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ARTIGO CIENTÍFICO

Analysis of the economic feasibility of organic polyculture

Analise da viabilidade econômica de policultivo orgânico

Luiz Emílio Vicentin Alves[1]; Sebastião Elviro de Araújo Neto[2]; Jacson Rondinelli da Silva Negreiros[3]; Romeu de Carvalho Andrade Neto[4]; Amauri Siviero[5]*

Abstract: The polyculture systems guarantees food to small farmers, would ensure sustainable agriculture, high productivity per unit area and lessen the natural risks of agriculture. Within this context the objective of this study was to evaluate the production cost and profitability of an organic polyculture system comprising passion fruit, maize, pineapple and cassava in association with the cover crops. This research was carried out at the Seridó Ecological Farm, in the Municipality of Rio Branco, Acre State, from 2009 to 2011, in the completely randomized block design in a split plot arrangement with three repetitions and comprised plots containing passion fruit supported by espaliers located 3 m or 4 m apart. Plots were divided into subplots containing the cover crops jack-bean, crotalaria, tropical kudzu, peanut forage or spontaneous plants (treatments), and maize. The pineapple and cassava were planted between the espaliers. The effects of different cover crops were not so evident in plots with 3 m-spaced espaliers ($P < 0.05$) which increased productivity and production cost, providing a lower cost benefit ratio. The organic polyculture of passion fruit with pineapple, maize and cass in plots with 4 m-spaced espaliers, with the soil covered by jack bean increased total and net revenue, cost benefit ratio and economic feasibility.

Key Words: *Passiflora edulis* f. *flavicarpa*; Green manure; Economic indicators; Intercropping.

Resumo: O policultivo garante alimentos para a agricultura familiar, contribui para a sustentabilidade no campo, aumenta a produtividade por unidade de área e reduz os riscos naturais da agricultura. Nesse contexto, o objetivo no presente estudo foi avaliar o custo de produção e a rentabilidade de um sistema de policultivo compreendendo maracujá, milho, abacaxi e mandioca em associação com as plantas de cobertura. Esta pesquisa foi realizada no Sítio Ecológico Seridó, no Município de Rio Branco, Acre, no período de 2009 a 2011, em delineamento de blocos completos casualizados em esquema de parcela subdividida com três repetições. As parcelas forma compostas por espaldeiras espaçadas 3 ou 4 m de distância. As parcelas foram divididas em subparcelas cobertas com os adubos verdes feijão-de-porco, crotalária, kudzu tropical, amendoim forrageiro ou plantas espontâneas (tratamentos) e o milho, o abacaxi e a mandioca foram plantados entre as espaldeiras. Não houve efeito das plantas de cobertura entre as espalderias distanciadas por 3 m ($P<0,05$), que aumentou a produtividade e o custo de produção proporcionando menor relação benefício custo. O policultivo orgânico de maracujazeiro com abacaxizeiro, milho e mandioca entre espalderias de 4 m, com o solo coberto por feijão de porco aumentou a receita total e líquida, a relação benefício custo e a eficiência econômica.

Palavras-chave: *Passiflora edulis* f. *flavicarpa*; Cobertura verde; Cultivo consorciado; Indicadores econômicos.

*Autor para correspondência
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[1]Engo. Agro. Mestre em Produção Vegetal, Instituto de Defesa Agropecuário de Rondônia. E-mail: vicentin@agronomo.eng.br
[2]Professor Doutor da Universidade Federal do Acre, BR 364, km04 – Distrito Industrial; CEP:69.920-900. E-mail:selviro2000@yahoo.com.br
[3]Eng. Agr. Doutor em Fitotecnia. Embrapa Acre, E-mail. jacson.negreiros@embrapa.br
[4]Eng. Agr. Doutor em Fitotecnia. Embrapa Acre, E-mail. romeu.andrade@embrapa.br
[5]Eng. Agr. Doutor em Fitotecnia. Embrapa Acre, E-mail. amauri.siviero@embrapa.br

INTRODUCTION

The agricultural sector of the Acre State, Brazil, of is characterized by cattle ranching and small-scale subsistence farms producing fruit and vegetables for family consumption and for the local market. Cassava [*Manihot esculenta* Crantz] is one of the main crops of the Amazonia region and Acre State with a production of 1,239,731 t year^{-1} and a yield of 28,902 kg ha^{-1} according to data recorded in 2014 (IBGE, 2014). Maize [*Zea mays* L.], pineapple [*Ananas comosus* (L.) Merr.] and passion fruit [*Passiflora edulis* f. *flavicarpa* Sims] are also grown in the region, but the production (96,000; 6,843 and 403 t year^{-1}) and productivities (2.4; 21.45 and 7.6 t ha^{-1}, respectively) of these crops are lower than the national averages.

