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No-tillage curly lettuce cultivated under different spacings

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ABSTRACT: The use of appropriate cultural practices is important for the sustainability of the production system. This study aims to evaluate the agronomic performance of lettuce cultivar 'Mônica', during two crop cycles, at the Instituto Federal Catarinense, Campus of Concórdia, SC, Brazil. Two experiments were conducted in the field, arranged in randomized block design, in a 3 x 2 factorial scheme, evaluating the effects of three spacings (0.20 × 0.20, 0.25 × 0.25 and 0.30 × 0.30 m), associated with two planting systems (conventional and no-tillage with millet), with four repetitions in the first cycle and five in the second. At 39 and 44 days after transplanting, six plants were harvested in the first and in the second cycles, respectively. Soil temperature, fresh and dry mass of the spontaneous plants, dry mass of roots, plant diameter, number of marketable leaves, fresh and dry mass of the plants were evaluated. Lettuce cultivated under no-tillage at larger spacings resulted in higher yield per plant, but higher yield per area was observed at smaller spacing. No-tillage reduced spontaneous plants and soil temperature in the West of Santa Catarina.

Key words: *Lactuca sativa* L., millet, weeds, yield

Plantio direto de alface crespa cultivada com diferentes espaçamentos

RESUMO: O uso de práticas culturais adequadas é importante para a sustentabilidade do sistema de produção. Este estudo objetiva avaliar o desempenho agronômico da cultivar de alface 'Mônica', durante dois ciclos de cultivo, no Instituto Federal Catarinense, Campus Concórdia, SC. Foram conduzidos dois experimentos no campo, dispostos em blocos casualizados, em esquema fatorial 3 x 2, sendo avaliados os efeitos de três espaçamentos (0,20 × 0,20; 0,25 × 0,25 e 0,30 × 0,30 m), associados a dois sistemas de plantio (convencional e plantio direto com milheto), com quatro repetições no primeiro ciclo e cinco no segundo. Decorridos 39 e 44 dias após o transplante foi feita a colheita de 6 plantas centrais no primeiro e no segundo ciclo, respectivamente. Foram avaliados a temperatura do solo, massa fresca e seca das plantas espontâneas, massa seca das raízes, diâmetro da planta, número de folhas comerciais por planta, massa fresca e seca das plantas. A alface cultivada em plantio direto em espaçamentos maiores obteve maior produtividade por planta, contudo, maior produtividade por área foi observada em menor espaçamento. O plantio direto reduziu as plantas espontâneas e a temperatura do solo no Oeste Catarinense.

Palavras-chave: *Lactuca sativa* L., milheto, plantas espontâneas, produtividade

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Introduction

Lettuce (*Lactuca sativa* L.), Asteraceae family, originated from wild species that can be found in Asian regions of mild climate, is the leafy vegetable most consumed fresh in the form of salad (Santos et al., 2015). In 2017, this vegetable was grown in 108,603 properties, with a production of 908,186 t in Brazil. Its production was equal to 18,976 t in the state of Santa Catarina and of 650 t in the municipality of Concórdia, SC (IBGE, 2018).

Techniques of conventional soil tillage, which consist in the intensive turning, breaking soil aggregates and with the absence of cover, have caused large losses of soil and water through erosive processes (Almeida, 2016). However, the use of adequate cultural practices in a sustainable agricultural production system, based on the preservation of soil, environment and mankind, is extremely important to produce healthy foods (Girardello et al., 2017).

The adoption of cover crop on the soil protects it from the direct action of sunlight, reducing its temperature and evaporation, keeping it wetter and protected from wind action. Soil cover also assists in weed control (Henz et al., 2007). Straw decomposition promotes incorporation of organic matter into the soil, necessary for greater and richer microbial activity, which enables greater nutrient recycling.

Increase of density and consequent reduction in spacing can cause a decrease in yield, because there are more plants competing for water, light and nutrients within the same physical space (Zanine & Santos, 2004).

In view of the above, this study was conducted to evaluate the agronomic performance of lettuce crop, cultivar 'Mônica', in two planting systems, one of which is no-tillage and the other is conventional with different spacings between plants, along two cycles, in the municipality of Concórdia in western Santa Catarina state, Brazil.

