

TAKAHASHI K; CARDOSO AII. 2014. Plant density in production of mini lettuce cultivars in organic system management. *Horticultura Brasileira* 32: 342-347. DOI - <http://dx.doi.org/10.1590/S0102-05362014000300017>

Plant density in production of mini lettuce cultivars in organic system management

Keiko Takahashi; Antonio II Cardoso

UNESP-FCA, Depto. Horticultura, C. Postal 237, 18610-307 Botucatu-SP; keiko.pontealta@gmail.com; ismaeldh@fca.unesp.br

ABSTRACT

Production of mini vegetables in organic system is a good alternative to improve profit, but there are no researches about the optimum plant density for these cultivars in Brazilian conditions. Two experiments were conducted to evaluate the production of mini lettuce cultivars in different plant densities. Experiment 1 was conducted from January 1st (sowing) to February 10th (harvesting), 2012. The experimental design was completely randomized blocks, with six treatments in factorial scheme, 3 mini lettuce cultivars (Tudela, Renoir and Sartre) x 2 spacing between plants (16 and 20 cm), with eight replications and plots (2.04 m²) with six rows, spaced 15 cm. Experiment 2 was conducted from June 6th (sowing) to July 18th (harvesting), 2012. The cultivars Sartre and Renoir were evaluated under four plant densities (444,444; 333,333; 266,667 and 200,000 plants ha⁻¹, corresponding to spacing of 15x15, 15x20, 25x15 and 25x20 cm, respectively). Eight treatments were defined by a factorial scheme 2 (cultivars) x 4 (plant densities) and arranged in a completely randomized block design, with nine replications and plots with 2.04 m². The evaluated characteristics in both experiments were total and marketable fresh weight per plant, plant dry weight, plant diameter and height, marketable yield and discard percentage. In first experiment, during the summer, cultivar Sartre showed the highest marketable fresh weight (72 g plant⁻¹). Heaviest plants (91.6 g plant⁻¹) were obtained with the higher plant spacing, but the highest yield (2.51 kg m⁻²) was obtained with the smaller spacing. In winter, plants with higher total (190 g plant⁻¹) and marketable (146 g planta⁻¹) fresh weight were obtained with cultivar Sartre, and the same was observed in low plant density. However, the higher plant density, the higher the yield.

Keywords: *Lactuca sativa*, spacing, yield.

RESUMO

Densidade de plantas na produção de cultivares de mini alfaces em sistema orgânico

A produção de mini hortaliças em sistema orgânico é uma boa alternativa para aumentar os lucros do produtor; no entanto, não há pesquisas sobre a melhor densidade de plantio para estas cultivares nas condições brasileiras. Dois experimentos foram conduzidos para avaliar a produção de cultivares de mini alface em diferentes densidades de plantio. O experimento 1 foi conduzido de 1 de janeiro (semeadura) a 10 de fevereiro (colheita) de 2012. O delineamento experimental utilizado foi blocos ao acaso, com seis tratamentos em esquema fatorial, 3 cultivares de mini alface (Tudela, Renoir e Sartre) x 2 espaçamentos entre plantas (16 e 20 cm), com oito repetições e parcelas (2,04 m²) com seis linhas espaçadas em 15 cm. O experimento 2 foi conduzido de 6 de junho (semeadura) a 18 de julho (colheita) de 2012. As cultivares Sartre e Renoir foram avaliadas em quatro densidades de plantio (444.444, 333.333, 266.667 e 200.000 plantas ha⁻¹, correspondendo aos espaçamentos, 15x15, 15x20, 25x15 e 25x20 cm, respectivamente). Os oito tratamentos foram definidos pelo esquema fatorial 2 (cultivares) x 4 (densidades de plantas) e dispostos em blocos ao acaso, com nove repetições e parcelas com 2,04 m². As características avaliadas em ambos experimentos foram massas de matéria fresca total e comercial, massa de matéria seca, diâmetro e altura das plantas, produtividade comercial e porcentagem de descarte. No primeiro experimento, durante o verão, a cultivar Sartre apresentou maior massa da matéria fresca comercial (72 g planta⁻¹). Foram obtidas plantas mais pesadas (91,6 g planta⁻¹) no maior espaçamento, porém, a maior produtividade (2,51 kg m⁻²) foi obtida com o menor espaçamento. No inverno, foram obtidas plantas com maiores massa fresca total (190 g planta⁻¹) e comercial (146 g planta⁻¹) na cultivar Sartre, assim como nas menores densidades de plantio. Porém, quanto maior a densidade, maior a produtividade.