Passion fruit is cultivated in 17 of the 22 municipalities of Acre (IBGE, 2014), although the crop is considered high-risk owing to problems relating to fructification, pollination, pests, diseases and weeds, which results in low quality. Moreover, cultivation is labor intensive with minimal technological and low input, especially in organic systems, resulting in low productivity, in the range 1.8 to 9.7 t ha^{-1}, and average production costs vary between 0.64 to R\$1.38 kg^{-1}, but Araújo Neto et al., (2008) report that in this condition the production to full coverage is of 2.662 kg ha^{-1} year^{-1}, According to Furlaneto et al., (2011), the productivity of a passion fruit crop must be higher than 28.3 t ha^{-1} in order to cover the operational costs (inputs and labor). It is clear, therefore, that there is a need to augment productivity of the crop in order to reduce the average cost and increase profitability (ARAÚJO NETO et al., 2008; 2009).

Polyculture systems offer a number of advantages over monocultures, in that they can enhance productivity, reduce environmental impact and lessen the natural risks of agriculture (PYPERS et al., 2011; CECÍLIO FILHO et al., 2011; BEZERRA NETO et al., 2012). The land-use efficiency in organic polyculture of passion fruit, pineapple, corn and cassava various between 2.45 and 2.77 (ARAÚJO NETO et al., 2014).

Furthermore, diversification of crop species within an area widens the market base, thereby reducing the vulnerability of the farmer to the cyclic effects that are common with monocultures (GRISA, 2007; PETINARI et al., 2008; SOUZA et al., 2008; SILVA et al., 2013; SIMONETTI et al., 2013). Polycultures are particularly advantageous when associated with the use of cover crops that may: (i) contribute to the fixation of atmospheric nitrogen and the accumulation of N, P and K, with consequent improvement in dry biomass production and nutrient recycling (GIACOMINI et al., 2003, 2004; BEZERRA et al., 2004); (ii) promote better particle aggregation with improved attenuation of fluctuations in soil temperature and humidity (PERIN et al., 2004); and (iii) reduce production costs by minimizing or even eliminating the use of herbicides (SILVA et al., 2009).

The cultivation of passion fruit in a polyculture system generally requires the amplification of space between espaliers with a consequent reduction in plant density. However, high-density cultivation can accelerate production, thereby decreasing the longevity of orchards, lessening the damage caused by pests and diseases (PIRES et al., 2011) and increasing productivity, although production costs may be somewhat higher (ARAÚJO NETO et al., 2005). And raising revenue is key to increasing crop diversification with fruit plants and reducing crop specialization (BAHIENSE; SOUZA 2015).

Within this context the objective of this study was evaluate the production cost and profitability of an organic polyculture system comprising passion fruit, maize, pineapple and cassava in association with the cover crops.

MATERIALS AND METHODS

The study was conducted between November 2009 and November 2011 in an experimental area of 0.25 ha at the Sítio Ecológico Seridó, Rio Branco, Acre, Brazil, located on highway AC-10, km 04 (coordinates 9º53'10.6'' S, 67º49'8.6'' W; altitude 170 m). The soil in this region is categorized as Argissolo Amarelo alítico plíntico according to the Brazilian Soil Classification System (EMBRAPA, 2013). Chemical analysis of the A horizon A (0 - 20 cm) revealed the following characteristics: pH 5.4; base saturation 52.1%; organic matter 1.8 g kg^{-1}; P 7 mg dm^{-3}; K 0.26 cmol$_c$ dm^{-3}; Ca 2.7 cmol$_c$ dm^{-3}; Mg 1.6 cmol$_c$ dm^{-3}; Al 0.1 cmol$_c$ dm^{-3}; A+H 4.1 cmol$_c$ dm^{-3}; Fe 530 mg dm^{-3}; Cu 1.6 mg dm^{-3}; Mn 99 mg dm^{-3}; Zn 2.6 mg dm^{-3} and B 0.17 mg dm^{-3}.

