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Polycultivation and agroforestry systems impact the vegetative growth of vegetables

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ABSTRACT

This study was carried out with the aim of evaluating the performance of vegetable production in different agrobiodiverse cropping systems, comparing two successive agroforestry systems (SAFS) with a non-tree vegetables polyculture. The experiment was conducted in an experimental design in randomized blocks, with three treatments and four replications. The treatments consisted of two SAFS with biological diversity: one SAFS with fruit trees (SAFS-F) and another with conilon coffee (SAFS-C), in addition to the non-tree vegetables polyculture (SC-H). The results showed that, on average, the agroforestry systems had a lower performance than the non-tree vegetables polyculture. However, the vegetables submitted to the non-tree polyculture and to the agroforestry system with fruit trees had a better vegetative growth, while the vegetables cultivated in agroforestry system with coffee did not show satisfactory results in the evaluated parameters. This study contributes to the development of sustainable agricultural production technologies, seeking solutions to mitigate the effects of climate change on agriculture.

Keywords: Sustainability**, S**yntropic agriculture, Horticulture.

Policultivo e sistemas agroflorestais impactam no crescimento vegetativo de hortaliças

RESUMO

Este estudo tem o objetivo de avaliar o desempenho da produção de hortaliças em diferentes sistemas de cultivo agrobiodiversos, comparando dois sistemas agroflorestais sucessivos (SAFS) com um policultivo de hortaliças sem a presença do componente arbóreo. O experimento foi conduzido em um delineamento experimental em blocos casualizados, com três tratamentos e quatro repetições. Os tratamentos consistiram em dois SAFS com diversidade biológica: um SAFS com árvores frutíferas (SAFS-F) e outro com café conilon (SAFS-C), além do policultivo de hortaliças sem árvores (SC-H). Os resultados mostraram que, em média, os sistemas agroflorestais apresentaram um desempenho inferior ao policultivo de hortaliças sem o componente arbóreo. No entanto, as hortaliças submetidas ao policultivo sem o componente arbóreo e ao sistema agroflorestal com frutíferas tiveram um melhor crescimento vegetativo, enquanto as hortaliças cultivadas em sistema agroflorestal com café não apresentaram resultados satisfatórios nos parâmetros avaliados. Esse estudo contribui para o desenvolvimento de tecnologias de produção agrícola sustentáveis, buscando soluções para mitigar os efeitos das mudanças climáticas na agricultura.

Palavras-chave: Sustentabilidade, Agricultura sintrópica, Horticultura.

1. Introduction

Conventional agricultural production is characterized by a less sustainable model from an environmental and social point of view, due to the high demand for natural resources, synthetic inputs and fossil fuels, which contributes to aggravating existing environmental problems (Rocha et al., 2016). Currently, the search for alternatives that promote more sustainable food production has become increasingly relevant, aiming to reduce the environmental impact and dependence on external inputs.

In this context, agroforestry systems have been identified as an important strategy to make agricultural production more productive and sustainable. These systems stand out for being highly diversified and capable of recovering degraded areas, combining production with conservation and improving the quality of natural resources (Schembergue et al., 2017; Tubenchlak et al., 2021). Furthermore, agroforestry systems play a crucial role in promoting food security and providing favorable working conditions for farmers. In addition, these systems contribute to the conservation and increase of water reserves in the soil, reducing water demand, reinserting abandoned or degraded areas into productive ones and reducing the use chemicals and external inputs (Chattopadhyay et al., 2021a).

However, the complexity of these systems demands specific studies to understand the ecological and productive relationships involved, in order to define the best management methods. It is important to highlight that the success of agroforestry systems is directly related to the way they are managed, considering spatial and temporal diversification (Nair et al., 2021).

Aiming to contribute to the sustainable and profitable development of agriculture, this study focuses on evaluating the performance of vegetable production in agroforestry systems, in order to generate relevant information for the proper management of these systems and the promotion of a more sustainable agriculture

2. Material and Methods

The study was carried out at the Experimental Farm of Bananal do Norte, belonging to the Capixaba Institute for Research, Technical Assistance and Rural Extension (INCAPER), located in Cachoeiro de Itapemirim-ES, Brazil. The total area is 6,069 m², with geographic coordinates of 20º45'15" S latitude, 41º17'21" W longitude and altitude of 81 m.

