Collard greens and chicory intercropping efficiency as a function of chicory (*Cichorium intybus*) transplant time

Eficiencia de los cultivos intercalados de col y achicoria en función del tiempo de transplante de la achicoria (*Cichorium intybus*)

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Abstract

Vegetable intercropping has advantages over single cultivation in terms of less environmental impact. However, to convince farmers to adopt this production system, it is necessary to prove greater efficiency in the production of more food per unit area and therefore an increase in productivity. An experiment was carried out aiming to evaluate the effect of the chicory transplant time in intercrops with collard greens on crop yields and land use efficiency index (LUE). The experimental design was a randomized block, with nine treatments in a 2 × 4 + 1 factorial scheme, and four replications. Crop systems (intercrop and monoculture) and chicory transplant time (0, 14, 28 and 42 days after transplant (DAT) of collard greens) were evaluated. The collard greens yield increased as the chicory transplant time was delayed. The total and per harvest yields of chicory were not influenced by its transplant time. Regardless of chicory transplant time, collard greens and chicory intercropping provided greater LUE than their monocultures and reached the maximum value (52% higher) when the chicory was transplanted 42 days after collard greens.

Keywords

Brassica oleracea L. var. *acephala* • *Cichorium intybus* • crop systems • intercropping feasibility • land use efficiency

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Resumen

El cultivo intercalado de hortalizas tiene ventajas sobre el monocultivo en cuanto a su menor impacto ambiental. Sin embargo, para convencer al productor de que adopte este sistema de producción, es necesario demostrar mayor eficiencia en la producción de más alimentos por unidad de superficie, y por tanto, un aumento de la productividad. Se llevó a cabo un experimento con el fin de evaluar el efecto del tiempo de trasplante de la achicoria en los cultivos intercalados con la col en el rendimiento de los cultivos y el índice de eficiencia del uso de área (LUE). El diseño experimental fue en bloques aleatorios, con nueve tratamientos en un esquema factorial 2 x 4 + 1, y cuatro repeticiones. Se evaluaron los sistemas de cultivo (intercalado y monocultivo) y el tiempo de trasplante de la achicoria (0, 14, 28 y 42 días después del trasplante (DAT) de la col). El rendimiento de la col aumentó al retrasarse el tiempo de trasplante de la achicoria. El rendimiento total y por cosecha de la achicoria no se vio influido por su tiempo de trasplante. Independientemente del tiempo de trasplante de la achicoria, la col y el cultivo intercalado de achicoria proporcionaron una mayor LUE en comparación con los sistemas de monocultivos, y alcanzaron el valor máximo (52% más alto) cuando la achicoria se trasplantó 42 días después de la col.

Palabras clave

Brassica oleracea L. var. *acephala* • *Cichorium intybus* • sistemas de cultivo • viabilidad de los cultivos intercalados • eficiencia del uso de área

Introduction

Vegetable production is an activity characterized by intense soil management and exposure, and intensive use of water and fertilizers, which provide considerable environmental impact (16). Developing technologies that allow the rational use of land for food production is therefore necessary, and intercropping is an available technology that can assist in production but which has less environmental impact, mainly due to complementary use of resources in time and space among different species (10, 13). In addition, intercropped cultivation allows a reduction of production costs, making the activity better remunerated and the producer more competitive in the market (6, 7, 9, 11).

Intercropped cultivation efficiency depends on the species involved in the system and the planting time of the second species, because these factors affect the period for which the species coexist and, consequently, the spatial and/or temporal complementarity, with impacts on crop yields and on the whole system (5, 6, 8).

Cecílio Filho *et al.* (2011, 2015) observed that land use efficiency decreased on increasing the transplanting time between tomato and lettuce (2011) and between cucumber and lettuce (2015), due to increased shading of tomato and cucumber on lettuce. The longer the period between transplantations, the larger were the tomato and cucumber plants when the lettuce was transplanted. Consequently, less solar radiation was available to the lettuce that grew under the tomato and cucumber canopy. Similarly, Ohse *et al.* (2012) evaluated the agronomic viability of broccoli and lettuce intercropping and they verified that the yield of lettuce was affected by its transplanting time. The authors obtained the best result when lettuce was transplanted on the same day as broccoli. Consequently, the effect of lettuce transplant time impacted intercropping efficiency in the same way.

