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## Intercropping of taro and sunn hemp with cutting periods during the cycle<sup>1</sup>

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### ABSTRACT

Intercropping using legumes is one of the ways to protect the main crop, and in long term improve the physical and chemical properties of the soil. The aim of this work was to evaluate the intercropping of *Colocasia esculenta* (L.) Schott (taro) and the tropical legume *Crotalaria juncea* L. (sunn hemp), cutting sunn hemp at ten periods during the cycle. The experiment was carried out under field conditions between 09/23/2010 and 06/04/2011. It consisted of 11 treatments related to the 10 cutting times of sunn hemp (55, 70, 85, 100, 115, 130, 145, 160, 190, and 220 days after sowing - DAS) plus a control of taro with no sunn hemp. During the cycle, taro was evaluated for plant height and incidence of leaf burn. At the time of cutting the sunn hemp, the plant height, fresh and dry matter masses, and nutrient content of the biomass were calculated. During taro harvest, we evaluated the productivity of the mother rhizomes and classified the cormels. Taro plants shaded by sunn hemp showed a lower incidence of leaf burn. The sunn hemp cut from 145 DAS onwards affected the yield of commercial rhizomes and total and agro-economic indexes. Sunn hemp cut up to 130 DAS provided better performance of taro, without compromising productivity and economic indicators, with the highest amounts of N and K observed in the biomass cut at 115 DAS.

**Key words:** *Colocasia esculenta* (L.) Schott; *Crotalaria juncea* L.; production; management.

### RESUMO

#### Consórcio taro com crotalaria com períodos de corte durante o ciclo

A consorciação com leguminosas é uma prática que permite proteger a cultura e no longo prazo promover melhoria das condições físicas e químicas do solo. O objetivo do trabalho foi avaliar o consórcio taro (*Colocasia esculenta* (L.) Schott) com crotalaria (*Crotalaria juncea* L.) com o corte da crotalaria em 10 épocas durante o ciclo. O experimento foi conduzido a campo entre 23/09/2010 a 04/06/2011. Consistiu de 11 tratamentos referentes a 10 épocas de corte da crotalaria (55, 70, 85, 100, 115, 130, 145, 160, 190 e 220 dias após a semeadura – DAS), mais o taro solteiro (controle). Durante o ciclo, foi avaliada a altura de planta e incidência da queima de folhas do taro. No momento do corte da crotalaria foram calculados a altura de planta, massas de matéria fresca e seca e teor de nutrientes da biomassa. Durante a colheita do taro, foi avaliada a produtividade de rizomas mãe e das classes de rizomas filhos. As plantas de taro sombreadas pela crotalaria apresentaram menor incidência de queima das folhas. O corte da crotalaria a partir dos 145 DAS afetou a produtividade de rizomas comerciais e total e índices agro-econômicos. O corte da crotalaria até 130 DAS proporcionou melhor desempenho do taro, sem comprometer a produtividade e indicadores econômicos, com as maiores quantidades de N e K observadas na biomassa cortada aos 115 DAS.

**Palavras-chave:** *Colocasia esculenta* (L.) Schott; *Crotalaria juncea* L.; produção; manejo.

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## INTRODUCTION

The taro plant (*Colocasia esculenta* L. Schott) is considered as the main vegetable of the family Araceae. In some regions, such as in South-Central Brazil, it is called “inhame” and often confused with the species *Dioscorea alata* L., also known as “cará”. According to Pedralli *et al.* (2002), after the first national symposium on inhame and cará cultivation (held in Venda Nova do Emigrante, Espírito Santo, Brazil in 2001), a new nomenclature was established, in which *Colocasia esculenta* was given the definitive name of “taro” and dioscoreáceas (*Dioscorea spp.*) are now known as “inhame.”

The species is native to Asia and currently ranks fourth among the tropical tubers harvested in the world with respect to volume produced. In Brazil, production is concentrated in the southeast region, which was responsible for supplying 94% of this product in the country between 2008 and 2013 (Conab, 2014). In hotter regions of the country, the crop can be cultivated all year round and the cultural cycle is about seven months; in the southeastern region of Brazil, the cultural cycle is about nine months (Puiatti, 2002). Because taro is a long-cycle vegetable, its cultivation becomes viable in the form of a consortium with other crops.

The use of leguminous cover crop plants with increased green mass is a good alternative method for prevention of soil degradation, as legumes improve soil fertility (Santos *et al.*, 2013). One of the most significant aspects of such an association is the possibility of increasing the N availability for the main crop after the legume is cut.

