

Weeds interference per nutrient in carrots grown with or without black oat mulch

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Abstract

The interaction with weeds jeopardizes the nutrients accumulation in the carrots' plants. The mulch can reduce competition effects and provide advantages to the cultivation. This research aimed to assess the black oat (*Avena strigosa* Schreb.) hay mulch effect on dry matter accumulation of weeds and nutrients (N, P, K, and S) accumulation in the carrots plants cultivar "Alvorada." The experiments were set during the crop seasons 2016/2017 and 2017/2018 in a randomized-block design with a factorial scheme 2 x 5, with five repetitions. The first factor corresponded to soil cover (with or without mulch), and the second factor, to the interaction time with weeds (0, 15, 30, 60, and 120 days after emergence). The interaction with the weed community reduced nutrients absorption and dry matter accumulation in the roots of the carrot's plants. Interference with nutrients absorption was more intense in crops without black oat hay mulch than with mulch. Mulch can reduce weeds' dry mass by 75.6% during the entire culture cycle. Therefore black oak oat mulch reduces the weed interference allowing higher nutrients accumulation and roots biomass in the carrots plants cultivar "Alvorada."

Keywords: *Daucus carota* L., haystack, Nutrients' absorption, weeds competition

Introduction

Carrot stands out as one of the world's most consumed greenery due to the high nutritional value of its roots. Carrot can be farmed in all Brazilian territory, both in the spring-summer, and autumn-winter seasons, with productivity from 30 to 95 t ha⁻¹ (Lopes et al., 2008; Paulus et al., 2012; Resende & Braga, 2014). However, the weeds' interference can reduce up to 91% of the roots' productivity (Bell et al., 2000; Colquhoun et al., 2017, 2019), requiring control measures.

In the Brazilian Northeastern Region, the critical periods for weeds' interference prevention occur from 19 to 36 and from 18 to 42 days after the carrot emergence, respectively for the spacings of 15 and 20 cm between the lines (Freitas et al., 2009). In Southern Ontario (Canada), the carrot must stay free from weeds until the four-leaves stage for the plants planted at the end of May and up to the twelve-leaves stage if planting occurred at the end of

April (Swanton et al., 2010).

The use of hay mulch of cover plants is an excellent alternative for integrated weeds management, mainly in organic production systems (Bernstein et al., 2014). One example of such handling is the black oat mulch (*Avena strigosa*).

Haystack suppresses the seeds' bank emergence by forming a physical barrier over the soil and releasing allelopathic compounds (Chase et al., 2008; Jabran et al., 2015; Halde & Entz, 2016). Mulch efficiency, however, depends on the covering plant's species, the hay amount, and the floristic community that exists in the area (Osipitan et al., 2018).

Mulch promotes other benefits, such as soil protection from erosive factors and stimulating microorganisms' development, improving nutrients' cycling (Hartwig & Ammon, 2002; Reddy et al., 2003). In addition, nutrients and organic compounds release

combined with humidity preservation form a favorable environment for the cultures' roots development, minimizing the competition with weeds during nutrients' absorption, and improving productivity (Halde & Entz, 2016; Brito et al., 2017; Mohler et al., 2018; Lowry & Brainard 2019).

For these reasons, the seeds' bank suppression and the improvement of the nutrients absorption conditions by using black oat mulch can improve the carrots' competitive ability to the weeds and improve the plants' nutritive value. Therefore, the work analyzed the macronutrients accumulation in carrots' plants cultivated with black oat hay mulch and weeds interaction to verify the hypothesis of black oat hay mulch utility to improve the carrots' production.

Material and Methods

The experiments were performed from October to February in the crop seasons 2016/2017 and 2017/2018 in Ponta Grossa, Paraná, Brazil, at the coordinates latitude 25°13'S and longitude 50°03'W. The experimental design was the randomized-block design with five repetitions in a 2x5 factorial scheme. The first factor corresponded to the soil cover (with or without black oat *Avena strigosa* Schreb. mulch), and the second factor, to the time of carrot interaction with weeds (0, 15, 30, 60, and 120 days after emergence). The parcels were cleared by hand after each interaction period. Each experimental unit consisted of a five-rows seedbed 2.0 m long and 1.0 m wide.

