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Article

Weed Interference in Soybean Crop Affects Soil Microbial Activity and Biomass

Interferência de Plantas Daninhas na Cultura da Soja Afeta a Atividade e Biomassa Microbiana do Solo

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ABSTRACT - Weeds and microorganisms interacting with their rhizosphere may influence nutrient absorption, which is an important factor for plant competition. The purpose of this study was to evaluate the microbiological activity, inorganic phosphorus solubilization (Pi) and acid phosphatase in the cultivated soil, in a combination of soybean (*Glycine max*) plants and weeds. Soybeans were cultivated in monoculture and in competition with *Bidens pilosa*, *Brachiaria decumbens* (Syn. *Urochloa decumbens*) and *Eleusine indica*, under two conditions: a) plants competing without contact between the roots b) plants competing with contact between the roots. A nylon screen with a 50 µm mesh was added to prevent contact between the roots of the species in competition so that the substratum could be separated in the vase. The experiment was conducted in randomized blocks, with four replications. The soybeans in competition with weeds led to lower oxidation of organic matter per unit of microbial biomass, resulting in a lower metabolic quotient, compared with the soybean monoculture. The contact between soybean roots and *B. pilosa*, *B. decumbens* and *E. indica* maintained a strong influence, raising the solubilization of Pi, respectively valued at 51, 39 and 31% in relation to the cultivation of each species with a nylon screen. Microbiological activity, inorganic phosphorus solubilization and acid phosphatase were altered by plant species, combinations of weeds and soybean plants in competition; by root contact in some cases. Thus, the microbiological activity of the soil can influence competition strategies and plant development.

Keywords: *Glycine max*, soil respiratory rate, metabolic quotient, inorganic phosphorus solubilization, phosphatase.

*RESUMO - As plantas daninhas e os microrganismos associados à sua rizosfera podem apresentar interações que influenciam na habilidade de absorção de nutrientes, fator importante em plantas em competição. Dessa forma, avaliou-se neste trabalho a atividade microbiana, o potencial de solubilização de fósforo inorgânico (Pi) e a atividade de fosfatases ácidas em solo cultivado com combinações de soja (**Glycine max**) e plantas daninhas. Para isso, cultivou-se a soja em monocultivo e em competição com **Bidens pilosa**, **Brachiaria decumbens** (Syn. **Urochloa decumbens**) e **Eleusine indica**, em duas condições de competição: a) sem contato entre raízes das espécies; e b) com contato entre raízes das espécies. Para evitar o contato entre raízes das espécies em competição, bem como separar o substrato em um mesmo vaso, utilizou-se uma tela de náilon de 50 µm de abertura. O experimento foi conduzido em blocos casualizados, com quatro repetições. A soja em competição com plantas daninhas reduziu a oxidação da matéria orgânica por unidade de biomassa microbiana, diminuindo o quociente metabólico, em*

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comparação com a soja em monocultivo. O contato entre as raízes da soja e das espécies de plantas daninhas promoveu o aumento da solubilização de Pi em 51%, 39% e 31% para ***B. pilosa****,* ***B. decumbens*** *e* ***E. indica****, respectivamente, em relação ao cultivo de cada espécie com a tela de separação. A atividade microbiana, a solubilização do Pi e a atividade de fosfatases ácidas foram alteradas pelas espécies de plantas e, pelas combinações de plantas daninhas e soja em competição, principalmente, quando houve contato entre raízes. Assim, a atividade microbiológica do solo pode influenciar nas estratégias de competição e desenvolvimento das plantas.*

Palavras-chave: *Glycine max*, taxa respiratória do solo, quociente metabólico, solubilização de fósforo inorgânico, fosfatase.

INTRODUCTION

Competition with weeds for resources in the environment (water, light and nutrients) is frequently reported as a direct cause of reduced crop yield. The magnitude of subsequent crop losses varies according to the competing species, duration of the competition, edaphoclimatic conditions, etc. Competition with weeds during the whole soybean (*Glycine max*) cycle may reduce the yield of this crop by up to 82% (Silva et al., 2008).

