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Mycorrhizal fungi increase coffee plants competitiveness against *Bidens pilosa* interference[1]

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ABSTRACT

Mycorrhizae provide several benefits to coffee plants. This study evaluated whether these benefits influence the damage caused by the *Bidens pilosa* competition with coffee seedlings. A randomized blocks design was used, with treatments established in a 2 x 3 factorial scheme (presence and absence of *B. pilosa* interference in non-inoculated control or plants inoculated with either *Claroideoglomus etunicatum* or *Dentiscutata heterogama*). Coffee seedlings were inoculated with fungi spores and developed for 120 days. Then, they were subjected to the interference of *B. pilosa* for more 120 days, when data were collected for growth traits, mycorrhizal colonization, dry matter and foliar nutrient concentrations in coffee plants. Dry matter and nutrient contents in *B. pilosa* plants were also evaluated. Inoculation provided better growth and nutrition of coffee plants. The competition with *B. pilosa* reduced mycorrhizal colonization, height, leaf area, leaf and stem dry mass, root dry weight, number of reproductive branches and levels of P and Fe in the coffee plants. However, the harmful effect of the interference was lower in inoculated coffee plants. The dry mass of *B. pilosa* decreased under the interference of inoculated coffee plants. The inoculation of *C. etunicatum* and *D. heterogama* in Arabica coffee seedlings increases the competitiveness of the crop against *B. pilosa* interference.

KEY-WORDS: *Claroideoglomus etunicatum*; *Coffea arabica* L.; *Dentiscutata heterogama*.

RESUMO

Fungos micorrízicos aumentam a competitividade de cafeeiro frente à interferência de *Bidens pilosa*

As micorrizas proporcionam diversos benefícios às plantas de cafeeiro. Avaliou-se se esses benefícios influenciam nos danos causados pela competição de *Bidens pilosa* com plantas jovens de café. Utilizou-se delineamento em blocos casualizados, com tratamentos estabelecidos pelo fatorial 2 x 3 (presença e ausência da interferência de *B. pilosa* em plantas inoculadas com *Claroideoglomus etunicatum* ou *Dentiscutata heterogama* e não inoculadas). Plântulas de café foram inoculadas com esporos dos fungos e se desenvolveram por 120 dias. Em seguida, foram submetidas à interferência de *B. pilosa* por mais 120 dias, quando foram coletados dados de crescimento, colonização micorrízica, massa seca e teores foliares de nutrientes no cafeeiro. Também foram avaliados a massa seca e os teores de nutrientes em plantas de *B. pilosa*. A inoculação proporcionou melhor crescimento e nutrição das plantas de café. A competição com *B. pilosa* reduziu a colonização micorrízica, altura, área foliar, massa seca de folhas e de caule, massa seca de raízes, número de ramos plagiotrópicos e teores de P e Fe das plantas de café, porém, esse efeito foi menor nas plantas inoculadas. A massa seca de *B. pilosa* diminuiu sob a interferência de plantas de café inoculadas. A inoculação de *C. etunicatum* e *D. heterogama*, em mudas de café arábica, aumenta a capacidade competitiva da cultura frente à interferência de *B. pilosa*.

PALAVRAS-CHAVE: *Claroideoglomus etunicatum*; *Coffea arabica* L.; *Dentiscutata heterogama*.

INTRODUCTION

Like all crops, coffee plants (*Coffea arabica* L.) are affected by the negative effects of weeds. The damage occurs mainly by competition for soil resources, particularly nutrients and water. The interference becomes even more damaging when plants are in the early stages of development, when weeds are more efficient in using resources (Ronchi & Silva 2006).

Weed interference in crops of economic interest is one of the major plant defense problems (Oerke 2006). Among various weed species, blackjack biotypes (*Bidens pilosa* L.), in some cases, are classified as the most important ones in coffee plantations, due to the fast initial growth and efficient use of environmental resources, especially nutrients and water (Ronchi et al. 2007, Santos & Cury 2011).

Herbicides are the main control method for weed management in coffee plantations, in Brazil.

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However, it is much recommended and widespread among producers the integrated weed control, whereby the chemical method is integrated with one or more techniques that favor the development of coffee plants.

Higher growth rates make coffee plants more competitive and less affected by weed interference. By diminishing herbicide application, the integrated weed control aids on the sustainability of the agricultural systems (Harker & O'donovan 2013).