The soil chemical analysis of the experimental area had the following characteristics: pH(CaCl₂): 5.2; H+Al: 6.2 cmol_c dm⁻³; Al: 0 cmol_c dm⁻³; Al: 5.5 cmol_c dm⁻³; Al: 2.4 cmol_c dm⁻³; Al: 0.56 cmol_c dm⁻³; Al: 25 mg dm⁻³; SO₄: 9.6 mg dm⁻³; Organic C: 31 g dm⁻³; CTC pH7: 14.67 cmol_c/dm³ and V: 58%.

Five days before seeding, 500 kg ha⁻¹ NPK (04-14-08) was incorporated into the soil. Thirty days after seeding, 50 to 80 kg ha⁻¹ potassium chloride and urea were applied as cover, as Van Raij et al. (1996) recommended. Next, the soil was graded, and then the seedbeds were prepared mechanically, with 1.0 width and 40.0 m length.

The black oat hay was deposited in the parcels with mulch manually immediately after the preparation of the seedbed, obtaining a 10.0 t ha⁻¹ cover, corresponding to 1.0 kg m⁻².

The experiments used the carrot cultivar "Alvorada." Seedlings were performed by hand in October 2016 and 2017. The spacing was 20 cm between lines (rows) and 10 cm between plants. **Figure 1** describes the climatic data during the experimental period.

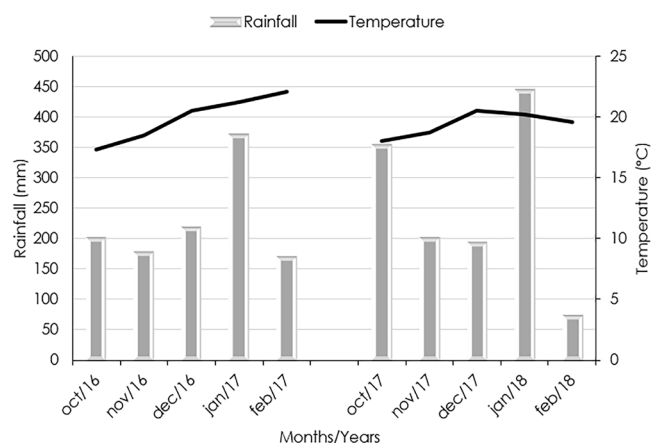


Figure 1. Climatic data during the experiment. (Data obtained by the weather station of the Fazenda Escola Capão da Onça – Ponta Grossa, Paraná, Brazil).

The carrots plants were picked by hand at harvest (February 2016 and 2017) from a 0.3 m² area. Plants were washed, the aerial part was separated from the root, and they were placed into an air circulation stove at 70°C for 72 to determine the dry mass (kg ha⁻¹). After this, samples of the aerial part and roots were picked to determine the macronutrients accumulation: N, P, K, and S (Kg ha⁻¹), as described by Malavolta et al. (1997).

At the end of each interaction period and before weeding, the weeds were sampled from each parcel with a metallic square (50 cm x 50 cm) cast twice to the center of each parcel. The Relative Importance Index (RII%) of the weed community species was determined on every interaction period as described by Mueller-Dombois & Elleberg (1974). The picked weeds were dried into an air circulation stove at 60 °C until dry mass stabilization and weighed in a precision scale (0.001g) to obtain the weeds' total mass of each period, which was extrapolated as kg ha⁻¹.

Results were submitted to analysis of variance. Means were submitted to regression analysis. The mathematical model was chosen considering normality, which is logical in biological phenomena, a high coefficient of determination (R²), and F test significance (p<0.05).