Palavras-chaves: *Lactuca sativa*, espaçamento, produtividade.

(Recebido para publicação em 1 de outubro de 2013; aceito em 4 de junho de 2014)

(Received on October 1, 2013; accepted on June 4, 2014)

Lettuce (*Lactuca sativa*) is originated in the Mediterranean region. It is the species of major economic importance among the leafy vegetables and the most consumed in Brazil. According to IBGE (2009a), Brazilian's lettuce purchase *per capita* is around 0.91 kg yr⁻¹, which corresponds to 3.4% of the

total vegetable species purchased per year. This quantity can be considered low, when comparing to tomato or potato, 4.9 and 4.0 kg yr⁻¹, respectively. However, when taking into account only leafy vegetables the amount corresponds to 28.2%, which can be considered very relevant.

The inbred nature of lettuce dictates the relatively limited genetic variability in the crop as compared to cross pollinated crops. Human selection and breeding efforts have resulted in changes in size, shape, color, texture, and taste of leaves and plants, yield, and adaptation to different

geographic areas and environments (Mou, 2011). As lettuce is originated in cool region, the physiological disorder known as bolting may occur when it is grown in hot regions. However, due to breeder's efforts nowadays lettuce can be cultivated all year round in most regions of Brazil.

The characteristics of the Brazilian families have changed regarding to the number of individuals which compose the family. According to a survey made between 2001 and 2009, families consisting of a single person raised from 9.2% to 11.5%, families with children decreased from 53.3% to 47.3% and families without children, on the other hand, raised from 13.8% in 2001 to 17.4% (IBGE, 2009b). This behavior can increase demand for differentiated products. Vegetables market is always innovating. Currently, demand for mini vegetables and baby leaf is increasing. Most of the mini vegetables seeds are imported, mainly from Japan and Europe and although the seed price of these kinds of vegetables are higher than of the normal sized vegetables, there is an increasing interest by growers to this market segment (Purquerio & Melo, 2011). Mini lettuce is considered a differentiated product due to its small leaf size, varied leaf colors, taste, crispness and shelf life. However, there are still few studies available providing technical information about management in Brazilian conditions, and no study in organic system.

Plant density largely influences several characteristics such as plant architecture, fresh weight, height and yield. Therefore, to the best utilization of the physical space it is necessary to know the productive capacity of each cultivar when submitted to different densities, mainly in protected cultivation where the cultivated area is limited by the cost of the structures. Even for normal size lettuce there are few researches, and in most of them the larger the plant density, the smaller the plants (Mondin *et al.*, 1989; Silva *et al.*, 2000; Echer *et al.*, 2001; Cecilio Filho *et al.*, 2007).

Due to the lack of information about mini lettuce management, mainly under organic cultivation system, the present

study was conducted to evaluate the production of mini lettuce cultivars in different plant densities.

MATERIAL AND METHODS

Two experiments were conducted in an organic farm (Santa Terezinha do Rio Bonito), certified by Ecocert Brasil, located in Itatinga São Paulo state, Brazil (23°06'06"S, 48°36'57"W, altitude of 845m). The first experiment was conducted in field under plastic tunnels (maximum height of 2 m, width of 3 m and length of 30 m) during the summer. The second experiment was conducted under greenhouse (height of 4 m, width of 28 m and length of 33 m) conditions during the winter.

