TECHNICAL FEASIBILITY OF CONVENTIONAL AND NONCONVENTIONAL VEGETABLES' INTERCROPPING UNDER ORGANIC FERTILIZATION

VIABILIDADE TÉCNICA DO CULTIVO CONSORCIADO DE HORTALIÇAS CONVENCIONAIS E NÃO CONVENCIONAIS SOB FERTILIZAÇÃO ORGÂNICA

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ABSTRACT: This work aimed to evaluate the technical feasibility of lettuce, Indian spinach and taro intercropping under organic fertilizer. The experiment was performed at Água Limpa Farm, belonging to the University of Brasília, located in Brasília - DF, from October 2014 to June 2015. A completely randomized block design with seven treatments and four replications was used. Each experimental plot had 18 m^2 (4.5 m x 4.0 m), totaling 28 plots. The following treatments were assessed: lettuce monoculture, Indian spinach monoculture, taro monoculture, lettuce/Indian spinach intercropping, lettuce/taro intercropping, Indian spinach/taro intercropping, and lettuce/Indian spinach/taro intercropping. In all treatments, the following spacings were used: 0.25 x 0.25 m (lettuce), 1.0 x 0.6 m (Indian spinach), and 1.0 x 0.3 m (taro). Crop production was evaluated from sample plants taken from the central part of each plot. Two harvests of lettuce, two of Indian spinach and one of taro were carried out during intercropping. In the first cycle, lettuce highest mean yield values were observed in the lettuce monoculture (3.5 kg m^{-2}) and lettuce/Indian spinach intercropping (3.4 kg m^{-2}). The crop reached the commercial size in both production cycles, except when intercropped with Indian spinach in the second cycle. The highest Indian spinach mean fresh mass was recorded in the lettuce/Indian spinach intercropping (974.7 g $plant^{-1}$; first harvest) and monoculture (327.5 g $plant^{-1}$; second harvest). The yield of taro rhizomes was significantly higher when intercropped with lettuce, showing a mean value of 16.8 kg m^{-2}. The intercropping arrangements with lettuce increased yield of nonconventional vegetables. The conventional and nonconventional vegetables' intercropping technique increased species diversity in the area without interfering in the agronomic performance and quality of the crops.

KEYWORDS: *Basella alba*. Biodiversity. *Colocasia esculenta*. *Lactuca sativa*. Sustainable production of neglected vegetables.

INTRODUCTION

Consumers are becoming more informed and demanding about the quality standards of the food they consume, as discussed by Nascimento et al. (2019). The increase in the demand for healthy food by the brazilian people follows world's tendencies of change in consumption habit resulting in a more diverse type of food production (CASINI et al., 2015; MÉNDEZ; EUPHRASIO, 2017). Nevertheless, the variety of plants consumed by humans has decreased over the last hundred years. More than half of the calories we consume are provided by only three plant species (rice, wheat, and corn), and 90% of the food consumed is solely supplied by 20 plant species (PROENÇA et al., 2018).

The consumption of nonconventional vegetables may diversify and improve the nutritional quality of the population's diet since they are rustic, resistant to pests and diseases and easy to grow plants. They have good productivity and can be grown in households or community gardens (DIAS et al., 2018).

However, the reduction in the cultivation and consumption of these vegetables has occurred due to the lack of knowledge about these group of plants. The population understanding of nonconventional food plants is still abstract and is lost or mixed in the concepts of medicinal plants and spontaneous plants. Therefore, the use of these species for food is still quite limited (BORGES; SILVA, 2018; LIBERATO et al., 2019).

Although these species have been neglected in their cultivation, several studies report that they

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have higher vitamin C and mineral contents than the conventionally used species, such as lettuce, cabbage, spinach, and cabbage (PINTO et al., 2001; KINUPP; BARROS, 2008; UUSIKU et al., 2010; ANDARWULAN, et al., 2012; OLIVEIRA et al., 2013; ALMEIDA et al., 2014). Additionally, some species are sources of antioxidant compounds, such as phenolic acids (SOUSA et al., 2014).

In agricultural production, the stability of vegetal biomass production is mainly sought in view of environmental stresses. Conversely, monoculture, one of the major problems of the currently practiced agricultural model, results in a greater instability of the production system, which is subjected to environmental adversities (SOUZA; RESENDE, 2014).

Vegetable intercropping may increase yield and the economic and biological stability of the agrosystem, along with an improvement in the use efficiency of available resources (soil, water, light, nutrients) and labor. It may also reduce the infestation of spontaneous plants, pests, and diseases. Furthermore, intercropping contributes to the stability of the rural activity, ensuring staggered harvests and enabling additional income to the producer (ALTIERI et al., 2003; SANTOS; CARVALHO, 2013; GEBRU, 2015).