The climate in the region is the Cwa type, with rainy summers and dry winters. The average annual temperature is 23ºC and the average annual precipitation is 1,200 mm (Inmet, 2022). The soil in the area is classified as Neosol Fluvial, located in smooth wavy relief with clayey texture, with 22% sand, 22% silt and 56% clay. Before this study, the experimental area was used for about 20 years in intercropping systems of conilon coffee (*Coffea canephora* Pierre ex. Froenher cv. Conilon) with peach palm (*Bactris gasipae* Kunth).

The experimental design adopted was randomized blocks, with three treatments and four replications. The treatments consisted of two biodiverse successional agroforestry systems (SAF's): SAFS's with fruit trees (SAFS-F) and with conilon coffee (SAFS-C), and a non-tree vegetables polyculture (SC-H). Plots SAFS-F, SAFS-C, SC-H were established with 75 m², 75 m², 90 m² each, respectively.

Before the installation of the experiment, the area was cleaned with the aid of a tractor, and the soil prepared with plowing and harrowing. Fertilization and liming were carried out according to the chemical analysis of the soil (Table 1). To increase soil base saturation to 60%, 3.5 t/ha were recommended for blocks 1 and 2, 2.4 t/ha for block 3 and 1 t/ha for limestone block 4, applied tossed and incorporated up to 30 cm deep. After 30 days of liming, to reach the nutritional needs of the plants, organic fertilization was carried out with chicken manure composted throughout the area - an average of 30 t/ha, incorporated with a rotary hoe coupled to a microtractor. Soon after, the soil was covered with crushed urban pruning remains (300 m³ ha-¹).

Initially, plants that make up the ‘tree line’ were introduced to the treatments that compose the agroforestry systems, such as *ingá* (*Inga edullis*), *gliricidia* (*Gliricidea sepium*), peach palm (*Bactris gasipae* Kunth) and eucalyptus (*Eucalyptus* spp.). These species fill the upper and emerging strata of agroforestry systems. In its “mature” phase, the middle stratum was occupied by orange trees (SAFS-F) and coffee (SAFS-C) and the lower stratum was occupied by food crops and, later, by vegetables.

The agroforestry systems were prepared and conducted in the same way, but in SAFS-F the main perennial crop was orange (*Citrus sinensis)* and in SAFS-C conilon coffee (*Coffea canephora*). In the first year of cultivation, in agroforestry systems, in the tree line, perennial species were planted: orange (SAFS-F), coffee (SAFS-C), banana (Musa sp.), eucalyptus (*Eucalyptus urograndis*), and to compose food crops: seedlings of yam (*Dioscorea* spp.), corn seeds (*Zea mays*) and beans (*Phaseolus vulgaris*) (Figures 1 and 2).

The vegetables were introduced in all treatments in the second year of cultivation, in the place where the food crops were previously inserted (Figure 3) and they are: lettuce (*Lactuca sativa*), arugula (*Eruca vesicaria* ssp. sativa), cabbage (*Brassica oleracea*), cauliflower (*Brassica oleracea* var. botrytis), broccoli (*Brassica oleracea* var. italica), eggplant (*Solanum melongena*) and okra (*Abelmoschus esculentus*).

Table 1. Chemical characterization of the soil in the study area

Block	pH	P	K	Na	Ca	Mg	Al	H+Al	SB	CEC	V	m	TOC	MO
	H_2O	----- mg dm^{-3} -----		--------------------- cmol$_c$ dm-³ -----------------							-----%-----		-- dag /kg--	
1	4.8	8.96	168	4.0	2.3	0.7	0.8	6.2	3.5	9.7	36.1	18.6	1.1	1.89
2	4.7	7.04	141	3.0	1.6	0.6	1.3	6.3	2.6	8.9	29.2	33.5	1.06	1.82
3	5.0	10.77	150	3.0	2.7	0.9	0.4	5.3	4.0	9.3	43.5	9.0	1.12	1.93
4	5.6	9.22	146	4.0	3.4	1.0	0.05	3.6	4.8	8.4	57.5	1.03	0.99	1.70

Legend: pH – hydrogen potential, P – phosphorous, K – Potassium, Na – Sodium, Ca – Calcium, Mg – Magnesium, Al – Aluminum, H+Al – potential acidity, SB – sum of bases, CEC – Cation Exchange Capacity, V – base saturation, m – aluminum saturation, TOC – total organic carbon, MO – organic matter – oxidation: Na2Cr2O7 4N + H2SO4 10N.