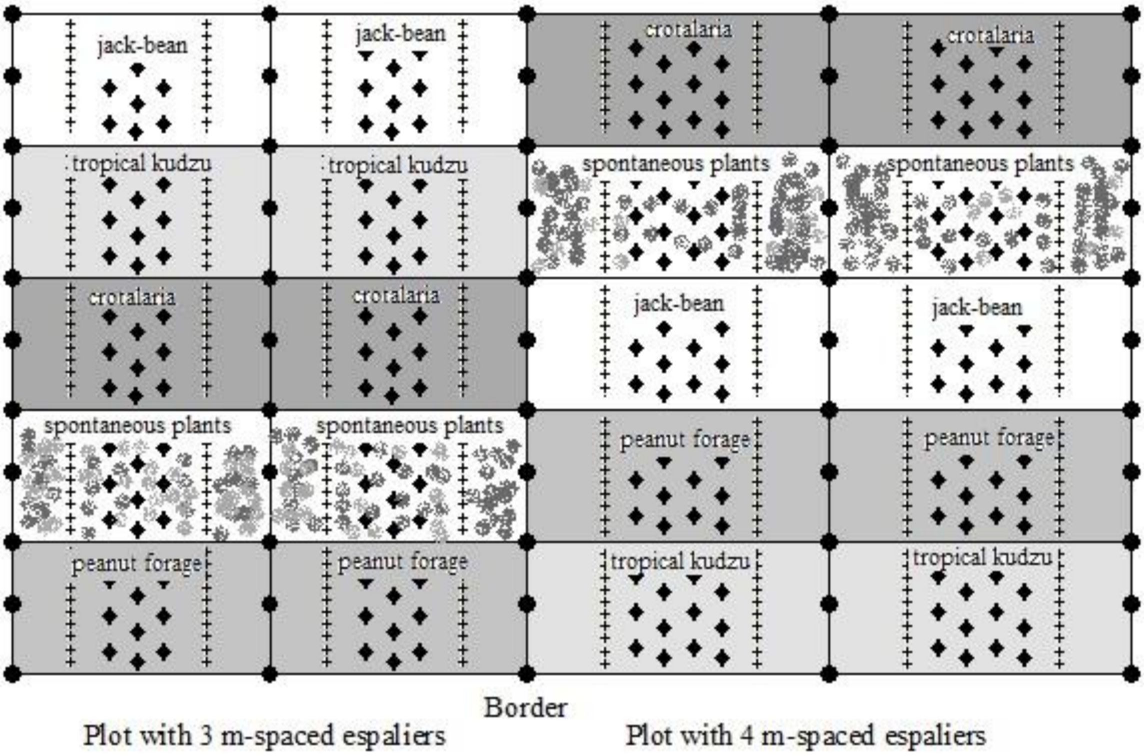
The cultivars employed in the polyculture system were: (i) passion fruit cultivar comprising a mixture of seven selected genotypes from the germplasm bank of Federal University of Acre, namely progenies UFAC 2, UFAC 22, UFAC 23, UFAC 35, UFAC 37, UFAC 33 and UFAC 20 originating from Viçosa (MG, Brazil), State University of North Fluminense (RJ, Brazil), Porto Acre, Brasiléia and Rio Branco (AC, Brazil); (ii) maize commercial cultivar Bona Gold; (iii) pineapple cultivar 'Rio Branco-1'; and (iv) cassava cultivar 'BRS Caipora'. The cover crops were jack-bean [*Canavalia ensiformis* (L.) DC.], crotalaria [*Crotalaria spectabilis* Roth], tropical kudzu [*Pueraria phaseoloides* (Roxb.) Benth], peanut forage [*Arachis pintoi* Krapov. & W.C.Greg.] and spontaneous plants controlled by frequent hoeing.

