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CHICORY AND ARUGULA IN INTERCROPPING WITH COLLARD GREENS[1]

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ABSTRACT – Vegetable intercropping systems use complementarity between species to increase agricultural profitability. This study evaluated the effects of intercropping chicory and arugula species with collard greens on crop yield and land use efficiency (LUE). Six treatments, consisting of species planted as monocultures or intercropped in various combinations, were evaluated in a randomized block design with four replicates. The cultivars 'Top Bunch' (collard greens), 'Pão de Açúcar' (chicory) and 'Folha Larga' (arugula) were used. The yield of collard greens in monoculture did not differ from those obtained when they were intercropped with chicory, arugula, or both species, whereas chicory and arugula yields were higher in monoculture. However, even with yield losses for chicory and arugula in intercropping, LUE indices were greater than 1.0 in all intercropping systems, indicating their viability. The highest LUE index (2.41) was obtained in the chicory-arugula-collard green intercropping system.

Keywords: *Brassica oleracea* L. *var. acephala. Cichorium intybus. Eruca sativa.* Competition indices. Land use efficiency.

ALMEIRÃO E RÚCULA EM CONSÓRCIO COM A COUVE

RESUMO – O consórcio de hortaliças é um sistema de cultivo que utiliza a complementaridade entre espécies para aumentar a rentabilidade da atividade agrícola. Nesse sentido, o objetivo deste trabalho foi avaliar o efeito das espécies almeirão e rúcula em consórcio com a couve na produtividade das culturas e no índice de eficiência do uso da área (EUA). Seis tratamentos (espécies em consórcio e em monocultura) foram avaliados em delineamento experimental de blocos casualizados, com quatro repetições. Foram utilizadas as cultivares 'Top Bunch' (couve), 'Pão de Açúcar' (almeirão) e 'Folha Larga' (rúcula). A produtividade da couve em monocultura não diferiu das obtidas em consórcios com almeirão, rúcula ou com ambas as espécies, enquanto as produtividades do almeirão e da rúcula foram maiores no monocultivo. Entretanto, mesmo com perdas de produtividade pelo almeirão e rúcula, os índices de EUA foram maiores que 1,0 em todas as consorciações indicando a viabilidade do consórcio. Maior índice EUA (2,41) foi obtido no consórcio de almeirão-rúcula-couve.

Palavras-chave: *Brassica oleracea* L. *var. acephala. Cichorium intybus. Eruca sativa.* Índice de competição. Eficiência de uso da área.

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INTRODUCTION

The growth of the world's population is increasing the demand for food and food security. In this context, the agricultural sector faces great challenges to supply the world market with diversified and healthy food (SOUSA et al., 2019).

Among agricultural products, the vegetable sector is expanding due to its positive impact on human health (SCHREINEMACHERS; SIMMONS; WOPEREIS, 2018). However, vegetable production has a considerable environmental impact, mainly due to high soil exposure, continuous irrigation and intensive use of pesticides and fertilizers (NASCIMENTO, 2018). In view of this, it is necessary to develop and/or improve technologies that allow for rational use of the soil and greater efficiency in the use of food production inputs. Intercropping of vegetables stands out as a good strategy for that purpose (YADAV; MALHOTRA; SINGH, 2017). Intercropping allows the simultaneous cultivation of two or more species in the same area (LAYEK et al., 2018), thus improving agricultural sustainability (PEREIRA; CECÍLIO FILHO; LA SCALA JR, 2021).

The potential advantages of intercropping are more efficient use of available resources, increased agricultural productivity per unit area, reduced agricultural inputs per unit of food production (BROOKER et al., 2015), improved physical soil conditions (organic matter aggregation, humic acid production and root activity), reduced soil erosion (WEISANY; RAEI; PERTOT, 2015), increased producer profitability (HUANG et al., 2015), greater resistance to pests and diseases (FRISON; CHERFAS; HODGKIN, 2011) and reduction of total harvest failure (LEPSE et al., 2017). However, the effective advantage of intercropping in relation to monoculture becomes more evident when the crops involved have different needs regarding available resources, either in quantity or in the demand period. Thus, intercropping efficiency depends directly on the selection of complementary species, the establishment of appropriate population densities and management factors (CECÍLIO FILHO et al., 2017; WAN; LEI, 2018).

