Research Article

Profitability of organic carrot cultivation under weed interference and sowing methods[1]

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ABSTRACT

Spontaneous plants in vegetable growing areas significantly impact yield and costs, regardless of the adopted cultivation system. This study aimed to evaluate weed interference periods on the profitability of organic carrot cultivation under different sowing methods. Two experiments were set up [weed control and coexistence, in a randomized block design arranged as split plots (5 x 2), with five cultivation periods: 15, 20, 25, 30 and 35 days after sowing] and two sowing methods were applied: direct and water-conditioned sowing. Based on the production data and technical coefficients, the economic evaluation of production was carried out, with calculation of production costs and revenues. The highest net revenue was obtained when the growing area was kept clean for 19 to 30 days. The total revenue increased linearly by R$ 0.33 m^{-2} for each day of weed control, while, for the coexistence treatment, it decreased by R$ -0.37 m^{-2}. The water-conditioned sowing increased the economic indicators of the organic carrot cultivation.

KEYWORDS: *Daucus carota*, agroecology, water-treated seeds.

RESUMO

Rentabilidade do cultivo orgânico de cenoura sob interferência de plantas espontâneas e métodos de semeadura

A presença de plantas espontâneas em cultivos de hortaliças apresenta grande impacto na produtividade e nos custos, independentemente do sistema de cultivo adotado. Objetivou-se avaliar períodos de interferência de plantas espontâneas na rentabilidade do cultivo orgânico de cenoura sob diferentes métodos de semeadura. Foram instalados dois experimentos [convivência e controle de plantas espontâneas, em delineamento de blocos casualizados, no esquema de parcelas subdivididas (5 x 2), com cinco períodos: 15, 20, 25, 30 e 35 dias após a semeadura] e utilizados dois métodos de semeadura: semeadura direta e sementes hidrocondicionadas. A partir dos dados de produtividade e coeficientes técnicos, foi realizada a avaliação econômica da produção, com cálculo de custos de produção e receitas. A maior receita líquida foi obtida quando o cultivo foi mantido limpo entre 19 e 30 dias. A receita total aumentou linearmente R$ 0,33 m^{-2} para cada dia de controle de plantas espontâneas, enquanto o decréscimo linear foi de R$ -0,37 m^{-2} para a convivência. A semeadura hidrocondicionada eleva os indicadores econômicos do cultivo orgânico de cenoura.

PALAVRAS-CHAVE: *Daucus carota*, agroecologia, sementes hidrocondicionadas.

INTRODUCTION

Brazil is the seventh largest carrot exporter in the world (Dossa & Fuchs 2017), with a total production of 714.509 t concentrated in the Southeast, Central-West and South regions. However, the carrot production in Northern Brazil is estimated at only 19 t, whereas no data are available for the Acre state, even though two carrot-growing properties have already been reported there (IBGE 2018).

The low carrot production in Northern Brazil is related to the lack of technical recommendations and the local olericulture tradition. Furthermore, controlling spontaneous plants (weeds) is one of the main challenges for carrot cultivation, given the variable growth and emergence of this crop and the slow initial development until canopy formation (Colquhoun et al. 2017).

This problem is further worsened in organic production, since herbicides are not allowed in

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this system, with weed control relying on crop management practices and physical and mechanical methods, in addition to the restricted use of highly soluble fertilizers and agrochemicals for pest and disease control. The damage to carrot yield caused by spontaneous plants may reach up to 98 % (Reginaldo et al. 2021), significantly increasing production costs and reducing revenue.

In this scenario, evaluating economic indicators and production costs is essential to determine the viability of agricultural crops. Therefore, assessing whether investments are compatible with the obtained revenues, or whether producers can continue developing the activity, becomes an essential pre-requirement for organic farming (Souza et al. 2015). Furthermore, the production economic evaluation may help to estimate costs and is decisive to reduce risks and assist in developing and diversifying agricultural activities (Oliveira et al. 2022).

In alternative cultivation systems, it is essential to pursue strategies that provide plants with greater competitiveness, accelerating plant emergence and favoring their growth in relation to weeds. This important aspect of crop management can be achieved by seed physiological conditioning techniques (Matias et al. 2018).