The study was conducted with the use of a Completely Randomized Block Design in a split plot arrangement with three repetitions. The plots encompassed the space between the rows of passion fruits (espaliers located 3 m or 4 m apart), while the subplots contained the treatments with cover crops (jack-bean, crotalaria, tropical kudzu, peanut forage and complex of the spontaneous plants). Pineapple, maize and cassava were cultivated between the rows of passion fruit in all treatments. The experimental unit consisted of nine passion fruit vines distributed in three rows, with the three central vines considered the applicable plot. The applicable plots for maize and cassava were taken as the 6 m^2 areas between the passion fruit rows, and for pineapple the production of 20 plants plot^{-1}. A schematic representation of the arrangement of crops in the experimental polyculture is shown in Figure 1.

The experimental area was ploughed and tilled, and maize was sown in rows 1 m apart with five plants linear m^{-1}. After emergence of the maize, wooden espaliers were erected in rows 3 or 4 m apart with the purpose of training the passion fruit vines. A total of 42,472 maizeplants ha^{-1} were cultivated in plots with 3 m-spaced espaliers and 44,192 plants ha^{-1} were cultivated in those with 4 m-spaced espaliers. Passion fruit plants (70 day-old exhibiting first tendrils) were transplanted to the experimental areas at final densities of 1,111 plants ha^{-1} in plots with 3 m-spaced espaliers and of 833 plants ha^{-1} in those with 4 m-spaced espaliers.

When the maize plants had developed secondary leaves (V2 stadium), the crop was weeded with the aid of a horse drawn half-moon hoe at the rate of 0.74 man-days ha^{-1}. Seven days after weeding the maize crop, pineapples were planted between the espaliers in rows spaced 0.4 m apart with 1.0 m between each plant in line. Three rows of pineapples were planted in plots with 3 m-spaced espaliers to give a final density of 9,300 plants ha^{-1}, while four rows of pineapples were planted in plots with 4-m spaced espaliers to give a final density of 9,200 plants ha^{-1}.

Figure 1. Schematic representation of the organic polyculture of passion fruit (●), pineapple (♦) and maize or cassava (+) in succession with the cover crops jack-bean, crotalaria, tropical kudzu, peanut forage or spontaneous plants.



Source: Authors

Fifteen days after planting the pineapple, the cover crops were introduced into the subplots. Jack-bean and crotalaria were planted between the rows of passion fruit and pineapple at final densities of 6,420 and 9,691 plants ha^{-1}, respectively, with 3 m-spaced espaliers, and at final densities of 6,157 and 8,704 plants ha^{-1}, respectively, with 4 m-spaced espaliers. Tropical kudzu and peanut forage were planted in parallel rows at a distance of 0.30 m from each side of the triple or quadruple pineapple rows. Cover crops were not planted in control plots, although spontaneous plants were allowed to accumulate between hoeing.

The spontaneous plants present were *Alternanthera tenella*; *Acalypha communis*, *Euphorbia heterophylla*, *Aristida longiseta*, *Desmodium adscendens*, *Stachys officinale*, *Brachiaria decumbens*, *Brachiaria brizantha*, *Rynchospora speciosa*, *Hyparrhenia rufa*, *Cenchrus echinatus*, *Amaranthus deflexus*, *Hyptis lophanta*, *Ipomoea grandifolia*, *Porophyllum ruderale*, *Croton lundianos*, *Chamaesyce hyssopifolia*, *Paspalum notatum*, *Sida glaziovii*, *Solanum viarum*, *Cyperus surinamensis*, *Symphytum officiale*, *Spigelia anthelmia*, *Sida cordifolia*, *Urena lobata*, *Galinsoga parviflora*, *Phyllantus niruri*, *Emilia sonchifolia*, *Cyperus esculentus*, *Cyperus difformis*, *Cyperus ferax*, *Commelina benghalensis* e *Cyperus distans*.

Immediately after harvesting the maize, the cassava was planted in two rows parallel to the pineapple rows at a density of 6,200 plants (3 m-spaced espaliers) and 4,600 plants (4 m-spaced espaliers). Culture management (pruning, weeding and fertilization) was conducted according to Brazilian legislation (Normative instruction, nº46 de 06 de October de 2011) regarding organic crop production (BRAZIL, 2017).