Results and Discussion

In general, both experiments identified ten weeds species distributed among seven Families. The Family Asteraceae pointed out with the highest number of species: *Bidens pilosa*, *Conyza bonariensis* and *Galinsoga ciliata* (**Table 1**).

The specific weeds community specific composition did not modify between the crop years. The species *Braquiaria mutica*, *Euphorbia heterophylla*,

Table 1. Weeds' species identified during the carrot "Alvorada" crop cycle and similarity index of the weeds communities between the crop years

Family	Species	Crop years			
		2016/2017		2017/2018	
		With mulch	Without mulch	With mulch	Without mulch
Asteraceae	<i>Bidens pilosa</i>	X	X	X	X
Asteraceae	<i>Conyza bonariensis</i>	X	X	X	X
Asteraceae	<i>Galinsoga ciliata</i>	X	X	X	X
Brassicaceae	<i>Raphanus raphanistrum</i>	X	X	X	X
Cyperaceae	<i>Cyperus rotundus</i>	X	X	X	X
Euphorbiaceae	<i>Euphorbia heterophylla</i>	X	X	X	X
Oxalidaceae	<i>Oxalis latifolia</i>	X	X	X	X
Plantaginaceae	<i>Plantago tomentosa</i>	X	X	X	X
Poaceae	<i>Braquiaria mutica</i>	X	X	X	X
Poaceae	<i>Eragrotis pilosa</i>	X	X	X	X

X: corresponds to the species presence inside the parcels with and without mulch.

Eragrotis pilosa, and *G. ciliata* were more competitive to the carrot culture, displaying higher RII% values during both assessed periods, in the first and second experiment (Figure 2).

Increasing the interaction period with the weeds' community reduced nitrogen (N) accumulation in the aerial part and roots (Figure 3). However, the carrot plants cultivated with black oat hay mulch displayed higher biomass N accumulation during both crop years.

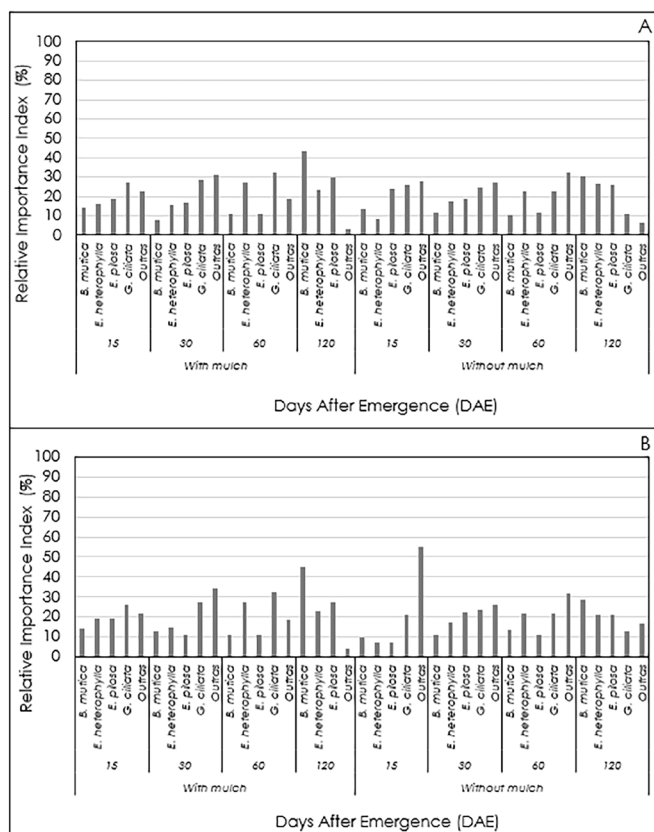


Figure 2. Relative Importance Index (RII%) of the weed community in different coexistence periods with the carrot "Alvorada" with or without black oat hay mulch during the first (A) or second (B) crop year