It is also important to determine the critical periods of coexistence between weeds and other crops, thus establishing the appropriate moment and control method, in order to increase the yield and revenues and reduce costs (Marques et al. 2016), especially in organic management systems, in which such recommendations are still non-existent.

It is thus essential to determine the period of greatest weed interference, highlighted by reduced revenue and increased production costs in organic carrot cultivation, in addition to checking the profit margin and the expenses percentage.

From this perspective, this study aimed to evaluate the periods of weed interference on the profitability of organic carrot cultivation under different sowing methods.

MATERIAL AND METHODS

The study was conducted at the Seridó Ecological Station, in Rio Branco, Acre state, Brazil (09º53’16’’S, 67º49’11’’W and altitude of 170 m a.s.l.), from July to September 2019. The property has been used to plant fruit and vegetable species under organic cultivation since 2008.

According to Köppen, the local climate is classified as *Am*, i.e., equatorial, hot and humid, with a mean temperature of 25.3 ºC, relative humidity of 79.2 % and mean rainfall of 194.7 mm, during the experimental period (Brasil 2019).

The local soil is classified as a Plinthic Alithic Red Yellow Ultisol (Santos et al. 2013), equivalent to Ultisols (USDA 2014), with a sandy-loam texture and pH (H_2O) = 7.0, showing the following nutrient contents: P = 49 mg dm^{-3}; K = 1.1 mmol$_c$ dm^{-3}; Ca = 49 mmol$_c$ dm^{-3}; Mg = 11 mmol$_c$ dm^{-3}; H = 11 mmol$_c$ dm^{-3}; OM = 17 g dm^{-3}; base saturation = 84.6 %; SB = 61.1 mmol$_c$ dm^{-3}; CEC = 72.2 mmol$_c$ dm^{-3}.

Two experiments were conducted, both set up in a randomized block design with a split-plot arrangement (5 x 2). The plot consisted of five control or coexistence periods with spontaneous plants, whereas the subplots consisted of two sowing methods: direct and water-conditioned sowing. The control and coexistence periods consisted of 15, 20, 25, 30 and 35 days after sowing (DAS). There were four replications, and each plot consisted of four rows of carrots, with the two central rows forming the experimental unit. The plots measured 1.20 x 1.20 m.

The evaluation periods were defined considering studies already conducted for carrot cultivation, in which the critical period of interference varies from 22 to 31 days (Coelho et al. 2009) and from 20 to 27 days (Reginaldo et al. 2021).

In the control experiment, the planting area remained free of spontaneous plants, according to each treatment. In the coexistence experiment, the crop coexisted with weeds until the end of each period, after which they were controlled until harvest.

The Brasília Irecê carrot cultivar was used in all the experiments, and the water conditioning consisted of seed imbibition in water using moistened paper towels.

The carrot cultivation area was initially cleaned, after which the soil was turned and ground using a compact tractor. Next, plant beds (1.20 m wide and 0.20 m high) were raised manually with a hoe.

The soil was corrected using 1 t ha^{-1} of dolomitic limestone and fertilized with 15 t ha^{-1} of organic compost based on weeds and 1 t ha^{-1} of natural thermophosphate. This procedure followed the recommendations of Souza & Resende (2014) and used inputs allowed by Brazilian regulations for organic cultivation (Brasil 2014).

Next, planting holes spaced 30 cm x 10 cm were opened in the experimental area, in which three seeds were sown for the direct sowing treatment (later thinned to one plant per hole), and one seed was sown per hole for the water-conditioning treatment. The crop management practices followed the recommendations for organic carrot cultivation provided by Souza & Resende (2014).

The total cost was initially calculated for the economic evaluation of organic carrot production, representing all inputs and services required by the activity during cultivation and resulting from the sum of fixed costs, which correspond to the portion of the total cost that does not depend on production, and variable costs, which depend on the production, and, therefore, vary with changes in the production volume (Reis 2007). The opportunity cost of land use was also added to the calculation. The values for equipment considered in the calculations were those as of 2021.