This study aims to evaluate the yields for intercropping between collard greens (*Brassica oleracea* var. *acephala*) and chicory (*Cichorium intybus*), two vegetables commonly grown by small farmers (family farming), which can easily incorporate the technology of an intercropping system to replace the monoculture system of those crops. Also, the two species have different characteristics such as size, height and foliar architecture, which are important to the success of intercropping (5, 12, 14).

No studies about collard greens and chicory intercropping have been found in the literature. However, Cecílio Filho *et al.* (2017) studied the effect of New Zealand spinach (*Tetragonia expansa*) transplanting time in intercropping with collard greens. The authors observed that the New Zealand spinach, regardless of the time at which it is transplanted in relation to collard greens, does not affect collard greens yield. However, collard greens cause a loss of New Zealand spinach yield, regardless of the spinach transplanting time, by about 13.5% in relation to the yield obtained in monoculture. It is expected that a simple change of the intercropped species can alter the crop system viability. In this case, chicory and New Zealand spinach have differences such as size and height, kind and velocity of growth, and architecture among other characteristics, which can cause different effects on spatial and/or temporal complementarity in intercropping with collard greens. Our hypothesis is that the production of collard greens and chicory in an intercropping system has greater land use efficiency than in monoculture systems and that the chicory transplanting time in the intercropping affects the yields of both species in the system.

Thus, this study was performed with the aim to evaluate the agronomic efficiency of collard greens and chicory intercropping as a function of the chicory transplant time in relation to that of collard greens.

Materials and methods

Characterization of experimental site

The experiment was carried out in the field at São Paulo State University (21°14'39'' S, 48°17'10'' W; 575 m a. s. l.) from May to November 2018.

The soil was classified as a Eutrudox with sand = 253 g kg^{-1}, silt = 132 g kg^{-1} and clay = 615 g kg^{-1}. The chemical attributes before installation of the experiment were: pH ($CaCl_2$) 5.6; 17 g dm^{-3} organic matter; 31 mg dm^{-3} P (resin); 3.3 $mmol_c$ dm^{-3} K; 22 $mmol_c$ dm^{-3} Ca; 10 $mmol_c$ dm^{-3} Mg; and soil base saturation = 71%.

During the experimental period, the climate parameters were: relative humidity 63.9%, rainfall 330 mm and average temperature 22°C, with maximum and minimum averages of 29.8 and 16.2°C, respectively.

Treatments and experimental design

Nine treatments were evaluated as result of combining two crop systems (intercropping and monoculture) and four chicory transplanting times (0, 14, 24 and 42 days after transplanting collard greens - DATCG). The treatments were arranged in a 2 × 4 + 1 factorial scheme, in a randomized block, with four replications. The additional treatment corresponded to collard greens monoculture. Collard greens was considered as the main crop and chicory as the secondary crop.

Each experimental unit (3.36 m^2) contained 14 collard greens plants and 70 chicory plants. Two rows of collard greens were transplanted in the centre of the bed, with 0.75 m between rows and 0.40 m between plants in a row. Five rows of chicory were transplanted to the bed, being three from their between the collard greens rows with 0.25 m spacing between rows and 0.20 m between plants in a row. The useful area for the evaluation of the experiment corresponded to the plants in the centre of the bed excluding two collard greens plants from each end of the row. For evaluation of chicory, three central rows were considered, excluding 0.40 m at the beginning and end of each row. In total, 30 chicory plants and 10 collard greens plants were evaluated (figure 1, page 94).

Installation of experiment

According to the results of the soil analysis, liming was carried out, applying lime to increase the soil base saturation to 80%. Planting and covering fertilization for both crops were performed according to Trani and Raij (1997) and Trani *et al.* (2018). At the planting time, 40, 320 and 80 kg ha^{-1} of nitrogen (urea), phosphorus (simple superphosphate) and potassium (potassium chloride) were supplied, respectively.

