

Agronomic and economic viability of intercropping onion and lettuce

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ABSTRACT

The study aimed to evaluate the agronomic and economic performance of intercropping onion and lettuce on four plant densities of each species. The experiment was set up in completely randomized blocks, with four replications and treatments arranged in a 4 x 4 factorial. Treatments resulted from a combination of four (100, 80, 60, and 40% of recommended plant densities in monoculture) plant densities for both lettuce and onion. Intercropping did not affect the agronomic performance of onion or lettuce. Higher plant densities (100% for both vegetables) resulted in higher lettuce and onion yields. The best economic results were observed using (a) onion at 80% of plant density combined with lettuce at 40 and 100% and (b) onion at 100% and lettuce at all densities (40 to 100%).

Keywords: *Lactuca sativa*, *Allium cepa*, crop association, cropping systems, plant density.

RESUMO

Viabilidade agroeconômica do cultivo consorciado de cebola e alface

O trabalho teve como objetivos avaliar o desempenho agro-econômico do consórcio de cebola e alface em quatro densidades populacionais de cada espécie. O delineamento experimental foi blocos casualizados, com quatro repetições, sendo os tratamentos arranjados em esquema fatorial 4 x 4. Os tratamentos resultaram da combinação de quatro populações (100, 80, 60 e 40% das populações recomendadas nos cultivos solteiros) tanto de alface, quanto de cebola. O consórcio não afetou o desempenho agrônomo da cebola, tampouco o da alface, e a densidade populacional de 100% para ambas as hortaliças propiciou maior produtividade de cebola e de alface. Do ponto de vista econômico, os melhores resultados foram observados nos consórcios (a) cebola a 80% da densidade de plantas em consórcio com alface a 40 e 100% e (b) cebola a 100% com alface em qualquer densidade (40 a 100%).

Palavras-chave: *Lactuca sativa*, *Allium cepa*, associação de culturas, sistemas de cultivo, densidade populacional.

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In Brazil, onion is the fourth most important vegetable crop in economic value, overcame only by potatoes, tomatoes, and watermelon (IBGE, 2009). Onion is commonly used *in natura* in salads or cooked as spices and condiments (Boeing, 2002). Lettuce, in its turn, is the leading leafy vegetable in consumer acceptance within the country, has high vitamin and mineral contents and, low content of mostly easy digestible calories. Brazilian domestic lettuce production reached 525,602 tons in 2006, 70% coming from the Southeast region (IBGE, 2009).

Information from EMATER-MG (Corporation for Rural Extension and Technical Assistance of the state of Minas Gerais) showed that lettuce and onions are amongst the foremost vegetables grown by small holders in the North of Minas Gerais state. Many of these farmers grow vegetables for subsistence and income increase. However, these farmers have many worries, such as limited cropping area

and lack of capital. Thus, intercropping becomes an alternative to diversify the diet and increase yields and profits. By raising incomes, intercropping contributes to the maintenance of the farm, preventing rural exodus. It should be stressed also that intercropping is a more sustainable agricultural system than monoculture. Onion has a long cycle for vegetable standards, slow until 80 days after sowing, and an upright growth habit. These characteristics are positive indications that it might intercrop well and profitably with vegetables with shorter cycles, such as lettuce.

Intercropping is an agricultural system in which two or more species coexist in the same area for a given period of time. The major challenge for establishing a successful intercropping system lies in determining which species to use (Rao *et al.*, 2006). Intercropping is an easy to implement technology that influences crop productivity and leads to numerous benefits, for

example, increased yields and profits per area (Montezano & Peil, 2006). Intercropping concurs also to reduce the environmental impact of vegetable production (Cecil Son *et al.*, 2007). Oliveira *et al.* (2005) observed better use of the available environmental factors in intercropping lettuce and coriander over the monoculture. Salt *et al.* (2006) confirmed the viability of the intercropping systems lettuce/carrot and lettuce/radish in organic farming. The intercropping lettuce/cucumber and radish/tomato were also proven to be viable (Rao *et al.*, 2005; Cecílio Filho *et al.*, 2007; Silva *et al.*, 2008).

This study aimed to evaluate the agronomic and economic performance of intercropping onion and lettuce in four plant densities for each species.