Material and Methods

Two experiments were carried out at Instituto Federal Catarinense, in the municipality of Concórdia, SC, Brazil, besides the Highway SC 283 km 17, with the following geographic coordinates 27° 12' 8.5" S and 52° 5' 8.1" W, at altitude of 596 m. The climate, according to the Köppen's classification, is predominantly subtropical humid (Cfa), with an average annual temperature of 18.8 °C and mean annual rainfall of 1937.2 mm.

The soil of the experimental area was classified as Rhodic Khandiudox of clay texture, showing on average 53% of clay. In the experimental area, the chemical characteristics were: pH in water of 5.3; organic matter of 3.5%; SMP index of 6.1; P and K contents of 15.9 and 220.0 mg dm^{-3}; and Al^{3+}; Ca^{2+} and Mg^{2+} contents of 0.2, 5.7 and 2.9 cmol dm^{-3}, respectively. Liming was carried out 70 days before transplanting the seedlings, by applying 3.8 t ha^{-1} of dolomitic limestone (RNV of 70%) broadcast, with subsequent incorporation in the 0-0.20 m layer. To facilitate the preparation of the beds, the area was subsoiled twice with a seven-shank subsoiler and harrowed once with a 24-disc harrow to systematize the terrain, and the beds were made with a rotary hoe, coupled to an agricultural tractor.

Along the experimental period, in the first cycle, the minimum and maximum air temperatures recorded were 5.0 and 31.5 °C, respectively, with rainfall of 192 mm in the period. In the second cycle, the minimum and maximum air temperatures were 12.0 and 34.5 °C, respectively, and the rainfall in the period was 113 mm. Data of temperature and rainfall were obtained at the Meteorological Station of Embrapa Suínos e Aves, 20 km away from the experimental area.

The experiment was conducted in a randomized block design, in a 3 x 2 factorial scheme, evaluating the effects of three spacings (0.20 x 0.20; 0.25 x 0.25 and 0.30 x 0.30 m), associated with two planting systems (conventional and no-tillage), with four replicates in the first cycle, totaling 24 plots, and five replicates in the second cycle, totaling 30 plots.

Soil cover (no-tillage system) was made with 25 kg of seed ha^{-1} of millet (*Pennisetum americanum*), which was sown broadcast on December 27, 2016. On December 21, 2017, at the vegetative stage of millet, preceding desiccation, 0.25 m^2 of material was collected in each plot in order to measure fresh and dry mass weights using a digital precision scale and a forced air circulation oven at 65 °C, obtaining yields of 80,560 kg ha^{-1} of fresh mass and 9,341 kg ha^{-1} of dry mass in the first cycle. In the second cycle, the yields were 69,400 and 7,752 kg ha^{-1} for fresh and dry mass, respectively.

Manual desiccation at the vegetative stage was carried out with glyphosate, using 1,440 g ha^{-1} of active ingredient. In the beds without soil cover (conventional cultivation system), millet was manually uprooted on the same day that desiccation was carried out.

The desiccated millet plants that remained standing up at the time of lettuce transplantation were accommodated on the soil to facilitate planting. However, excess straw hampered the establishment of lettuce seedlings in the first cycle.

The fertilization used consisted of 140 kg ha^{-1} of N, 80 kg ha^{-1} of P_2O_5 and 120 kg ha^{-1} of K_2O according to the recommendations of CQFS (2016). On the day before transplanting the seedlings, 20 kg ha^{-1} of N and 80 kg ha^{-1} of P_2O_5 were applied. At 10, 20 and 30 days after transplantation, top-dressing fertilization was performed with 20, 35 and 45%, respectively, of the remainder of N (120 kg ha^{-1}) and the total K_2O recommended (120 kg ha^{-1}). The sources used for supplying N, P_2O_5 and K_2O were urea, triple superphosphate and potassium chloride, respectively.