The 'HS-20' collard greens seedlings were transplanted on a single date and the 'Pão de Açúcar' chicory seedlings were transplanted on the dates established in the treatments. At the time of chicory transplanting at 0, 14, 28 and 42 DATCG, the height of collard greens plants was measured and corresponded to 4.6, 11.9, 19.3 and 39.9 cm, respectively. The chicory seedlings were formed on several dates in order to obtain plants with four leaves for all treatments (transplanting times).

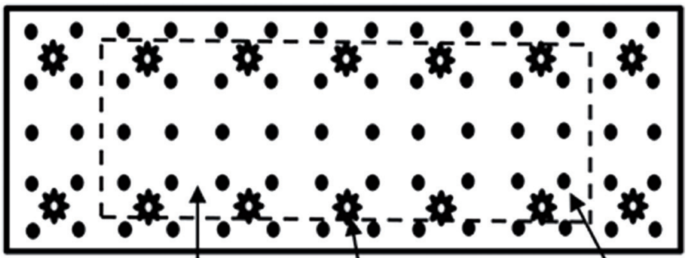

Figure 1. Graphical representation of an experimental unit of intercropping system showing the arrangement of crops.

Figura 1. Representación gráfica de una unidad experimental de sistema de cultivo intercalado en la disposición de los cultivos.

The cover fertilization for collard greens was carried out by applying 40 kg ha^{-1} of N (urea) and 20 kg ha^{-1} of K_2O (potassium chloride) every 15 days after the transplant until completing 45 days. For the chicory, 30 kg ha^{-1} of N and 20 kg ha^{-1} K_2O were applied at 14 and 24 days after transplanting the chicory and immediately after each harvest for both cultures. The experiment was irrigated periodically by spraying throughout the crop cycle. Weed control was performed by manual weeding, weekly.

Every 10 days, leaves of collard greens were harvested, totalling 14 harvests. The chicory was harvested when the head was formed, which happened twice.

Characteristics evaluated

Yield (kg ha^{-1}): obtained by summing the harvests carried out throughout the crop cycle.

Relative yield (RY %): obtained by the ratio between crop yields in intercropping and in monoculture. RY was proposed by Wit and Bergh (1965) and calculated from the following equations:

$$RY_{cg} = \frac{Y_{12}}{Y_{11}} \times 100 \qquad RY_{c} = \frac{Y_{21}}{Y_{22}} \times 100$$

where:

RYcg and RYc correspond to relative yields of collard greens and chicory, respectively

Y_{12} = collard greens yield when intercropped with chicory

Y_{11} = collard greens yield obtained in monoculture

Y_{21} = chicory yield when intercropped with collard greens

Y_{22} = chicory yield obtained in monoculture.

Land use efficiency (LUE): obtained by the equation proposed by Willey (1979):

$$LUE = RY_{cg} + RY_{c}$$

Statistical analysis

The average value for monocultures (blocks) was considered as the denominator of the indices, as recommended by Bezerra Neto *et al.* (2012).

The data of total and per harvest yields of collard greens and chicory were subjected to variance analysis (F test) and, when significant, the means of the intercropped and monoculture systems were compared by the Tukey test at 5%. For collard greens, a complete randomized block design was used, with five treatments (four intercrops and one monoculture) and four replications. For chicory, a complete randomized block design was used in a 2 × 4 factorial scheme, with two cultivation systems and four transplant times. For LUE and RY indices, a randomized complete block design was used, with four treatments (intercrops). The regression equations were obtained according to the chicory transplanting time. In all analyses, the AgroEstat statistical program was used (2).

Results

Collard greens yield

The total and per harvest yields were influenced by the crop system (table 1). The collard greens total yield in the intercropping system established by chicory transplant at 42 DATCG did not differ from the yield obtained in monoculture. On the other hand, the collard greens total yields obtained in intercropping systems established with chicory transplanted at 0, 14 and 28 DATCG were lower than that obtained in monoculture, reaching 36% less when both crops were transplanted on the same day (table 1).

In the partial harvests, the yields of intercropped crops sometimes did not differ from those in monoculture; sometimes they differed, sometimes being higher or lower (table 1). Table II shows adjusted polynomial equations for total and per harvest yields of collard greens when intercropped with chicory. The collard greens total yield increased linearly as the chicory transplant was performed later in relation to the collard greens transplant. The collard greens yield increased by 438.11 kg ha^{-1} for each day of delaying the chicory transplant (table 2, page 96).