Coffee plants have an intimate relationship with soil microorganisms, especially with arbuscular mycorrhizal fungi (AMF). AMF are responsible for increasing seedling growth (França et al. 2014), better water and nutrient absorption (especially low solubility ones), and tolerance to adverse environmental factors (Smith & Smith 2012). However, in the conventional seedling production, plants are not inoculated with AMF, and natural colonization is slow. Because of that, many researchers have reported evident increases in seedling growth after the artificial inoculation with AMF spores, especially from the Claroideoglomus and Dentiscutata groups (Pagano et al. 2010, Trejo et al. 2011, Ferrazzano & Williamson 2013, Carvalho et al. 2014).

Interactions between AMF inoculations in crops with competition by weeds have already been demonstrated by Veiga et al. (2011). According to these authors, the artificial inoculation of AMF on maize and wheat is beneficial not only because it provides better nutrition to crops, but also because it decreases the biomass accumulation of the weeds *Echinocloa crus-galli*, S*etaria viridis* and *Solanum nigrum*. In addition, some AMF species are parasites of many weeds considered highly aggressive (Rinaudo et al. 2010).

Thus, in a situation of competition between coffee seedlings and *B. pilosa*, the artificial inoculation with AMF can be beneficial, because it can provide better crop development, helping the proper weed management. Therefore, this study aimed at evaluating the growth and nutrient content of young coffee plants inoculated with AMF and submitted to competition with *B. pilosa*.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse, from November 2013 to June 2014. The treatments were established by a 2 x 3 factorial scheme, where the first factor consisted of coffee plants grown with and without the interference of *B. pilosa* and the second of coffee inoculation with *Claroideoglomus etunicatum*, *Dentiscutata heterogama* or a non-inoculated control. A randomized blocks design, with four replications, was used.

Coffee seeds (*Coffea arabica* L.; Catuaí Vermelho IAC 99 cultivar) were selected and germinated in washed sand, where the seedlings developed to the "matchstick" stage. After that, they were transferred to polyethylene bags with 1.6 dm^3 of a non-sterilized Red-Yellow Latosol. The soil was previously sieved (4 mm mesh) and physicochemically characterized (Table 1).

At the time of the transference to the bags, the seedlings of the inoculated treatments received on the roots either 9.1 g of the inoculum *Dentiscutata heterogama* (TH Nicolson & Gerd.) (PNB102A) or 7.14 g of *Claroideoglomus etunicatum* (Becker & Gerdemann) (RJN101A) Walker & Schüssler. This amount was sufficient to provide 100 spores of each fungus per seedling, as determined by the protocol proposed by Gerdemann & Nicholson (1963). In addition to spores, the inoculum consisted of sand, expanded clay and fragmented roots, and they were obtained from the Coleção Internacional de Culturas de Glomeromycota (CICG), in Blumenau, Santa Catarina State, Brazil. Non-inoculated plants did not receive any type of inoculant.

Table 1. Characterization of the dystrophic Red-Yellow Latosol used for the cultivation of coffee seedlings.

pH	P	K	Ca^{2+}	Mg^{2+}	Al^{3+}	H + Al	T	t	OM
(H_2O)	mg dm^{-3}		cmol$_c$ dm^{-3}						dag kg^{-1}
4.9	1.3	8.0	0.1	0.1	0.3	46	4.9	0.6	1.9
P-rem	Zn	Fe	Mn	Cu	B		sand	silt	clay
mg L^{-1}	mg dm^{-3}						%		
7.1	0.2	30.5	0.7	0.1	0.1		38	8	56

OM: organic matter; SB: sum of bases; t: effective cation exchange capacity; T: cation exchange capacity at pH 7.0; m: aluminum saturation; V: base saturation.

At 115 days after the transplant of coffee seedlings, *B. pilosa* seeds were placed separately to germinate in washed sand. After 120 days, coffee seedlings with six pairs of developed leaves were transferred to pots with 20.0 L of the same soil previously described, fertilized with 450 g m^{-3} of P, 500 g m^{-3} of K and 30 g m^{-3} of N. Half of these plants was subjected to the interference of two *B. pilosa* seedlings, 3.0 cm height, at the first true leaf stage. *B. pilosa* plants were placed 10 cm apart from the coffee plant, in opposite cardinal positions. At 30 and 60 days, additional fertilizations with nitrogen were carried out (35 g m^{-3}).

After 60 days of competition, *B. pilosa* plants began the flowering process and were cut close to the ground and discarded. One budding of each plant was maintained for more 60 days, for evaluations.