In both experiments, seedlings were grown in 288 cells of polypropylene trays filled with coconut fiber organic substrate, in greenhouse conditions. Preplanting fertilization was made by adding 4.07 kg m⁻² of organic compost, 193.75 g m⁻² of bone meal, 193.75 g m⁻² of gypsum and 193.75 g m⁻² of lime, fifteen days before transplant. During the crop cycle water supply was made through three dripper lines with drippers at each 30 cm. Beds, 85 cm wide and 20 cm in height, were covered with black polyethylene mulch.

Experiment 1 - The experiment was conducted from January 1th (sowing) to February 10th (harvest), 2012. Seedlings were transplanted to field at four leaves stage (28 days after sowing). Treatments were arranged in a completely randomized block design, with eight replications. Treatments were defined by a factorial combination of three cultivars [Tudela (romaine type), 'Renoir' (red butterhead type) and 'Sartre' (green butterhead type)] and two spacing between plants (16 and 20 cm). The space between rows (six rows per plot) was 15 cm and the area of each plot was 2.04 m² for all treatments. Plants from lateral rows and the first and the last plants of each row were not evaluated.

Experiment 2 - The experiment was conducted from June 6th (sowing) to July 18th (harvest), 2012. Seedlings were grown as in experiment 1 and

transplant was made 29 days after sowing. In this experiment only 'Sartre' and 'Renoir' were evaluated under four plant densities: 444,444, 333,333, 266,667 and 200,000 plants ha⁻¹, corresponding to the following spacings: 15x15, 15x20, 25x15 and 25x20 cm, respectively. Treatments were defined by a factorial scheme 2 (cultivars) x 4 (plant density) and arranged in a completely randomized block design, with nine replications and plots with 2.04 m². As in experiment 1, lateral rows, the first and last plants of each row were not evaluated.

The evaluated characteristics in both experiments were total and marketable fresh weight; marketable dry weight; marketable yield (g m⁻²); plants diameter and height and discard percentage. Marketable weight was obtained after removing all damaged or dirty leaves. Dry weight was obtained from the average of three plants per plot after drying them at 60°C until constant weight. Discard percentage was obtained by the ratio of no marketable by total plant fresh weight.

Data were tested by analysis of variance and means were compared by Tukey test at 5% of probability. Regression analyses were used for plant density in experiment 2.

RESULTS AND DISCUSSION

In experiment 1, the cultivars Tudela and Sartre were superior to Renoir for total fresh weight (Table 1). For marketable fresh weight 'Sartre' (72.06 g plant⁻¹) showed the highest mean, followed by 'Tudela' (64.63 g plant⁻¹) and finally by 'Renoir' (56.00 g plant⁻¹). Regarding to marketable yield, 'Tudela' (2.69 kg m⁻²) and 'Sartre' (2.44 kg m⁻²) showed the highest means and differed from 'Renoir' (2.10 kg m⁻²). Despite 'Renoir' has shown inferior performance in previous three characteristics evaluated, it was the cultivar that obtained the lowest discard percentage (22.96%). This result was due to highest tolerance to diseases observed in 'Renoir', since the period in which the experiment was conducted, temperature (average of 24°C) and

Table 1. Total (TFW) and marketable (MFW) fresh weight, marketable yield (MY), plant diameter and height, and discard percentage from three mini lettuce cultivars cultivated in two spacing between plants in experiment 1 (massas de matéria fresca total e comercial por planta, produtividade comercial, diâmetro e altura da planta e porcentagem de descarte de três cultivares de mini alface cultivadas em dois espaçamentos entre plantas no experimento 1). Itatinga, Faz. Sta. Terezinha do Rio Bonito, 2012.

Cultivar	TFW	MFW	MY	Diameter	Height	Discard ¹
	(g plant ⁻¹)	(g plant ⁻¹)	(kg m ⁻²)	(cm)	(cm)	(%)
Tudela	99.44 a	64.63 b	2.44 a	7.19 c	11.44 a	41.18a
Sartre	92.44 a	72.06 a	2.69 a	16.31 a	8.00 c	32.45 b
Renoir	60.06 b	56.00 c	2.10 b	14.19 b	10.75 b	22.96 c
Spacing (cm)						
16x15	76.38 b	59.83 b	2.51 a	12.13 b	10.04 a	34.17 a
20x15	91.58 a	68.63 a	2.31 b	13.00 a	10.08 a	28.68 b
CV (%)	17.34	11.70	12.24	10.33	7.69	7.70

Means followed by same letters do not differ according to Tukey test 5%. ¹Data transformed according to log x (médias seguidas por letras iguais não diferem entre si pelo teste de Tukey 5%). ¹Dados transformados de acordo com log x).