Table 1. Summary of variance analysis for total yield (TY) and yield per harvest (HY) (kg ha^{-1}) of collard greens as a function of crop system.

Tabla 1. Resumen del análisis de varianza del rendimiento total (TY) y el rendimiento por cosecha (HY) de la col en función del sistema de cultivo.

Source of variation	TY	HY1	HY2	HY3	HY4
	kg ha^{-1}				
Treatment	11.73**	1.48ns	25.68**	8.07**	16.82**
CV %	10.49	25.30	23.97	23.40	13.07
I-0 DATCG	47870.69c	5007.05a	1242.84b	2157.11c	3317.81c
I-14 DATCG	54029.20bc	5518.49a	1099.98b	2646.39bc	5235.63b
I-28 DATCG	58037.71bc	6542.76a	1603.55b	3977.80ab	4932.07b
I-42 DATCG	66979.71ab	7080.84a	1747.12b	4517.79ab	6667.76a
Monoculture	75384.59 a	7185.61a	3985.66a	4999.93a	4092.80bc
Source of variation	**HY5**	**HY6**	**HY7**	**HY8**	**HY9**
	kg ha^{-1}				
Treatment	11.90**	9.33**	2.44ns	4.60*	1.88ns
CV %	14.89	13.10	21.02	21.45	21.61
I-0 DATCG	5074.92b	5903.49b	4664.21a	2778.53b	3389.24a
I-14 DATCG	4999.93b	5678.49b	5875.63a	3178.53b	4024.94a
I-28 DATCG	5928.48b	5585.63b	5360.64a	3421.38ab	4371.36a
I-42 DATCG	8353.45a	7089.48ab	5414.20a	3628.76ab	4295.18a
Monoculture	8289.16a	8685.58a	7428.46a	4960.64a	5128.50a
Source of variation	**HY10**	**HY11**	**HY12**	**HY13**	**HY14**
	kg ha^{-1}				
Treatment	5.89*	3.24ns	7.62**	2.17ns	0.90ns
CV %	15.77	20.05	18.58	19.72	24.20
I-0 DATCG	3839.23b	3985.67a	2042.83b	2414.25a	2053.54a
I-14 DATCG	4257.08b	4249.94a	2466.63b	2790.43a	2007.11a
I-28 DATCG	4378.50ab	3642.81a	2271.40b	3389.24a	2632.10a
I-42 DATCG	5128.49ab	5574.92a	2207.11b	2857.10a	2417.82a
Monoculture	6146.34a	5171.35a	3657.09a	3439.23a	2214.25a

The number beside HY corresponds to the collard greens harvest number (*e.g.* HY1 = Yield of the first harvest); I = Intercropping; DATCG = days after transplant of collard greens; means followed the same letter in a column do not differ by Tukey test ($p > 0.05$); F Test: ns: not significant; *: $p \leq 0.05$; ** $p \leq 0.01$.

El número delante de HY corresponde al número de la cosecha de col (ej.: HY1 = rendimiento de la primera cosecha) I = Intercambio de cultivos; DATCG = días después del transplante de col; las medias seguidas de la misma letra en la columna no difieren por la prueba de Tukey ($p > 0,05$); Prueba F: ns: no significativo; *: $p \leq 0,05$; ** $p \leq 0,01$.

Table 2. Adjusted equations, significance (F values) and determination coefficients (R^2) for yields per harvest (HY) and total yield (TY) of collard greens as a function of the chicory transplanting time.

Tabla 2. Ecuaciones ajustadas, significancia (valores F) y coeficientes de determinación (R^2) para los rendimientos por cosecha (HY) y el rendimiento total (TY) de la col en función del tiempo de trasplante de la achicoria.