Fixed costs represent goods with a long lifespan, e.g., micro tractors, irrigation system, etc. However, only the useful lifespan was considered, calculated through the depreciation: D = (Cv - Rv)/Lf, where D is the depreciation (R$ cultivation^{-1}); Cv the current value of the new good; Rv the residual value (final value of the good); and Lf the lifespan. The variable costs, referring to all inputs and services required during cultivation, included manpower, fuel, fertilizers, seeds, electricity, etc. (Reis 2007).

The manpower was determined based on the daily wage of R$ 69.63, which, in turn, was based on the monthly minimum wage of Brazil (R$ 1,100.00 - equivalent to US$ 214,78, in 2021) plus payroll taxes of 12 % (National Institute of Social Security) and 8 % (Length-of-Service Guarantee Fund), 13th salary, vacations, insurance and education salary, all divided by 22 working days per month.

The lifespan of materials and equipment used to estimate the depreciation was obtained in the table of agricultural production costs developed by the Conab (2010). The technical coefficients, i.e., the time to prepare and fertilize plant beds, sowing, crop management practices, cleaning and harvest, were obtained throughout the experimental period.

Administrative costs amounting to 3 %, referring to office services, were also included (Reis 2007). The land rent cost of the most common activity in the region is that of cattle raising. The opportunity cost, defined by Reis (2007) as the return provided by the capital if applied to other investments, was applied at a 6 % rate per year, close to the revenue provided by saving accounts.

No costs were considered for organic certification, since there are no local certifying agencies and producers only employ social control with the direct sale to customers, following current regulations (Brasil 2003, Brasil 2014). The total revenue corresponded to the product between the organic commercial yield (kg m^{-2}) and the carrot kilogram price in the organic market, corresponding to R$ 6.00 kg^{-1}.

The following financial indicators were evaluated: net revenue (R$); benefit to cost ratio; profit margin (%); profitability index (%); family labor remuneration (R$ day^{-1}); production to cover total costs (kg m^{-2}); and cost for weed control.

The data were evaluated for normality of residuals and homogeneity of variances. Then, the F-test was applied for the analysis of variance, which, when significant ($p < 0.05$), indicated differences between the treatments for sowing. On the other hand, the analysis of the interference periods was performed by polynomial regression for the variables total revenue, profitability index, profit margin and benefit to cost ratio.

The net revenue means were subjected to non-linear regression by the Boltzmann's sigmoidal model (Pitelli et al. 2013). Subsequently, the period before interference, total prevention period against interference and the critical prevention period against interference were determined considering 5 % of losses in production and revenue.

RESULTS AND DISCUSSION

The highest net revenue (R$ 5.99 m^{-2}) was obtained when the carrot plants coexisted for the shortest time with spontaneous plants. However, this variable decreased by 116.36 % when the crop was maintained for up to 35 days in coexistence with weeds, resulting in a negative net revenue (Figure 1).

Therefore, in order to obtain a satisfactory net revenue, considering acceptable losses of up to 5 %, weed control should be performed from 19 to 30 days (Figure 1), considering the commercial yield for organic markets.

The interference periods estimated for net revenue differed from those obtained for the yields,

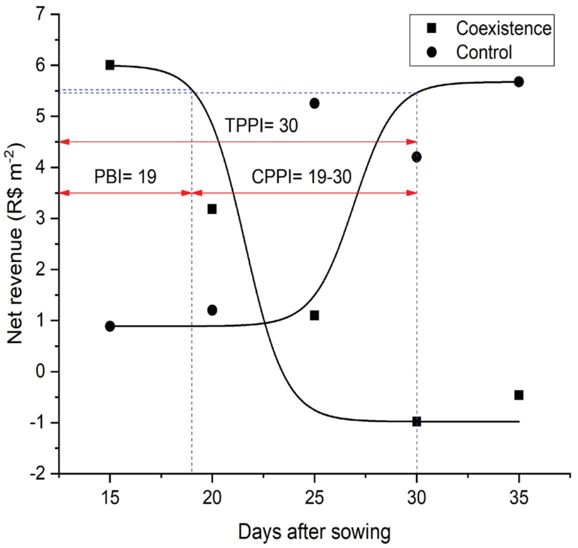

Figure 1. Interference periods of spontaneous plants on carrot net revenue (Rio Branco, Acre state, Brazil, 2019). TPPI: total prevention period against interference; PBI: period before interference; CPPI: critical prevention period against interference.

since this calculation also includes the sale price and production costs, which vary depending on the number of cleaning interventions performed in the treatments.