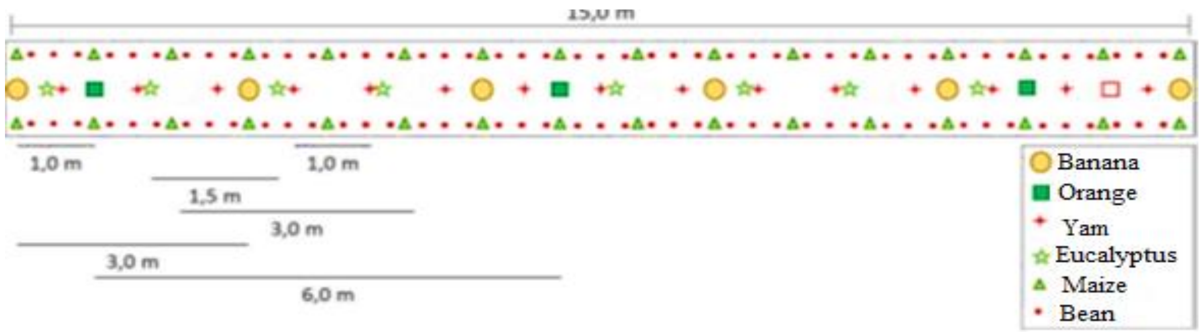

Figure 1. Sketch of the agroforestry system with fruit trees (SAFS-F) **.**

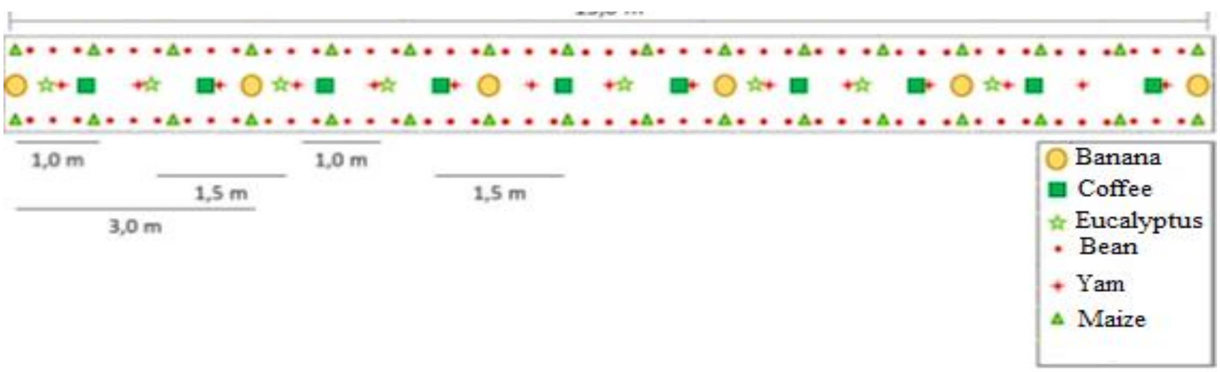

Figure 2. Sketch of the coffee agroforestry system (SAFS-C)

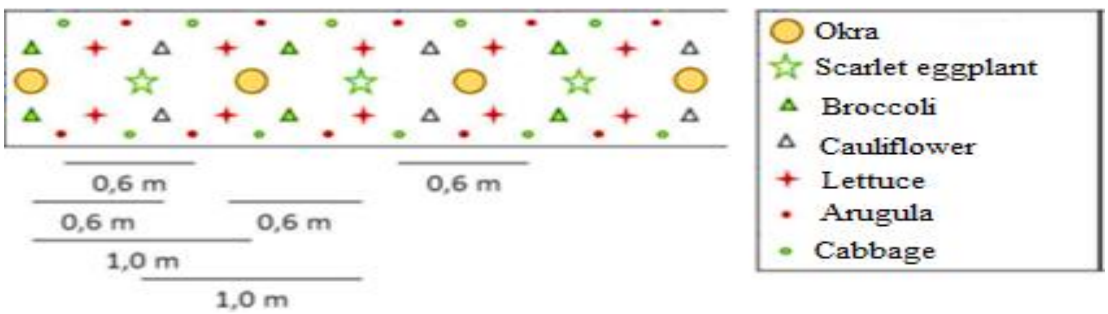

Figure 3. Arrangement of the vegetable patch in the study area present in all treatments.

