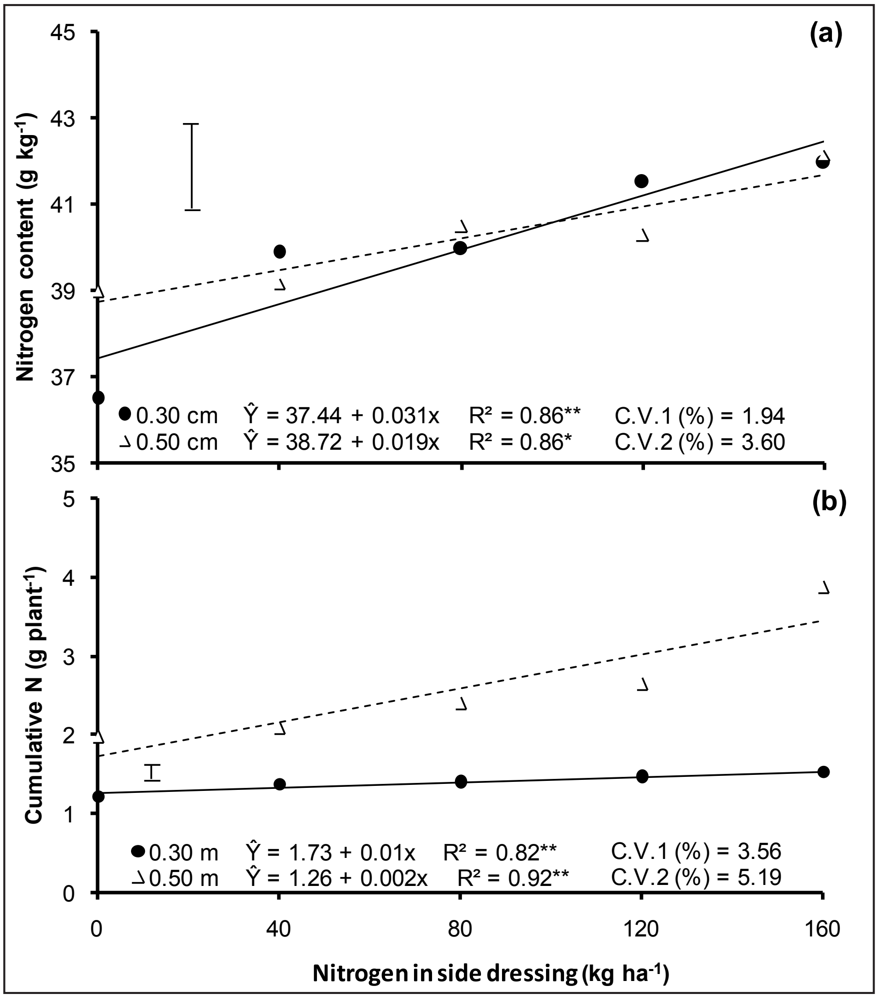

Figure 3. Nitrogen content (a) and cumulative N (b) in the shoots of Swiss chard grown at 0.30 (●) and 0.50 m (Δ) plant spacing with different doses of nitrogen application in side dressing (teor de nitrogênio (a) e N acumulado (b) na parte aérea de plantas de acelga cultivadas no espaçamento entre plantas de 0,30 (●) e 0,50 m (Δ) com a aplicação de nitrogênio em cobertura). ** and * significant at 1 and 5% probability, respectively. Vertical bar represents the LSD ($p<0.05$)). Marechal Cândido Rondon, UNIOESTE, 2009.

the fresh weight production of leaves and roots. Assessing the effect of spacing and N doses on cabbage heads yield, Aquino *et al*. (2005) obtained a quadratic adjustment at 0.40 and 0.60 m row spacing and linear increase at 0.80 m spacing. Also working on cabbage under N fertilization, Moreira *et al*. (2011) obtained quadratic adjustment for fresh weight production with maximum production at 277.8 kg ha^{-1} N.

Total N content of Swiss chard shoots was not affected by spacing between plants. However, there was significant effect of N application in side dressing (Figure 3a). For each 40 kg ha^{-1} N in side dressing there was 1.24 and 0.76 g kg^{-1} N increase at 0.30 and 0.50 m spacing, respectively. These results corroborate those obtained by Aquino *et al*. (2005) who, evaluating productivity, quality and nutritional status of table beet under N application, found linear increase in sugar beet's leaf N content according to N dose increase. Similarly, Trani *et al*. (2005) showed linear increase in leaf N content of sugar beet with ammonium sulfate application in side dressing.

For N amount accumulated in shoots, there were 0.08 and 0.40 g $plant^{-1}$ increment for each 40 kg N ha^{-1} applied at 0.30 and 0.50 m spacing, respectively (Figure 3b). The highest N accumulation in shoots was obtained at 0.50 m plant spacing (Figure 3b). This result is probably because plants have higher production of fresh weight in shoots when grown at this plant spacing and hence higher dry weight, since there was no difference among plant spacing for total-N content in the shoot.

There was no influence of plant spacing and nitrogen application in side dressing on plant height with 67 cm average height.

The 0.50 m plant spacing promoted highest fresh weight production of total and marketable shoot per plant. However, the highest total and marketable yield is achieved with less spacing between plants (0.30 m). Doses of up to 160 kg N ha^{-1} applied in side dressing promoted increased production of fresh weight in total and marketable shoots, total and marketable yield, N content and N accumulated in Swiss chard plants.

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