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Weed interference on organic carrot yield under different sowing methods

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Abstract

Weed cause serious problems to vegetable cultivation, justifying the importance of studies on the interference of these plants in agricultural crops and management techniques in the context of organic production. From this perspective, this study aimed to evaluate the interference of weed on the yield of carrot grown under different sowing methods. The study was conducted at the Seridó Ecological Station in Rio Branco, Acre, Brazil. Control and coexistence experiments with weeds were set up in a split-plot design (5 x 2), with the plot corresponding to the coexistence or control periods: 15, 20, 25, 30, and 35 days after sowing, and the subplots corresponding to the sowing methods: direct seeding and water conditioning. Cultivation followed the recommendations for carrot and for the organic system. The harvest and evaluations were performed after 80 days by evaluating the biometric variables, the carrot yield, and the weed mass. The statistical analysis consisted of the test of assumptions followed by analysis of variance. Non-linear regression was used for the yield parameters by determining the interference periods. In contrast, linear regression was used for the other variables. Carrot coexistence with weeds reduced the conventional commercial yield by 75.73% and the organic commercial yield by 57.07%. Organic carrot cultivation should occur free of weed from 21 to 28 days. Water conditioning increased the organic carrot yield.

Keywords: Agroecology, *Daucus carota*, Water-treated seeds

Introduction

Wild carrot (*Daucus carota* L.) is a species of the family Apiaceae whose roots have significant commercial importance, ranking as one of the five most cultivated and commercialized vegetables in Brazil (Conab, 2019), with an intense production in the Southeast region of the country (476.284 t), although still incipient in its North region (19 t) (IBGE, 2018).

Weeds constitute a great problem for agriculture, especially in areas with vegetable crops, which favor weed growth and development, making them more competitive due to the intense soil use and causing drastic reductions in crop yield in the absence of adequate control (Bachega et al., 2013).

In this scenario, organic agriculture emerges as an ever-growing model driven by the increased awareness of producers and consumers (Sediyama et al., 2014). Furthermore, this production system does not allow herbicides and favors carrot yield by promoting less root discard and higher product quality, in addition to higher vitamin C contents (Bender et al., 2020).

Weed interference in agricultural areas limits resources such as water, light, and nutrients (Isik et al. 2015), causing secondary problems such as allelopathy and hosting pests and phytopathogens. With these problems, the damage to carrot yield can reach up to 98% when the crop coexists with weeds throughout cultivation (Reginaldo et al., 2021).

However, there is a period during which weeds cause greater problems, which justifies the importance of knowing the interference period in the weed community and recognizing the main plant features in order to develop efficient management strategies (Albuquerque et al., 2017; Marques et al., 2016; Souza et al., 2016).

Furthermore, giving conditions for the main crop to grow and develop faster is essential to reduce

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competition with weeds. In this scenario, one of the most widespread techniques for vegetable crops is seed conditioning, which accelerates germination and emergence and has low costs (Bisognin et al., 2016; Mendonça et al., 2018).

From this perspective, this study aimed to evaluate weed interference on carrot yield under different sowing methods.

Material and Methods

The experiments were set up from July to September 2019 at the Seridó Ecological Station in Rio Branco, Acre, Highway AC 10, km 4, Branch José Rui Lino, at the coordinates 09°53'16'' S, 67°49'11'' W, and at an elevation of 170 m a.s.l. The property traditionally performs organic cultivation for 14 years.

The regional climate is equatorial, hot, humid, and classified as *Am*. During the conduction of the experiments, the mean temperature was 25.3 °C, the mean relative humidity was 79.2%, and the total rainfall amounted to 194.7 mm (Inmet, 2019).

The soil is classified as a Plinthic Alithic RED YELLOW ULTISOL with a sandy loam texture, pH (H_2O) = 7.0, and 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}; O.M.= 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 (coexistence and control), both in a randomized block design with a split-plot arrangement (5 x 2) with four blocks. The plot consisted of five control or coexistence periods with weeds: 15, 20, 25, 30, and 35 days after sowing (DAS), whereas the subplots consisted of two sowing methods: direct seeding (DS) and water-treated seeds (WT). The experimental plot consisted of four rows, with the experimental unit corresponding to the two central rows.

In the control experiment, carrot cultivation remained free of weeds, according to each treatment, growing without cleaning interventions until harvest. In the coexistence experiment, the crop coexisted with weeds until the end of each period, after which weed control was applied until harvest.

The experiment employed the carrot cultivar 'Brasília Irecê', which belongs to the Brasília group. For the water conditioning treatment, the seeds were soaked in water using paper towels until radicle emergence, which took an average period of four days.