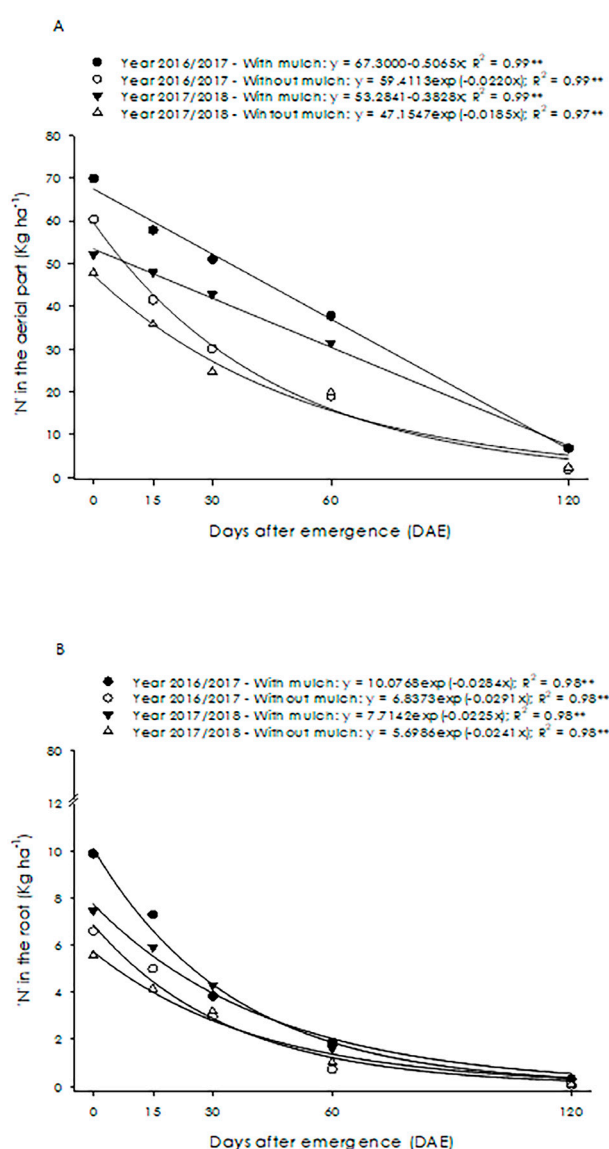


Figure 3. Nitrogen (N) accumulation in the aerial part (A) and roots (B) of carrots plants cultivated with or without mulch during different interaction periods with weeds during two crop harvests. ** Significant at 1% probability by the F test.

Without interaction with the weed community, the carrot plants cultivated with and without mulch in both crop years accumulated mean 87.2% and 89.4% absorbed N in the aerial part, respectively. On the other side, the plants which grew under mulch displayed a mean 12.8% N absorbed in the roots, as long as those without mulch displayed just a 10.6% mean absorption.

The mean N accumulation in the aerial part of plants that coexisted with weeds during all crop highlighted a 34.6% and 30.1% superiority of the plants with mulch for the 2016/2017 and 2017/2018 harvests, respectively, compared to the plants without mulch (Figure 3A). The mean N root accumulation displayed similar results: 34.2% and 31.1% more accumulation in the plants with mulch in 2016/2017 and 2017/2018 crops, respectively (Figure 3B).

Phosphorus (P), Potassium (K), and Sulphur (S) accumulation in the aerial part of carrot plants cropped with or without oat hay mulch displayed a gradual reduction of nutrients absorption as the interaction with the weeds' community increased in both crop harvests (Figures 4, 5, and 6).

The carrot plants which did not coexist with weed and cultivated with mulch displayed 15.9%, 19.2%, and 1.7% higher P, K, and S accumulation in the aerial part (crop years mean value) than those cultivated without mulch. On the other side, the carrot plants which coexisted with weeds displayed a P, K, and S accumulation reduction in their aerial part of 0.29, 1.16, and 0.08 kg ha⁻¹ per interaction day, respectively in the 2016/2017 harvest, and 0.24, 0.91, and 0.07 kg ha⁻¹ per interaction day in the 2017/2018 harvest (Figures 4, 5 e 6).