For any plant consortium to be successful, the selection of the intercrop species is critical. Sunn hemp (*Crotalaria juncea*) is an annual legume characterized by an erect stem, rapid growth, and short growth cycle (ranging between 120 and 150 days). It shows substantial biomass content with appreciable ability to fix  $N_2$  and recycle the various constituents of the soil nutrient profile. The legume has almost no pest-related problems and/or diseases (Souza & Resende, 2006) and is, therefore, suitable for growing in a consortium with other species.

Besides the species selected and the planting season, spatial arrangement and green manure management are also important aspects that contribute to the success of a crop consortium. Thus, green manure management and main crop management – in that order – reduce the competition for light, water, and nutrients. They also increase the efficiency of the synchronization between nutrient mineralization by the green manure mass and the absorption of these nutrients by the crops (Silva & Menezes, 2007).

A study by Oliveira *et al.* (2004) focused on the involvement of the taro consortium with sunn hemp and demonstrated its ability to produce significant amounts of N in the plant biomass. The taro and sunn hemp consortium also promotes nutrient cycling and shows a large increase in the organic matter due to the high dry matter content after pruning (Silva *et al.*, 2006; Oliveira *et al.*, 2007). This does not compromise the productivity of the commercial rhizomes produced by taro (Oliveira *et al.*, 2007).

Taro plantations in Rio de Janeiro (Recope - RJ, 1999) and Minas Gerais states (Puiatti, 2002) are often affected by extensive leaf burn due to exposure to direct sunlight. As these injuries from the sun rays result in the reduction of leaf area, there is a consequent decrease in the production of the assimilates, which may affect the rhizome development. Leaf blight reduction by shading is another benefit provided by the taro and sunn hemp consortium (Oliveira *et al.*, 2004; 2007).

Several research studies have revealed the possibility of intercropping vegetables with green manure, such as broccoli with velvet bean (Siqueira *et al.*, 2009), taro with pigeon pea (Oliveira *et al.*, 2006), taro with dwarf velvet bean, and *Crotalaria spectabilis* Roth (Tivelli *et al.*, 2013) with sunn hemp (Oliveira *et al.*, 2004; Silva *et al.*, 2006; Oliveira *et al.*, 2007). However, these studies were performed with the vegetables being cultivated in the interim form and banded with green manure. Co-cultures in the same planting row were not investigated. Interim cultivation has difficulties with respect to crop management and, depending on the arrangement, loss of the taro population resulting in yield reduction.

Therefore, this study aimed at evaluating the performance of taro and sunn hemp grown in the same row of planting, with variation in the cutting times of sunn hemp during the crop cycle.

## MATERIAL AND METHODS

The experiment was conducted from 9/23/2010 to 6/4/2011 under field conditions. The red-yellow Argisol Cambic soil in this study exhibited the following chemical characteristics at 0-20 cm of depth: pH ( $H_2O$ ) = 5.6;  $K^+$  = 76.0 mg  $dm^{-3}$ ;  $P$  = 57.9 mg  $dm^{-3}$ ;  $Ca^{2+}$  = 2.8 cmol<sub>c</sub>  $dm^{-3}$ ;  $Mg^{2+}$  = 0.5 cmol<sub>c</sub>  $dm^{-3}$ ;  $Al^{3+}$  = 0.0 cmol<sub>c</sub>  $dm^{-3}$ ;  $H+Al$  = 3.47 cmol<sub>c</sub>  $dm^{-3}$ ;  $SB$  = 3.49 cmol<sub>c</sub>  $dm^{-3}$ ;  $CEC(T)$  = 6.96 cmol<sub>c</sub>  $dm^{-3}$ ;  $V$  = 50%; organic matter = 2.7 dag  $kg^{-1}$ ;  $P_{rem}$  = 35.9 mg  $L^{-1}$ ;  $Zn$  = 10.4 mg  $dm^{-3}$ ;  $Fe$  = 37.7 mg  $dm^{-3}$ ;  $Mn$  = 78.1 mg  $dm^{-3}$ ;  $Cu$  = 2.1 mg  $dm^{-3}$ ; and  $B$  = 0.2 mg  $dm^{-3}$ . The physical analysis of soil textural class showed 28% sand, 17% silt, and 55% clay. As this area was used to cultivate vegetables, based on the chemical and physical analyses recommended for

the taro crop, neither soil amendment nor fertilizer application with macro- and micronutrients was required.

The experiment was conducted in a randomized complete block design, with four replications. It included 11 treatments, corresponding to the taro monoculture (control) and 10 periods of consortium before cutting (55, 70, 85, 100, 115, 130, 145, 160, 190, and 220 days after sowing; DAS) of sunn hemp.

The plot consisted of four rows, each of 3.0 m long and spaced 1.0 m apart. Each row contained ten taro plants spaced at 0.30 m. In the intercropping area, sunn hemp was sown at 10 cm from the taro line, with 40 seeds sowed per meter. Thinning was performed 15 DAS, leaving only 20 plants per meter. The net area consisted of a 4.0 m<sup>2</sup> area with its borders set at 0.5 m from each row of taro and each border of the plot.