Commercial beds of 1.2 m width and 20 m length (24 m^2), with 0.30 m distance between beds for cultural practices, were considered to measure the number of plants. On one hectare, there are 328 beds of 24 m^2, which totals an area of 7,872 m^2. At the spacings of 0.20 x 0.20, 0.25 x 0.25 and 0.30 x 0.30 m, the obtained populations were 196,800, 125,952 and 87,248 plants ha^{-1}, respectively.

The leaf lettuce cultivar 'Mônica' was used. Seedlings were produced with organic plant substrate in 128-cell expanded polystyrene trays and transplanted at 28 days of age to the experimental units. Transplanting was carried out at 36 and 38 days after desiccation in the first and second cycles, respectively, in four lettuce rows with seven plants each, totaling 28 plants, harvesting the six central plants.

Spontaneous plants were evaluated at 21 and 30 days after transplanting in the first and second cycles, respectively, using a wooden square of 40 x 40 cm placed on the beds twice, totaling a sampled area of 0.32 m^2. One collection was made to measure the weight of the fresh and dry mass of spontaneous plants, using a digital scale, with accuracy of 0.05 g. Dry mass was obtained after the material was dried in a forced air circulation oven at 65 °C until constant weight. The fresh (FMSP) and dry masses (DMSP) of spontaneous plants were measured considering 20 m long, 1.2 m wide beds and 0.30 m distance between beds for cultural practices, obtaining an area of 7,872 m^2 ha^{-1}. After evaluation, all plots were manually weeded.

At 34 and 35 days after transplanting in the first cycle and at 38 and 39 days in the second cycle, soil temperatures (°C) were measured in all plots using two digital thermometers, in the 0-5 cm layer at 13h 00min.

The diameter (mm) of plants (PD) was measured one day before harvest in both cycles, measuring from one end to the other, in centimeters, with an industrial caliper of 300 mm.

Six plants were collected on May 6, 2017, at 39 days after transplanting in the first cycle, and on March 10, 2018, at 44 days after transplanting in the second cycle. These plants were carefully uprooted with a gardening shovel, in such a way to preserve as much as possible the integrity of the root system, which was separated from the aerial part using a knife, in the collar region of the plant.

The following agronomic characteristics were evaluated in both cycles: marketable fresh mass (MFM) in g $plant^{-1}$, obtained by dividing the total mass by the number of plants (6) in the experimental unit, using a digital precision scale; and number of leaves (NL) per plant, considering those longer than 3 cm.

Shoot dry mass (SDM) and root dry mass (RDM), in g $plant^{-1}$, were determined after drying in a forced air circulation oven at 65 °C until reaching constant weight, using a digital scale with accuracy of 0.05 g. SDM and RDM per plant were measured by drying all plants evaluated per plot (6) and dividing the result by the same number of plants. MFM and SDM were quantified per hectare, considering the weight per plant, multiplied by the number of plants in the area.

The data were subjected to descriptive statistical analysis to evaluate frequency distribution pattern and detect outliers. The analyses were carried out using R software, with the aid of the packages Agricolae, version 1.2-8, and ExpDes.pt, version 1.2.0. After testing the normality of residuals by the Shapiro-Wilk test, analysis of variance was carried out and the means were compared by Tukey test ($p \leq 0.05$) (Gomes, 1990).

Results and Discussion

In the analysis of distribution of residuals, the data showed normality in terms of their distribution, as well as an adequate coefficient of variation for field experiments, except for FMSP and DMSP, which tend to have higher CVs because of their characteristics of evaluation. In the first cycle, the planting system had significant effect by F test on all variables studied, whereas for planting spacing, only the FMSP was not significantly affected (Table 1).

In the second cycle, according to the summary of the analysis of variance, there were significant differences in the sources of variation system and spacing for FMSP, DMSP, RDM, PD, NML, PFM and PDM, except for soil temperature (Ts), which was not significantly affected by the spacings used. For the interaction between system and spacing (St x Sp), according to the F test, there was no significance for Ts in the first cycle and for Ts and NML in the second cycle (Table 1).