After 120 days of growth in pots of 20 L, coffee plants height, leaf area and number of reproductive branches were determined (Antunes et al. 2008). Then, the plants were cut close to the ground, separated into leaves and stems and dried for 72 hours, at 65 ºC, for evaluating dry weight. Roots were washed with tap water until the total elimination of soil. Root length and percentage of colonized length were determined (Giovannetti & Mosse 1980), as well as roots dry weight.

The dried leaves of coffee seedlings were ground in a mill (Willey) for estimating the contents of P (Braga & De Fellipo 1974), K, Ca, Mg, Cu, Mn, Fe and Zn (AOAC 1975). In addition, the *B. pilosa* plants were also subjected to the same procedures for determining the dry matter and foliar nutrients contents, in the pre-flowering stage.

Treatments were compared with analysis of variance and the levels of significant factors were compared by the Tukey test, at 5 %. Moreover, for better visualization, growth and inoculated coffee biomass data were compared with those from plants under interference, using the effect of percentage compared to the control.

RESULTS AND DISCUSSION

The analysis of variance ($p < 0.05$) detected the significance of the *B. pilosa* competition, AMF inoculation and the interaction between them for all growth variables and biomass accumulation in coffee plants. The exception occurred for the stem and leave dry mass, in which only the effect of the *B. pilosa* competition was significant. The effect of mycorrhizal colonization was significant for the coffee roots and biomass, as well as for the nutrient contents in *B. pilosa* plants. Finally, there was no interaction among the factors for nutrient content in coffee leaves, but there was a significant inoculation effect for all nutrients and a significant *B. pilosa* competition effect for P and Fe contents.

Height, leaf area, root and leaf dry mass and number of reproductive branches in the coffee plants were negatively affected by the competition with *B. pilosa*, but this effect was dependent on the inoculation with AMF. The stem dry weight was also reduced, however, independently of inoculation (Table 2).

Table 2. Growth parameters and mass accumulation by *Coffea arabica* (Catuaí Vermelho IAC 99 cultivar), according to the inoculation with mycorrhizal fungi and competition with *Bidens pilosa* seedlings, for 120 days.

Coffee plant	*Bidens pilosa*					
	Absent	Present	Absent	Present	Absent	Present
	Height (cm)		Leaf area (m^2)		Root dry mass (g)	
Non-inoculated	37.0 bA[1]	22.9 bB	0.21 bA	0.08 bB	10.8 bA	7.5 bB
Claroideoglomus etunicatum	41.1 aA	31.2 aB	0.28 aA	0.12 aB	12.9 aA	11.4 aB
Dentiscutata heterogama	42.1 aA	31.8 aB	0.25 aA	0.11 aB	13.2 aA	11.5 aB
Average	40.1	28.6	0.25	0.10	12.3	10.1
CV (%)	8.3		7.4		8.6	
	Leaf dry mass (g)		Stem dry mass (g)		Number of plagiotropic branches	
Non-inoculated	16.9 A	9.3 B	8.5	7.3	6.5 bA	4.3 bB
Claroideoglomus etunicatum	18.7 A	9.5 B	9.5	8,2	9.3 aA	5.0 aB
Dentiscutata heterogama	18.3 A	9.4 B	9.4	8.0	8.0 abA	4.3 abB
Average	18.0 A	9.4 B	9.1 A	7.9 B	7.9	4.5
CV (%)	11.2		16.2		20.1	

[1] For each variable, averages followed by the same lowercase letter in the column do not differ by the Tukey test ($p < 0.05$), and averages followed by the same capital letter in the line do not differ by the F test ($p < 0.05$).

Inoculation reduced the harmful effect of the weed for height, leaf area and root dry mass. Coffee plants under the interference of *B. pilosa* and not inoculated were reduced by 38 % for height, 60 % for leaf area and 45 % for root dry mass. These values, when the plants were inoculated, were 24 % for height, 57 % for leaf area and 12 % for root dry weight (Table 2).

The coffee growth reduction was due to the competition with *B. pilosa*, because it has a higher use efficiency of water, light and nutrients. *B. pilosa* is known for its efficient root system, and also as one of the most important weeds in the world (Santos & Cury 2011). Its higher initial growth promotes the decrease in coffee seedlings growth in the field (Ronchi & Silva 2006). However, given the inoculation of coffee seedlings with AMF spores, the crop was more competitive and had minor damages caused by *B. pilosa*. This may be due to the beneficial effect of symbiosis in increasing the growth of the crop root system and thus absorption of water and nutrients (Ferrazzano & Williamson 2013).