Taro was planted on 9/23/2010. Clones of the taro corms BGH 5925 ('Japanese') were used as seedlings. Weighing about 60 g on average, the corms were sowed in 12-cm-deep grooves. Sunn hemp was sowed on 10/26/2010 in grooves at a depth of 2 cm, open laterally to the taro line. Weeding was performed thrice in all the plots up to 30 DAS of sunn hemp. Irrigation, whenever necessary, was done using the conventional sprinkler.

At each cutting time, sunn hemp was cut close to the ground; weighing was done to obtain the fresh weight, after which a representative plant sample containing about 0.5 kg of the fresh material cut from each plot was minced and oven-dried using forced-air at 70 °C, until constant weight was achieved. After drying, it was weighed again to calculate the dry weight. The dried material was then ground using a Wiley mill and analyzed to determine the nutrient content. All the remaining sunn hemp cuttings were placed laterally to the taro plants in the range of about 0.60 m width.

When sunn hemp was cut, the height of the taro plants (soil level until the insertion of the petiole in the leaf blade) was measured in three plants representative of the two central rows of each plot. The length of the cut sunn hemp plants was measured in six plants representative of the two central rows of each plot.

When sunn hemp reached 130 DAS (163 days after planting DAP taro), the incidence of radiation-induced leaf burn in the taro plants was assessed. This was estimated by the percentage of the injured area according to the diagrammatic method described by Michereff *et al.* (2000) modified as follows: diseased leaf area (%) of 1 to 3, 3 to 6, 6 to 12, 12 to 25, 25 to 50 and > 50%, were respectively denoted as 1, 2, 3, 4, 5, and 6.

Once taro reached maturity at 225 DAP, six plants were removed from the soil of each plot. The fresh weight and number/class of the cormels (daughter rhizomes) were evaluated. The cormels were classified based on their

transverse diameter, according to Puiatti *et al.* (2000) as follows: great (> 47 mm), middle (40-47 mm), small (33-40 mm), and waste (< 33 mm). The sum of classes of the great, medium, and small cormels were considered marketable.

Using the production data of the rhizomes and the trading price, we evaluated the economic efficiency of the intercropping systems using the following agro-economic indicators (indexes): land use efficiency index (LUE), gross income (GI), net income (NI), monetary advantage (MA), corrected monetary advantage (CMA), rate of return (RR), and profitability index (PI).

The LUE index consortium was calculated using the following expression:  $LUE = (Ptc/Pts)$ , in which Ptc is the taro crop yield in the consortium with sunn hemp and Pts is the productivity of the single taro crop (monoculture). The average nominal wholesale price in June 2011 (harvest month) used to calculate the GI was obtained from the major regional produce distribution center, CEASA-MG in Contagem, Minas Gerais State (CEASA-MG, 2011). The mother and waste rhizomes were not included in this calculation.

The NI was calculated as the difference between the gross income and total operating costs (TOC). The TOC in both cropping systems were estimated from the technical coefficients for taro production costs submitted by Puiatti (2002), with modifications based on the requirements of the operations and inputs presented in the experiment. The costs of inputs, services, packaging, and transport were calculated from the prices in Viçosa - Minas Gerais, Brazil, from September/2010 to June/2011.

The MA and CMA were calculated using the following expressions:  $MA = GI \times (LUE - 1)/LUE$  and  $CMA = NI \times (LUE - 1)/LUE$ . The RR per dollar invested in each treatment was obtained through the relationship between the gross income and the cost of production. The PI was obtained from the relationship between the NI and GI and expressed as a percentage, according to Oliveira *et al.* (2005) and Cecílio Filho *et al.* (2008).

The data were subjected to analysis of variance for each harvesting date and compared to the control using Dunnett's test ( $p < 0.05$ ). Average values by treatment were grouped by the Scott-Knott criterion ( $p < 0.05$ ).

Treatments were screened for their effect(s) on fresh and dry masses and were measured only for *C. juncea*. Plant height was measured for *C. esculenta* and *C. juncea*. Models were chosen based on biological relevance. The significance of regression coefficients was determined using the t test, adopting the 10% level of probability and

the coefficient of determination 
$$R^2 = \frac{SS_{Regression}}{SS_{Treatment}}$$