In general, the competition with weeds for nutrients adsorption was more intense in the plants cultivated without mulch than in those which used mulch. The P, K, and S accumulation in the carrot plants' aerial part declined exponentially extending the weeds' interaction (Figures 4A, 5A, and 6A). The roots' P, K, and S accumulation highlighted similar results (Figures 4B, 5B, and 6B).

The P, K, and S accumulation percentage between the aerial part and roots in carrots plants grown with or without mulch during the two years of analyses did not display significant variations without the interaction with weeds. The accumulation distribution percentage between the aerial part: roots was respectively: 87.7%:12.3% (P), 90.7%:9.3% (K), and 95.0%: 5.0% (S). The assessment factors (mulch and interaction extension) did not modify the nutrients' exigence order of the carrots' plants considering the two years of study, being in the

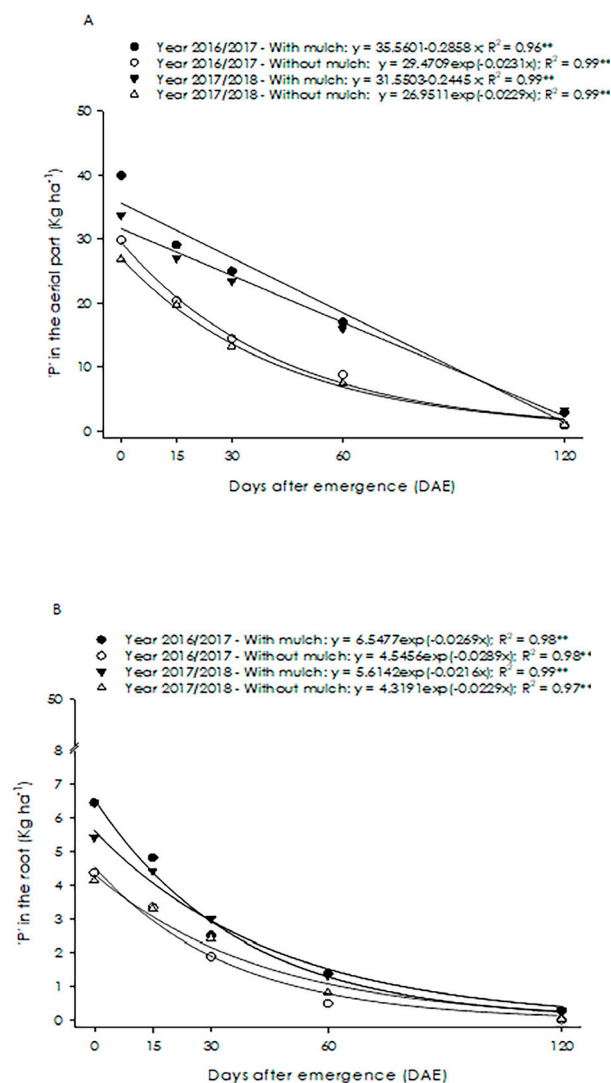
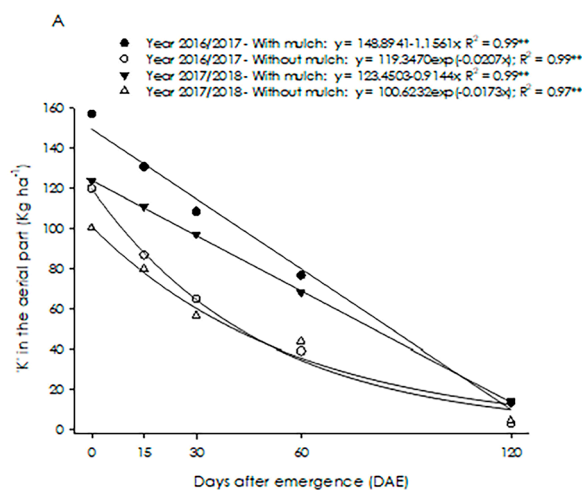


Figure 4. Phosphorus (P) accumulation in the aerial part (A) and roots (B) of carrots plants cultivated with or without mulch during different interaction periods with weeds during two crop harvests. ** Significant at 1% probability by the F test.