The inoculation of the two fungi promoted the highest growth of coffee plants, especially when there was no interference of *B. pilosa*. Inoculated with AMF (independently of the species) and in competition, the coffee plants had an increase in height (12 %), leaf area (24 %) and root dry mass (21 %). When the plants were grown without weed interference, the increases were 38 % for height, 32 % for leaf area and 53 % for root dry mass. The number of plagiotropic branches was affected only by the *C. etunicatum* inoculation, wherein the values increased by 43 % when the coffee plants were grown without competition and 16 % under competition (Table 2).

The *C. etunicatum* inoculum produced more plagiotropic branches, when compared to the *D. heterogama* inoculation (Table 2). It is known that there is a great diversity of the AMF that enhance the growth of coffee plants, but the species are influenced by environmental factors, particularly edaphic ones (Bainard et al. 2011, Trejo et al. 2011). In this study, the advantage provided by *C. etunicatum* was probably due to its absolute establishment, evidenced by the highest percentage of root colonization (Table 3).

The percentage of coffee root length colonized was reduced by the competition with *B. pilosa*, and was different among AMF fungi. Colonization by *D. heterogama* was 2.9 times higher, when compared to non-inoculated plants, and colonization by *C. etunicatum* was 3.8 times higher. Furthermore, in non-inoculated coffee plants, the interference of *B. pilosa* reduced the percentage of root colonization by 36 %. On the other hand, the seedlings inoculated with *D. heterogama* reduced colonization by 20 % with the *B. pilosa* interference, while the inoculation with *C. etunicatum* reduced colonization by 27 % (Table 3).

The highest colonization percentage of coffee plants inoculated with *C. etunicatum* may be related to the colonizing system of this fungus. *C. etunicatum* is known for its root colonization using spores, hyphae or other propagules. On the other hand, species from the Gigasporaceae family, such as *D. heterogama*, only do it via spores (Morton 1990, Smith & Smith 2012).

Coffee plants have mycorrhizal colonization increased by living with two plants. However, this is dependent on fungal colonization (Cardoso et al. 2003), as well as by the interference of other plants, due to lower development of the root system or impaired nutritional balance (Trejo et al. 2011). This fact may be related to the lower percentage of colonization in roots under interference.

The coffee seedling production phase, as well as the first year of cultivation in the field, is extremely important for a sustainable crop establishment, mainly due to its slow initial growth. At this stage, plants are more sensitive to weed interference, and are affected by poorly managed consortia, when other plants can cause shading and reduce the access to nutrients and water (Damatta 2004). For this reason, the AMF inoculation provides a better development of coffee plants, because the association can improve

Table 3. Percentage of root length colonized by mycorrhizal fungi in coffee seedlings (Catuaí Vermelho IAC 99 cultivar) under inoculation and *Bidens pilosa* competition treatments.

Coffee Plant	*Bidens pilosa*		Average
	Absent	Present	
Non-inoculated	12.9 A[1]	8.2 B	10.6 c
Claroideoglomus etunicatum	45.6 A	33.4 B	39.8 a
Dentiscutata heterogama	34.7 A	27.8 B	31.3 b
Average	31.1 A	23.3 B	
CV (%)	6.6		

[1] Averages followed by the same capital letter in the line do not differ by the F test, and averages followed by the same lowercase letter in the column do not differ by the Tukey test ($p < 0.05$).

the soil exploration area, and therefore a greater absorption of water and nutrients. Thus, despite the reduced growth of the coffee plants caused by the competition with *B. pilosa*, the inoculation with AMF reduces the negative effects caused by the interference (Figure 1).

The inoculation of coffee plants with *C. etunicatum* or *D. heterogama* reduced the shoot dry mass of *B. pilosa* by 55 % and the root dry mass by 26 % (Table 4). This is due to the better growth rate of inoculated coffee plants (Table 2). Coexisting plants compete for resources, and this competition is detrimental to both species. Under coexistence, plants with higher growth rate have the ability to suppress the development and outcompete the plants surroundings (Knezevic & Datta 2015).