MATERIAL AND METHODS

The experiment was carried out at the State University of Montes Claros

(UNIMONTES), *Campus* of Janaúba (15°47'18"S, 43°18'18" W, 515 m over sea level). Janaúba is in the Brazilian semi-arid region, with an Aw climate (Tropical Savanna), according to the Köppen classification (Jacomine *et al.*, 1979). The average annual rainfall is 740 mm, with showers from November to March. The average maximum and minimum temperatures are 32 and 19.5°C, respectively (Souto, 1998). We set up the experiment in a sandy Fluvic Entisol. Chemical analysis indicated the following characteristics on the top soil layer (0-20 cm): pH (CaCl₂)= 6.8; P= 80.6 mg resin dm⁻³; organic matter = 2.6 g dm⁻³; V= 80%, and values for H + Al, K, Ca, Mg, SB, CEC, expressed in mmol dm⁻³ of 1.0, 0.22, 2.6, 1.0, 3.9, and 4.9, respectively. Soil physical characteristics were 840, 40, and 120 g kg⁻¹ of sand, clay, and silt, respectively.

We studied the following plant densities: 100 (100%), 80 (80%), 60 (60%), and 40 (40%) plants m² for onion and 25 (100%), 20 (80%), 15 (60%), and 10 (40%) plants m² for lettuce. The highest densities (100%) were in agreement to Filgueira's (2000) recommendation for both species as monocultures. We designed the experiment in randomized blocks, with treatments in a 4 x 4 factorial, in four replications. Each plot (1.20 m²) consisted of five lettuce rows interspersed with four onion rows, the two outer rows of each species functioning as borders. Therefore, the plot working area corresponded to the three and two central rows of lettuce and onion, respectively. Lettuce planting distances (between x within rows) were 20x20, 20x25, 20x30, and 20x40cm, while onion's were 20x5, 20x6, 20x8, and 20x12cm.

We fertilized the soil using cattle manure (10 t ha⁻¹), superphosphate (278 kg ha⁻¹), potassium chloride (86 kg ha⁻¹), and ammonium sulfate (273 kg ha⁻¹), the latter in three split applications, according to the interpretation of the soil analysis (Ribeiro *et al.*, 1999).

On May 19, 2008, we sow the lettuce, cultivar Grand Rapids TBR, in 128-cell polystyrene trays, filled with the substrate Plantmax[®]. Seedlings were transferred to beds, in the field, 19 days later. We sow the onion, cultivar Texas Early Grano 502 PRR, directly in the field beds, 20 days before transplanting lettuce. The cropping practices were the usual for both crops.

Onions were harvested 115 days after sowing, when 80% of the plants presented leaves flopping over (Finger & Casali, 2002). Lettuce was harvested when plants reached the peak of vegetative growth, with marketable, compact and well-formed heads (Yuri, 2004).

At harvest, we took five lettuce plants at random from the plot working area and assessed: (a) plant height in cm, measured from ground level to the tip of the longest leaf; (b) plant diameter in cm, corresponding to the distance between the opposite edges of the leaf disc; (c) number of leaves longer than 3.0 cm per plant, measured from the base to the last opened leaf; (d) shoot fresh weight in t ha⁻¹ (yield), estimated considering that lettuce used actually 63.5% of a hectare.

To evaluate onions, we harvested the bulbs and placed them for curing for three days in the sun and for more 12 days in the shade, in a ventilated shed. Next, we separated the marketable bulbs (transverse diameter above 35 mm) and assessed: (a) total and marketable yield in t ha⁻¹; (b) fresh weight loss, in percentage, by weighing the bulbs, without removing the leaves, at harvest and after the first and second curing periods; (c) bulb length, in cm, measuring from the bulb base up to the beginning of the pseudostem; (d) bulb diameter, in cm, measured in the bulb midpoint using a caliper; (e) bulb total dry matter, in g, obtained by slicing the bulbs after the second curing and drying the slices in an oven, at 65°C, with forced air circulation, until constant mass; (f) total soluble solids (TSS), in °Brix, using 10 g samples. Samples were mixed with

90 mL of distilled water and shaken in a plant tissue homogenizer. Then, we collected a subsample used to measure TTS in refractometer; (g) total titratable acidity (TTA): we added three drops of the indicator phenolphthalein 1% to a second 10 mL subsample, prepared as described in (f). The volume was completed to 100 mL and the solution was employed to titration using NaOH 0.2 mol L⁻¹; and (h) TSS/ATT.