## RESULTS AND DISCUSSION

### Plant growth

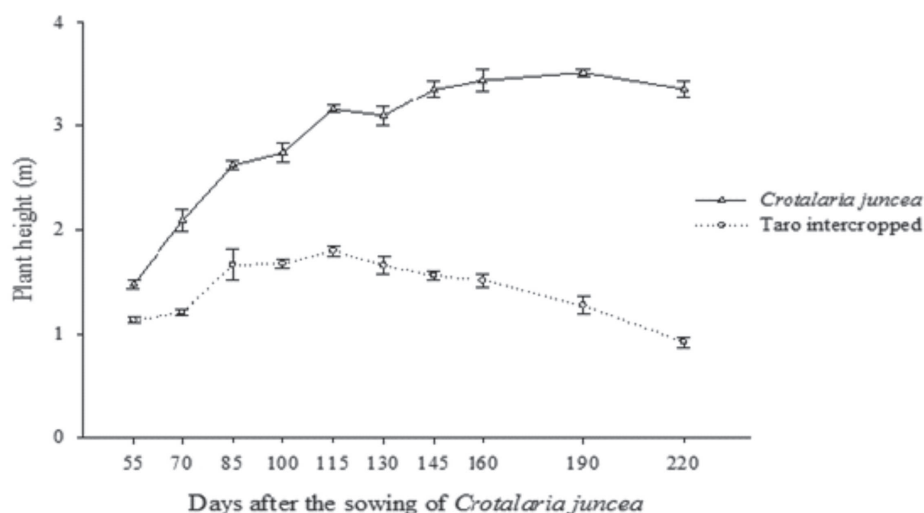
The height of taro plants in the consortium with sunn hemp ranged from 0.92 to 1.80 m, with the highest value achieved in the cut done at 115 DAS (148 DAP taro). Sunn hemp ranged in length from 1.48 to 3.52 m, with the highest value observed at 190 DAS (Figure 1).

The height values of taro plants in the intercropping system observed in this study were higher than those recorded by Gondim *et al.* (2007) in the same soil conditions. They recorded a value of 151.8 cm at 139 DAP taro ('Japanese') grown under conditions of 50% shading. It should be noted that the height of sunn hemp in the cut at 115 DAS was 3.16 m, which may have represented shading

of taro plants above 50%. Light restriction stimulates the leaf petiole elongation in taro plants in search of greater sunlight capture (Gondim *et al.*, 2007; 2008).

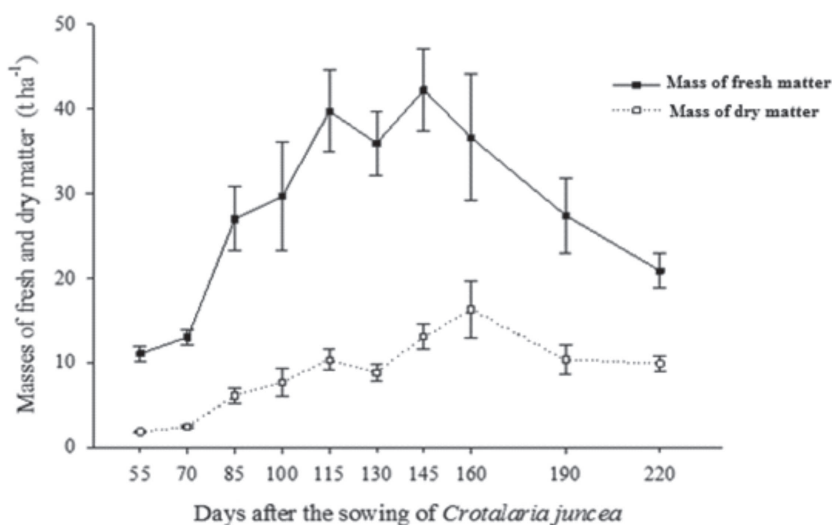
In this study, the growth of taro shoots occurs until approximately 115 DAS of sunn hemp (148 DAP taro). In fact, Puiatti *et al.* (1992) verified the accumulation of dry mass in 'Japanese' taro leaves up to 165 DAP and, later, the process of foliar senescence with photoassimilate translocation to the reserve organs occurred. The consortium system possibly had no effect on the phenological stages of taro, as the minor differences in relation to the work could be due to the planting season and edaphoclimatic factors.

Regarding sunn hemp, the greatest length was found higher than the 1.80 m observed by Oliveira *et al.* (2004)



Data are presented as means  $\pm$  standard error ( $n=4$ ).

**Figure 1:** Height of the taro and *C. juncea* plants recorded during the respective cutting periods of the sunn hemp.



Data are presented as means  $\pm$  standard error ( $n=4$ ).

**Figure 2:** Masses of fresh and dry matter of the sunn hemp (*Crotalaria juncea*) plants observed at their dates of cutting.



in the consortium with taro 'Chinese' variety intercropped without pruning in Nova Friburgo - RJ, Brazil, with 0.50-m spacing between rows. It is possible that the greater spacing employed in that study may have provided greater plant vigor in sunn hemp with greater shoot development.