Table 2. Average dry weight (g plant⁻¹) from three mini lettuce cultivars depending on spacing between plants in experiment 1 (massa de matéria seca por planta de três cultivares de mini alface em função do espaçamento entre plantas no experimento 1). Itatinga, Faz. Sta. Terezinha do Rio Bonito, 2012.

Cultivar	Spacing (cm)	
	16x15	20x15
Tudela	3.09 aA	3.48 aA
Sartre	3.44 aA	3.91 aA
Renoir	1.95 bA	1.06 bB
CV (%)	23.11	

Means followed by different lowercase letters in the column, and capital letters in the line, significantly differ according to Tukey test 5% (médias seguidas por letras distintas, minúsculas nas colunas e maiúsculas nas linhas, diferem entre si pelo teste de Tukey 5%).

Table 3. Total (TFW) and marketable (MFW) fresh weight, dry weight (DW), marketable yield (MY), plant diameter and height, and discard percentage from two mini lettuce cultivars cultivated in four planting densities in experiment 2 (massas de matéria fresca total e comercial por planta, produtividade comercial, diâmetro e altura da planta e porcentagem de descarte de duas cultivares de mini alface cultivadas em quatro densidades de plantio no experimento 2). Itatinga, Faz. Sta. Terezinha do Rio Bonito, 2012.

	TFW	MFW	DW	MY	Diameter	Height	Discard ¹
	(g plant ⁻¹)	(g plant ⁻¹)	(g plant ⁻¹)	(kg m ⁻²)	(cm)	(cm)	(%)
Sartre	190 a	146 a	4.30 a	4.32 a	19.4 a	11.1 b	24 a
Renoir	108 b	90 b	3.24 b	2.66 b	18.2 b	11.5 a	18 b
CV (%)	7.3	10.5	13.8	11.3	4.3	3.0	4.0

Means followed by same letters do not differ according to Tukey test 5%. ¹Data transformed according to log x (médias seguidas por letras iguais não diferem entre si pelo teste de Tukey 5%). ¹Dados transformados de acordo com log x).

rainfall (297 mm) were high, conditions that are favorable to fungus diseases development (Pavan & Kurosawa, 2005). These conditions reflected in high infection by *Septoria lactucae* on 'Tudela' and by *Rhizoctonia solani* on

'Sartre'.

Plant diameter was largest for 'Sartre' (16.31 cm). 'Tudela' (7.19 cm) showed the lowest diameter. For plant height, 'Tudela' (11.44 cm) showed the highest mean, and 'Sartre'

(8.00 cm) the lowest (Table 1). These differences in plant characteristics are due to peculiarities of each cultivar, since 'Tudela' is a mini romaine type lettuce, which forms heads taller than the other cultivars.

For dry weight, interaction between cultivars x plant spacing was significant. Cultivars Tudela and Sartre obtained higher means than 'Renoir' in both spacing (Table 2). Only for 'Renoir' dry weight was affected by spacing, with high value for 16 cm between plants.