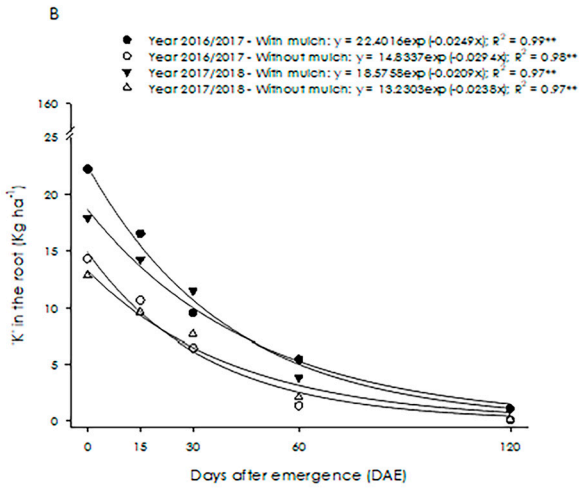


Figure 5. Potassium (K) accumulation in the aerial part (A) and roots (B) of carrots plants cultivated with or without mulch during different interaction periods with weeds during two crop harvests. ** Significant at 1% probability by the F test.

decreasing order K>N>P>S both for the aerial part and roots accumulation. Kaseker et al. (2014) and Assunção et al. (2016) obtained similar results as the nutrients' rate in the carrots' plants. In the lack of interaction with the weed community, the nutrients' rates obtained were optimal for carrots' crops (Gonçalves et al., 2017).

The study results pointed out that the coexistence of carrots with the weeds' community can cause nutrients' deficiency both in the aerial part and roots, inducing a significant nutritional quality loss in the plant. However, the black oat haystack mulch application minimized the detrimental effects of the competition for the absorption of the soil's nutrients and dry mass accumulation in the carrots plants' roots (**Figure 7A and 7B**).

Even if the dry mass accumulation suffered linear losses in the roots of the carrots which interacted with the weeds community in both experiments, the mulch use

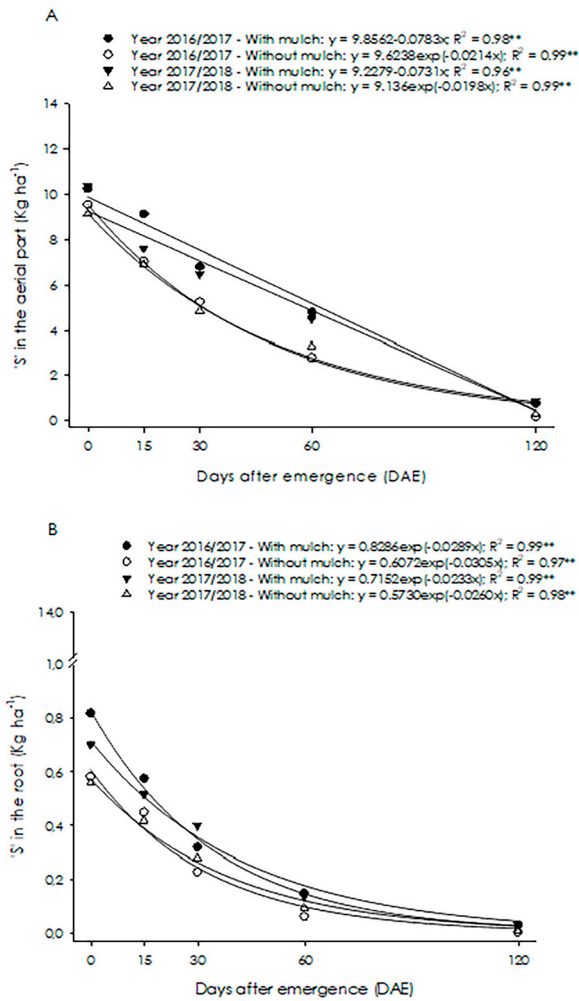


Figure 6. Sulphur (S) accumulation in the aerial part (A) and roots (B) of carrots plants cultivated with or without mulch during different interaction periods with weeds during two crop harvests. ** Significant at 1% probability by the F test.