Intercropping requires species with a good interspecific combining ability and, consequently, higher production and agroeconomic efficiency in the intercropped systems (CAMILI et al., 2013). Hence, it is necessary to compose a diversity of plant species, whether of commercial interest or not, recommending that local species be chosen since they are adapted to the edaphoclimatic conditions of the region (SOUZA; RESENDE, 2014). Intercropping of conventional with nonconventional vegetables has great potential as a crop management tactic in alternative and diversified food production systems. Thereby, it contributes to the cultural and cultivation retrieval of nonconventional species and increases the rural producer income.

Lettuce (*Lactuca sativa* L.) has the highest sales volume of any leafy vegetable sold in Brazil (MARTINS et al., 2017). In 2017, Brasil produced 1.701.872 tons of the vegetable in 91.172 hectares (CNA, 2017). It is suited for *in natura* consumption and various types of salads (ZUFFO et al., 2016). Lettuce has reasonable amounts of vitamins A and C, niacin, folates, minerals, and dietary fiber, which make up the human diet (MARTINS et al., 2017; ABREU et al., 2010). This vegetable has high nutraceutical value and low value added to the marketed product. For this reason, its association with other vegetables may contribute to the reduction of production costs and increase of the producer income (CAMILI et al., 2013). Moreover, according to Silva et al. (2018), the crop may significantly contribute to the productive efficiency and sustainability of the intercropping system.

Indian spinach (*Basella alba*) is a nonconventional vegetable, also known as Ceylon spinach, vine spinach, Malabar spinach, among other denominations (KINUPP; AMARO; BARROS, 2004; ROY et al., 2010). It is native to tropical and subtropical areas of South America. The Indian spinach belongs to the Basellaceae family and is a vigorous climbing plant with thick leaves (MADEIRA et al., 2013). Its leaves can be consumed in salads, sautéed, cakes, and others. It is a vegetable source of protein and fiber and can be used for diet enrichment through the preparation of bread (MARTINEVSKI et al., 2013). Besides, Indian spinach leaves have anti-inflammatory and antibiotic properties (RODDA et al., 2012). Several parts of the plant can be used to treat diseases, such as hypertension and anemia, mainly in India and China (SHRUTHI et al., 2012). Indian spinach presents low market value because it is little known and demanded. As a consequence, its cultivation is only economically feasible if intercropped with profitable crops (TELLES et al., 2018).

Colocasia esculenta is also a nonconventional vegetable and the main species in the Araceae family within the "tuberous vegetables" group. It is worldwide known as taro (PEDRALLI et al., 2002). In South, Southeast, and Midwest Brazil, it is well-known as “yam” (BALBINO et al., 2018). Taro is a low-cost production crop with low demand in soil fertility and inputs (HEREDIA ZÁRATE et al., 2013). It can be grown under adverse soil and climatic conditions and, as a result, taro may be suitable for family farming. However, its long cycle, from 7 to 9 months, may impair the cultivation by small farms. Thus, taro intercropped with other vegetables that result in anticipated harvests may be an alternative for allowing economic returns throughout the cycle of the species (VIEIRA et al., 2014; BRITO et al., 2017; COLOMBO et al., 2018).

Therefore, the objective of this study was to evaluate the technical feasibility of the conventional and nonconventional vegetable intercropping, aiming at increasing yield and quality, as well as enabling the cultivation retrieval of nonconventional vegetables.

MATERIAL AND METHODS

The experiment was performed at Água Limpa Farm (FAL), belonging to the University of Brasília (UnB), located in Brasília - DF, from October 2014 to June 2015. The FAL is located at latitude 15°56'00 "S, longitude 57°56'00"W, and approximately 1,100 meters above sea level. The climate of the region falls between the tropical savanna and warm temperate rainy climate with dry winter, according to the Köppen classification. Two seasons are well defined in the region: the hot and rainy (October to April) and the cold and dry (May to September).

The soil of the vegetable production area at FAL-UnB is classified as clayey Red Yellow Latosol. Soil analysis in the 0 - 20 cm layer showed pH = 6.7; OM = 33.9 g/kg; P = 67.6 mg/dm^{-3}; K = 0.32 mE/100ml; Ca = 4.2 mE/100ml; Mg = 2.4 mE/100ml; S = 7.1 mg/dm^{-3}; H + Al = 3.0 mE/100ml; SB = 6.98 mE/100ml; CEC = 9.98 mE/100ml; V = 70%.