It is known that competition between plants depends on several physiological, nutritional and environmental characteristics and it is also related to the interaction of these species with several groups of microorganisms (Santos et al., 2013; Massenssini et al., 2014). According to Fialho et al. (2016), there is a positive interaction for the mycorrhizal colonization of soybeans and weeds, especially when there is contact between the root system of the species. However, further studies of these interactions are necessary to better understand these mechanisms. Thus, microbiological analysis can be used to assess whether changes in the rhizosphere, due to monoculture and competition plant cultivation, influences the dynamics of microorganisms and soil quality.

Soil microbiological activity can be estimated by variables such as rhizosphere soil respiration, microbial biomass, metabolic quotient, inorganic phosphorus solubilization potential and phosphatase activity (Chaer and Tótola, 2007). Some competing species, such as *Leonotis nepetaefolia*, *B. pilosa* and *Amaranthus retroflexus*, are able to associate with certain groups of microorganisms in the rhizosphere, which increase the efficiency in phosphorus solubilization, suggesting that they favor growth and the ability to acquire this nutrient (Santos et al., 2013).

Studies on the interaction between plants and soil microorganisms in the rhizosphere are important for understanding a series of processes such as nutrient cycling, ecosystem functioning and carbon sequestration (Singh et al., 2004). Therefore, the objective of this study was to evaluate the microbial activity, the activity of acid phosphatases and the potential for inorganic phosphorus solubilization by soil microorganisms, cultivated with a soybean monoculture in competition with different weed species with and without contact of their root systems.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse, in rectangular pots with a volume of 4 dm^3. Half of the pots were divided into two compartments using a nylon screen with a 50 µm mesh, preventing contact between the roots of the species in competition. In the other half of the pots, there were plants grew without any kind of division. The experiment consisted of soybean treatments in competition with *Bidens pilosa*, *Brachiaria decumbens* and *Eleusine indica,* soybeans cultivated in monoculture and weeds cultivated alone. All combinations were cultivated with and without the use of a nylon screen. The experiment was carried out in a 4 x 2 factorial scheme (soybeans in coexistence with three competing species and in monoculture, with or without the use of a nylon screen), in a randomized complete block design, with four replications.

After dividing the pots with the nylon screen, they were filled with samples of a Red-Yellow Latosol, a soil with a sandy-clay texture, presenting the following chemical characteristics: pH (water) = 4.7; organic matter = 2.40 dag kg^{-1}; P = 2.3 mg dm^{-3}, K = 48.0 mg dm^{-3}; Ca^{+2}, Mg^{+2}, Al^{+3}, H + Al, SB and effective Cation Exchange Capacity (CEC) = 1.4, 0.4, 0.6, 6.27, 1.92 and 2.52 $cmol_c$ dm^{-3}, respectively; base saturation = 24% and aluminum saturation = 23%. Before filling the pots, the base saturation of this soil was increased to 60%, dolomitic limestone was used at a dose of 0.78 g dm^{-3}. Subsequently, the soil was fertilized with urea (200 g m^{-3} soil), simple superphosphate (300 g m^{-3} soil) and potassium chloride (180 g m^{-3} soil).

'Conquista' soybeans were seeded simultaneously with *Bidens pilosa, Brachiaria decumbens* and *Eleusine indica* seeds, separating the crop in one compartment and weeds in another, in order to separate roots using the nylon screen. For the treatment without the nylon screen, seeds were sown in the single compartment of the pot. After seedling emergence, some were removed, leaving one soybean plant and three of each competing species per pot. Soil moisture was maintained close to field capacity through daily irrigations.

At 60 days after the emergence of the studied species, one sample from each treatment had samples of dry soil collected. Samples were packed in plastic bags, sieved in a 4 mm mesh and placed in a refrigerator.