After the foliar analysis of coffee seedlings, regarding nutrient contents, it was observed that the concentrations of P, K, Ca, Cu, Fe and Zn were higher in inoculated plants, when compared to the non-inoculated ones. Moreover, among such nutrients, only the Zn content was affected by the inoculated fungal species. In the coffee plants leaves, Mg and Mn were not influenced by the competition with *B. pilosa* or by inoculation with AMF (Table 5).

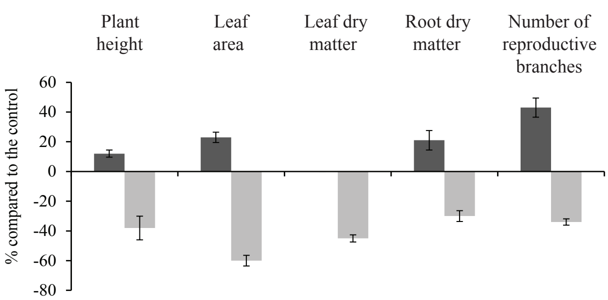

Figure 1. Positive effects caused by inoculating *Dentiscutata heterogama* and *Claroideoglomus etunicatum* (dark grey bars) and negative effects caused by competition with *Bidens pilosa* (light grey bars), in *Coffea arabica* seedlings. * Averages were significantly different at 5 %, by the F test. Standard errors are presented at the end of the bars.

Table 4. Dry mass of *Bidens pilosa* after 120 days of competition with coffee plants inoculated or not with mycorrhizal fungi.

Coffee plant	Dry mass (g plant^{-1})	
	Shoot	Root
Non-inoculated	25.2 a[1]	9.3 a
Claroideoglomus etunicatum	11.0 b	6.6 b
Dentiscutata heterogama	11.8 b	7.3 b
CV (%)	16.2	16.3

[1] Averages followed by the same letter in the column do not differ by the Tukey test ($p < 0.05$).

One of the advantages of the direct association with mycorrhizal fungi is the greater absorption of nutrients, primarily those of low solubility, and when it comes to low fertility areas, such as the soil used in this study (Table 1). In addition, the gain obtained with AMF may be most evident in areas under management with low investment in technology (Trejo et al. 2011), which often leads to low fertility soils.

Regarding the P content in coffee leaves, it was observed that inoculated plants have an average of 2.5 g kg^{-1}, while non-inoculated plants showed 1.5 g kg^{-1}. In other words, the AMF inoculation caused an increase of 67 % in the accumulation of P. In the same way, the plants under *B. pilosa* interference suffered a reduction of 75 % in foliar P content (Table 5).

The mycorrhizal colonization is primarily related to higher P uptake by plants. According to Smith & Smith (2012), the nutrient uptake by inoculated plants can exceed 50 %, when plants are grown in low fertility soil, if compared to the non-inoculated ones. The P accumulation and biomass gain are positive and exponentially related to the root colonization rate by fungi. In this sense, Hoeksema et al. (2010) demonstrated that plants inoculated with AMF can increase their biomass by 3.1 times more than uncolonized plants.

The K content in the leaves was not influenced by the competition with *B. pilosa*. However, AMF inoculation doubled the concentration of this element in coffee leaves. Likewise, Ca and Cu concentrations were elevated by 39 % and 52 %, respectively, with AMF inoculation (Table 5).

Regarding the micronutrient Fe, it was observed that the interference of *B. pilosa* caused an average reduction of 15 % in its concentration only under AMF inoculation. In addition, independently of weed interference, AMF caused an increase of 19 % in the Fe content. It was also observed that the inoculation of *C. etunicatum* promoted an increment of 38 % of Zn on coffee leaves. However, there was no interference of *B. pilosa* on this nutrient (Table 5).

The *B. pilosa* interference on micronutrients accumulation by crops is less important, when compared to the macronutrients assimilation. This is because the critical levels of micronutrients for this weed are low (Santos & Cury 2011). For coffee seedlings, the critical levels of Zn and Fe are respectively 3.68-4.08 mg kg^{-1} and 209-214 mg kg^{-1} (Gontijo et al. 2007). The Zn content provided is above the critical range for coffee plants. On the other hand, the Fe content is below, what may explain the improvements in coffee seedlings nutrition after AMF inoculation.

It was observed in this study that the process of inoculation was effective to raise the K content values from ~10 g kg^{-1} to more than 20 g kg^{-1}, which are greater than the critical value for the production of seedlings in this development stage (Clemente et al. 2008). Moreover, AMF inoculation was beneficial to the accumulation of most nutrients (P, K, Ca, Cu and Zn), what goes toward sustainable coffee production, especially considering the high fertilization cost.