Crotalaria juncea was planted in the area, prior to experiment implementation, to be used as green manure incorporated into the soil. It was used aiming at soil surface protection, as well as the maintenance and improvement of soil physical, chemical, and biological characteristics. The planting area consisted of a 504 m^2 (18 m x 28 m) plot. An offset disk was used twice to disintegrate the soil and incorporate the organic matter resulted from spontaneous plants and green manure. Limestone and thermophosphate (Yoorin®, 200 g m^{-2}) were applied throughout the area after green manure incorporation.

For planting fertilization, the organic fertilizer (tanned bovine manure) was calculated as follows: lettuce, 3.0 kg m^{-2} (SAMINÊZ, 2002); Indian spinach, 3.0 kg m^{-2}; and taro, 2.0 kg m^{-2} (SOUZA; RESENDE, 2014). Fertilizer was applied as outlined above. Therefore, the amount of fertilizer applied in the intercropped plots was the sum of the doses recommended for each crop within the intercropping system, as suggested by Cecílio Filho et al. (2007).

Two cover fertilization were performed in the lettuce plots at 15 and 30 days after transplanting. The tanned bovine manure was applied following doses recommended by Resende et al. (2007): 100 g m^{-2}. The taro production cycle is longer in regions of higher altitude. Therefore, cover fertilization was performed 120 days after planting in taro plots, as recommended by Souza and Resende (2014), as 200 grams of tanned bovine manure was applied per plant.

A completely randomized design with seven treatments and four replications was used. Each experimental plot had 18 m^2 (4.5 m x 4.0 m), totaling 28 plots. Treatments comprised the following arrangements: lettuce monoculture, Indian spinach monoculture, taro monoculture, lettuce/Indian spinach intercropping, lettuce/taro intercropping, Indian spinach/taro intercropping, and lettuce/Indian spinach/taro intercropping. Crop production was evaluated from sample plants taken from the central part of each plot. The evaluated vegetables were lettuce, Indian spinach, and taro.

Lettuce was chosen as the main component crop of the intercropping system. Cultivar Vanda, a variety of crisp lettuce, was selected to represent this crop. The lettuce seedlings were produced in styrofoam trays of 200 cells filled with commercial agricultural substrate, under protected cultivation, at FAL-UnB. In all treatments comprising lettuce, seedlings were field transplanted at a spacing of 0.25 m (between plants) and 0.25 m (between rows), as recommended by Souza and Resende (2014). Two lettuce cycles were planted during the intercropping period. In the first cycle, the lettuce monoculture treatments were comprised of 16 planting lines, totaling 256 lettuce plants per plot; double intercropping, ten planting lines with a total of 160 lettuce plants per plot; and triple intercropping, four planting lines, resulting in 64 lettuce plants per plot. Due to the large size of the nonconventional vegetables, in the second lettuce cycle, double and triple intercropping treatments consisted of six planting lines with a total of 96 lettuce plants per plot.

Both lettuce cycles were harvested 60 days after field transplanting. The experimental unit was comprised of ten plants per plot, and the yield was calculated per unit area. Plants were washed, dried, and then the following variables were evaluated: shoot fresh mass, plant diameter, and plant height.

The Indian spinach seedlings were produced from seeds in styrofoam trays of 128 cells filled with commercial agricultural substrate, under protected cultivation, at FAL-UnB. Seedlings were field transplanted when a height of 10 cm was reached, according to the MAPA (2010) recommendation. Plants were spaced at 1.0 m between plants and 0.6 m between rows in all treatments (MADEIRA et al., 2013). Two Indian spinach harvests were carried out during the intercropping period. The Indian spinach monoculture and lettuce/Indian spinach intercropping treatments were comprised of three planting lines, resulting in 21 plants of Indian spinach per plot. The Indian spinach/taro intercropping treatment consisted of four planting lines, totaling 28 plants of Indian spinach per plot. In its turn, the triple intercropping treatment included two planting lines with a total of 14 plants of Indian spinach per plot.

Indian spinach was first harvested 140 days after field transplanting. The second harvest was performed 30 days from the date of the first cut. The experimental unit was comprised of five plants per plot, and the yield was calculated per unit area. Cleaning and selection of the Indian spinach aboveground shoots were carried out after cutting. Defective aboveground shoots were discarded. The following variables were evaluated: shoot fresh mass, number of leaves per stem, number of commercial packs per plant, stem height, and number of stems per plant. The number of commercial packs was calculated according to the MAPA (2010) recommendation, considering stems of 30 to 40 cm in length, and a mean fresh mass value of 300 g.