The no-tillage system was efficient in maintaining soil temperature at 5 cm, with values between 17 and 18 °C, regardless of the spacing used. Conversely, in the conventional planting, temperatures ranged from 20.43 to 21.10 °C, with higher values as the spacing between plants increased in the first crop cycle (Table 2). In the second cycle, the no-tillage system was also more efficient in reducing soil temperature compared to the conventional system. Soil temperature was not influenced by the plant spacing in the second cycle.

Torres et al. (2006), studying soil cover in the municipality of Uberaba, MG, Brazil, found temperatures of 27.5, 25.6 and 24.2 °C in an area with remaining millet straw under soybean cultivation in January, February and March, respectively. The measurements were taken by the authors at 14h 30min, at 5 cm depth. The temperatures observed by these authors in conventional planting without cover in the same period, time and depth were 29.3, 26.3 and 24.5 °C. The data of this study show a slight increase of temperature in the conventional

Table 1. Summary of the analysis of variance, for both cycles, of soil temperature (Ts), fresh mass of spontaneous plants (FMSP), dry mass of spontaneous plants (DMSP), root dry mass (RDM), plant diameter (PD), number of marketable leaves (NML), plant fresh mass (PFM) and plant dry mass (PDM)

Source of variation#	Calculated F								
	DF	Ts	FMSP	DMSP	RDM	PD	NML	PFM	PDM
					First cycle				
B	3	9.36*	0.76ns	0.49ns	0.85ns	3.93*	0.49ns	1.16ns	1.14ns
Sys	1	1,412.39*	387.12*	332.57*	30.80*	34.42*	556.64*	877.63*	741.16*
Sp	2	6.68*	8.55ns	8.20*	77.56*	225.10*	215.68*	485.10*	467.17*
Sys x Sp	2	5.96*	8.55ns	8.20*	14.93*	30.395*	45.14*	97.50*	90.10*
CV (%)		1.72	34.83	37.17	4.74	3.00	2.30	3.90	4.08
					Second cycle				
B	4	0.82ns	1.6ns	1.79ns	6.46ns	2.55ns	1.30ns	3.70*	2.34ns
Sys	1	1,037.73*	65.26*	80.08*	78.38*	14.21*	121.62*	150.43*	172.49*
Sp	2	2.16ns	6.12*	3.87*	69.38*	149.03*	20.48*	114.90*	116.19*
Sys x Sp	2	2.16ns	6.12*	3.87*	19.11*	5.73*	22.94ns	3.70*	5.89*
CV (%)		1.88	67.80	61.21	4.89	2.51	4.2	3.81	4.12

B - Block; Sys - System; Sp - Spacing; ns - Not significant, * - Significant at $p \leq 0.05$ by F test

Table 2. Soil temperature, for both cycles, in both planting systems (conventional and no-tillage), considering the plant spacings

Spacing (cm)	Soil temperature (ºC)	
	Conventional	No-tillage
	First cycle	
20 × 20	20.43 Ab	17.96 Ba
25 × 25	20.71 Ab	17.96 Ba
30 × 30	21.10 Aa	17.98 Ba
	Second cycle	
20 × 20	29.31 Aa	23.88 Ba
25 × 25	30.11 Aa	23.79 Ba
30 × 30	30.09 Aa	23.98 Ba

Means followed by the same lowercase letter in the column (spacings, for each planting system) and means followed by the same uppercase letter in the row (planting systems) do not differ by Tukey test ($p \leq 0.05$)

system, compared to the system with soil cover. These data corroborate the results found in the present study.

Gasparim et al. (2005), evaluating the temperature at 5 cm depth, obtained value of 28.1 ºC in uncovered soil, whereas in soil with two densities of black oat dry mass, 4,000 and 8,000 kg ha^{-1}, the temperatures reached 26.2 and 26.1 ºC, respectively. These data confirm the increase of temperature in the soil without vegetation cover.