Leafy vegetables stand out for their varied organoleptic and functional characteristics in the human body (FU et al., 2017). Brazil has a wide variety of leafy vegetables, produced predominantly in conventional systems; however, intercropping systems have been the subject of numerous studies and are demonstrated to be sustainable and profitable enhancers of land use efficiency when adopted by farmers (BARBOSA; MALDONADO JÚNIOR, 2015; NASCIMENTO; NASCIMENTO; CECÍLIO FILHO, 2018, GUIMARÃES et al., 2020). Collard greens, chicory and arugula are some of the main leafy vegetables produced in Brazil (ABSEM, 2016). However, studies on the intercropping of these species are lacking. Therefore, this study evaluated the agronomic performance and land use efficiency (LUE) of a collard greens-chicory-arugula intercropping system in order to better understand the responses of these crops when grown in this cropping system. The expectation was that the intercropping of these three species would promote higher LUE.

MATERIAL AND METHODS

Location and characterization of the experimental area

The experiment was conducted in the field, from 5 July to 30 November 2018, at Universidade Estadual Paulista, Jaboticabal campus, São Paulo State, Brazil (21°14'05" S, 48°17'09" W, altitude 615 m).

The climate characteristics during the experiment are shown in Table 1.

Table 1. Weather data of the experimental period.

Month	maxT. (°C)	minT. (°C)	averT. (°C)	HR (%)	Rainfall (mm)	Solar radiation (hours month^{-1})
July	29.7	13.3	20.7	52.6	4.2	272.2
August	28.8	14.2	20.4	62.8	39.7	233.3
September	30.7	16.7	22.9	60.3	64.9	200.5
October	31.1	19.5	24.4	70.3	157.0	202.0
November	29.7	19.7	23.8	74.8	330.1	170.7
Mean	30.0	16.7	22.4	64.2	-	-

maxT: maximum temperature; minT: minimum temperature; averT: average temperature; HR: humidity relative of the air.

The soil of the experimental area is a typical Eutroferric Red Latosol, moderate A, with a very clayey texture, kaolinitic-oxidic and a smooth wavy to wavy relief (SANTOS et al., 2018). Soil chemical analysis performed prior to the installation of the experiment indicated a pH ($CaCl_2$) of 5.7; organic matter of 16 g dm^{-3}; $P_{(resin)}$ = 27 mg dm^{-3}; K = 2.7 $mmol_c$ dm^{-3}; Ca = 25 $mmol_c$ dm^{-3}; Mg = 15 $mmol_c$ dm^{-3}; H + Al = 27 $mmol_c$ dm^{-3}; cation exchange capacity of 72 $mmol_c$ dm^{-3} and base saturation of 59%.

Treatments and experimental design

Six treatments (Table 2) were evaluated in a randomized block design with four replications.

Table 2. Characterization of treatments.

Treatments	Collard greens	Chicory	Arugula
Collard greens (Cg) - monoculture	Present	-	-
Chicory (Ch) - monoculture	-	Present	-
Arugula (A) - monoculture	-	-	Present
Cg + Ch - intercropping	Present	Present	-
Cg + A - intercropping	Present	-	Present
Cg + Ch + A - intercropping	Present	Present	Present

The experimental unit had an area of 2.4 m^2 (1.2 m x 2.0 m). In the intercropping of collard greens and chicory (Figure 1a), the experimental unit had 10 collard green plants and 40 chicory plants, with two collard green rows in the centre of the bed. For collard greens, spacing was 0.40 m between rows and 0.50 m between plants. In turn, chicory plants were distributed in four rows spaced 0.20 m apart, with 0.25 m spacing between plants. In the intercropping of collard greens and arugula (Figure 1b), the plots were also made up of 10 collard greens plants at the same spacing as above, in addition to four rows of arugula, sown in furrows spaced 0.20 m apart, with 0.05 m spacing between plants. In the intercropping of collard greens, chicory and arugula (Figure 1c), arugula was sown in three longitudinal furrows, between the rows of chicory and in the rows of collard greens, at the same spacing as above. All species were transplanted and sown on the same day. Data collection considered the six central collard green plants. For arugula and chicory, the useful area of the experimental unit corresponded to the central 2 m^2.