Taro rhizomes, variety Japanese, were directly sowed in the soil 15 days prior to lettuce and Indian spinach seedling transplanting into the field. Plants were spaced at 1.0 m between plants and 0.3 m between rows in all treatments (MADEIRA et al., 2013). The taro monoculture and double intercropping treatments were comprised of three planting lines, resulting in 39 taro plants per plot. Treatments consisting of taro in triple intercropping were comprised of two lines of the crop, totaling 26 taro plants per plot.

Taro was harvested seven months after field planting of rhizomes when more than 50% of the leaves of plants from different plots showed leaf yellowing as a symptom of senescence. The experimental unit was comprised of five plants per plot, and the yield was calculated per unit area. The following parameters were evaluated: rhizome fresh mass, number of rhizomes, rhizome diameter, and rhizome length.

Data were subject to analysis of variance, and means were grouped through similarity by the Scott-Knott test, at 5% probability, using the SISVAR program, version 2015.

RESULTS AND DISCUSSION

In the first lettuce cycle, no difference was observed among treatments for the trait shoot fresh mass, which had a mean of 277.5 g plant^{-1} (Table 1). According to results obtained by Algeri et al. (2018), lettuce did not suffer intraspecific competition among the other crops in the intercropping, which were not yet in full development. However, at the end of their cycle, they received benefits from a more humid soil provided by the coverage of non-conventional vegetables.

In the second cycle, shoot fresh mass from lettuce plants in monoculture and triple intercropping showed values of 247.2 and 218.0 g plant^{-1}, respectively. These values are significantly higher than those obtained in the lettuce/Indian spinach and lettuce/taro double intercropping. The greater amount of fertilizer in the triple intercropping plot may have contributed to the result. In addition, the shading of lettuce plants caused by unconventional vegetables in the double intercropping influenced negatively in the fresh weight. In the triple intercropping, lettuce lines were arranged at the edges of the plot and, therefore, were not influenced by shading.

Likewise, Camili et al. (2011) evaluated the behavior of the lettuce and taioba intercropping and recorded that the lettuce production data (fresh mass, leaf number, and yield), when intercropped, presented better results in the first cultivation cycle.

In the first production cycle, the mean lettuce yield in monoculture (3.5 kg m^{-2}) and lettuce/Indian spinach intercropping (3.4 kg m^{-2}) was significantly higher than the mean yield recorded for lettuce/taro (2.3 kg m^{-2}) and lettuce/Indian spinach/taro (1.3 kg m^{-2}) intercropping (Table 1). Plant stand influenced the total production since monoculture comprised 15 plants m^{-2}, double intercropping presented 9.2 plants m^{-2}, and triple intercropping had only 3.7 plants m^{-2}. Similarly, Heredia Zárate et al. (2005) reported that lettuce intercropped with taro yielded a mean of 2 kg m^{-2}.

In the second production cycle, the mean lettuce yield in monoculture (3.6 kg m^{-2}) was significantly higher than the intercropping treatments lettuce/Indian spinach (0.5 kg m^{-2}), lettuce/taro (0.8 kg m^{-2}), and lettuce/Indian spinach/taro (1.2 kg m^{-2}). This difference may be due to the plant stand in each treatment and effects of shading on lettuce caused by the Indian spinach and taro plants growth. Although the intercropped lettuce presented lower yield in the second cycle than in the first, the commercial size was reached in both cultivation cycles, except when intercropped with Indian spinach. For this reason, it is recommended to cut the stems of Indian spinach before planting a second cycle of lettuce.

Table 1. Lettuce shoot fresh mass recorded in monoculture and double and triple intercropping arrangements with Indian spinach and taro. Água Limpa Farm - UnB, 2015.

Treatment	Fresh Mass			
	First Cycle		Second Cycle	
	(g plant^{-1})	(kg m^{-2})	(g plant^{-1})	(kg m^{-2})
Lettuce	239.5 a	3.5 b	247.2 b	3.6 b
Lettuce/Indian spinach	270.5 a	3.4 b	89.4 a	0.5 a
Lettuce/Taro	246.4 a	2.3 a	149.5 a	0.8 a
Lettuce/Indian spinach /Taro	353.5 a	1.3 a	218.0 b	1.2 a
CV (%)	31.2	39.7	27.5	40.7

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

Plant diameter is an important commercial feature in the selection of lettuce plants by consumers. In the first production cycle, lettuce presented maximum mean diameter when intercropped with Indian spinach (26.7 cm), which did not statistically differ from the remaining treatments. However, in the second lettuce cycle, the highest diameters were observed in lettuce plots cultivated in monoculture and triple intercropping systems. In both treatments, the lettuce plants reached 21.5 cm in diameter (Table 2). This is probably due to less intraspecific competition between lettuce plants in monoculture and to the greater fertilizer input in the triple intercropping. In addition, the shading caused by nonconventional vegetables in the double intercropping plots may have caused the lettuce plants to grow vertically, contributing to the production of plants with a smaller diameter.