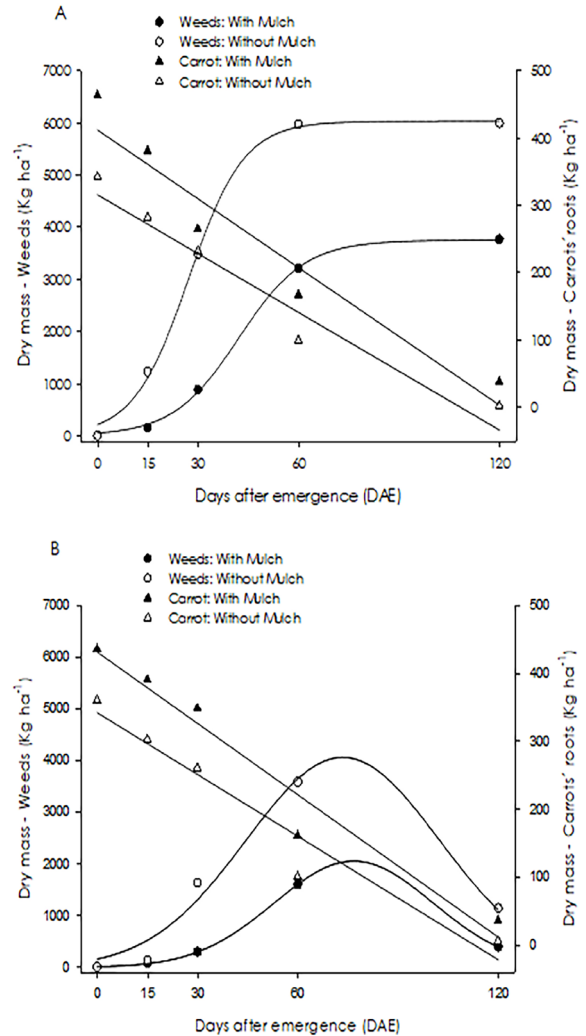


Figure 7. Dry mass of weeds and carrots' roots (kg ha⁻¹) cropped with or without mulch during different periods of interaction with weeds during the 2016/2017 (A) and 2017/2018 (B) crops.

induced higher dry mass accumulation than its absence, pointing out the black oat hay mulch capacity to reduce a mean 63.2% (2016/2017 crop) and 75.6% (2016/2017 crop) the weeds' dry matter during the entire crop cycle (120 DAE).

Table 2 presents the equations for the curves of Figures 7A and 7B.

Table 2. Equations for the weeds and carrots' roots dry mass (kg ha⁻¹) during interactions in seedbeds with or without mulch during the 2016/2017 (A) and 2017/2018 (B) crops.

Dry mass (Kg ha ⁻¹)	Crop	Mulch	Equation	R ²	Figures
Weeds	2016/2017	With	$y = 3746.2966/(1+\exp\{-(x-42.2069)/9.8183\})$	0.99**	6A
		Without	$y = 6022.7890/(1+\exp\{-(x-27.2414)/8.2376\})$	0.99**	
Root - Carrot	2016/2017	With	$y = 411.3026-3.4028x$	0.91**	
		Without	$y = 315.1926-2.9002x$	0.91**	
Weeds	2017/2018	With	$y = 2051.0082\exp\{-0.5((x-76.7325)/23.7319)^2\}$	0.99**	6B
		Without	$y = 4056.7564\exp\{-0.5((x-73.4656)/28.8553)^2\}$	0.97*	
Root - Carrot	2017/2018	With	$y = 430.7950-3.4923x$	0.96**	
		Without	$y = 341.7172-3.0265x$	0.94**	

** and * significant at 1% and 5% error probability.

The mean dry mass accumulation in the carrots' roots was 23.4% and 20.7% higher in the plants cropped with mulch and without weeds' competition in the 2016/2017 and 2017/2018 harvests.