The soil of the planting rows was corrected with 1 t ha^{-1} of dolomitic limestone and fertilized with 15 t ha^{-1} of a plant-based organic compost and 1 t ha^{-1} of thermophosphate, following the recommendations of Souza and Resende (2014) and using inputs allowed by organic farming regulations (Brasil, 2014).

The crop management practices followed the recommendations for organic carrot cultivation (Souza e Resende, 2014), and harvest was performed after 80 days.

The variables analyzed were the shoot length, root length, and root diameter. The evaluation of the mean root mass considered two classifications: the conventional commercial mass (CCM) – following the classification rules of the Brazilian Program for the Modernization of Horticulture (Prohort, 2019), considered as standard, and the commercial organic mass – which added to the CCM the roots that did not fit the conventional classification for having defects, some of which severe, but still being useful for commercialization in organic markets. The yield parameters considered the mass classifications to obtain the conventional commercial yield and the organic commercial yield.

The dry mass of weeds was determined by collecting plants from a specific area using a square (50 cm x 50 cm). In the coexistence experiment, the evaluation was performed at the end of each period. In contrast, the evaluation was performed at harvest in the control experiment. Subsequently, the plants were dried to constant weight in a forced-air oven at 65 °C.

The percentages (%) of roots within the classes (length) established by the Brazilian Program for the Modernization of Horticulture were used for the classification of commercial roots (Prohort, 2019). Furthermore, the percentage of standard commercial roots was also considered for this parameter.

The data were initially evaluated for normality of residuals by the Shapiro-Wilk test and homogeneity of variances by the Bartlett test. Then, the F-test was applied for the analysis of variance, which, when significant ($p<0.05$), indicated significant differences between treatments for the sowing factor. On the other hand, regression analysis was performed in all variables for the interference periods, except for the yields.

For the conventional and organic commercial yields, the means were subjected to non-linear regression by Boltzmann's sigmoidal model, according to the methodology proposed by Pitelli et al. (2013). Then, the following periods were determined: the period before the interference (PBI), the total period of interference prevention (TPIP), and the critical period of interference prevention (CPIP), considering 5% of yield and revenue losses.

The non-parametric test of Friedman and the ranking of means by the Conover test were performed for the percentage of commercial roots.

Results and Discussion

The conventional commercial yield ranged from 1.03 kg m^{-2} (coexistence) to 1.11 kg m^{-2} (control). However, carrot coexistence with weeds during the whole cycle decreased the commercial yield by 75.73% (**Figure 1**).

Carrot plants can coexist with weeds for up to 18 days without interference in the yield or quality. The same occurred from 30 days after sowing, during which the crop can coexist with other plants without damage to the yield. In that case, the critical period of interference prevention (CPIP), i.e., when the control should be performed, is recommended to occur from 18 to 30 DAS (Figure 1).

The reduction in crop yield is severe when there is coexistence with weeds. Therefore, maintaining the cultivation areas free of weeds for a given period is essential to ensure satisfactory yields. The CPIP varies as a function of the crop of interest, the weed community, the management adopted, soil, climate, and other factors (Souza et al., 2016).

The end of the critical period, coinciding with the total period of interference prevention (TPIP), is determined by various plant and cultivation factors. In this period, plants increase their competitive capacity with other plants that coexist in the environment due to canopy closure and the consequent reduction in weed competition (Lins et al., 2019).

The maximum yield of carrots that can be commercialized in the organic market was 2.05 kg m^{-2} in coexistence and 1.83 kg m^{-2} in the control treatment. When the crop coexisted with weeds, the yield decreased by 57.07% (**Figure 2**).

According to Dotor et al. (2018), the carrot crop obtains maximum agronomic yield when it remains free of weeds during the whole cycle, reaching values 38.76%

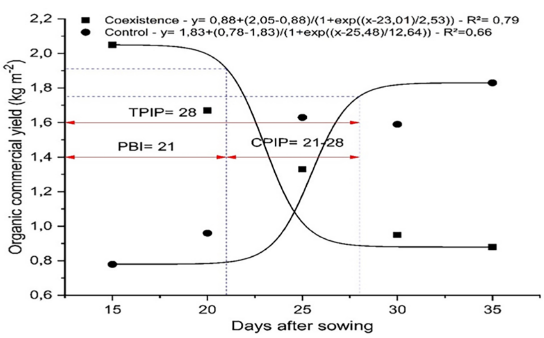

Figure 1. Periods of weed interference with the conventional commercial yield of organic carrot. Rio Branco, AC, 2019. TPPI: Total Prevention Period Against Interference; PBI: Period Before Interference; CPPI: Critical Prevention Period Against Interference.