Koefender et al. (2016) reported a mean diameter of 42.8 cm in lettuce heads intercropped with onion. According to the authors, the lettuce reduced cycle and rapid development decrease the interference among the intercropped plants and do not affect crop growth.

Lettuce plant height did not differ statistically among treatments in the first cycle, showing a mean value of 16 cm. In the second cycle, maximum lettuce plant height was recorded in triple intercropping (20.2 cm). However, this value did not differ statistically from those found in monoculture and lettuce/taro intercropping. The lowest lettuce plant height, in the second cycle, was recorded in the lettuce/Indian spinach intercropping (14.9 cm) (Table 2). This result was probably due to the Indian spinach indeterminate growth habit. This crop spreads through the soil and competes with lettuce plants for light, water and nutrients.

Table 2. Lettuce plant diameter and height recorded in monoculture and double and triple intercropping arrangements with Indian spinach and taro. Água Limpa Farm - UnB, 2015.

Treatment	Diameter (cm)		Height (cm)	
	First Cycle	Second Cycle	First Cycle	Second Cycle
Lettuce	21.2 a	21.5 c	14.4 a	19.8 b
Lettuce/Indian spinach	26.7 a	14.8 a	17.1 a	14.9 a
Lettuce/Taro	22.9 a	17.8 b	16.2 a	19.1 b
Lettuce/Indian spinach/Taro	26.5 a	21.5 c	16.5 a	20.2 b
CV (%)	16.4	9.6	9.9	8.1

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

The highest Indian spinach shoot fresh mass, in the first harvest, was observed in the lettuce/Indian spinach intercropping (974.7 g plant^{-1}), which did not differ statistically from the remaining treatments. In the second Indian spinach harvest, the highest mean fresh mass value was observed in monoculture (327.5 g plant^{-1}), which also did not differ statistically from the other treatments (Table 3). The fresh mass of Indian spinach leaves in the second cut was 33.6% of the fresh mass of the first cut. This is probably due to the fact that plants were already weakining and in the process of senescence. The first harvest of Indian spinach was carried out according to the recommendation of Madeira et al. (2013), four months after transplanting the seedlings, and the second harvest, one month after the first cut.

Nevertheless, Indian spinach in triple intercropping exhibited lower mean of fresh mass (150 g plant^{-1}) than the other treatments in the first harvest (Table 3). This result may be due to the higher interspecific competition among the plants composing the triple intercropping system. As stated by Varalakshmi & Devaraju (2010), the fresh mass of Indian spinach plants may vary from 68.5 to 260.4 g depending on the genotype. In accordance with these authors, the high species variability may be a basis for effective selection of superior lines in *Basella alba*. Soares (2017) reported that Indian spinach reached a fresh mass of 325.8 g plant^{-1}. In its turn, Campos et al. (2011) showed that Indian spinach propagated via seeds and cultivated in pots exhibited fresh mass of 96 g plant^{-1}.

The lowest Indian spinach yield values in the first (0.5 kg m^{-2}) and second (0.1 kg m^{-2}) harvests were recorded in the triple intercropping system. The Indian spinach mean yield values in monoculture and double intercropping did not differ statistically from each other in the first and second harvests. In the first harvest, a mean of 1.1 kg m^{-2} was observed, whereas 0.4 kg m^{-2} was recorded in the second harvest (Table 3). The Indian spinach was, probably, the dominated culture within the spatial arrangement, due to its growth habit, and, therefore, presented a lower yield average when combined with lettuce and taro.

Table 3. Indian spinach fresh mass in monoculture and double and triple intercropping arrangements with lettuce and taro. Água Limpa Farm - UnB, 2015.