Nutrients' release after the black oat haystack decomposition is considered low compared to legumes species (Aita & Giacomini, 2003; Halde & Entz, 2016). Nonetheless, due to the high C/N rate, the black oat haystack decomposition occurred slowly, gradually releasing the nutrients in the soil and compensating for the losses of the mineral fertilizers applied. Crusciol et al. (2008) observed that the N, P, K, and S accumulation in the black oat haystack was respectively 69.7, 13.7, 89.2, and 6.9 kg ha⁻¹ and that after drying handling, the gradual nutrients release to the soil lasted up to 53 days after hay drying, with rates of 55.7; 13.2; 87.3, and 6.9 kg ha⁻¹ N, P, K, and S, respectively. These results may vary according to the variety and soil handling (Mello et al., 2011).

Haystack decomposition also releases organic compounds (humic and fulvic acids) that improve the soil chemical constitution, promoting pH and toxic compounds (Fe and Al) equilibrium (Pavinato & Rosolem, 2008; Baldotto & Baldotto, 2014). These organic compounds present in the rhizosphere region can access the cellular membranes and induce several physiological responses in plants (Canellas et al., 2012), such as the induction of lateral roots in corn plants treated with the humic acid (50 mg C L⁻¹) (Canellas et al., 2008). The nutrients and organic compounds input, combined with the soil humidity preservation (Resende et al., 2005; Wells et al., 2014), may have promoted the higher nutrients'

absorption and the dry matter accumulation in the roots of carrots cropped with the black oat hay mulch, although the mineral fertilizers applied during the experiment. In areas with natural high soil fertility, there would be the possibility to reduce the use of mineral fertilizers by using the no-tillage system over covering plants' haystacks (Caron et al., 2014).

The nutrients and organic compounds released to the soil are inversely proportional to the haystack decomposition. Therefore, preserving the vegetal cover over the soil should occur until the critical period ends to prevent the weeds' interference. For example, Santos et al. (2011) observed over 300% reduction of the weeds reinfestation for 80 days after the carrots seeding in mulch areas, especially legumes residuals (*Gliricidia sepium* e *Cajanus cajan*). The authors pointed out that this activity increased productivity significantly, improved the commercial aspects, and increased the carrots' roots' nitrogen, potassium, and calcium. In a similar form, the black oat mulch (*Avena strigosa* – 2197 kg ha⁻¹) controlled up to 90% of weeds during about 84 days (Brust & Gerhards, 2012; Schappert et al., 2019).

In general, these periods were more extended than the total weeds control period (42 days after crop emergence) determined by Freitas et al. (2009) for the carrot crop in the conventional system. The present study pointed out that carrots plants did not tolerate the coexistence with the weeds community, independently from the use of the black oat mulch (10 t ha⁻¹), or not. This study pointed out the necessity of weeds control practices during the initial period of carrot development. On the other hand, the mulch efficiency in suppressing the seed bank reduced the operation costs for mechanical or manual weeds control and herbicide use (Reddy et al., 2003; Teasdale et al., 2005).

Therefore, the black oat mulch is an excellent strategy to reduce the emergence of the weeds and, consequently, their harmful interference on the

development of carrots plants in conventional or organic production systems. It is also crucial to point out that mulch can improve the nutritional quality of the carrots' roots.

Conclusion

Black oat mulch promoted a higher nutrients accumulation K>N>P>S, both in the aerial part and roots of the carrots cultivar "Alvorada," and reduced the weeds number, minimizing the effects of the weeds competition on the soil nutrients absorption, dry mass accumulation, and roots' nutritional quality.

Acknowledgements

The authors would like to thank financial support the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) – Financing Code 001, and from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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