Cultivation continued throughout the development of the plants, with weeding and mowing in the non-tree vegetables polyculture and manual harvesting of weeds in agroforestry systems, in addition to pruning and pest and disease control with a focus on alternative principles. Irrigation was carried out in a localized way with microsprinklers during the same period of time for all treatments. Only lettuce (iceberg, butterhead and crisphead), arugula and okra were evaluated, as they could be harvested during the period in which the evaluations took place. The vegetative growth of them was evaluated.

The evaluations took place according to the end of the cycle of each culture, being 50 days after planting - (DAP) for arugula, 50 days DAP for lettuce and 70 days DAP for okra. With the aid of a ruler graduated in centimeters, the height of the plants and the length of the largest root were evaluated. The stem diameter, only for the okra culture, was measured with an analog caliper, taken 1 cm from the ground, the total chlorophyll by means of a portable chlorophyll content meter (ClorofiLOG Falker model FL1030) and to count the number of leaves, leaves unfit for consumption were discarded.

The data were submitted to analysis of variance, using the F test at $p>0.05$ of probability, and for the variables that showed significant differences, the Tukey's test was applied at $p< 0.05$ to compare means using the R software (R Core Team, 2021).

3. Results and Discussion

The different types of systems tested in the production of arugula, lettuce (crisphead, green leaf and butterhead) and okra promoted effects by the Tukey's test ($P<0.05$). According to the analysis of variance, there were no statistical differences for the variable number of leaves and chlorophyll for arugula plants in different cropping systems. However, there is a significant effect of the non-tree vegetables polyculture in relation to the agroforestry systems, with greater values of leaf length and greater root length of arugula plants (Table 2).

For lettuce, it was observed that there was no significant effect for the plant height variable in the different systems. However, for the variables number of leaves, root length and total chlorophyll, there are statistical differences with higher values for lettuce grown in a non-tree polyculture system, like we observe in Table 3. Similar behavior can be observed in crisp lettuce responses when cultivated in the three cultivation models. As there was no statistical difference for the plant height variable, for the other variables, higher values were observed for the plant grown in polyculture without the tree component as we can observe in Table 4.

Table 2. Length of the largest leaf – LLL (cm), Number of leaves - NL, Length of the largest root – LLR (cm) and Total Chlorophyll – TC, of arugula cultivated in two different successional agroforestry systems and in the non-tree polyculture system.

TREAT.	LLL	NL	LLR	TC
SAFS-C	31.99* b	12.85 a	15.90 b	34.22 a
SAFS-F	33.03 b	13.85 a	18.2 ab	33.87 a
SC-H	36.95 a	12.80 a	20.4 a	34.77 a
CV (%)	10.43	28.49	19.67	11.18

*The means followed by the same lowercase letter in the column do not differ by Tukey's test (p>0.05).

Table 3. Length of the largest leaf – LLL (cm), Number of leaves - NL, Length of the largest root – LLR (cm), and Total Chlorophyll – TC, of iceberg lettuce cultivated in two different successional agroforestry systems and in the non-tree polyculture system.

TREAT.	LLL	NL	LLR	CT
SAFS-C	19.95* a	11.80 b	5.93 b	24.98 b
SAFS-F	20.10 a	11.95b	6.0 b	26.08 b
SC-H	21.05 a	17.85 a	8.1 a	31.11 a
CV (%)	13.82	24.33	27.37	21.70

*The means followed by the same lowercase letter in the column do not differ by Tukey's test (p>0.05).

The results found in this study differ from those of Nair et al. (2021) who found that the best performances in terms of visual appearance, green plant mass, rootless plant mass, vertical and horizontal leaf size for lettuce plants were found in consortiums submitted in agroforestry systems, while the worst were found in the treatments in which lettuce was planted in the conventional system. Likewise, Oliveira et al. (2010), who comparing the organic and conventional systems, obtained higher averages for the variable number of leaves in organic cultivation, 16.1 leaves and in the conventional system 13.8 leaves on average.