Treatment	Fresh Mass			
	First Harvest		Second Harvest	
	(g plant^{-1})	(kg m^{-2})	(g plant^{-1})	(kg m^{-2})
Indian spinach	777.0 a	0.9 b	327.5 a	0.4 b
Lettuce/Indian spinach	974.7 a	1.2 b	334.0 a	0.4 b
Indian spinach/Taro	683.0 a	1.1 b	240.0 a	0.4 b
Lettuce/Indian spinach/Taro	736.0 a	0.5 a	150.0 a	0.1 a
CV (%)	27.2	27.1	35.4	37.4

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

No statistical difference was detected in the number of leaves stem^{-1}, in the first and second Indian spinach harvests (Table 4). The highest mean values in the first and second harvests were both registered in the Indian spinach monoculture system, with 10.2 and 13.3 leaves stem^{-1}, respectively. The Indian spinach fresh mass was reduced in the second harvest in relation to the first harvest. However, a higher number of leaves per stem was observed in the second harvest since leaves from the latter were smaller than the leaves from the first harvest. This result derived from the shading caused by the presence of taro plants, which have large leaves known as “elephant ear” and can reach 2 meters in height during growth (NAKADE et al., 2013). Shading may have reduced the photosynthesis process in Indian spinach leaves, reducing its size.

No statistical difference was observed in the number of Indian spinach commercial packs, both in the first and second harvests, reaching 300 g each pack (Table 4). The highest number of commercial packs, in the first harvest, was observed in the Indian spinach and lettuce intercropping (3.2 packs plant^{-1}), which did not differ statistically from the remaining treatments. In the second harvest, a mean of 0.9 packs plant^{-1} was recorded among treatments. The number of commercial packs of Indian spinach obtained in the second harvest was reduced compared to the first harvest, in absolute values. This fact may be explained by the lowest fresch weight of Indian spinach leaves in the second harvest, wich refected in the number of commercial packs.

Table 4. Number of leaves and commercial packs of Indian spinach recorded in monoculture and double and triple intercropping arrangements with lettuce and taro. Água Limpa Farm - UnB, 2015.

Treatment	Leaves		Commercial Packs	
	First Harvest (leaves stem^{-1})	Second Harvest (leaves stem^{-1})	First Harvest (packs plant^{-1})	Second Harvest (packs plant^{-1})
Indian spinach	10.1 a	13.3 a	2.6 a	1.1 a
Lettuce/Indian spinach	10.0 a	11.5 a	3.2 a	1.0 a
Indian spinach/Taro	8.4 a	10.2 a	2.3 a	0.9 a
Lettuce/Indian spinach/Taro	9.1 a	9.2 a	2.4 a	0.5 a
CV(%)	9.4	17.9	27.2	37.1

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

The number of stems per Indian spinach plant was not affected by the treatments in either the first or second harvests (Table 5). Mean values of 9.4 and 5.1 stems plant^{-1} were verified in the first and second harvests, respectively. The highest mean plant height values, in the first harvest, were observed in the Indian spinach/taro (2.3 meters) and triple (2.4 meters) intercropping. These values were significantly higher than those obtained in monoculture (1.6 m) and lettuce/Indian spinach intercropping (1.7 m). However, no statistical difference was detected among treatments for stem height in the second harvest, showing a mean of 2.1 m. The shading of Indian spinach plants caused by taro in the double and triple intercropping may have provided larger stems in the search for luminosity. The spatial arrangement can be manipulated to improve the use of resources and increase the efficiency of intercropping practices in vegetables. According to Larcher (2000), this may be due to systems' capacity for self-regulation that is based on the relationships between species.

Table 5. Plant height and number of stems per plant of Indian spinach recorded in monoculture and double and triple intercropping arrangements with letucce and taro. Água Limpa Farm - UnB, 2015.

Treatment			Stems	
	First Harvest Height (m)	Second Harvest Height (m)	First Harvest (stems plant^{-1})	Second Harvest (stems plant^{-1})
Indian spinach	1.6 a	1.6 a	9.2 a	5.1 a
Lettuce/Indian spinach	1.7 a	2.1 a	12.4 a	5.2 a
Indian spinach/Taro	2.3 b	2.3 a	7.3 a	5.4 a
Lettuce/Indian spinach/Taro	2.4 b	2.4 a	8.6 a	4.9 a
CV(%)	21.4	21.7	31.9	7.1

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

No significant statistical difference was identified in the fresh mass of taro rhizomes, which had a mean of 49 grams rhizome^{-1} (Table 6). Vieira et al. (2014) reported a mean fresh mass of 53.9 grams rhizome^{-1} in the cultivation of taro intercropped with snap bean. Colombo et al. (2018) observed a mean fresh mass of 30.5 grams rhizome^{-1} in taro and cucumber intercropping.