We carried out the agricultural economic evaluation as suggested by Oliveira *et al.* (2004). Costs of hiring labor were calculated considering the monoculture system. We calculated: (a) gross income (GI), obtained by multiplying crop yield in each treatment by the prices of lettuce in July, 2008 (BRL\$ 1.78 kg⁻¹)¹ and onion, in September, same year (US\$ 1.06 kg⁻¹)² (CEASA-MG, 2008); (b) net income (NI), obtained by deducting the production costs (inputs and services) from GI; (c) production costs (C), calculated for each treatment, taking as basis the cost coefficients for inputs and services used in an hectare of lettuce and onion carried out as an experiment, considering the current prices during the experimental period; (d) return rate (RR) for invested Real (BLR \$), calculated using the formula $RR = GI/C$ for each treatment and; (e) profitability index (PI), calculated as $PI = NI/GI$, expressed in percentage.

The results were submitted to analysis of variance. Where the calculated F value was significant ($p < 0.05$), we performed regression analysis for the factors. We chose the response surface models based on the significance of the regression coefficients, using the Student t test ($p < 0.05$) for the determination coefficient, as well as for potential to explain the biological phenomenon in question.

RESULTS AND DISCUSSION

Lettuce

There was significant interaction between plant densities of onion and

¹ The conversion rate from American Dollars (USD) to Brazilian Reais (BRL) in July 1st, 2008, was USD\$ 1.00 = BRL\$ 1.61 (Brazilian Central Bank, <http://www4.bcb.gov.br/pec/conversao/conversao.asp>).

² The conversion rate from American Dollars (USD) to Brazilian Reais (BRL) in September 1st, 2008 was USD\$ 1.00 = BRL\$ 1.64 (Brazilian Central Bank, <http://www4.bcb.gov.br/pec/conversao/conversao.asp>).

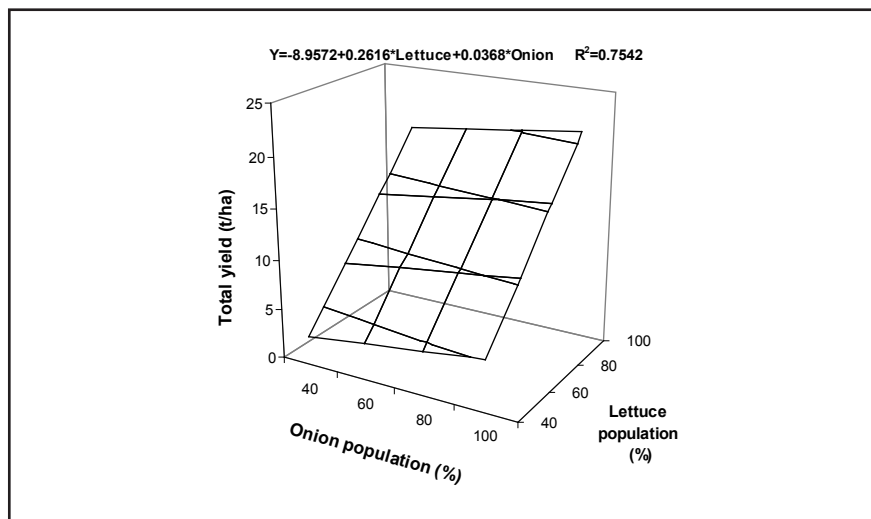


Figure 1. Lettuce total yield estimates as function of the range of lettuce and onion plant densities used for intercropping (estimativa da produtividade total de alface em função das diferentes densidades de plantio de alface e cebola utilizadas na consorciação). Janaúba, UNIMONTES, 2008.