In order to perform an economic analysis of the polyculture system, parameters relating to investment (production cost) and total and net revenues were assessed (Reis 2007; Hafle et al., 2010). Total production costs were defined as the sum of all inputs and services used in the production process and comprised operational and opportunity (or alternative) costs. The operational cost was determined *in loco* during the execution of the experiment according to Reis (2007), while opportunity cost was calculated considering an increase of 6% per year over the operational cost according to the methodology proposed by the Companhia Nacional de Abastecimento (2010). The parameters eventually analyzed were fixed costs, variable costs, total costs, working capital, total and net revenues, profitability index, family wage, profit margin and cost benefit ratio (EMBRAPA; SEBRAE, 2003).

Productivity variables in this journal are of the (passion fruit 18,064.9 kg ha^{-1}; Pineapple 14,358.6 kg ha^{-1}; Maize 3,255.9 kg ha^{-1}; and Cassava 8,782.6 kg ha^{-1} published and discussed in another publication of the main author (ARAUJO NETO et al., 2014).

Data were submitted to the Grubbs test to detect outliers in the univariate data set, to the Shapiro-Wilk test to establish normality of residuals, and to the Bartlett test to verify homogeneity of variances. Following confirmation of normality and homogeneity, analysis of variance (ANOVA) and F tests were performed and the mean values obtained in the various treatments were compared using the Scott-Knott test, utilizing the statistical program SISVAR (FERREIRA, 2014). In all tests, the significance level was fixed at 5% probability. Fixed and variable total costs and working capital ware not calculated in each plot and therefore have no variance and not be statistically analyzed.

RESULTS AND DISCUSSION

The results presented in Tables 1 and 2 show that the interaction between espalier spacing and type of cover crop exerted a significant influence only on total and net revenues. The total revenue generated by passion fruit cultivated in plots with 3 m-spaced espaliers and covered with tropical kudzu or spontaneous plants was significantly higher than that generated by less compact plots (4 m-spaced espaliers) with similar green cover. Net revenue was also increased significantly when passion fruits were cultivated in plots containing 3 m-spaced espaliers and covered with tropical kudzu. Although the more dense arrangement of passion fruit plants increased the total production, costs and profitability. Moreover, cultivation of Passion fruit plants in a dense configuration offered the extra advantage of accelerating harvesting, thereby diminishing the longevity of orchards and preventing damage by pests and diseases (PIRES et al., 2011).

Any increase in production costs associated with high-density planting must be accompanied by increased productivity in order to diminish the total average cost (ARAÚJO NETO et al., 2005). Two factors explain the economic efficiency in this work, (1) The productivities of passion fruit and pineapple are higher 72 and 34%, respectively, through cultivation in plots comprising 3 m-spaced espaliers in comparison with plots containing 4 m-spaced espaliers and (2) the increased productivity obtained when leguminous species (ARAÚJO NETO et al., 2014). This increased productivity are employed as ground cover is probably related to their efficiency in producing green biomass, with consequential enhancement of nutrient cycling, and in augmenting the N, P, K content of the soil (PERIN et al., 2004; ESPINDOLA et al., 2006; PERIN et al., 2009).

In the present study, for example, the total production cost of cultivating passion fruits in plots containing 3m-spaced espaliers was 16.6% higher than that associated with their 4 m-spaced counterparts (Table 1), mainly because of the greater expenditure on inputs and the increased fixed costs in installing a larger number of espaliers. Furthermore, augmentation of fruit productivity in plots with a higher density of plants increased the costs of harvesting and transporting the fruits. Similar results have been reported by Pimentel et al., (2009) which estimated the costs of production and the net present value, internal rate of return and payback, considering the productivity of passion fruit from the Zona da Mata, in the state of Minas Gerais, which is closer to consumer centers compared with the state of Acre.

Table 1. Cost analysis of organic polycultures comprising passion fruit, pineapple, maize and cassava in soil covered with different types of green manure (spontaneous plants, jack-bean, crotalaria, tropical kudzu and peanut forage).