The mass of spontaneous plants clearly demonstrates that the presence of straw in the no-tillage system was efficient in controlling the emergence of spontaneous plants (Table 3). For the conventional system in the first cycle, there were on average 6.0, 7.0 and 8.0 spontaneous plants, with average fresh mass of 107.99, 150.80 and 182.52 kg ha^{-1} at the spacings of 20 x 20, 25 x 25 and 30 x 30 cm, respectively. In the second cycle, the number of spontaneous plants was on average 5.0, 4.0 and 6.0 at the spacings of 20 x 20, 25 x 25 and 30 x 30 cm, with average fresh mass of 630.99, 482.65 and 1,365.79 kg ha^{-1}, respectively, with statistical difference for the spacing of 30 cm between plants. It is evident that the fresh mass of spontaneous plants increases as the spacing increases from 20 x 20 cm to 30 x 30 cm.

In an experiment analyzing the influence of several soil covers on lettuce cultivation, Carvalho et al. (2005) found that the covers were effective in controlling weeds and observed the lowest lettuce yield in the treatments with uncovered soil, which may be attributed to the significant competition with weeds.

The effects promoted by millet straw in this study coincide with the results found by Hirata et al. (2014), who obtained excellent responses with virtually total control of weeds by the straw of millet (*P. glaucum*).

In a study conducted in Eldorado do Sul, RS, Brazil, Trezzi & Vidal (2004) reported that the common millet ‘RS’ had 96% efficiency in the control of *Brachiaria plantaginea* infestation. Due to its fast growth and high biomass production, millet is competitive in the reduction of weeds.

Reghin et al. (2002), evaluating the dry mass of spontaneous plants in bare soil under lettuce cultivation, found, in 0.25 m^2, values above 10 g, which are higher than those of the present study. These authors used 30 x 30 cm spacing between plants.

According to Silva et al. (2017), the formation of cover (straw) protects the soil from the impacts of raindrops, maintains it wetter, increases porosity, reduces weed infestation, contributes to organic matter content and improves soil microbial activity.

In the first cycle, there was no significant difference between the cultivation systems for root dry mass, except in the conventional system, at the spacing of 20 x 20 cm, with an average of 0.53 g, a value lower than the others (Table 4). With regard to spacing in the no-tillage system, the root system showed no statistical difference, whereas in the conventional system, the largest spacing promoted higher dry mass of the root system, 0.66 g.

In the second cycle, the results referring to root dry mass were statistically higher in the conventional system. As for the spacings, the means ranged from 0.89 g at 20 x 20 cm up to 1.25 g at the 30 x 30 cm spacing between plants, in the conventional system. In the no-tillage system, the means were 0.81 to 0.94 g also in the respective spacings of 20 x 20 and 30 x 30 cm. As for the spacings, in the conventional system, there was an increase in root dry mass as the spacings increased, and the three spacings showed different masses. It was also found that, in the no-tillage system, the largest spacings between plants led to an increase in root system dry mass.

Santos et al. (2016) found similar results in the lettuce crop cultivated in the field, with several water depths and different types of fertilizer. The authors, evaluating three different water depths, obtained results of 0.8, 1.2 and 2.4 g root^{-1}, which are proportional to the increase in shoot fresh mass.

Plant diameter in the first cycle was higher in the conventional system and at the spacing of 30 x 30 cm (29.09 cm), while for the other spacings, the no-tillage system is superior

Table 3. Fresh (FMSP) and dry mass of spontaneous plants (DMSP), for both cycles, in the different systems and planting spacings

Spacing (cm)	FMSP (kg ha^{-1})		DMSP (kg ha^{-1})	
	Conventional	No-tillage	Conventional	No-tillage
	First cycle			
20 × 20	107.99 c	0	10.82 c	0
25 × 25	150.80 b	0	13.53 b	0
30 × 30	182.52 a	0	18.45 a	0
	Second cycle			
20 × 20	630.99 b	0	101.60 b	0
25 × 25	482.65 b	0	79.70 b	0
30 × 30	1,365.79 a	0	164.33 a	0

Means followed by the same lowercase letter in the column do not differ by Tukey test ($p \leq 0.05$)

Table 4. Root dry mass, for both cycles, in both planting systems (conventional and no-tillage), considering the plant spacings

Spacing (cm)	Systems	
	Conventional	No-tillage
	Root dry mass (g)	
	First cycle	
20 × 20	0.53 Bb	0.61 Aa
25 × 25	0.58 Ab	0.62 Aa
30 × 30	0.66 Aa	0.66 Aa
	Second cycle	
20 × 20	0.89 Ac	0.81 Bb
25 × 25	0.98 Ab	0.90 Ba
30 × 30	1.25 Aa	0.94 Ba