Defining the control period is an important strategy for choosing the most efficient and economical management method. Although the mechanical control by hoeing demands more manpower, this treatment showed similar results to herbicide application in sesame, with regard to the net revenue, return rate and profitability index. However, the cost and availability of manpower should also be considered (Lins et al. 2021).

All variables in Figures 2 and 3 showed isolated responses for the coexistence or control periods with weeds and the type of sowing.

The total revenue increased linearly by R\$ 0.33 m^{-2} for each weed control day. In contrast, in the coexistence treatment, there was a linear decrease of R\$ -0.37 m^{-2} (Figure 2A). The same occurred with the profitability margin, which increased by 2.29 % in the control treatment and decreased by -3.50 % in the coexistence treatment for each day of cultivation (Figure 2C).

The longer the weed control period, the higher the profitability index in carrot cultivation (Figure 2B) and the faster the return for the invested capital. On the other hand, the weed coexistence in carrot cultivation decreased the return rate, reaching a minimum of -12.54 % with 33.45 days of cultivation (Figure 2B). The profitability index is an important variable that demonstrates the economic viability of the agricultural activity resulting from the relationship between revenue and costs (Barros Júnior et al. 2019).

The benefit to cost ratio showed a growing linear regression when the spontaneous plants were controlled, demonstrating the viability of the activity throughout the entire period evaluated. In contrast, in coexistence, the carrot production showed a benefit to cost ratio below 1, starting from 27 days and reaching 0.90 after 33 days of coexistence. The activity is economically viable in treatments whose values are above 1, since this is the result of the financial return for each monetary unit invested (Silva et al. 2020, Uchôa et al. 2021) (Figure 2D).

The production to cover total costs responded in a quadratic function for both the experiments, with the maximum requirement of 0.94 kg m^{-2} in the control treatment (46.7 days) and 1.18 kg m^{-2} in the coexistence treatment (24 days) (Figure 3A).

Carrot cultivation along with spontaneous plants demands higher yields due to the higher total costs in the period (R\$ 6.94 m^{-2} after 23.5 days) (Figure 3C), increased by the weed control costs, which represented 54.55 % of total costs after 24 days of cultivation (Figure 3B). Similar responses were obtained in the experimental control. However, the total costs of cleaning interventions amounted to 41.69 % after 24 days (Figures 3A, 3B and 3C).

The family labor remuneration increased as the crop remained free from spontaneous plants for longer periods, i.e., with a greater control. On the other hand, when there was coexistence, this parameter decreased, reaching negative values at R\$ 10.12 after 33 days (Figure 3D), resulting in a deficit.

The number of cleaning interventions performed to control weeds was determinant to increase the family labor remuneration, since this activity demands time and manpower. There was a decreasing trend when the crop coexisted for more time with other plants, since weed management decreased. The use of family labor in agricultural activities, in addition to generating income, also generates jobs/employment due to the use of internal labor.

Although the longest coexistence period with weeds implied in reductions in the total costs (Figure 3C), since no cleaning interventions were