Yield	Equations	R^2	F
HY1	no adjust	-	-
HY2	no adjust	-	-
HY3	y = 2062.7535 + 60.0961x	0.96	18.23**
HY4	y = 3575.3720 + 69.6164x	0.84	42.97**
HY5	y = 50599.56500 – 57.0398x + 3.1887x2	0.99	7.76**
HY6	no adjust	-	-
HY7	no adjust	-	-
HY8	no adjust	-	-
HY9	no adjust	-	-
HY10	y = 3802.4447 + 28.4943x	0.92	5.64*
HY11	no adjust	-	-
HY12	no adjust	-	-
HY13	no adjust	-	-
HY14	no adjust	-	-
TY	y = 47528.9923 + 438.11105x	0.98	15.04**

The number beside of HY corresponds to the collard greens harvest number (*e.g.* HY1 = yield of the first harvest);*: $p \leq 0.05$; **$p \leq 0.01$.

El número delante de HY corresponde al número de la cosecha de col (Ej.: HY1 = rendimiento de la primera cosecha);*: p ≤ 0,05; **p ≤ 0,01.

Chicory yield

The total and per harvest yields of chicory were not influenced by the chicory transplant time or by interaction of the evaluated factors, but they were influenced by the crop systems. Monoculture produced more than the intercropping system (table 3). There was no adjustment of regression equations for chicory yield (total and per harvest) according to the chicory transplanting time.

Table 3. Summary of variance analysis for total yield (TY) and per harvest yield (HY) of chicory as a function of crop system (CS) and chicory transplanting time (CTT) in relation to collard greens transplant.

Tabla 3. Resumen del análisis de varianza del rendimiento total (TY) y por cosecha (HY) de la achicoria en función del sistema de cultivo (CS) y el tiempo de trasplante de la achicoria (CTT) en relación con la col.

Source of variation	TY		HY1		HY2	
F value						
CS	111.26**		206.94**		36.38**	
CTT	0.85ns		0.67ns		1.75ns	
CS x CTT	0.10ns		0.52ns		0.39ns	
CV %	11.2		8.18		19.69	
Yield (kg ha^{-1})						
	TY		HY1		HY2	
	I	M	I	M	I	M
	44068.40b	67330.73a	24208.86b	36917.00a	19859.55b	30413.72a

The number beside HY corresponds to the chicory harvest number (*e.g.* HY1 = yield of the first harvest); I = Intercropping; M = Monoculture; F test: ns: not significant; ** $p \leq 0.01$; means followed by the same letters in a row do not differ by Tukey test ($p > 0.05$).

El número delante de HY corresponde al número de cosecha de achicoria (Ej.: HY1 = rendimiento de la primera cosecha); I = Intercambio de cultivos; M = Monocultivo; prueba de F: ns: no significativo; ** p ≤ 0,01; las medias seguidas de las mismas letras en la fila no difieren por la prueba de Tukey (p > 0,05).

Relative yields and land use efficiency

RYcg was influenced by treatments, which was not observed for RYc (table 4). RYcg increased linearly as function of chicory transplanting time and reached 28% more when the chicory transplant happened 42 DATCG in relation to the RYcg obtained when both crops were transplanted on the same day.

Table 4. Summary of variance analysis for relative yield of collard greens (RYcg), relative yield of chicory (RYc) and land use efficiency (LUE) as a function of chicory transplanting time (CTT) in relation to collard greens transplant.

Tabla 4. Resumen del análisis de variaciones del rendimiento relativo de la col (RYcg), el rendimiento relativo de la achicoria (RYc) y la eficiencia del uso de la tierra (LUE) en función del tiempo de trasplante de la achicoria (CTT) en relación con el trasplante de la col.

Source of variation	RYcg (%)	RYC (%)	LUE
	F value		
CTT	5.5*	0.17ns	2.96ns
CV %	12.47	13.29	8.22
	kg ha^{-1}		
0 DATCG	63.50b	67.33a	1.31a
14 DATCG	71.67ab	63.41a	1.35a
28 DATCG	76.99ab	66.52a	1.44a
42 DATCG	88.85a	64.52a	1.53a

DATCG = days after transplant of collard greens; F Test: ns: not significant; *: p ≤ 0.05; means followed by the same letter in a column do not differ by Tukey test (p > 0.05).

DATCG = días después del transplante de col; Prueba F: ns: no significativo; *: p ≤ 0,05; las medias seguidas de la misma letra en la columna no difieren por la prueba de Tukey (p > 0,05).