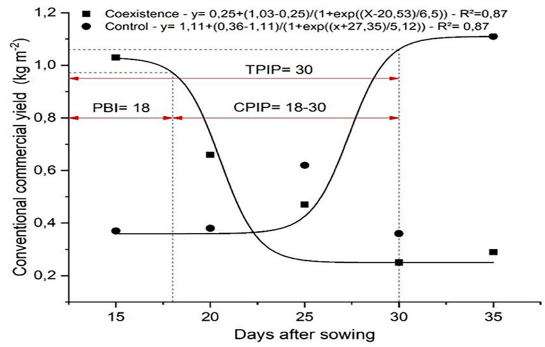

Figure 2. Periods of weed interference with the organic commercial yield of carrot. Rio Branco, AC, 2019. TPPI: Total Prevention Period Against Interference; PBI: Period Before Interference; CPPI: Critical Prevention Period Against Interference.

higher than in the critical period of competition.

The estimated interference periods differ from those seen in the conventional yield. In this case, carrot plants coexist without interference for up to 21 days, with the critical period occurring from 21 to 28 DAS. After 28 days, the crop competes better with other plants, and no controls are required.

According to Colquhoun et al. (2017), carrot plants initially show low competition capacity due to the slow germination and growth of this crop. In this scenario, although breeding programs have not targeted these features, organic producers prefer cultivars with faster emergence rates since they can use crop and mechanical control more efficiently.

Other vegetable species (e.g., okra) also show slow growth, which reduces the period prior to the interference and requires earlier control interventions. Furthermore, it is essential for organic fertilization management to be free of seeds of other species in order not to serve as propagation ways for future problem causers (Santos et al., 2020).

The differences in the yield and interference periods in relation to the two classifications occur as a function of the higher demand for roots in the organic market, which does not discard forked and cracked roots or other severe defects unaccepted in the conventional classification of horticultural products.

Although some treatments were not significant, water conditioning increased the yields of the control and coexistence treatments (**Table 1**).

The conditioning of carrot seeds was achieved by water treatment. This technique provides the conditions to trigger the germination metabolism. However, the absorption capacity of seeds is related to the osmotic potential of their cells (Bisognin et al., 2016).

The higher carrot yield in the treatments with

Table 1. Commercial yield of conventional and organic carrot as a function of the sowing method. Rio Branco, AC, 2019

Sowing	Commercial yield of conventional (kg m^{-2})		Commercial yield of organic (kg m^{-2})	
	Coexistence	Control	Coexistence	Control
Water-treated	0.55^{ns}	0.69 a*	1.48 a*	1.40^{ns}
Direct seeding	0.53	0.45 b	1.27 b	1.32
CV (%)	30.11	37.88	20.09	14.58

*Means followed by different letters differ (p<0.05) by the F-test. ^{ns}Non-significant

water-treated seeds is due to the higher emergence uniformity and the beginning of plant development in relation to direct seeding. Also, under high-temperature conditions (> 30 °C), carrot seeds can undergo thermal inhibition, with the use of conditioning techniques favoring germination (Nascimento et al., 2013; Nascimento et al., 2009).

The production of shoot matter by the weed community is inversely proportional to the carrot yield (**Figure 3**), i.e., the yields increased and weed infestation decreased when the crop remained free of weeds. Likewise, when the carrot crop coexisted for a longer time with weeds, the yields decreased significantly (Figures 2 and 3).

The reduction in the yield indices is related not only to weed growth and development but also to the diversity of species in the area as the environment provides ideal conditions (Souza et al. 2020) since some weed species, e.g., *Commelina benghalensis L.* and *Amaranthus viridis* L., interfere with plant physiology, including by reducing the leaf chlorophyll content, as observed by Cabral et al. (2020) in yacón.

The type of sowing did not influence the production of weed biomass, showing a mean value of 143.40 g m^{-2} in coexistence and 80 g m^{-2} in the control treatment.

All variables of **Figure 4** showed the same tendency for the two treatments, i.e., the more prolonged coexistence with weeds reduced the diameter, shoot length, and root mass. The interaction between sowing and control periods was significant when plant control was performed, except for the conventional commercial mass. For these variables, water conditioning provided the best results.

The evaluated parameters seen in Figure 4 and the yields were all affected by weed interference. The limited availability of resources such as light, water, and nutrients reduces crop growth and development, preventing the species from manifesting its maximum potential. However, the sufficient availability of some resources can favor weed development since these plants show a higher ability to capture resources than agricultural crops, in addition to the slow initial growth characteristic of carrot plants (Cunha et al., 2015; Isik et al., 2015; Reginaldo et al., 2021).