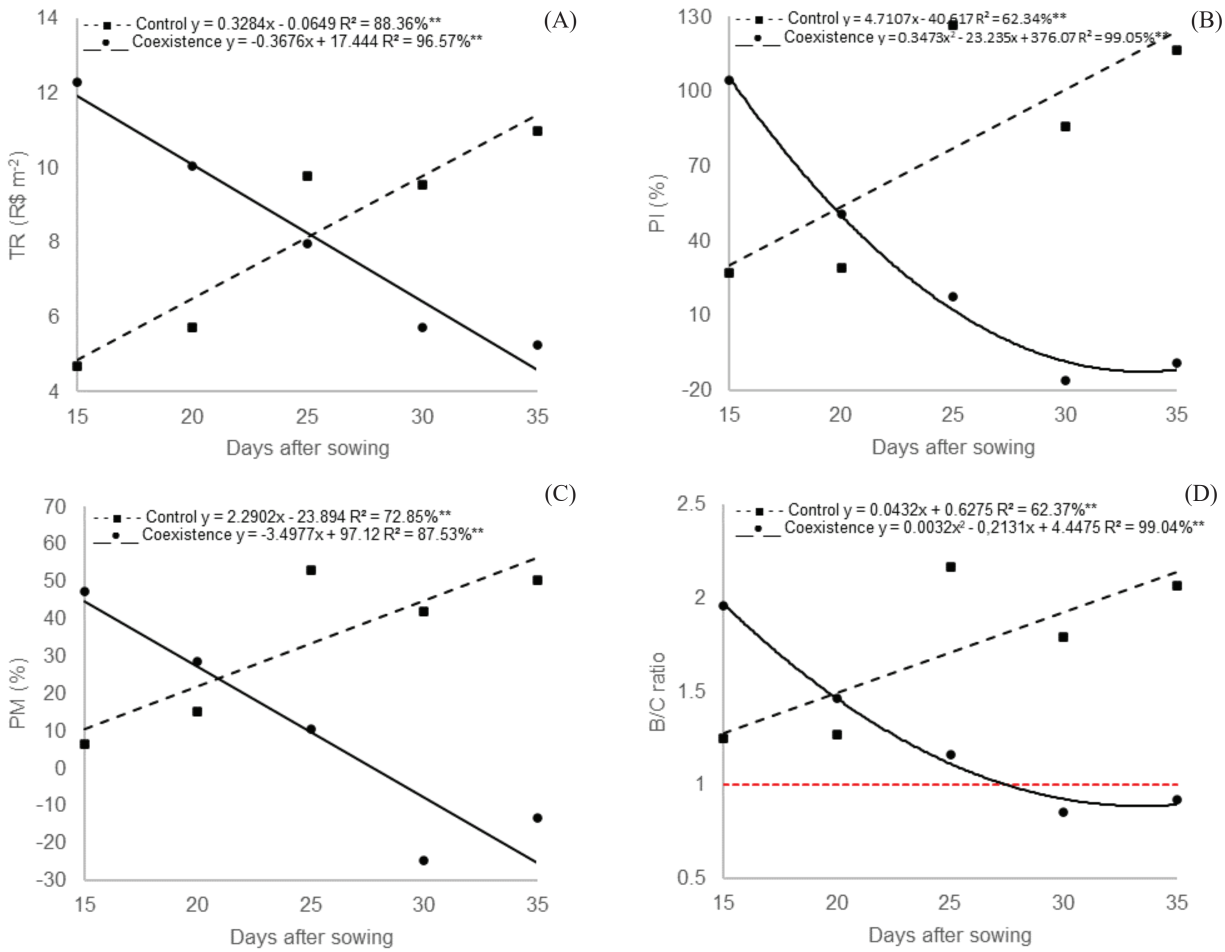

Figure 2. Total revenue (TR) (A), profitability index (PI) (B), profit margin (PM) (C) and benefit to cost ratio (B/C ratio) (D) of organic carrot production as a function of coexistence with spontaneous plants and control periods (Rio Branco, Acre state, Brazil, 2019). Red line: ≤ 1.0, not economically viable. ** Significant at 1 % by the F-test.

required, the yield decreased in these treatments, reaching up to 57 % of losses, which increased the average costs.

The economic variables were significantly affected by the types of sowing when the carrot plants coexisted with weeds and/or when these were controlled (Tables 1 and 2).