Therefore, the later the chicory transplant, the higher the intercropped collard greens yield and the nearer it is to the monoculture yield (figure 2).

Regarding LUE, there was no effect of the treatments (table 4), but there was a significant adjustment of the linear equation (figure 2).

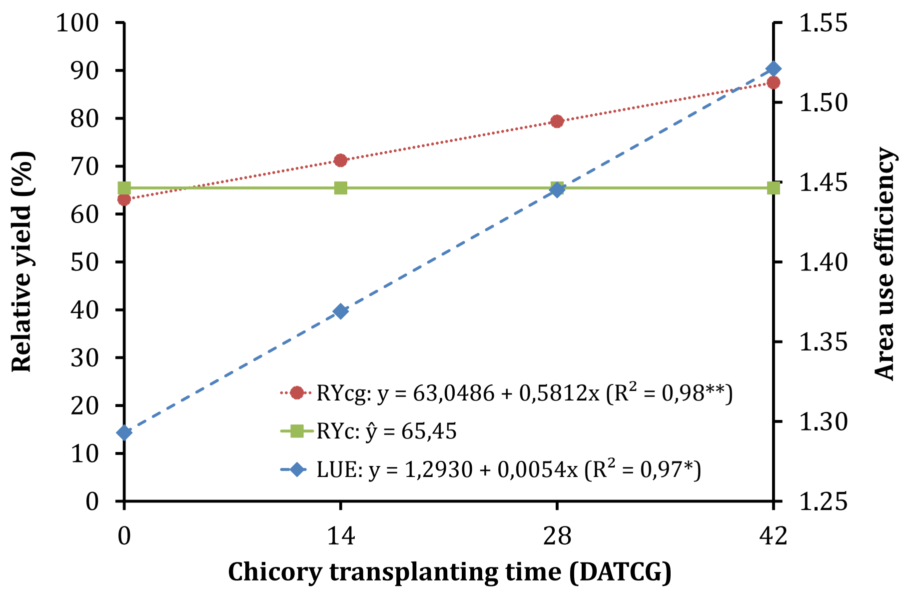

Figure 2. Relative yield of collard greens (RYcg) and chicory (RYc) and land use efficiency (LUE) as a function of chicory transplanting time in relation to collard greens transplant (DATCG).

Figura 2. Rendimiento relativo y eficiencia en el uso de la tierra (LUE) de la col (RYcg) y la achicoria (RYc) en función del tiempo de trasplante de la achicoria en relación con el trasplante de la col (DATCG).

Discussion

According to the results, the chicory affected the collard greens yield, especially when both species were transplanted on the same day. The chicory grew faster than the collard greens and quickly occupied the area. Due to that and the proximity to collard greens plants, the chicory leaves intercepted the solar radiation and reduced the availability of this resource for collard greens plants. However, the later the chicory was transplanted, the weaker its interference with the collard greens since that was itself more developed. When chicory was transplanted at 14, 28 and 42 DATCG, the height of the collard greens plants was 11.9, 19.3 and 39.9 cm, respectively, while when transplanted at 0 DATCG it was 4.6 cm.

The delay in the chicory transplant determined lower interference capacity of the chicory in the interception of solar radiation to the collard green. In an intercropping system, competition between plants is greater for light than for water and nutrients (3), which are adequately supplied to crops according to the management of the production system.

The results observed for collard greens and chicory intercropping differ from those found by Cecílio Filho *et al.* (2017), who evaluated collard greens and New Zealand spinach intercropping. The authors observed that total and per harvest yield of collard greens was influenced neither by crop system (intercropping and monoculture) nor by New Zealand spinach transplanting time (0 to 98 DATCG). Therefore, the secondary species associated with collard greens determines the collard greens performance, since in the collard greens and chicory intercropping system, the chicory grew faster. On the other hand, according to Cecílio Filho *et al.* (2017), collard greens grows faster than New Zealand spinach and quickly positions its photosynthetic canopy above the stratum occupied by the spinach, which has prostrate growth. Then, the collard greens intercepted the incident solar radiation, causing shading and negatively impacting the chicory yield. Despite the chicory yield reduction was no observed harmful to the commercial aspect.