There was no effect of spacing for plant height (mean of 10.06 cm, Table 1). Spacing between plants of 20 cm (density of 33.33 plants m⁻²) resulted in superior means for total (91.58 g plant⁻¹) and marketable (68.63 g plant⁻¹) fresh weight per plant and plant diameter (13.00 cm), when compared to 16 cm (density of 41.67 plants m⁻²). These results were due to the lesser competition within plants afforded by the largest spacing between plants. On the other hand, marketable yield was superior in spacing of 16 cm (2.51 kg m⁻²), due to the increase in number of plants per area unit. Biomass production is positively correlated to the density. Therefore, high plant densities result in high biomass production (Reghin *et al.*, 2002; Oliveira *et al.*, 2011). However, increasing the density resulted in high discard percentage. This result was due to the higher incidence of diseases on the lower leaves caused by the microclimate

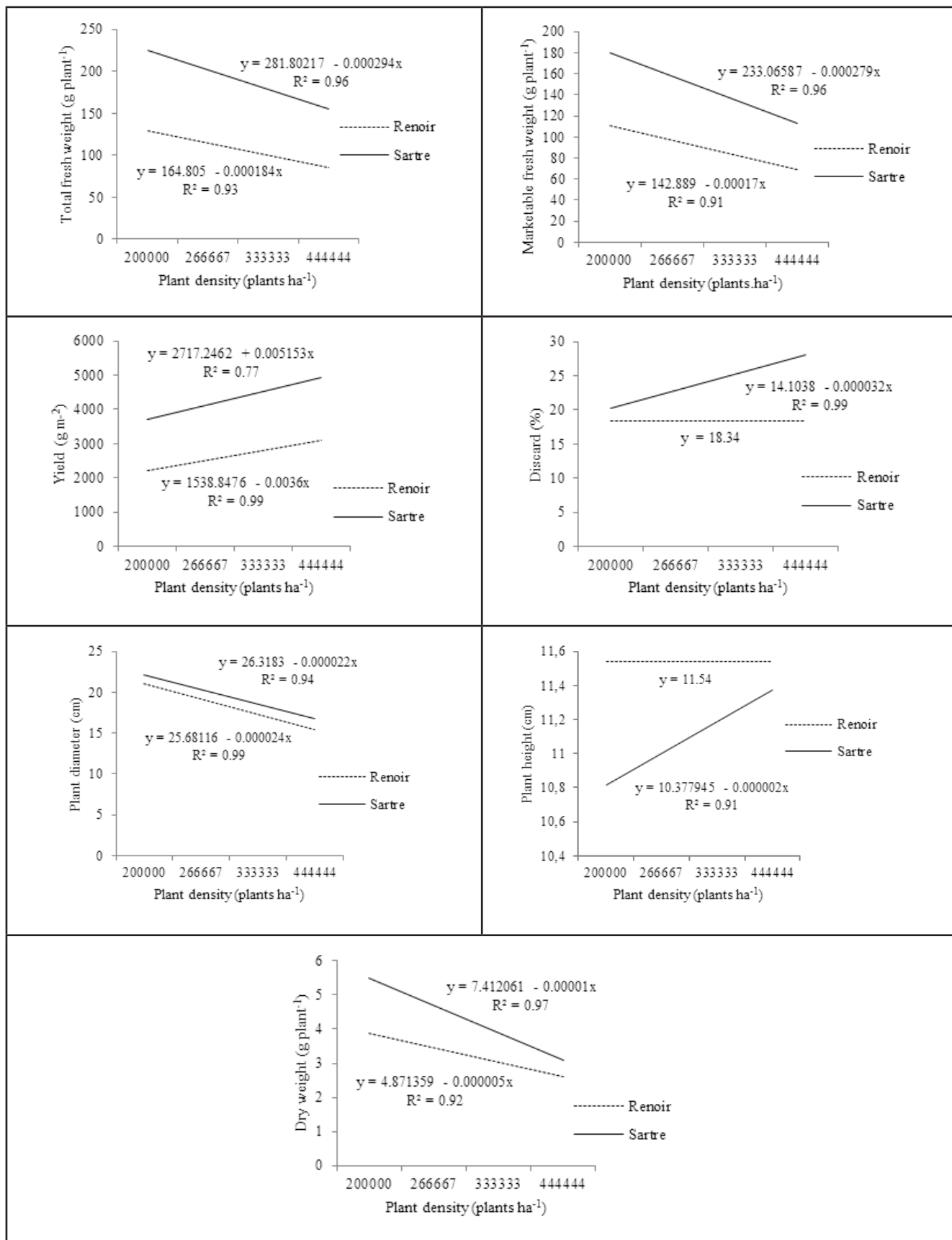


Figure 1. Total and marketable plant fresh weight, marketable yield, discard rate, plant diameter and height and plant dry weight from two mini lettuce cultivars cultivated in four planting densities in experiment 2 (massas de matéria fresca total e comercial por planta, produtividade comercial, diâmetro e altura da planta e porcentagem de descarte de duas cultivares de mini alface cultivadas em quatro densidades de plantio no experimento 2). Itatinga, Faz. Sta. Terezinha do Rio Bonito, 2012.

formed within the plants in closest spacing.