Treatments presented significant responses in the rhizome fresh mass (Table 6). The highest mean rhizome fresh masses were observed in the lettuce/taro (7.5 kg plant^{-1}) and triple (6.7 kg plant^{-1}) intercropping. These values were significantly higher from those of other treatments. Even with a lower plant stand, the triple intercropping matched the lettuce/taro intercropping in the fresh mass production of rhizomes plant^{-1}. Taro intercropped with Chinese cabbage had already shown higher values of yield and number of rhizomes per plant than those recorded in monoculture (BRITO et al., 2017). As stated by the authors, this is a beneficial association for both crops. In the associations of taro with lettuce and Indian spinach, the "Facilitation Mechanism" may have occurred. In this mechanism, one specie affords some benefits for other species. Also, the crops may modify the environment of another crop in a positive way, although not necessarily reciprocally, according to Vandermeer (1989).

Fresh mass of taro was significantly higher in the lettuce/taro intercropping (16.8 kg m^{-2}) than in the other treatments (Table 6). In the species composition of an intercropping system, it is necessary to pay attention to the spatial arrangement, seeking for better use of natural resources such as soil, water, light, and nutrients, and reduces interspecific competition for these resources. Thus, the choice of crops that have roots which explore different soil depths, as the case of lettuce and taro, where lettuce has superficial roots with a habit of growing the leaves vertically and did not provide competition with taro plant in the short period of coexistence, is a fact that may also have contributed to the better development of taro. Similar results were observed by Brito et al. (2017) in the taro and chicory intercropping. Likewise, Heredia Zárate et al. (2005) found that taro and lettuce intercropping is technically and economically viable. Heredia Zárate et al. (2006) also report that the highest averages of rhizome productivity were obtained in taro intercropped with lettuce.

The mean yield of taro rhizomes in monoculture did not differ statistically from the mean values obtained in the taro/Indian spinach and triple intercropping. However, the results of this work were superior to those obtained by Heredia Zárate et. (2009), who evaluated the productivity of four taro clones and observed that the “Japanese” taro, in monoculture, produced 1.7 kg m^{-2} of commercial rhizomes. The 0.50 meter spacing between taro lines, adopted by the authors, may have contributed to a lower productivity than that observed in this work, where the spacing between lines was 1 meter. With more space to grow and spread roots and leaves, the fresh mass of taro was higher in this research than in the condition presented by the authors.

According to the "Principle of Competitive Production" (VANDERMEER, 1981), "two crops will produce more than their respective monocultures if the mutual competition is sufficiently weak." The results obtained in this work suggest that there was a beneficial biological interaction among taro and the other crops.

The number of rhizomes per taro plant was significantly higher in the taro/lettuce (29.3 rhizomes $plant^{-1}$) and taro/lettuce/Indian spinach (24 rhizomes $plant^{-1}$) intercropping (Table 6). The lowest mean values were observed in taro cultivated in monoculture (16.1 rhizomes $plant^{-1}$), and taro/Indian spinach intercropping (18.7 rhizomes $plant^{-1}$). The presence of lettuce plants in intercropping with taro was beneficial and may have provided the production of a greater number of rhizomes per plant, probably due to the highest imput of organic fertilizer in these plots.

Vieira et al. (2014) evaluated the agronomic viability of taro intercropping with pod beans of indeterminate growth habit, in three data of implantation of the crops - 0, 21 and 41 - days after planting (DAP) taro rhizomes. The authors concluded that the association of pod beans at 0 DAP provided the lowest values of rhizome yield, due to competition for growth factors between cultures in the two initial months of cultivation. On the other hand, the planting of taro rhizomes in this work was carried out 15 days before transplanting lettuce and Indian spinach seedlings, and this fact may have prevented the taro germination process from being influenced negatively by competition between plants during the sowing of crops.

The number of rhizomes per plant was higher than the averages obtained by Colombo et al. (2018), who reported 8.4 rhizomes per taro plant in intercropping with cucumber, and 11.3 rhizomes per taro plant in monoculture. According to the authors, the habit of indeterminate growth and tutored cultivation of cucumber promoted shading of taro plants for approximately two months, resulting in an average reduction of 29% in the production of commercial rhizomes. In this research taro was the crop with the highest height and was not influenced negatively by lettuce and Indian spinach. On the contrary, the number of rhizomes increased with the intercropping technique, making it clear that the choice of crops is of the utmost importance.

Table 6. Taro fresh mass and number of rhizomes per plant recorded in monoculture and double and triple intercropping arrangements with lettuce and Indian spinach. Água Limpa Farm - UnB, 2015.