	Passion fruit cultivated with 3 m-spaced espaliers				
	Cover crop				
Cost assessment (R$ ha^{-1})*	Spontaneous plants	Jack-bean	Crotalaria	Tropical kudzu	Peanut forage
Fixed operational cost	5,582.93	5,582.93	5,582.93	5,582.93	5,582.93
Variable operational cost	17,678.80	17,457.99	17,614.45	18,207.13	18,106.25
Total operational cost	23,261.73	23,040.92	23,197.38	23,790.05	23,689.18
Fixed production cost	6,097.90	6,097.90	6,097.90	6,097.90	6,097.90
Variable production cost	18,739.53	18,505.47	18,671.32	19,299.56	19,192.63
Total production cost	24,837.43	24,603.37	24,769.22	25,397.46	25,290.53
	Passion fruit cultivated with 4 m-spaced espaliers				
Cost assessment (R$ ha^{-1})*	Spontaneous plants	Jack-bean	Crotalaria	Tropical kudzu	Peanut forage
Fixed operational cost	4,282.08	4,282.08	4,282.08	4,282.08	4,282.08
Variable operational cost	15,168,81	15,877.33	14,566.64	14,705.74	15,712.03
Total operational cost	19,452,89	20,161.41	18,850.72	18,989.81	19,996.11
Fixed production cost	4,721,12	4,721.12	4,721.12	4,721.12	4,721.12
Variable production cost	16,078,94	16,829.97	15,440.64	15,588.08	16,654.75
Total production cost	20,800,07	21,551.10	20,161.76	20,309.20	21,375.88

* Indicators that have no sampling variability and therefore does not have any statistical analysis.

In plots with 4 m-spaced espaliers, significant increases in revenues were obtained when jack-bean was employed as cover crop (Table 2). In plots with the lower-density configuration, the productivities of passion fruit, pineapple and jack-bean seed were 25,993 16,399 and 319 kg ha^{-1}, respectively, and these high productivities represented the determining factor for enhanced profitability. Previously, Carvalho et al., (2002) reported that the use of jack-bean as a cover crop gave rise to an increase in orange fruit productivity as a result of enhanced soil structure and higher accumulation of N, P, K, Ca, Mg and S.

It is of interest to note the table 2 that, while the production costs associated with the polyculture system employing 4 m-spaced espaliers with tropical kudzu as cover crop were among the lowest, the resulting productivities of passion fruit and pineapple were minimal at 15,445 and 12,310 kg ha^{-1}, respectively. In addition, the pineapple fruits obtained were of inferior quality, indicating that there was competition between tropical kudzu and the fruit plants. All of these factors contributed to the reduction in the profitability index of this specific polyculture system to the lowest value recorded in the study.

Table 2. Economic indicators of organic polycultures comprising passion fruit, pineapple, maize and cassava in soil covered with different types of green manure (spontaneous plants, jack-bean, crotalaria, tropical kudzu and peanut forage)