The water-conditioned sowing increased the economic indicators of the organic carrot production (benefit to cost ratio, family labor remuneration, profitability index, net revenue, total revenue, total cost and weed control cost) (Tables 1 and 2), justified by the higher production obtained with this treatment, which is probably influenced by the faster canopy

Table 1. Benefit to cost (B/C) ratio, production to cover total costs (PTC), family labor remuneration (FLR) and profitability index (PI) of organic carrot production under direct and water-conditioned sowing (Rio Branco, Acre state, Brazil, 2019).

Sowing methods	B/C ratio		PTC (kg m^{-2})		FLR (R$)		PI (%)	
	[1]Ce	[2]Ct	Ce	Ct	Ce	Ct	Ce	Ct
Water conditioning	1.38 a	1.77^{ns}	1.07 b	0.77 b	32.73 a	73.30^{ns}	41.54 a	84.48^{ns}
Direct	1.16 b	1.65	1.09 a	0.79 a	14.41 b	60.01	17.72 b	62.82
Mean	1.27	1.71	1.08	0.78	23.57	66.65	29.63	73.65
CV (%)	20.32	15.79	1.62	2.22	94.40	55.97	95.15	38.13

* Means followed by different letters in the column differ ($p < 0.05$) by the F-test. ^{ns} not significant. [1] Ce: coexistence; [2] Ct: control.