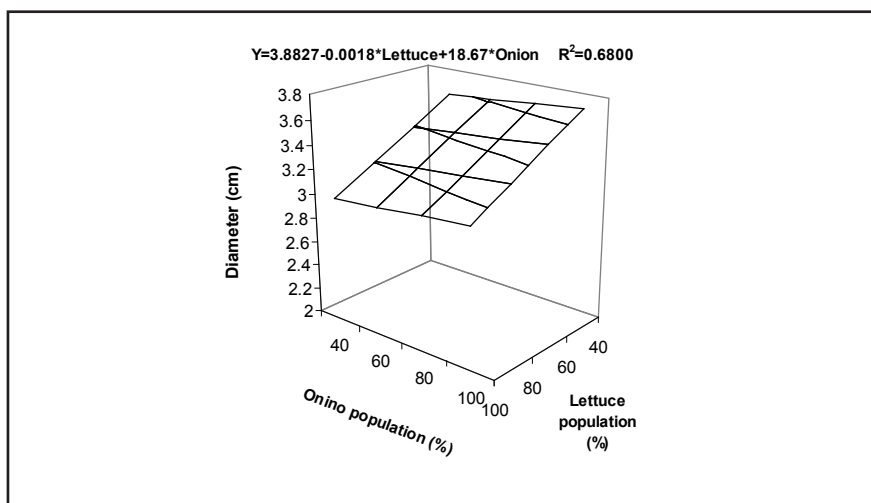


Figure 2. Estimates for bulb diameter in onion as function of the range of lettuce and onion plant densities used for intercropping (estimativa do diâmetro do bulbo em cebola em função das diferentes densidades de plantio de alface e cebola utilizadas na consorciação). Janaúba, UNIMONTES, 2008.

lettuce only for lettuce total yield. For all the other evaluated characteristics (diameter, height and number of leaves) no significant interactions were observed.

Lettuce total yield increased linearly as lettuce and onion densities grew. The highest lettuce yield (20.88 t ha⁻¹) was observed with 100% of lettuce plants (spacing of 20x20 cm) with 100% onion (spacing 20x5 cm), while the lowest yield (2.98 t ha⁻¹) was recorded with 40% of both lettuce and onion densities (spacing 20x40 and 20x12, respectively for lettuce and onion) (Figure 1). Lima

et al. (2004) also found that narrow spaces, i.e., higher plant densities, were responsible for increasing the yield of lettuce, cultivar Vera. The highest average yield observed at the density of 100% of lettuce and onion plants, was higher than the national average, which is below 10 t ha⁻¹. This result was due to the use of appropriate agronomic techniques, in particular higher stand or more plants per unit of area (25 lettuce plants per m²), but also a consequence of the intercropping benefits (lower temperatures both in the microenvironment and soil and

moderate shading) and sowing in the fall-winter season, when temperatures are not too high.

As plant diameter, height, and number of leaves were not significantly affected by lettuce and onion densities, we concluded that there was no evidence of competition between species. However, considering that lettuce yields can be as high as 58 t ha⁻¹ (Grangeiro *et al.*, 2006), it is important to continue evaluating cultivars with high yielding potential. It is also advisable to test higher plant densities, since we observed no yield decrease in the plant density range we studied, to be precise, no inflection of the curve of total lettuce yield.

Bezerra Neto *et al.* (2006), when intercropping lettuce and carrots, also found no significant interference from one crop over the other. However, the results found in our study contrast with those reported by Rao *et al.* (2005), who observed lower lettuce yields in intercropping with tomato than in monoculture, probably because the tomato, due to its steady vertical development might have caused shading over lettuce.

Onion

There were significant interactions between onion and lettuce plant densities for total and marketable yield and bulb diameter. For the other traits, namely bulb length, dry matter, loss of water after curing in the sun and shadow, total soluble solids (TSS), total titratable acidity and TSS/acidity, no significant interactions between onion and lettuce plant density were observed. Santos (2008), working with the intercropping onion/okra, also found no significant interference from intercropping over the onion evaluated characteristics.

Bulb diameter varied as function of plant density. Bulb diameter was the highest (3.68 cm) at a plant density of 40% lettuce and 100% onion and, the lowest (3.01 cm), at 100% lettuce and 40% onion (Figure 2). The increase in lettuce density enhanced plant competition, resulting in bulbs with smaller diameters, especially in the onion lowest density. It is likely that lettuce shading over onion was higher at lower onion densities. May *et al.*