The results for interspecific competition between collard greens and chicory for light corroborate the results observed for tomato–lettuce intercropping by Cecílio Filho *et al.* (2011), broccoli-lettuce intercropping by Ohse *et al.* (2012), cucumber-lettuce intercropping by Cecílio Filho *et al.* (2015) and collard green–New Zealand spinach intercropping by Cecílio Filho *et al.* (2017). These authors observed that, similar to what happened with chicory in relation to collard greens, the photosynthetic process and, consequently, growth of lettuce and spinach was harmed, due to their low height and shading by broccoli, tomato and cucumber, respectively. In the present study, the highest chicory yield was obtained in the monoculture system and, unlike the intercropping systems mentioned above, there was no effect of the time at which chicory was transplanted on its yield.

The RYcg and RYc indices were less than 1, showing that there was competition between species. The lowest RYcg happened when both crops were transplanted on the same day, determined by greater interference of the chicory on collard greens.

All collard greens–chicory intercropping systems showed a LUE greater than 1, which reflects the complementarity of the species, *i.e.*, there was an advantage in food production per unit area in the intercropping system due to the better use of environmental resources (1). The LUE was at a maximum (1.52) when chicory transplant was performed at 42 DATCG, meaning that 1 ha in the intercropping system yielded the same quantity of food (collard greens and chicory) as 1.52 ha in the monoculture system.

Conclusion

The later chicory transplanting is performed, the greater the collard greens yield.

The chicory total yield is not influenced by chicory transplanting time in relation to collard greens transplanting time.

Collard greens–chicory intercropping promotes greater LUE than their monocultures and the efficiency is at a maximum (+52%) when the chicory transplant is performed at 42 DATCG.