The fresh and dry masses of sunn hemp resulting from the cuttings ranged from 11.06-42.23 to 1.82-16.82 t ha<sup>-1</sup>, respectively. The maximum values of the fresh biomass were observed at 145 DAS in sunn hemp, while for dry matter, the highest values were observed at 160 DAS (Figure 2).

No other studies were identified in the literature in which sunn hemp was cut up to 160 DAS. Silva *et al.* (2006) reported values corresponding to 4.5 t ha<sup>-1</sup> of dry matter at 60 DAS, corresponding to the findings in this work; however, it must be pointed out that the spacing of 0.50 m between rows in that study featured twice the plant density. Oliveira *et al.* (2007) reported values of 6.85 t ha<sup>-1</sup> at 120 DAS, which are lower than those found in this study, utilizing the same plant density.

#### Nutrient quantity present in the sunn hemp biomass

The nutrient quantity present in the cut sunn hemp mass varied with the cutting times, forming mean groups for each nutrient (Table 1). The treatments that gave the highest average values for N, K, Ca, S, Zn, and B were cutting sunn hemp at 115 and 160 DAS.

We observed lesser amounts of nutrients in the first two cutting times, a fact which is assumed to be due to the smaller amount of mass being produced by the plants in the initial growth phase. At 85 DAS, an increase was observed in most nutrients due to higher aggregate mass by the plants, especially after the cutting at 100 DAS. This was especially evident for N, K, and B, which formed group means distinct from the other nutrients, with higher values for the earlier cuts.

This study revealed that the quantities of N, K, Zn, Cu, and B found in sunn hemp were lesser than those observed by Puiatti *et al.* (2015). However, the amounts of Mn, Fe, S, Mg, and Ca were higher using the same plant density.

#### Leaf burn

In assessing the incidence of leaf burn in the taro leaves at 130 DAS of sunn hemp (163 DAP taro), we recorded two groups of averages: one in which the plants had already been cut (including the control and treatment of cutting at 130 DAS) with higher leaf damage and the group of plants yet to be cut (DAS 145 onwards), which had lower incidences of leaf burn that statistically differed from that of the control (Table 2).

Table 1: Quantities of macro and micronutrients recorded in sunn hemp (*C. juncea*) shoots intercropped with the taro plants at each harvest date

Cut (DAS)	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
	kg ha <sup>-1</sup>						g ha <sup>-1</sup>				
55	40.51 c	4.56 d	47.45 c	23.36 c	6.02d	3.10 c	49.27 c	208.05 d	135.05d	10.95d	49.82c
70	56.05 c	6.38 d	42.57 c	38.55 c	8.27 d	3.78 c	47.30 c	683.48 d	146.63 d	11.82d	64.56 c
85	92.03 b	12.80 c	97.52 b	67.65b	16.46 c	8.53b	127.99 b	1,810.21c	426.65 d	42.66c	166.39b
100	120.97a	18.49 b	129.45a	62.41b	20.03 c	10.02b	184.92 b	3,259.21b	729.60 c	38.52c	282.77a
115	171.48a	21.69 b	173.54a	84.70a	28.92b	13.43a	278.91a	4,090.68a	940.03 c	51.65c	345.02a
130	135.56a	18.48 b	109.15a	51.93c	24.64 b	7.92b	184.85 b	4,296.21a	677.80 c	44.01c	279.92a
145	152.68a	26.10a	151.38a	70.47b	27.40b	13.05a	287.10a	1,897.20 c	965.70 c	65.25b	336.69a
160	161.22a	30.94a	162.85a	83.23a	42.34a	13.01a	374.55a	2,068.19 c	1,025.95 c	81.42a	330.58a
190	118.02a	17.60 b	157.35a	35.20c	19.67 c	8.28b	289.87a	2,526.01 c	1,625.34 b	51.76c	238.11a
220	130.15a	18.06 b	134.09a	58.17b	24.65 b	9.86b	207.06 b	2,317.10 c	4,742.66a	59.16b	240.58a
CV(%)	24.99	28.20	26.37	24.70	28.75	25.74	30.11	27.12	31.35	28.39	26.85
Mean	117.87	17.51	120.54	57.57	21.84	9.10	203.18	2,312.94	1,141.54	45.72	233.45

DAS - days after sowing.

Means, in the columns, followed by at least one letter show no difference by the Scott-Knott test ( $p < 0.05$ ).

Soon after cutting was done, sunn hemp showed an increase in the incidence of leaf burn as the shading was abruptly removed and the taro leaves, which are sensitive to solar radiation and are grown in shade, were exposed to the full sunlight. A similar phenomenon was observed by Puiatti *et al.* (2000) in taro and sweet corn after the corn plants were removed. Taro was subjected to shading with Sombrite® meshes at 18, 30, and 50% shading after the removal of meshes corn, and it resulted in a reduction of the leaf area (Gondim *et al.*, 2007).