In experiment 2, higher values for total and marketable fresh weight per plant, dry weight, plant diameter and yield were obtained for cultivar Sartre (Table 3), similar to experiment 1, but plant height was higher for 'Renoir', differing from the first experiment. Besides significant, this difference for plant height was very low, only 0.4 cm.

For total and marketable fresh weight a linear reduction with increasing plant density was observed, for both cultivars (Figure 1). The same occurred for dry weight and plant diameter, showing that competition for light, water, space and nutrients affected plant weight and dimensions. According to Schroeder & Janos (2005), higher plant densities increase competition for these factors, affecting plant growth. In general, higher plant densities prejudice plant growth in several vegetables, such as beet (Corrêa *et al.*, 2014), cabbage (Aquino *et al.*, 2005; Silva *et al.*, 2011), in onion (Cardoso & Costa, 1999; Vargas *et al.*, 2007), in radish (Minami *et al.*, 1998) and in rocket (Reghin *et al.*, 2005; Purquerio *et al.*, 2007; Freitas *et al.*, 2009). In normal size lettuce, Mondin *et al.* (1989), Silva *et al.* (2000), Echer *et al.* (2001) and Cecílio Filho *et al.* (2007) related heavier and higher plant diameter in the higher plant spacing. Lima *et al.* (2004) related higher fresh weight the higher the spacing in cultivar Veronica, but not for Vera.

In experiment 2, plant density also did not affect plant height in cultivar Renoir (Figure 1), result also observed by Castoldi *et al.* (2012) in three crisp mini lettuce cultivars. On the other hand, a little but significant increasing in plant height was observed for 'Sartre' the higher the plant density (Figure 2). Moniruzzaman (2006) also observed that for cultivar Green Wave (a normal sized lettuce), plant height increased with the decrease in spacing. Silva *et al.* (2000) also related plant height increase in three normal size lettuce cultivars in the smallest spacing. Closest spacing may cause plant etiolation in some crops due to light competition resulting in tallest plants (Taiz & Zeiger, 2004). However, it seems that for mini lettuce

the response of plant height depends on cultivars.

Even under greenhouse conditions, the cultivar Sartre showed the highest discard percentage (24%), when compared to 'Renoir' (Table 3). The closest spacing resulted in the highest discard percentage for 'Sartre' (Figure 1). Despite water supply was made by drip irrigation, the high plant density associated with high temperatures inside the greenhouse favored disease development mainly on 'Sartre' due to its flat architecture of the leaves. For 'Renoir', plant density did not affect discard rate (average of 18%), probably due to its plant architecture and disease tolerance.

Besides plant diameter and weight decreases in higher plant densities, a linear increasing was obtained for marketable yield in this conditions (Figure 1), showing that reduction in plant characteristics by competition was smaller than the benefit of having more plants in the same area.

According to Janick (1966), increasing in yield due to plant density has a limit. After this, the competition among plants is so high that the decreasing in plant characteristics is not compensated by increasing plant number. In this study, it did not occur.

For the cultivars studied, the highest plant densities demonstrated to be the best option, because a smaller area is necessary to produce the same quantity of marketable product, mainly in protected cultivation where the cost per area is higher. The producers where the experiments were set up commercialize mini lettuce in polystyrene trays with 150 g of cleaned leaves, so, the higher the yield (g m²) the better for them.

Concluding, the plant population of 444,444 plants ha⁻¹ was the best plant density for the studied mini lettuce cultivars.

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