Means followed by the same lowercase letter in the column (spacings, for each planting system) and means followed by the same uppercase letter in the row (planting systems, for each spacing used) do not differ by Tukey test ($p \leq 0.05$)

(Table 5). In relation to spacings, the three differed significantly in the conventional system, with the largest diameter for 30 x 30 cm (29.09 cm), intermediate diameter for 25 x 25 cm (24.79 cm) and the smallest diameter at the spacing of 20 x 20 cm (22.88 cm). In the no-tillage system, the largest plant diameters were observed at the spacings of 25 x 25 and 30 x 30 cm, with mean values of 27.94 and 28.36 cm, respectively, while the smallest diameter was observed at the spacing of 20 x 20 cm (24.09 cm). These results are lower than those found by Nespoli et al. (2017) with the lettuce cultivar 'TE 112', whose diameter was 35.6 cm under no-tillage system with millet and 33.1 cm under conventional planting, at the spacing 30 x 30 cm between plants. The larger plant diameter found by the authors may be related to the environmental conditions of the region of Cáceres, MT, Brazil.

The largest spacings were the ones that led to largest diameters of lettuce plants in the experiment conducted by Silva et al. (2000), who obtained values of 27.31 cm at the spacing between plants of 20 x 20 cm and 30.88 cm at the spacing of 30 x 30 cm, which demonstrate lower competition between plants at larger spacings.

In the second production cycle, there were no statistical differences between the planting systems under study in relation to the average plant diameter (Table 5). For the spacing, the values ranged from 27.33 to 32.01 cm for 20 x 20 and 30 x 30 cm, respectively, in the no-tillage system. However, in the second cycle, in the conventional system, statistical difference was only observed at the smallest spacing, with a mean of 27.36 cm. At the spacings of 25 x 25 and 30 x 30 cm, the values were statistically similar, with means of 30.84 and 34.29 cm, respectively.

Ferreira et al. (2013), evaluating several lettuce cultivars under field conditions, working with spacings between plants of 35 x 35 cm, obtained similar results of plant diameter, with no statistical difference between the cultivars evaluated, with means ranging from 24.33 to 31.00 cm. This experiment was conducted under the environmental conditions of Areia, PB, Brazil.

Regarding the number of marketable leaves (Table 5), in the first cycle there was greater number of leaves in the no-tillage system, compared to the conventional system, at all plant spacings, with an average number of leaves ranging from 11.90 to 16.58 leaves. Among the spacings, 30 x 30 cm led to the highest average in both systems, 16.58 leaves for the no-tillage system and 15.50 leaves for the conventional system. In the conventional system, it was possible to identify that all spacings were different, with increase in the number of marketable leaves as plant spacing increased.

Table 5. Plant diameter and number of marketable leaves (un), for both cycles, in both planting systems and different spacings

Spacing (cm)	Plant diameter (cm)		Number of marketable leaves (un)	
	Conventional	No-tillage	Conventional	No-tillage
	First cycle			
20 × 20	22.88 Bc	24.09 Ab	11.90 Bc	15.25 Ab
25 × 25	24.79 Bb	27.94 Aa	13.06 Bb	15.65 Ab
30 × 30	29.09 Aa	28.36 Ba	15.50 Ba	16.58 Aa
	Second cycle			
20 × 20	27.36 Ab	27.33 Ac	19.13 Ab	22.33 Ab
25 × 25	30.84 Aa	31.76 Ab	19.97 Aab	23.00 Ab
30 × 30	34.29 Aa	32.01 Aa	20.87 Aa	25.70 Aa

Means followed by the same lowercase letter in the column (spacings, for each planting system) and means followed by the same uppercase letter in the row (planting systems) do not differ by Tukey test (p ≤ 0.05)

In the second cycle, the number of marketable leaves was statistically the same in both cultivation systems. As for the plant spacings, the largest distance between plants (30 x 30 cm) promoted greater number of marketable leaves: 25.70 leaves in the no-tillage system and 20.87 leaves in the conventional system.