The presence of sunn hemp after the cutting treatment at 130 DAS resulted in a reduced incidence of leaf burn in the taro leaves. Oliveira *et al.* (2007) also found that the cultivation of taro with *C. juncea*, in the intermediate stage (planted in alternate rows), reduced the intensity of leaf blight caused by solar radiation in the city of Nova Friburgo - RJ, Brazil. A study conducted in Magé - RJ, Brazil, by Oliveira *et al.* (2004), demonstrated a 100% reduction in leaf burn up until the fifth month of the crop cycle. In the eighth month, the shading continued to protect the plants, although less efficiently.

Taro leaves in the tropics experience necrosis during summer (Puiatti *et al.*, 2000; 2002; Oliveira *et al.*, 2004) caused by the photo-oxidation of chlorophyll due to excess incident radiation (Taiz & Zeiger, 2010). These lesions can cause a reduction in the photosynthetic area (Gondim *et al.*, 2007) and, therefore, productivity loss. In taro, the soluble sugars (the reducing ones, in particular) synthesized in the leaf get translocated to the rhizomes after undergoing “temporary storage” in the petiole (Hashad *et al.*, 1956). Thus, any morphophysiological changes can affect the synthesis and translocation of the quantity of sugar during the rhizomes growth, thus influencing productivity. Therefore, under conditions of high solar radiation, the taro and sunn hemp consortium may reduce the incidence of leaf burn, thus providing conditions for optimal rhizome development.

#### **Taro production**

For taro, the average yield of commercial rhizomes, total rhizomes, and number of commercial rhizomes/plant shoots formed two groups (Scott-Knott). *Crotalaria juncea* cut after 130 DAS showed lower production than that of the group formed by the remaining treatments and the control (Table 3).

For the production of “large” daughter rhizomes, the means of the treatment group in which sunn hemp was cut at 145 DAS and underwent further cutting treatments at 55 and 115 DAS showed a decrease relative to the other treatments. Compared with the control, only the cutting treatments at 160 and 220 DAS revealed lower yields of large rhizomes. Regarding the number of large daughter rhizomes per plant, two group means were formed in which the sunn hemp that underwent cutting treatments at 85, 115, 145, 160, and 220 DAS were found to be lower than the other treatments, but not different from the control (Table 3).

The taro and sunn hemp consortium did not significantly affect the productivity of mother rhizomes. Oliveira *et al.* (2007) also observed no change in the productivity of the mother corm when sunn hemp was intercropped with taro during the entire cycle, even when it was pruned up to 120 DAS.

In general, the yield and number of rhizomes in the large class revealed a similar pattern, in which the plants grown in a consortium with the taro for a period of more than 130 DAS showed a decrease relative to the control. Silva *et al.* (2006) also showed lower productivity in the larger classes of rhizomes when sunn hemp was grown in double rows with 0.50 m spacing between the rows of taro. In that research, sunn hemp was sown at 90 DAP of taro and cutting was done at 60 DAS when the plants grew to an average of 2.50 m high. The reduction in the productivity of the largest rhizome classes is not beneficial, as it is of higher value (Puiatti, 2002).

The reduction in the mass and number of commercial cormels per plant was also reported by Oliveira *et al.* (2007) when sunn hemp was not cut. However, Oliveira *et al.* (2004) reported no decrease in the yield of commercial cormels when this crop was sown at 60 DAP with taro and maintained when intercropped with taro. Silva *et al.* (2006) also did not observe any effect on the commercial rhizomes when sunn hemp was left uncut.

Despite the high amounts of nutrients inserted by sunn hemp after the cutting at 100 DAS (Table 1), the cutting treatments done with sunn hemp at 130 DAS resulted in lower values for commercial cormels, total cormels, and total yield of the rhizomes (Table 3). The sunn hemp mass obtained from the cuts done at 145 and 160 DAS showed

**Table 2:** Leaf burn incidence in the taro leaves measured at 130 DAS of sunn hemp (*C. juncea*) (163 DAP taro) in the monoculture treatment of taro (control) and the taro and sunn hemp consortia cut at different times, in days after sowing (DAS)

Cut (DAS)	Cont.	55	70	85	100	115	130	145	160	190	220	CV(%)
Notes	3.25a	3.25a	3.00a	3.75a	3.00a	3.25a	3.75a	1.00b*	1.00b*	1.25b*	1.25b*	39.28

Means, in the lines, followed by the same letter, do not differ by the Scott-Knott test ( $p < 0.05$ ); the medium followed by an asterisk (\*) differs from the control by Dunnett's test ( $p < 0.05$ ).