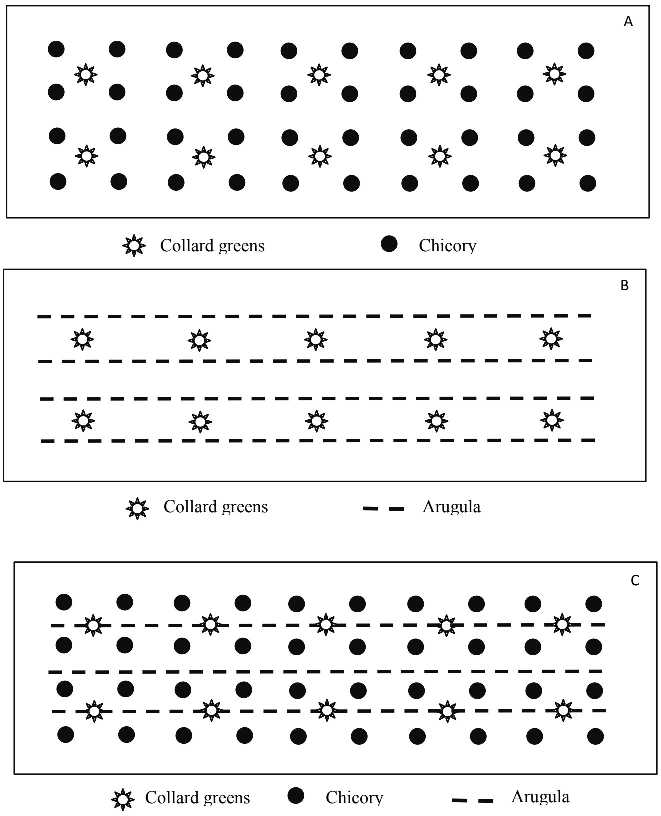

Figure 1. Graphical representation of the intercroppings of collard greens and chicory (A); collard greens and arugula (B); and collard greens, arugula, and chicory (C).

Experiment installation and execution

For the installation of the experiment, the soil was prepared by ploughing, harrowing and construction of the beds. Liming was performed three months before planting to increase base saturation to 80% (TRANI et al., 2018). 'Top Bunch' collard green seedlings and 'Pão de açúcar' chicory seedlings were produced in 200-cell polypropylene trays filled with the commercial substrate Bioplant® and kept in a greenhouse until they had four expanded leaves. 'Folha Larga' arugula was sown directly on the bed in 1-cm-deep furrows spaced 0.20 m apart. Thinning was carried out at 13 and 20 days after sowing to adjust the spacing between plants to 0.05 m.

Planting fertilization was the same for all intercropping treatments, with application of 40, 180 and 60 kg ha^{-1} of N, P_2O_5 and K_2O, respectively, following the recommendations of Trani et al. (2018) for collard greens. In side dress fertilization, 30 kg ha^{-1} of N (urea) and 20 kg ha^{-1} of K_2O (potassium chloride) were applied to collard greens every 15 days after transplantation. For chicory and arugula, fertilizers were distributed along the sowing row, approximately 3 cm away from it, in the following doses: 30 kg ha^{-1} of N (urea) and 20 kg ha^{-1} of K_2O (potassium chloride) for chicory; 50 kg ha^{-1} of N and 30 kg ha^{-1} of K_2O for arugula. For chicory, fertilization was carried out at 10, 20 and 30 days after transplanting; for arugula, at 10 and 20 days after transplanting (TRANI et al., 2018).

Weeds were controlled by manual weeding. Phytosanitary control was carried out according to the needs of each crop, mainly for the control of aphids (*Aphis gossypii* Glover), whiteflies (*Bemisia tabaci* Genn.) and collard green caterpillars (*Ascia monuste* Orseis). Sprinkler irrigation was performed at a rate of 5 mm day^{-1}. Collard greens was harvested every 10 days, starting on August 16, 2018, totalling 10 harvests. Arugula was harvested only once, on August 16, 2018. Chicory was harvested twice, with the first harvest on 2 October and the second on 26 November 2018.