It is believed that the lower productive performance of lettuce plants subjected to non-tree treatment can be explained due to the relationship with the efficiency of converting solar radiation into phytomass, since in cultivation in agroforestry systems, due to the shade, the radiation that reaches the canopy is lower, resulting in less significant production of leafy plants such as lettuce. For okra, the significant effect between the results obtained was observed only in the stem diameter variable, with the highest values for plants submitted to non-tree polyculture SC-H. There was no statistical difference between the two agroforestry systems for this variable and for the other variables among all tested treatments (Table 5). In the case of okra, highlighted in this study, the results of the agroforestry systems did not statistically differ with the non-tree polyculture (with the exception of the stem diameter), but with the imposition of adequate management, higher values are expected, providing the generation of resources with cultures that have a fast economic return and high value, as is the case of vegetables in general.

Results found by Moura et al. (2009), in participatory research, corroborate those found in this study, since the aforementioned authors concluded that the development of cauliflower and asparagus in agroforestry systems was not satisfactory, probably due to the relatively longer life cycle of these crops and their demand for light, which are not well developed due to the shade of the other intercropping species (mainly maize and cassava), which means that to grow these crops in intercropping it is necessary that they reach the upper stratum.

Even though indirectly the results in average terms of agroforestry systems were lower than those of non-tree polyculture, these successional systems considerably increase the efficiency of land use by plants and by man, as they optimize the use of space and time. Agroforestry systems not only offer environmental and social benefits, but also have advantageous economic aspects. Through the diversification of cultures and the combination of species of economic value, these systems can provide multiple sources of income to the farmer. Diversified production allows the marketing of different products, reducing dependence on a single crop.

Table 4. Length of the largest leaf – LLL (cm), Number of leaves - NL, Length of the largest root – LLR (cm), and Total Chlorophyll – TC, iceberg lettuce cultivated in two different successional agroforestry systems and in the non-tree polyculture system.

TREAT.	LLL	NL	LLR	TC
SAFS-C	20.78* a	10.20b	6.53 b	16.43b
SAFS-F	21.35 a	11.95 ab	6.5 b	15.97 b
SC-H	22.27 a	14.3 a	8.6 a	18.92 a
CV (%)	11.49	30.64	23.42	17.91

*The means followed by the same lowercase letter in the column do not differ by Tukey's test (p>0.05).

Table 5. Length of the largest leaf – LLL (cm), Number of leaves - NL, Stem diameter – SD (cm), and Total Chlorophyll – TC, of okra cultivated in two different successional agroforestry systems and in the non-tree polyculture system.

TREAT.	LLL	NL	SD	TC
SAFS-C	43.65* a	13.60 a	10.81 b	43.79 a
SAFS-F	44.90 a	12.70 a	10.67 b	42.73 a
SC-H	50.50 a	14.15 a	15.23 a	45.74 a
CV (%)	20.51	30.80	39.52	9.71

*The means followed by the same lowercase letter in the column do not differ by Tukey's test (p>0.05).

In addition, the use of agroecological practices in agroforestry systems can reduce costs with external inputs, such as fertilizers and agrochemicals, making production more economically viable (Murthy et al., 2016). In the longer term, these systems can also increase farmers' financial resilience, as crop diversification helps mitigate the risks associated with adverse weather conditions and market swings. Therefore, agroforestry systems present a sustainable economic approach, contributing to agricultural development in a balanced and profitable way (Gonçalves et al., 2021).

4. Conclusions

The non-tree polycultures and agroforestry systems with fruits promoted better vegetative growth of arugula, lettuce and okra. However, the agroforestry system with coffee did not show positive results in the vegetative growth of these crops.

Authors' Contribution

Juliana Elias de Oliveira led the study's planning and execution, including the selection of vegetable species and agrobiodiverse cropping systems. Jhonatah Albuquerque Gomes contributed by producing relevant study images. Lorena Abdalla de Oliveira Prata Guimarães analyzed collected data and interpreted results. Lorenza Bandeira de Paula focused on assessing the impact of climate change on the studied cultivation systems.

Joab Luhan Pedrosa played a crucial role in implementing and maintaining field experiments, ensuring soil quality and phytosanitary control for healthy plant development. Fábio Luiz de Oliveira provided the study's design overview, shaping research objectives related to sustainable agricultural technologies.

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