The results for the mean number of leaves of 10.94 plant^{-1} obtained by Medeiros (2015) are lower than those found in the present study. The author obtained 11.50 leaves plant^{-1} at the largest spacing of 30 x 30 cm and 10.41 leaves plant^{-1} at the reduced spacing of 15 x 15 cm, confirming that larger spacings promote less competition between plants, with tendency to produce a greater amount of leaves per plant (Table 5).

Carvalho et al. (2005), in a study evaluating several soil covers (rice straw, coffee straw, *Brachiaria brizantha* L., sawdust, control without mulch), found that control plants showed an average number of 21 leaves plant^{-1}, which was the lowest result, considerably below those obtained in the other treatments, which oscillated between 35 and 40 leaves plant^{-1}. According to the authors, the lowest number of leaves in the control may be attributed to the competition with weeds.

In both cycles, the values of fresh and dry mass were higher in the no-tillage system than in the conventional system (Table 6). There was also an increase in the fresh and dry mass of the plants, in g plant^{-1}, in both cycles as the distance between plants increased from 20 x 20 to 30 x 30 cm. Rodrigues et al. (2008) evaluated eight lettuce cultivars under the climatic conditions for field cultivation in the region of Manaus, Brazil, and obtained average values much lower than those of the present study for total fresh mass, 70.86 plant^{-1}.

The results found in this study, in the first cycle, are similar to those observed in Cáceres, MT, Brazil, by Nespoli et al.

Table 6. Fresh and dry mass of lettuce plants for both cycles and planting systems (conventional and no-tillage) and spacings

Spacing (cm)	Systems			
	Conventional	No-tillage	Conventional	No-tillage
	First cycle			
	Fresh mass (g plant^{-1})		Fresh mass (kg ha^{-1})	
20 × 20	99.78 Bc	184.88 Ac	19,636 Ba	36,384 Aa
25 × 25	140.13 Bb	197.27 Ab	17,649 Bb	24,846 Ab
30 × 30	197.50 Ba	216.45 Aa	17,232 Bb	18,884 Ac
	Dry mass (g plant^{-1})		Dry mass (kg ha^{-1})	
20 × 20	4.77 Bc	8.65 Ac	938 Ba	1,701 Aa
25 × 25	6.67 Bb	9.29 Ab	840 Bb	1,170 Ab
30 × 30	9.38 Ba	10.44 Aa	818 Bb	911 Ac
	Second cycle			
	Fresh mass (g plant^{-1})		Fresh mass (kg ha^{-1})	
20 × 20	226.33 Bc	261.03 Ac	44,541 Ba	51,370 Aa
25 × 25	256.38 Bb	304.22 Ab	32,291 Bb	38,317 Ab
30 × 30	285.60 Ba	346.22 Aa	24,918 Bc	30,207 Ac
	Dry mass (g plant^{-1})		Dry mass (kg ha^{-1})	
20 × 20	12.30 Bc	14.64 Ac	2,421 Ba	2,881 Aa
25 × 25	13.92 Bb	16.61 Ab	1,754 Bb	2,092 Ab
30 × 30	15.72 Ba	19.91 Aa	1,371 Bc	1,737 Ac

Means followed by the same lowercase letter in the column (spacings, for each planting system) and means followed by the same uppercase letter in the row (planting and spacing systems used) do not differ from each other by the Tukey test (p ≤ 0.05)

(2017), who obtained marketable fresh mass of 188.4 g plant^{-1} in the conventional planting of leaf lettuce cultivated at spacing of 30 x 30 cm; conversely, in the no-tillage with millet mulch, the data found were lower, 178.4 g plant^{-1}.

Vasconcelos et al. (2017), using different spacings in the cultivation of lettuce, cultivar 'Vera', obtained 187.60 g plant^{-1} at the spacing 20 x 20 cm and 195.16 g plant^{-1} at the spacing of 25 x 25 cm, in a study conducted in the field under the environmental conditions of Pombal, PB, Brazil.