The superiority of the variables in the water conditioning treatment is probably due to the faster growth in this treatment in relation to direct seeding and the higher competitive capacity with other plants since emergence occurred along with most weed species. The water conditioning treatment increased dry matter accumulation, favoring plant vigor and making plants

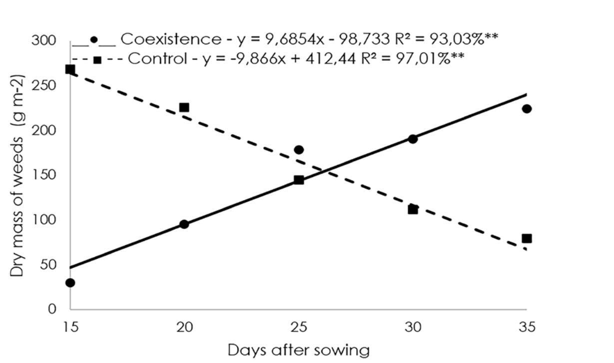

Figure 3. Dry mass of weeds as a function of coexistence and control periods in organic carrot cultivation. Rio Branco, AC, 2019.

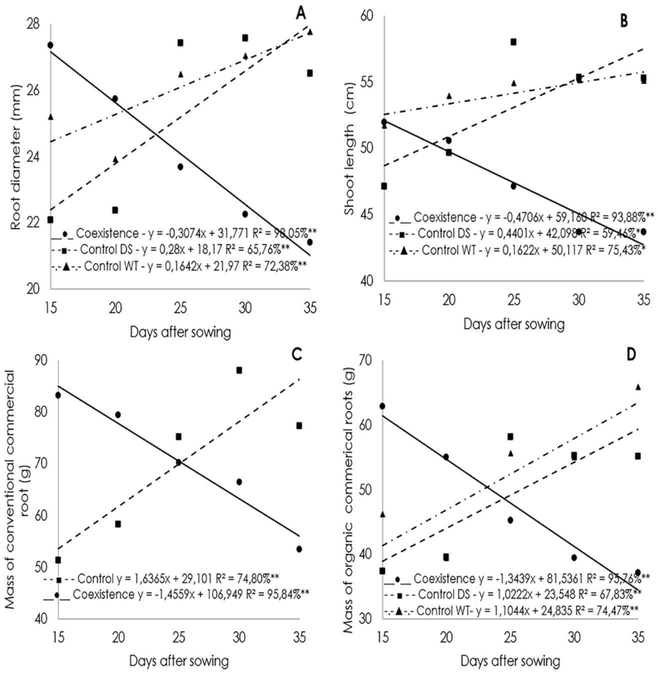

Figure 4. Root diameter (A), shoot length (B), mass of conventional commercial roots (C), and mass of organic commercial roots (D) of carrot as a function of the coexistence and control periods with weeds under direct seeding (DS) and water conditioning (WT). Rio Branco, AC, 2019.

more resistant to field adversities (Ramalho et al., 2020).

The coexistence of carrot with weeds for a longer time (30 and 35 days) reduced the percentage of commercial roots (**Figure 5**A), mainly influenced by the shorter length of roots (Figure 5B), which could not develop due to competition and did not reach commercial values for conventional or organic classification.

Note: Figure 5A – Means followed by the same lowercase letter in the coexistence treatment and uppercase letter in the control treatment did not differ ($p>0.05$) by the non-parametric test of Conover.

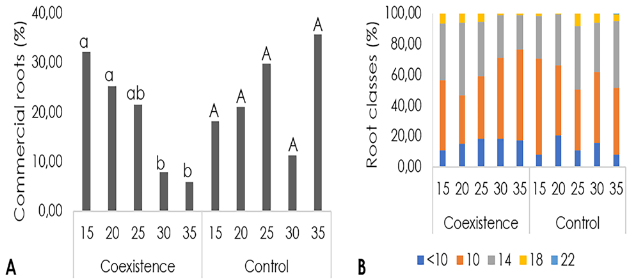

Figure 5. Commercial roots (A) and classification of organic carrot (B) as a function of the coexistence and control periods with weeds. Rio Branco, AC, 2019.

There was no difference between the coexistence and control periods for the carrot root classes, with class 10 showing the highest percentage in both experiments, corresponding to roots with lengths between 10 cm and 14 cm. However, when the crop remained for a long time without other plants, the percentage of higher classes increased (Figure 5B).

The carrot crop responds positively to organic fertilization and has a moderate nutrient demand. In some cases, carrot is grown as a subsequent crop in crop rotation under organic agriculture (Kjellenberg et al., 2015).

The evaluation of the weed impact on agricultural crops generates important information to minimize negative effects and design the best planning strategies to manage these plants aiming to increase production and reduce costs (Campos et al., 2023).

Conclusions

Carrot coexistence with weeds reduced the conventional commercial yield by 75.73% and the organic commercial yield by 57.07%.

Organic carrot cultivation should be maintained free of weeds from 21 to 28 days.

There is no difference in the weed interference periods between types of sowing.

Water conditioning increased the yield of organic carrot.

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