Indicator	Passion fruit cultivated with 3 m-spaced espaliers Cover crop					
	Spontaneous plants	Jack-bean	Crotalaria	Tropical kudzu	Peanut forage	C.V. (%)
Working cap. (R$ ha^{-1})	6,412.53	6,065.11	6,100.27	6,529.78	6,213.27	-
Total revenue (R$ ha^{-1})	79,064.70^{aA}	71,945.8^{aA}	76,825.40^{aA}	78,042.80^{aA}	75,878.20^{aA}	14,3
Net revenue (R$ ha^{-1})	54.227.30^{aA}	47,342.4^{aA}	52,056.20^{aA}	52,645.30^{aA}	50,586.70^{aA}	21,3
Profitability index (%)	233.00^{aA}	205.70^{aA}	224.30^{aA}	221.30^{aA}	213.30^{aA}	20,1
Family wage (R$ day^{-1})	309.86^{aA}	265.28^{aA}	285.64^{aA}	268.47^{aA}	267.37^{aA}	20,8
Profit margin (%)	68.6^{aA}	65.80^{aA}	67.80^{aA}	67.50^{aA}	66.70^{aA}	7,4
Cost benefit ratio	3.17^{aA}	2.93^{aA}	3.13^{aA}	3.10^{aA}	3.00^{aA}	13,7
Indicator	Passion fruit cultivated with 4 m-spaced espaliers					
	Spontaneous plants	Jack-bean	Crotalaria	Tropical kudzu	Peanut forage	C.V. (%)
Working cap. (R$ ha^{-1})	5,044.77	5,357.64	4,825.66	4,760.21	4,929.15	-
Total revenue (R$ ha^{-1})	59,543.40^{bB}	84,670.30^{aA}	60,103.8^{bA}	52,210.50^{bB}	59,002.80^{bA}	14,3
Net revenue (R$ ha^{-1})	38,743.30^{bA}	63,119.20^{aA}	39,942.10^{bA}	31,901.30^{bB}	37,626.9^{bA}	21,3
Profitability index (%)	199.30^{aA}	313.00^{aA}	212.00^{aA}	168.00^{aA}	188.00^{aA}	20,1
Family wage (R$ day^{-1})	209.34^{aA}	328.59^{aA}	229.30^{aA}	173.64^{aA}	193.23^{aA}	20,8
Profit margin (%)	65.10^{aA}	74.50^{aA}	66.50^{aA}	61.10^{aA}	63.80^{aA}	7,4
Cost benefit ratio	2.87^{aA}	3.93^{aA}	2.96^{aA}	2.53^{aA}	2.73^{aA}	13,7

* Indicators that have no sampling variability and therefore does not have any statistical analysis. In each row, mean values followed by dissimilar superscript lower case letters (relating to the same spacing between espaliers but to a different type of cover crop) or dissimilar superscript capital case letters (relating to different spacing between espaliers but to the same type of cover crop) are significantly different according to the Scott Knott test ($P < 0.05$).

According to Furlaneto et al., (2011), the productivity of passion fruit cultivated using conventional methods in Marília, state of São Paulo, must be higher than 28.3 t ha^{-1} in order to cover the total production costs, of which 33.2% (approximately R$9,000 or US$4,000 ha^{-1}) represent the cost of inputs alone. In this context, Simonetti et al. (2013) maintain that increasing the profitability of agriculture can be readily achieved through diversification, preferably of specialty crops and value-added products

In the state of Acre, the productivity of passion fruit cultivated using organic farming methods is very low. However, this system is still considered attractive since the minimization of external inputs, such as fertilizers, pesticides and fungicides, leads to a reduction in production costs and increases profitability (ARAÚJO NETO et al., 2008, 2009). The results obtained in the present study demonstrate that a polyculture system employing organic methods can be highly profitable depending on the conditions employed. Thus, a profitability index of 313% with a cost benefit ratio of 3.93 could be achieved using a polyculture with 4 m-spaced espaliers and jack-bean as ground cover, and this would yield a family wage of R$328.59 ha^{-1}. In the worst case scenario, involving the polyculture system with 4 m-spaced espaliers and tropical kudzu as ground cover, the profitability index and cost benefit ratio fell to 168% and 2.53, respectively, and the family wage was reduced to R$173.64 ha^{-1}.

Grisa (2007) states that a family farm becomes more efficient and economical when the goods produced, apart from being consumed, generate an extra income. In this way, expenditure on food can be minimized and spare labor time can be utilized in the production of added-value goods, thereby guaranteeing greater economic stability. Moreover, a monoculture system is high risk since it is largely dependent on market price and demand (GRISA, 2007; PETINARI et al., 2008; SOUZA et al., 2008; SILVA et al., 2013), while a polyculture system can reduce the vulnerability of the producer by expanding market possibilities whereby one crop can compensate for the others. Moreover, the organic polyculture system proposed in the present study is not only feasible for small-scale family farming but could also be adopted by medium sized farms that rely on hired labor (fixed or temporary workers) known in Brazil as *agricultura patronal*.

CONCLUSIONS

The cultivation in plots comprising 3 m-spaced espaliers increased productivity and production cost, providing a lower cost benefit ratio. The organic polyculture of passion fruit with pineapple, maize and cass in plots with 4 m-spaced espaliers, with the soil covered by jack bean increased total and net revenue, cost benefit ratio and economic feasibility.

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