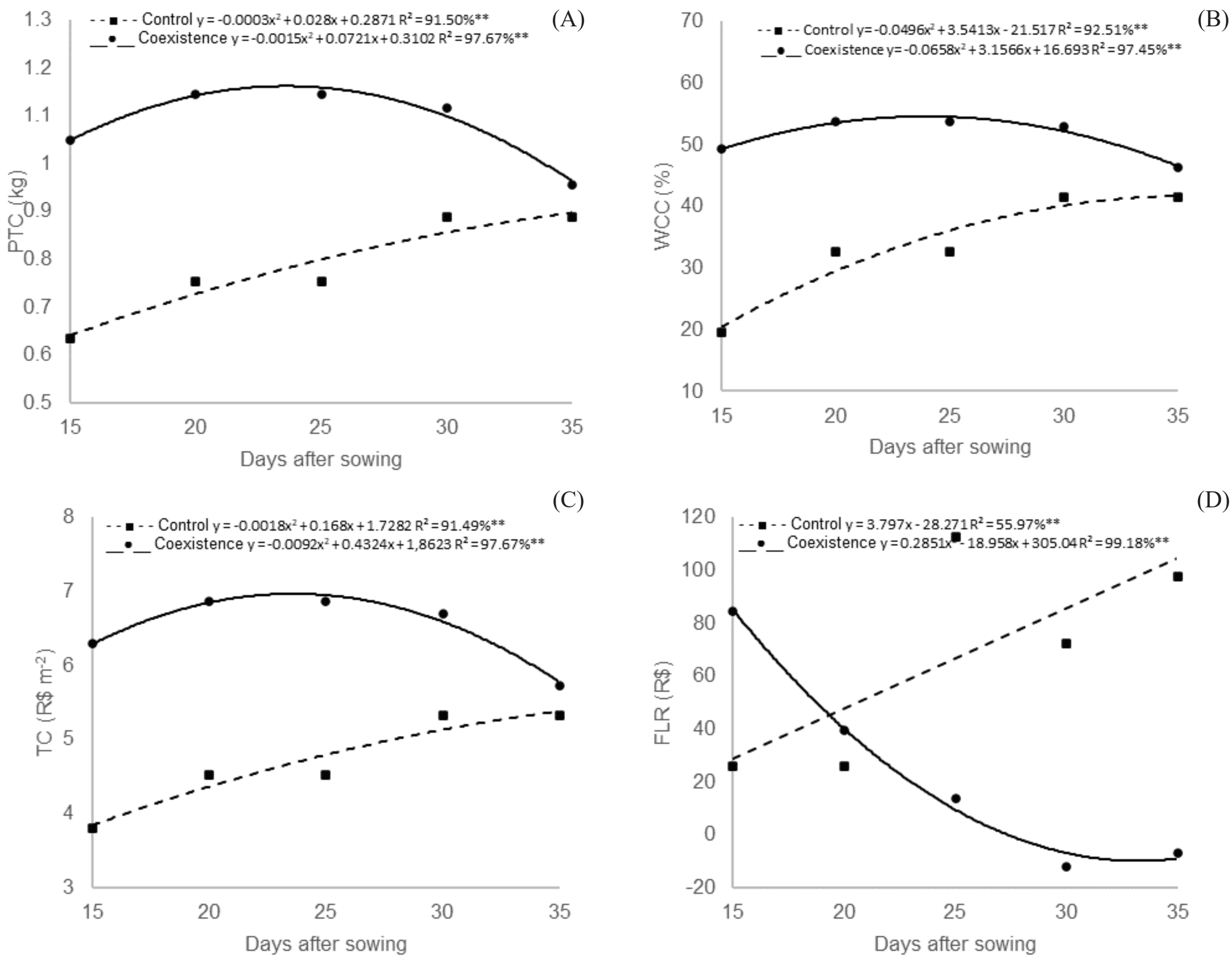

Figure 3. Production to cover total costs (PTC) (A), weed control cost (WCC) (B), total cost (TC) (C) and family labor remuneration (FLR) (D) of organic carrot production as a function of coexistence with spontaneous plants and control periods (Rio Branco, Acre state, Brazil, 2019). ** Significant at 1 % by the F-test.

Table 2. Net revenue (NR), total revenue (TR), total cost (TC) and weed control cost (WCC) of organic carrot production under direct and water-conditioned sowing (Rio Branco, Acre state, Brazil, 2019).

Sowing methods	NR (R$ m^{-2})		TR (R$ m^{-2})		TC (R$ m^{-2})		WCC (%)	
	[1]Ce	[2]Ct	Ce	Ct	Ce	Ct	Ce	Ct
Water conditioning	2.48 a	3.75^{ns}	8.90 a	8.39^{ns}	6.42 b	4.64 b	55.66 a	33.94 a
Direct	1.06 b	3.14	7.61 b	7.90	6.55 a	4.76 a	50.67 b	33.12 b
Mean	1.77	3.45	8.26	8.15	6.49	4.70	53.17	33.53
CV (%)	94.19	34.86	20.18	14.97	1.62	2.23	1.47	1.38

* Means followed by different letters in the column differ ($p < 0.05$) by the F-test. ^{ns} not significant. [1] Ce: coexistence; [2] Ct: control.

closure. In turn, the canopy closure reduced the need to control weeds and increased the yield.

Direct sowing increased the production to cover total costs variables, requiring more carrots to cover costs and resulting in a higher total cost (Tables 1 and 2). In this treatment, more seeds were deposited per hole to ensure emergence, thus increasing the manpower required for plant thinning. This intervention was not necessary for water-conditioned seeds, since only one seed was deposited at sowing, with the same sowing time.

The highest costs in carrot production stem from the acquisition of inputs (Bezerra Neto et al. 2019), seeds, organic fertilizers, plastic for solarization, labor for sowing and irrigation represented most of the expenses. The water-conditioned sowing resulted in a net income of R$ 2.48 m^{-2}, thus indicating the profit obtained by the producer after discounting variable costs and equipment and capital depreciation (Machado Neto et al. 2018).

Costs with weed control were the same for both types of sowing. However, since the weed control cost variable refers to the percentage of this control among total costs, this variable showed higher values in the water conditioning treatment, since the total costs were inferior to those of direct sowing, resulting in a higher weed control cost percentage.

Weed interference does not negatively influence only the crop yield, but also the financial management of the activity, since there are significant investments with control and reduced revenues. Therefore, it should always be considered that the interference is intimately related to the choice of the cultivar, soil and crop management, and control methods, among other factors (Helvig et al. 2020).

CONCLUSIONS

1. The coexistence of spontaneous plants in the carrot production, throughout the cultivation period, reduces the producer's net income by 116.36 %;
2. In order to obtain a greater net income, the carrot crop must be kept free of weeds for 19 to 30 days;
3. The profitability index of the activity increases with a greater weed control;
4. Water-conditioned seeds increase the production and economic indicators in the organic carrot cultivation.

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