Characteristics evaluated

a) Yield (kg ha^{-1}): Result of all harvests during the crop cycle. The harvests took place from dawn until 8 am; immediately afterwards, the plants were weighed on a scale to two decimal places.

b) Land use efficiency (LUE): The index was calculated using the formula proposed by Willey and Osiru (1972), as follows:

For intercropping of collard greens and chicory:

$$\text{LUE}_{\text{(cg,ch)}} = \frac{Ycg(ch)}{Ycgm} + \frac{Ych(cg)}{Ychm}$$

For intercropping of collard greens and arugula:

$$\text{LUE}_{\text{(cg,a)}} = \frac{Ycg(a)}{Ycgm} + \frac{Ya(cg)}{Yam}$$

For intercropping of collard greens, chicory and arugula:

$$\text{LUE}_{\text{(cg,ch,a)}} = \frac{Ycg(ch,a)}{Ycgm} + \frac{Ych(cg,a)}{Ychm} + \frac{Ya(cg,ch)}{Yam}$$

Where:

$Ycgm$, *Ychm* and Yam are the yields of collard greens, chicory and arugula in monoculture, respectively; *Ycg (ch)*: Yield of collard greens intercropped with chicory; *Ych (cg)*: Yield of chicory intercropped with collard greens; *Ycg (a)*: Yield of collard greens intercropped with arugula; *Ya (cg)*: Yield of arugula intercropped with collard greens; *Ycg (ch, a)*: Yield of collard greens intercropped with chicory and arugula; *Ych (cg, a)*: Yield of chicory intercropped with collard greens and arugula; *Ya (cg, ch)*: Yield of arugula intercropped with collard greens and chicory.

Intercroppings will be considered more efficient than monocultures when the LUE is greater than 1.0 (VIEIRA, 1998).

c) Crop relative contribution (CRC): Relative contribution of each crop in the composition of the LUE index of the intercropping in which it participates. It is calculated as the ratio between two terms: the ratio between crop yield in intercropping and monoculture and the LUE index of the intercropping in question. It is expressed as a LUE percentage, e.g. CRCcg(ch) = [(Ycg(ch) / Ycgm) / LUEcg(ch)]*100.

Where:

CRCcg (ch) is the relative contribution of collard greens in the composition of the LUE index of its intercropping with chicory.

Statistical analysis

Analysis of variance was performed (F test, $\alpha \leq 5\%$) and the means were compared using the Tukey test. The statistical program *AgroEstat* (BARBOSA; MALDONADO JÚNIOR, 2015) was used.

RESULTS AND DISCUSSION

Yield of intercropped species

The yields of species in intercropping and monoculture are shown in Table 3. The presence of chicory and/or arugula did not influence collard green yield. In other words, collard green yield did not differ between intercropping and monoculture (Table 3). Cecílio Filho et al. (2017) also observed that collard green yield was not affected by the presence of 'New Zealand' spinach, regardless of transplanting time. On the other hand, Hendges et al. (2019) transplanted collard greens on the same day as coriander and observed that collard green yield was 18.6% lower in intercropping than in monoculture.

Table 3. Analysis of variance summary and collard green (Cg), chicory (Ch) and arugula (A) yield averages as a function of crop systems.

Crop systems	Yield (kg ha^{-1})		
	Collard greens	Chicory	Arugula
Cg	60421.88a	-	-
Ch	-	79225.00a	-
A	-	-	9145.84a
Cg + Ch	61932.29a	65966.68ab	-
Cg + A	56869.79a	-	5437.50b
Cg + Ch + A	61166.67a	52950.00b	6631.95b
CV (%)	6.9	9.3	10.4

Averages followed by the same letter in the same column do not differ by Tukey test ($p > 0.05$).

In intercropping systems, the placement of species differing in architecture, size, growth rate and nutritional demand, among others, in contact with the main crop can cause positive effects, negative effects, or no effects on that crop. The agronomic performance of intercropped crops is therefore dependent on the interspecific complementarity or competition established in the coexistence of species. In the present study, the absence of competition of arugula and chicory with collard greens may have been due to irregularities in the interception of light radiation caused by rapid and vertical growth of collard greens, an architecture that positioned their photosynthetic canopy above that of the other two species, where it was not shaded by them.