The results found in the present study, in the second cycle, are consistent with those found in Ribeirão Preto, SP, for the lettuce cultivar 'Verônica', which produced fresh mass of 302.29 g plant^{-1} at the spacing between plants of 20 x 30 cm, whereas at the spacing of 20 x 20 cm, the fresh mass was 236.15 g plant^{-1} (Lima et al., 2004).

Meneses et al. (2016), working with different polyethylene and plant covers, found significant increases in the fresh mass of the leaf lettuce cultivar 'Vera', when compared to the uncovered soil. The authors obtained total fresh mass of 232.40 g plant^{-1} in uncovered soil and 334.80 g plant^{-1} in soil with vegetation cover, data that are similar to those found in the second cycle of the present study. Lower yield of lettuce in the uncovered soil may be attributed to the competition for water, light and nutrients exerted by the invasive plants, which were not adequately suppressed in the area.

Increased lettuce yield with the use of soil cover was also observed by Machado et al. (2008), in a study conducted in Várzea Grande, MT, Brazil, with seven different covers (rice husk, Brachiaria grass, sawdust, elephant grass, corn straw, *decumbens* grass, cut grass) and a control without cover.

Lima et al. (2004), in a study with spacings of 20 x 20 and 20 x 30 cm, using the cultivar 'Verônica', obtained greater dry mass per plant at the largest spacing under the environmental conditions of Ribeirão Preto, SP, Brazil.

The dry mass corresponds to about 5% of the fresh mass of the plants. The results found in both cycles are close to those available in the TACO UNICAMP/NEPA Table (Lima, 2011), which indicates 96.1% moisture in fresh leaf lettuce consumed in salads.

It was observed in the first cycle that the values of fresh and dry mass per hectare in no-tillage are higher than those in the conventional system. There was also a reduction in yield per area with the decrease in plant stand per hectare as the spacing increased from 20 x 20 to 30 x 30 cm, resulting in lower production of total fresh and dry mass per hectare, regardless of the planting system (Table 6). With regard to the fresh mass per hectare, it was found that the increase in spacing from 20 x 20 to 30 x 30 cm resulted in reductions of 17.5 t ha^{-1} in the first cycle and 19.6 t ha^{-1} in the second cycle in the no-tillage system, whereas in the conventional system, an increase in spacing from 20 x 20 to 30 x 30 cm resulted in reductions of 2.4 and 21.1 t ha^{-1} in the production in the first and second cycles, respectively.

In an experiment conducted by Lima et al. (2004), with interaction of spacing for each cultivar, it was found that the largest spacing (20 x 30 cm) promoted greater shoot fresh mass per plant in the cultivar 'Verônica'. According to Echer et al. (2001), higher planting density is more advantageous because it leads to higher yield per unit area, with plants exhibiting commercial standard, and may be advantageous for the producer.

Silva et al. (2000) conducted a study in Mossoró, RN, Brazil, with the iceberg lettuce cultivar 'Great Lakes', and obtained lower yields compared to the second cycle of the present study: 31.25 t ha^{-1} at the spacing of 20 x 20 cm, 21.60 t ha^{-1} at the spacing of 25 x 25 cm and 21.72 t ha^{-1} at the spacing of 30 x 30 cm. The reduction in yield may be associated with the weather in the period of planting (June to July) and with the fact that the study was conducted in the field under the conditions of Mossoró, RN, Brazil.

In the study conducted by Carvalho et al. (2005), with the lettuce cultivar 'Regina 2000', the dry mass data were higher under no-tillage, and *Brachiaria brizantha L.* grass proved to be efficient in comparison to the control without soil cover. According to the authors, the lower yield of lettuce in uncovered soil may be related to the high infestation of weeds, creating competition. Dry mass accumulation followed a trend similar to that of fresh mass accumulation, with the lowest average data found at the largest spacings between plants.

Conclusions

1. Increase in lettuce planting density results in higher yield per hectare, although with lower average mass per plant.
2. The use of no-tillage system increases lettuce yield when compared to the conventional system.
3. The use of cover crops prior to lettuce cultivation reduces the emergence of spontaneous plants.

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