References

1. Banik, P.; Midya, A.; Sarkar, B. K.; Ghose, S. 2006. Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering. European Journal of Agronomy. Amsterdam. 24 (4): 325-332. DOI: https://doi.org/10.1016/j.eja.2005.10.010.
2. Barbosa, J. C.; Maldonado Júnior, W. 2015. Experimentação agronômica e AgroEstat: Sistemas para análises estatísticas de ensaios agronômicos. Jaboticabal. Ed. Gráfica Multipress Ltda. 396 p.
3. Barrilot, R.; Louarn, G.; Escobar-Gutiérrez A. J.; Huynh, P.; Combes, D. 2011. How good is the turbid medium-based approach for accounting for light partitioning in contrasted grass-legume intercropping systems?. Annals of Botany. United Kingdom. 108(6): 1013-1024. DOI: https://doi.org/10.1093/aob/mcr199.
4. Bezerra Neto, F. B.; Porto, V. C. N.; Gomes, E. G.; Cecílio Filho, A. B.; Moreira, J. N. 2012. Assessment of agroeconomic indices in polycultures of lettuce, rocket and carrot through uni-and multivariate approaches in semi-arid Brazil. Ecological Indicators. Amsterdam. 14(1): 11-17.
5. Cecílio Filho, A. B. C.; Rezende, B. L. A.; Barbosa, J. C.; Grangeiro, L. C. 2011. Agronomic efficiency of intercropping tomato and lettuce. Anais da Academia Brasileira de Ciências. Rio de Janeiro. 83(3): 1109-1119. DOI: http://dx.doi.org/10.1590/S0001-37652011000300029.
6. Cecílio Filho, A. B.; Neto, B. F.; Rezende, B. L. A.; Barros Júnior, A. P.; Lima, J. S. S. 2015. Indices of bioagroeconomic efficiency in intercropping systems of cucumber and lettuce in greenhouse. Australian Journal of Crop Science. Australia. 9(12): 1154-1164.
7. Cecílio Filho, A. B.; Bianco, M. S.; Tardivo, C. F.; Pugina, G. 2017. Agronomic viability of New Zealand spinach and kale intercropping. Anais da Academia Brasileira de Ciências. Rio de Janeiro. 89(4): 2975-2986. DOI: https://doi.org/10.1590/0001-3765201720160906.
8. de Andrade Filho, F. C.; Queiroga de Oliveira, E.; Suerda Silva de Lima, J.; Nonato Moreira, J.; Nunes Silva, Í.; Lins, H. A.; Cecílio Filho, A. B.; Paes Barros Júnior, A.; Bezerra Neto, F. 2020. Agro-economic viability from two croppings of broadleaf vegetables intercropped with beet fertilized with roostertree in different population densities. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 52(1): 210-224.
9. Garmendia, I.; Bettoni, M. M.; Goicoechea, N. 2020. Assessing growth and antioxidant properties of greenhouse-grown lettuces (*Lactuca sativa* L.) under different irrigation and carbon fertilization management. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 52(1): 87-94.
10. Gou, F.; Ittersum, M. K.; Werf, W. 2017. Simulating potential growth in a relay-strip intercropping system: model description, calibration and testing. Field Crops Research. Amsterdam. 200(1): 122-142. DOI: https://doi.org/10.1016/j.fcr.2016.09.015.
11. Huang, C.; Liu, Q.; Heerink, N.; Stomph, T.; Li, B.; Liu, R.; Zhang, H.; Wang, C.; Li, X.; Zhang, C.; Werf, W.; Zhang, F. 2015. Economic performance and sustainability of a novel intercropping system on the North China Plain. PloS One. San Francisco. 10(2): 1-16. DOI: https://doi.org/10.1371/journal.pone.0135518.
12. Jensen, E. S.; Peoples, M. B.; Hauggaard-Nielsen, H. 2010. Faba bean in cropping systems. Field Crops Research. Amsterdam. 115(3): 203-216. DOI: https://doi.org/10.1016/j.fcr.2009.10.008.
13. Nascimento, C. S.; Cecílio Filho, A. B.; Mendoza-Cortez, J. W.; Nascimento, C. S.; Bezerra Neto, F.; Grangeiro, L. C. 2018. Effect of population density of lettuce intercropped with rocket on productivity and land-use efficiency. PloS One. San Francisco. 13(4): 1-14. DOI: https://doi.org/10.1371/journal.pone.0194756.
14. Nunes, R. L. C.; Neto, F. B.; Lima, J. S. S.; Júnior, A. P. B.; Chaves, A. P.; Silva, J. N. 2018. Agro-economic responsiveness of radish associations with cowpea in the presence of different amounts of *Calotropis procera*, spatial arrangements and agricultural crops. Ciência e Agrotecnologia. Lavras. 42(4): 350-363. DOI: https://doi.org/10.1590/1413-70542018424010318.
15. Ohse, S.; Rezende, B. L. A.; Silveira, L. S.; Otto, R. F.; Cortez, M. G. 2012. Viabilidade agronómica de consórcio de brócolis e alface estabelecidos em diferentes épocas. Idesia. Chile. 30(2): 29-37. DOI: http://dx.doi.org/10.4067/S0718-34292012000200004.
16. Rezende, B. L. A.; Cecílio Filho, A. B.; Pôrto, D. R. Q.; Barros Júnior, A. P.; Silva, G. S.; Barbosa, J. C.; Feltrim, A. L. 2010. Consórcios de alface crespa e pepino em função da população d
17. Trani, P. E.; Raij, B. van. 1997. Hortaliças. In: Raij, B. van, Cantarella, H.; Quaggio, J. A.; Furlani, A. M. C. (Eds.) Recomendação de adubação e calagem para o estado de São Paulo. Campinas. Instituto Agronômico. 155-186.
18. Trani, P. E.; Purquerio, L. F. V.; Figueiredo, G. J. B.; Tivelli, S. W.; Blat, S. F. 2018. Alface, almeirão, agrião-d'água, chicória, coentro e rúcula. In: Trani, P. E.; Raij, B. V.; Cantarella, H. Figueiredo, G. J. B. (Eds.). Hortaliças: Recomendações de calagem e adubação para o Estado de São Paulo. Campinas. CATI. 23-26.
19. Willey, R. W. 1979. Intercropping - It's Important and Research Needs. Part 1. Competition and Yield Advantages. Field Crop Abstracts. 32: 1-10.
20. Wit, C. T. de; Bergh, J. P. van den. 1965. Competition between herbage plants. Journal of Agricultural Science. Netherlands. 13(2): 212-221.