Treatment	Fresh Mass			Number of Rhizomes
	(g $rhizome^{-1}$)	(kg $plant^{-1}$)	(kg m^{-2})	
Taro	45.3 a	4.1 a	9.2 a	16.1 a
Lettuce/Taro	50.0 a	7.5 b	16.8 b	29.3 b
Taro/Indian Spinach	45.8 a	4.7 a	10.6 a	18.7 a
Lettuce/Indian spinach/Taro	54.0 a	6.7 b	10.0 a	24.0 b
CV(%)	11.7	14.1	14.1	16.2

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

Rhizome diameter in lettuce/taro and lettuce/Indian spinach/taro intercropping was significantly higher than in the other treatments, with mean values of 40.6 mm and 42.2 mm, respectively (Table 7). No significant statistical difference was observed among treatments for rhizome length. The mean rhizome length was 50 mm.

Table 7. Taro rhizome diameter and length recorded in monoculture and double and triple intercropping arrangements with lettuce and Indian spinach. Água Limpa Farm - UnB, 2015.

Treatment	Diameter (mm)	Length (mm)
Taro	37.8 a	50.0 a
Lettuce/Taro	40.6 b	51.3 a
Taro/Indian Spinach	39.2 a	49.4 a
Lettuce/Indian spinach/Taro	42.2 b	48.6 a
CV(%)	3.1	5.4

[1]Means followed by the same letter in the column do not differ by the Scott-Knott's test ($p < 0.05$); CV: Coefficient of variation.

CONCLUSION

The intercropping arrangements increased or maintained yield and quality of taro, lettuce and Indian spinach. No negative result was observed due to the crop arrangement adopted.

Intercropping between lettuce and the two nonconventional crops was positive and increase lettuce production by 33%.

For taro, the intercropping, due to an increment in the organic fertilizer per plot, increased production, and number o rhizomes per plant in 40% and 45%, respectively.

Indian spinach had an increase of 20% in production when intercropped with lettuce. This crop needs a more comphreensive management, considering that can be affected by shading.

The technique of intercropping conventional and nonconventional crops increased the species diversity in the area with no negative interference in the agronomic performance and quality of the crops. Additionally, it has great potential as a management strategy for alternative systems of vegetable production and allows the rescue of species, which are rich in nutrients, but currently in disuse.

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RESUMO: Este trabalho teve como objetivo avaliar a viabilidade técnica do consórcio de alface, bertalha e taro sob fertilização orgânica. O experimento foi realizado na Fazenda Água Limpa - Universidade de Brasília, em Brasília - DF, no período de outubro de 2014 a junho de 2015. O delineamento experimental foi de blocos ao acaso, com sete tratamentos e quatro repetições. Cada parcela experimental possuía 18 m^2 (4,5 m x 4,0 m), totalizando 28 parcelas. Os tratamentos foram: monocultura de alface, monocultura de bertalha, monocultura de taro, consórcio alface/bertalha, consórcio alface/taro, consórcio bertalha/taro e consórcio alface/bertalha/taro. Em todos os tratamentos foram utilizados os seguintes espaçamentos: 0,25 x 0,25 m para a alface, 1,0 x 0,6 m para a bertalha, e 1,0 x 0,3 m para o taro. Para a avaliação da produção das culturas, as plantas amostradas foram retiradas da parte central de cada parcela. Durante o consórcio foram realizadas duas colheitas de alface, duas de bertalha e uma de taro. As maiores médias de produtividade no primeiro ciclo de alface foram observadas no monocultivo (3,5 kg m^{-2}) e no consórcio alface/bertalha (3,4 kg m^{-2}). A cultura atingiu tamanho comercial em ambos os ciclos de produção, exceto quando consorciada com a bertalha, no segundo ciclo. A maior média de massa fresca das plantas de bertalha, na primeira colheita, foi observada no consórcio alface/bertalha (974,7 g $planta^{-1}$), e na segunda colheita, no monocultivo (327,5 g $planta^{-1}$). A produtividade de rizomas de taro foi expressivamente maior quando consorciado com a alface, com média de 16,8 kg m^{-2}. Os arranjos de consórcio proporcionaram incremento na produtividade das hortaliças não-convencionais. A técnica da consorciação de alface com culturas não-convencionais aumentou a diversidade de espécies na área sem interferir no desempenho agronômico e qualidade das culturas.

PALAVRAS-CHAVE: *Basella alba*. Biodiversidade. *Colocasia esculenta. Lactuca sativa*. Produção sustentável de hortaliças negligenciadas.

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