The C-CO_2 evolved from the soil, or respiratory rate, was obtained by the respirometric method, according to the methodology described by Vivian et al. (2006). After the incubation period, 18 g of soil were collected from each pot to determine the microbial biomass carbon (MBC), following the methodology described by Vance et al. (1987).

From the values obtained of the C-CO_2 evolved from the soil and MBC, the metabolic quotient (qCO_2 - µg C-CO_2 µg^{-1} MBC d^{-1}) was calculated, dividing the daily average of C-CO_2 evolved from the soil by MBC determined in the soil, according to Anderson and Domsch (1993). The activity of acid phosphatase was determined using the method described by Tabatabai and Bremner (1969). The methodology described by Nautiyal (1999) was used to estimate the potential for solubilization of inorganic phosphate in liquid medium. After incubation for 15 days at 27 ^oC, the liquid phase was subjected to centrifugation at 8.000 rpm for 20 minutes. In the supernatant, the amount of inorganic P was determined by the colorimetric method of modified vitamin C, at a wavelength of 725 nm.

Data from C-CO_2 evolved from the soil, MBC, qCO_2, acid phosphatase activity and inorganic phosphate solubilization were submitted to analysis of variance by the F test at 5% probability. The Tukey test ($P \leq 0.05$) was performed when there was a significant interaction.

RESULTS AND DISCUSSION

The competition between soybeans and *B. pilosa*, *B. decumbens* and *E. indica* differently changed the activity of the microbial community associated with the rhizosphere of the species. Between the tested factors (weed x nylon screen), an interaction was observed and opened out. The effect of the contact between roots (without the nylon screen) on the microbial biomass of the soil was observed only for the cultivation of soybeans and *B. pilosa*, with an increase of 30% when there was contact between the roots of the intercropped plants. Rhizospheric soybean soil competing with *B. pilosa* showed higher microbial biomass in relation to the other species, regardless of the use of the nylon screen. It is also important to highlight soybean cultivation with *B. decumbens*, where there was separation of the root system (nylon mesh) (Table 1).

In systems experiencing competition for nutrients, there may be an increase in microbial biomass, which is more evident when there is contact with the roots of the species (Table 1). Concerning nutritional limitation, the plant can release more root exudates to stimulate microbial biomass, influencing the growth of bacteria and fungi that colonize the rhizosphere, which can help plants acquire nutrients (Cocking, 2003). Microbial biomass is responsible for controlling essential functions in the soil, such as the decomposition and accumulation of organic matter and for various transformations involving mineral nutrients and soil compounds (Sardans et al., 2016).

The total amount of C-CO_2 evolved from the soil ranged from 1677.50 to 2266.78 µg of C-CO_2 g^{-1} soil after 60 days of cultivation in the soybean rhizosphere in competition with *E. indica* and soybeans in monoculture (Table 2), which represents a difference of 26% in the oxidation of organic matter between the two cultivation systems.

Table 1 - Microbial biomass carbon (MBC) of soil cultivated with soybeans submitted to competition with *B. pilosa*, *B. decumbens* and *E. indica* for 60 days

Species	Microbial Biomass Carbon (g g^{-1} MBC)	
	Nylon screen	No nylon screen
Soybean + *Bidens pilosa*	167.89 aB	246.05 aA
Soybean + *Eleusina indica*	106.14 bA	153.42 bcA
Soybean + *Brachiaria decumbens*	176.50 aA	196.84 bA
Soybean in monoculture	127.36 bA	141.26 cA
CV (%)	25.08	

Means followed by the same letter, lowercase in the column and uppercase in the row for each variable, do not differ by the Tukey test ($P<0.05$).