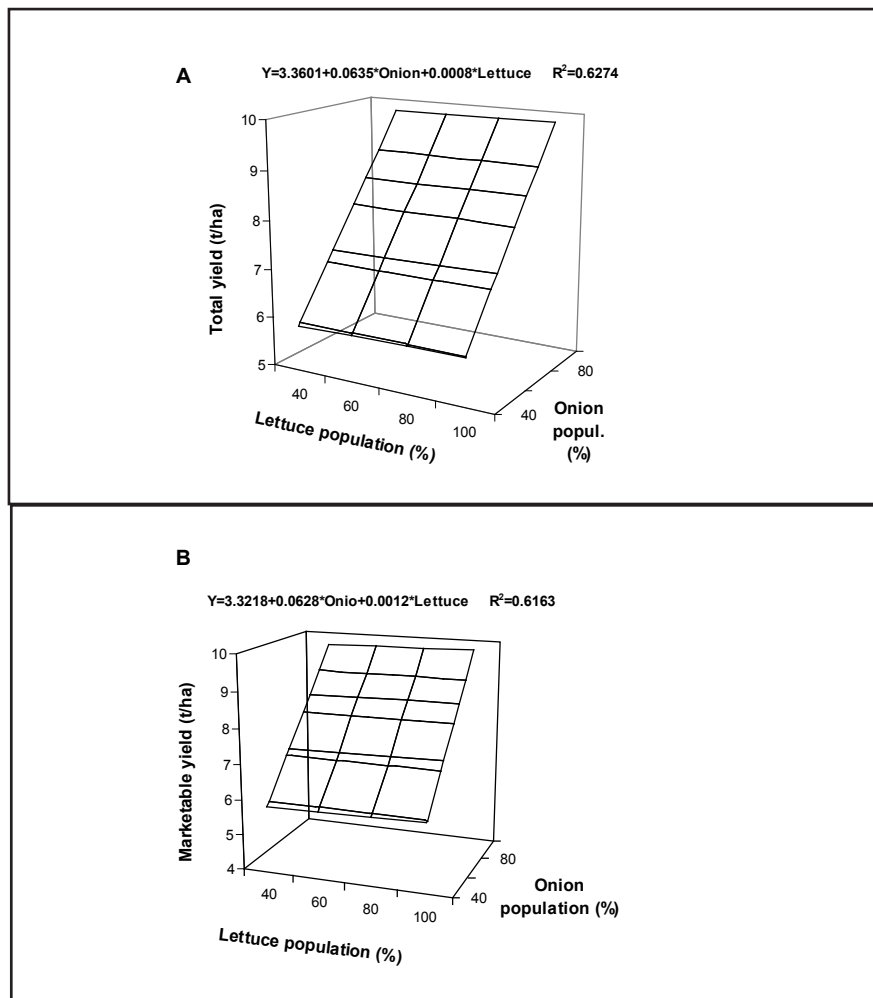


Figure 3. Estimates for total (A) and marketable (B) onion bulb yield as function of the range of lettuce and onion plant densities used for intercropping (estimativa das produtividades (A) total e (B) comercial de bulbos de cebola em função das diferentes densidades de plantio de alface e cebola utilizadas na consorciação). Janaúba, UNIMONTES, 2008.

(2007) also observed interference of plant density in the percentage of bulbs graded as classes 0 and 1: increasing plant densities led to active competition among plants, with consequent reduction in bulb diameter. The same authors observed higher yield of larger bulbs, Class 3, in lower plant densities.

However, even if increases in lettuce density resulted in reduction in bulb diameter, when it comes to total yield, we observed the contrary. Onion total yield increased as lettuce and onion densities rose, reaching 9.79 t ha⁻¹ with 100% of both onion and lettuce plants. On the other hand, the lowest onion yield, 5.93 t ha⁻¹, occurred at the lowest

plant density, namely 40% of onion and lettuce plants (Figure 3). As there was no change in bulb average dry weight and length, we believe that plant metabolism was not influenced by the variation in lettuce and onion density. Thus, the increase in onion density up to 100 plants per m² offset the reduction in bulb diameter and, moreover, increased yield.

Onion marketable yield also grew with the increase in plant density, and ranged from the top (9.72 t ha⁻¹) with the highest density (100% of lettuce and onion plants) to the bottom (5.88 t ha⁻¹) with the lowest density of the two vegetables (Figure 3). Onion yield in the experiment was lower than the national

average, 20.4 t ha⁻¹ (IBGE, 2009). The incidence of anthracnose throughout the experiment, although it was later controlled, may have to do with the yield drop.