Table 5. Nutrient levels in coffee plants (Catuaí Vermelho IAC 99 cultivar) leaves, according to the inoculation with mycorrhizal fungi and competition with *Bidens pilosa*.

Fungi	*Bidens pilosa*					
	Absent	Present	Average	Absent	Present	Average
	P (g kg^{-1})			K (g kg^{-1})		
Non-inoculated	1.7	1.2	1.5 b	11.2	9.9	10.6 b[1]
Claroideoglomus etunicatum	2.9	2.1	2.5 a	21.5	19.2	20.3 a
Dentiscutata heterogama	2.7	2.1	2.4 a	24.8	18.7	21.7 a
Average	2.4 A	1.8 B		1.2	15.9	
CV (%)	9.9			33.6		
	Ca (g kg^{-1})		Average	Mg (g kg^{-1})		Average
Non-inoculated	1.1	1.2	1.2 b	0.24	0.23	0.24
Dentiscutata heterogama	1.8	1.5	1.7 a	0.21	0.16	0.19
Claroideoglomus etunicatum	1.4	1.7	1.5 a	0.24	0.24	0.25
Average	1.4	1.5		0.23	0.21	
CV (%)	18.2			39.7		
	Cu (mg kg^{-1})		Average	Fe (mg kg^{-1})		Average
Non-inoculated	8.1	6.9	7.5 b	59.4 A	58.8 A	59.1 b
Dentiscutata heterogama	11.3	11.9	11.6 a	74.5 A	64.1 B	69.2 a
Claroideoglomus etunicatum	11.1	11.4	11.3 a	77.4 A	65.2 B	71.3 a
Average	10.2	10.1		70.4 A	62.7 B	
CV (%)	8.1			10.2		
	Mn (mg kg^{-1})		Average	Zn (mg kg^{-1})		Average
Non-inoculated	60.6	59.2	59.9 a	4.8	4.5	4.7 b
Claroideoglomus etunicatum	59.4	66.3	62.8 a	6.6	6.3	6.4 a
Dentiscutata heterogama	60.1	57.9	58.9 a	5.8	5.7	5.8 ab
Average	60.0	61.1		5.7	5.5	
CV (%)	14.9			19.4		

[1] For each variable, averages followed by the same lowercase letter in the column do not differ by the Tukey test ($p < 0.05$), and averages followed the same capital letter in the line do not differ by the F test ($p < 0.05$).

Table 6. Nutrient contents in *Bidens pilosa* leaves after 120 days in competition with coffee seedlings inoculated with mycorrhizal fungi.

Coffee seedling	Nutrient							
	P	K	Ca	Mg	Fe	Cu	Mn	Zn
	g kg^{-1}				mg kg^{-1}			
Non-inoculated	4.0 a[1]	33.5 a	0.91 a	0.21 a	11.4 a	78.2 a	27.3 a	11.5 a
Claroideoglomus etunicatum	3.6 a	30.1 a	1.13 a	0.28 a	11.2 a	80.3 a	28.3 a	14.3 a
Dentiscutata heterogama	3.6 a	27.9 a	1.14 a	0.22 a	11.3 a	87.1 a	27.8 a	15.3 a
CV (%)	16.9	21.8	64.1	57.5	1.6	11.7	37.7	14.3

[1] Averages followed by the same letter in the column do not differ by the Tukey test ($p < 0.05$).

The best growth of coffee plants did not affect the nutrient content in leaves of *B. pilosa* (Table 6). Santos & Cury (2011) emphasize that *B. pilosa* plants have high phenotypic plasticity. Even under adverse growing conditions, *B. pilosa* is efficient in assimilating the environmental resources and complete the cycle. The non-interference of inoculated coffee plants on the foliar nutrient content of *B. pilosa* is an indication of its high competitiveness power.

CONCLUSIONS

1. The inoculation of *Claroideoglomus etunicatum* and *Dentiscutata heterogama* in Arabica coffee seedlings increases the competitive power of the crop against the *Bidens pilosa* interference.
2. The inoculation of *Claroideoglomus etunicatum* and *Heterogama Dentiscutata* increases growth, dry matter accumulation and leaf contents of P, K, Ca, Cu, Fe and Zn, in coffee seedlings.
3. The artificial inoculation in coffee seedlings with mycorrhizal fungi indirectly decreases the dry matter accumulation by *Bidens pilosa*.

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