**Table 3:** Productivity (t ha<sup>-1</sup>) and number per plant (N°/pl) of rhizome mothers (RM), rhizome classes great, medium, small, and waste, commercial, total cormels, and total production (TP) of taro corms 'Japanese' in the monoculture treatments, taro (control), and taro and sunn hemp (*C. juncea*) cut at different times, in days after sowing (DAS)

Cut (DAS)	RM		Great		Medium		Small		Waste		Commercial		Total cormels		TP	
	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl	t ha <sup>-1</sup>	N°/pl
Control	31.21a	2.71a	15.69a	5.62a	16.79a	5.33a	10.04a	5.58a	4.56a	5.58a	42.53a	13.67a	47.10a	19.25a	78.31a	19.25a
55	25.33a	2.29a	11.77b	4.92a	14.85a	4.54a	8.39a	6.62a	5.51a	6.62a	35.44a	11.75a	40.95a	18.37a	66.28a	18.37a
70	26.32a	3.63a	18.05a	4.29a	12.64a	5.79a	10.55a	7.08a	4.99a	7.08a	41.24a	13.71a	46.22a	20.79a	72.61a	20.79a
85	28.53a	1.58b	13.21a	3.17a	12.15a	4.46a	9.52a	5.21a	4.13a	5.21a	34.89a	9.21*	39.02a	14.42a	67.56a	14.42a
100	24.71a	2.58a	16.21a	3.92a	11.78a	4.91a	9.19a	5.25a	3.64a	5.25a	37.18a	11.42a	40.83a	16.67a	65.54a	16.67a
115	23.99a	1.75b	10.80b	3.79a	11.82a	5.04a	10.04a	7.33a	6.43a	7.33a	32.66a	10.5b	40.00a	17.91a	63.09a	17.91a
130	24.09a	3.00a	15.76a	4.41a	11.70a	4.17a	6.35a	5.54a	3.38a	5.54a	33.95a	12.00a	37.33a	17.54a	61.28a	17.54a
145	20.96a	1.42b	7.64b	3.42a	9.26a	4.58a	7.01a	5.83a	4.00a	5.83a	23.91b*	9.00*	27.91b*	14.83a	48.87b*	14.83a
160	20.96a	1.21b	6.87b*	3.79a	10.92a	3.37a	6.71a	5.54a	4.79a	5.54a	24.51b*	8.37*	29.30 b*	13.92a	50.26b*	13.92a
190	19.24a	2.17a	8.47b	2.79a	7.58a	3.96a	7.72a	6.75a	5.66a	6.75a	23.80 b*	8.92*	29.32 b*	15.67a	48.67b*	15.67a
220	18.18a	1.42b	6.57b*	3.75a	10.04a	4.16a	7.40a	5.83a	4.45a	5.83a	24.01 b*	9.33*	28.46 b*	15.16a	46.56b*	15.16a
CV(%)	23.30	44.24	35.61	34.39	32.21	20.77	27.89	39.10	43.91	39.10	17.35	19.12	15.82	20.01	17.03	20.01
Mean	23.96	2.16	11.91	3.99	11.78	4.58	8.45	6.05	4.69	6.05	32.19	10.72	36.87	16.78	60.82	16.78

Means in the columns followed by the same letter show no difference by the Scott-Knott test ( $p < 0.05$ ); and the means in the columns, followed by an asterisk (\*), are different from the control by Dunnett's test ( $p < 0.05$ ).

high amounts of all the nutrients evaluated. However, these nutrients, if available, were not likely used by taro as the leaf senescence process in taro had already begun. Leaf senescence is accompanied by the photosynthetic translocation from the shoot to the daughter rhizomes, which begins to occur at this developmental phase (Puiatti *et al.*, 1992).

Although the smaller taro leaves experienced burn damage due to the cutting performed at 145 DAS, this benefit did not prevent that, in these treatments, the productivity of commercial daughter rhizomes, total daughter rhizomes, and total production rhizomes were damaged (Table 3). In addition to the absence of synchrony for the absorption of nutrients provided by the cut mass of sunn hemp, the light restriction caused by taro shading may have been excessive and/or the solar radiation may have been deficient due to the high cloudiness that is normally observed in the region of Viçosa - MG, Brazil.

Under severe conditions of light restriction, taro plants showed better shoot growth and leaf area expansion at the expense of production of child rhizomes (Gondim *et al.*, 2007; Oliveira *et al.*, 2011). However, Gondim *et al.* (2007) and Oliveira *et al.* (2011) found that at 25 and 18% shading, respectively, their taro plants 'Chinese' and 'Japanese' did not change the growth patterns and nutrient accumulation, indicating that taro may benefit from intercropping, which provides moderate shading.