Although all intercropping designs we tested had positive financial results (Table 1), the best performances were obtained with (a) onion at 80% of plant density combined with lettuce at 40 and 100% and; (b) onion at 100% and lettuce at 40, 60, 80 and 100%. Net incomes for these intercropping designs were R\$ 32,433.19¹, R\$ 36,376.87, R\$ 28,820.49, R\$ 30,135.05, R\$ 31,449.61 and R\$ 31,652.17 ha⁻¹, respectively, while return rates were, in average, R\$ 8.51¹, R\$ 9.32, R\$ 7.30, R\$ 7.56, R\$ 7.83, and R\$ 6.52 for each R\$ 1.00 invested, respectively. Profitability rates in the same designs reached 88.24, 89.27, 86.30, 86.78, 87.22 and 84.66%, respectively. Cecílio Filho *et al.* (2007), who intercropped lettuce and radish, found the most promising results when lettuce was planted in high density. Even facing yield reduction in onion, while lettuce yields did not go further than the average, the abovementioned intercropping designs resulted in reasonable incomes, since the financial inflows came from two sources, lettuce and onion, but in the same unit of area. The best net income was R\$ 7,500.00³ ha⁻¹ by month, in average, during the production cycle. Therefore, intercropping confirms its condition as an excellent income opportunity for farmers.

In general terms, intercropping designs with onion density at 40% of the plants had lower GI and NI than the other designs. Intercropping designs established using onion densities corresponding to 60 and 80% of the plants and any of the lettuce densities showed intermediate results, except for onion at 80% and lettuce at 100 and 40%. Other authors, Oliveira *et al.* (2005) and Silva *et al.* (2008), evaluating the intercropping systems coriander/lettuce and cucumber/lettuce, respectively, also observed higher

¹ The conversion rate from American Dollars (USD) to Brazilian Reais (BRL) in September 1st, 2008, was USD\$ 1.00 = BRL\$ 1.64 (Brazilian Central Bank, <http://www4.bcb.gov.br/pec/conversao/conversao.asp>).

Table 1; Economic indexes for intercropping lettuce and onion using different plant densities (indicadores econômicos do sistema consorciado de cultivo de alface e cebola estabelecido com diferentes densidades de plantio). Janaúba, UNIMONTES, 2009;

Onion density (plants/m ²)	Lettuce density (plants/m ²)	Gross income (R\$/ha) ¹	Costs (R\$/ha) ¹	Net income (R\$/ha) ¹	Return rate (R\$) ^{1,2}	Profitability index (%)
40	40	9,620.12	3,815.71	5,804.41	2.52	60.34
40	60	17,722.32	3,832.51	13,889.81	4.62	78.37
40	80	12,282.84	3,849.31	8,433.53	3.19	68.66
40	100	13,614.20	3,866.11	9,748.09	3.52	71.60
60	40	13,030.98	4,068.43	8,962.55	3.20	68.78
60	60	27,904.01	4,085.23	23,818.78	6.83	85.36
60	80	29,235.37	4,102.03	25,133.34	7.13	85.97
60	100	23,795.89	4,118.83	19,677.06	5.78	82.69
80	40	36,754.34	4,321.15	32,433.19	8.51	88.24
80	60	17,773.20	4,337.95	13,435.25	4.10	75.59
80	80	19,104.56	4,354.75	14,749.81	4.39	77.21
80	100	40,748.42	4,371.55	36,376.87	9.32	89.27
100	40	33,394.36	4,573.87	28,820.49	7.30	86.30
100	60	34,725.72	4,590.67	30,135.05	7.56	86.78
100	80	36,057.08	4,607.47	31,449.61	7.83	87.22
100	100	37,388.44	5,736.27	31,652.17	6.52	84.66

¹The conversion rate from American Dollars (USD) to Brazilian Reais (BRL) in September 1st, 2008 was USD\$ 1,00 = BRL\$ 1,64 (Brazilian Central Bank, <http://www4;bcg.gov.br/pec/conversao/conversao.asp>) [A taxa de conversão de Dólares Americanos (USD) para Reais (BRL), em 1^a de setembro de 2008 era USD\$ 1,00 = BRL\$ 1,64 (Banco Central do Brasil, <http://www4;bcg.gov.br/pec/conversao/conversao.asp>)];

²Return rate per unit of Real invested (taxa de retorno por unidade de Real investido);

economic efficiency in intercropping than in monoculture.

We concluded that intercropping lettuce and onion is beneficial, since there was no negative interference of the evaluated plant densities over lettuce or onion yields. The best agronomic results were observed when we intercropped lettuce and onion at 100% of plant density. The economic performance of the intercropping increased along with lettuce and onion densities.

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