Chicory yield was only lower in intercropping than in monoculture when collard greens and arugula were present. In intercropping with collard greens, although the difference was not significant, chicory yield was 16.7% lower (Table 3), demonstrating the interference of collard greens with chicory. Carlos (2019) analysed an intercropping system with close transplanting dates for chicory and collard greens (chicory transplanting at 0, 14 and 28 days after collard green transplantation). The author observed that, in this system, collard green yields were lower than those obtained in monoculture. The difference between the results of the present study and those of Carlos (2019) was probably due to the intercropping period, with installation in July in this study and in May in that of Carlos (2019). When chicory was grown intercropped with collard greens and arugula, its yield decreased by 33% in comparison with that of monoculture. This is because, arugula grown between chicory rows grew rapidly, reducing the area available for the development of chicory. Notably, the rapid development of arugula and the shading promoted by collard greens determined significant damage to the chicory crop. Andreani et al. (2016) also observed a negative effect of arugula on the fresh and dry matter production of chicory.

The highest arugula yield was obtained in monoculture (9,145.84 kg ha^{-1}). Arugula yield did not differ between the intercropping system with collard greens and the one with collard greens and chicory, both being an average of 34% lower than that of the arugula monoculture.

In short, collard greens intercepted solar radiation while shading the intercropped species by producing broad leaves and positioning them quickly above the canopies of chicory and arugula. Reports on intercropping systems address light as the predominant factor in interspecific interactions (RIBAS et al., 2020). According to the authors, light strongly interferes with species growth and development because the shading caused by the vegetative canopy of larger plants reduces the passage of photosynthetically active radiation (PAR) to smaller plants. This type of radiation (PAR) is a portion of global solar radiation that directly influences plant growth and, consequently, crop yield (SUN et al., 2017). Hendges et al. (2017) observed that taller species can reduce solar radiation on lower species, leading to competition for light, affecting physiological responses of the shaded crop, such as stomatal closure and decreases in the respiration rate and photosynthesis.

Land use efficiency and relative contribution

All intercropping systems proved to be more efficient in terms of land use than monocultures, with increases ranging from 54% to 141%. The intercropping of the three species accounted for the highest LUE index. In this condition, 1.0 hectare of intercropping produced an amount of food equivalent to that produced in 2.41 hectares of monoculture. This intercropping was 30% and 56% more efficient than intercroppings Cg + Ch and Cg + A, respectively (Table 4).

Table 4. Land use efficiency index and contribution of collard greens, chicory and arugula in the composition of the LUE indices.

Intercroppings	LUE	Relative contribution (%)		
		Collard greens	Chicory	Arugula
Cg + Ch	1.86b	55.4a	44.6a	-
Cg + A	1.54c	61.0a	-	39.0a
Cg + Ch + A	2.41a	42.0a	27.8b	30.2a
CV (%)	4.1	4.8	7.0	11.1

Averages followed by the same letter in the same column do not differ by Tukey test (p > 0.05).

For Oliveira et al. (2005) and Heredia et al. (2007), increasing crop yield per unit area is one of the most important reasons for using intercropping systems, as it improves the use of land and other available resources, increasing profitability.

The contribution of collard greens to the composition of the LUE index did not differ between intercroppings with chicory and those with arugula. The same situation was observed for arugula when intercropped with one or two species. However, the contribution of chicory to the LUE index was lower when chicory was intercropped with two species (Table 4). Although the yield of both chicory and arugula decreased in intercropping with collard greens, the three combinations of intercropping under study were shown to be economically beneficial to the producer. In addition, the three intercropping systems positively impact society. This is because the optimization of cultivated areas reduces the need to open new areas for cultivation, creating the possibility of increasing the area destined for the preservation of natural resources. Pereira, Cecílio Filho and La Scala JR (2020) compared the intercropping and monoculture of tomato, cucumber and lettuce in a protected environment. The authors conclude that intercropping systems show economic and, more importantly, environmental advantages.

CONCLUSION

Chicory and arugula do not affect collard green yield in intercropping systems. Regardless of intercropping, collard greens are the dominant species; chicory and arugula, the dominated species. Intercropping of collard greens, chicory and arugula increases land use efficiency, producing in 1 hectare an amount of food corresponding to the production of 2.41 hectares in monoculture.

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