When sunn hemp is intercropped with taro as a method of providing nutrients to the soil without significantly affecting the yield of the commercial rhizomes, total cormels, and total productivity, cutting up to 130 DAS appears to be the most appropriate period. During this time, sunn hemp accumulates high amounts of biomass as well as macro and micronutrients. It is possible that the nutrient release of the cut sunn hemp coincides with the period of greatest nutrient absorption by the taro crop, without affecting the productivity of commercial daughter rhizomes. In addition, the residues which remain in the soil become a nutrient source for subsequent crops.

### Agroeconomic indicators

The cutting of sunn hemp performed after 130 DAS affected the agroeconomic indexes of LUE, GI, NI, RR, and PI compared with the control and was below the average of the other treatments (Table 4). The LUE formed three groups, with the highest averages observed in the control treatment (the sunn hemp value was not considered) and the treatment of cutting hemp at 70 DAS, followed by the group formed by the cutting



**Table 4:** Agroeconomic indicators: land use efficiency index (LUE); gross income; net income; monetary advantage (MA); corrected monetary advantage (CMA); rate of return (RR), and profitability index (PI) of the taro crops in the monoculture treatments of taro (control) and taro and sunn hemp (*C. juncea*) cut at different times, in days after sowing (DAS)

Cut (DAS)	LUE	Gross Income	Net Income	MA	CMA	RR	PI
			US\$ ha <sup>-1</sup>			US\$/ US\$	(%)
Control	1.00a	16,707.37a	12,020.94a	0.00	0.00	3.56a	71.83a
55	0.83b	13,726.48a	9,399.53a	-1,957.24	-1,270.32	3.15a	67.81a
70	0.96a	16,272.63a	11,598.55a	-330.07	-189.61	3.47a	71.00a
85	0.78b	13,712.84a	9,369.89a	-2,984.40	-2,032.22	3.15a	68.14a
100	0.87b	14,669.80a	10,188.68a	-1,831.06	-1,264.76	3.27a	69.40a
115	0.77b	12,798.74a	8,582.31a	-2,879.36	-1,912.93	3.02a	66.87a
130	0.80b	13,368.36a	9,031.23a	-2,616.76	-1,756.76	3.08a	67.45a
145	0.56c*	9,361.3b*	5,549.12b*	-3,143.61	-1,585.96	2.36b*	53.52b*
160	0.57c*	9,571.56b*	5,746.26b*	-3,958.58	-2,341.47	2.48b*	59.40b*
190	0.56c*	9,331.02b*	5,511.97b*	-4,078.63	-2,395.76	2.44b*	58.80b*
220	0.56c*	9,370.82b*	5,570.70b*	-3,942.08	-2,331.30	2.45b*	58.57b*
CV (%)	16.64	17.67	23.29	—	—	12.24	8.88
Mean	0.75	12,626.45	8,415.38	-2,520.16	-1,549.80	2.95	64.80

Means, in the columns, followed by at least one letter show no difference by the Scott-Knott test ( $p < 0.05$ ); and the means in the columns, followed by an asterisk (\*) are different from the control by Dunnett's test ( $p < 0.05$ ).

Dollar exchange rate: US\$ 1.00 = R\$ 4.0

treatments at 55, 85, 100, 115, and 130 DAS, and lastly, the group formed by the cutting treatments of 145 DAS onwards (Table 4).

The lowest values of the agroeconomic indicators were observed at the time of cutting performed at 145 DAS. It is possible that the reduced productivity of the commercial rhizomes was caused by cutting sunn hemp later than 145 DAS (Tables 3 and 4).

In all the treatments of the consortium, LUE was less than 1.0. From the agronomic and pragmatic perspective, it is assumed that both crops are suitable for intercropping as LUE is greater than 1.0 (Ajalla *et al.*, 2009). However, LUE value alone is not sufficient to determine whether the consortium is advantageous. It is the income indicators that will define the viability. In this case, unlike the other consortia, the culture intercropped with taro (sunn hemp) was considered as being without commercial value. Thus, in interpreting these indicators, we considered the best consortia as those that provided higher rate.

Therefore, according to the agroeconomic indicators, the best intercropping system was observed when sunn hemp was cut at 130 DAS, but this treatment showed no significant difference in comparison with the control. However, it is the income indicators that will define whether the GI values, NI, RR, or PI were affected when sunn hemp was cut at 130 DAS. This indicates that up to this time, the sunn hemp legume may be adopted in association with taro cultures without any reduction in the economic profitability.

## CONCLUSIONS

The taro and sunn hemp intercropping system is viable, both agronomically and economically, when sunn hemp is cut at 130 days after sowing.

Focusing only on the nutrient supply, cutting sunn hemp at 115 days after sowing provides greater contribution of N and K to the system without impairing commercial taro production.

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