Table 2 - Accumulation of CO_2 (C-CO_2) and metabolic quotient (qCO_2) of the soil cultivated with soybean submitted to competition with *B. pilosa*, *B. decumbens* and *E. indica* for 60 days

Species	C-CO_2 (µg g^{-1} soil)	qCO_2 (µg C-CO_2 g MBC^{-1})
Soybean + *Bidens pilosa*	1893.52 ab	9.14 b
Soybean + *Eleusina indica*	1677.50 b	12.92 ab
Soybean + *Brachiaria decumbens*	1965.42 a	10.52 b
Soybean in monoculture	2266.78 a	16.87 a
CV	17.84	22.61

Means followed by the same lowercase letter for each variable do not differ by the Tukey test ($P<0.05$).

By assessing the metabolic quotient (qCO_2), a representative estimate of changes in soil microbiota may be obtained. The metabolic quotient (qCO_2) represents the relationship between the evolution of CO_2 and carbon in the microbial biomass. For soybean treatments in competition with weeds, there was generally less oxidation of organic matter per unit of microbial biomass, resulting in a low metabolic quotient ($<qCO_2$). This suggests that this system is less susceptible to carbon losses. In the soybeans in monoculture, a higher metabolic quotient was observed, suggesting less biomass efficiency in the use of carbon and energy (Table 2). Melo et al. (2014) found a higher metabolic quotient for maize in monoculture in relation to weeds and competition arrangements in different fertility managements, suggesting greater susceptibility of this system to carbon losses.

In the monocultured soybean rhizosphere, there was a higher metabolic quotient in comparison to competing soybean treatments. On the other hand, *E. indica* showed no difference for any of the three microbiological variables when cultivated in monoculture or in competition with soybeans. Carbon efficiency was maintained, regardless of the competition with soybeans (Table 2).

The samples from the soybean rhizospheric soil in competition with weeds showed differences in the solubilization of inorganic phosphorus (Pi), according to the two cultivation conditions (with and without a nylon screen) (Table 3). When the nylon screen was used to separate the roots of the species in competition, there was no difference in the solubilization of Pi in the soybean rhizosphere in monoculture or in competition with weeds. However, when there was contact between the roots (without a nylon screen), there was an increase of 8.92 µg per gram of soil in Pi solubilization in soybean treatments in competition with weeds, in relation to soybeans in monoculture (Table 3). The contact of soybean roots and *B. pilosa*, *B. decumbens* and *E. indica* roots had a strong influence on the increase in Pi solubilization, 51%, 3% and 31%, respectfully, for each competing species, in comparison to the respective cultivation with a nylon screen (Table 3).

The cultivation of soybeans in competition with weeds altered the activity of acid phosphatase (Table 4). Approximately 22% less mineralization was observed for the treatment of soybeans in coexistence with *B. pilosa*, compared to soybeans in monoculture. Even though the cultivation conditions were kept homogeneous, such as soil type, irrigation, fertilization and light intensity,

Table 3 - Inorganic phosphorus solubilization potential ($Ca_3(PO_4)^2$) by the rhizospheric soil microorganisms of soybean plants, after 60 days in competition with *B. pilosa*, *B. decumbens* and *E. indica*

Species	Solubilization of inorganic phosphorus (µg g soil^{-1})	
	Nylon screen	No nylon screen
Soybean + *Bidens pilosa*	12.37 aB	25.63 aA
Soybean + *Eleusina indica*	15.72 aB	26.16 aA
Soybean + *Brachiaria decumbens*	16.39 aB	23.89 aA
Soybean in monoculture	15.55 aA	16.31 bA
CV (%)	9.58	

Means followed by the same letter, lowercase in the column and uppercase in the row for each variable, do not differ by the Tukey test (P<0.05).

Table 4 - Activity of acid phosphatases from the rhizospheric soil of soybean plants after 60 days in competition with *B. pilosa, B. decumbens* and *E. indica*

Species	mg *p*-nitrophenol g^{-1} soil h^{-1}
Soybean + *Bidens pilosa*	173.15 b
Soybean + *Eleusina indica*	208.75 ab
Soybean + *Brachiaria decumbens*	211.22 ab
Soybean in monoculture	221.33 a
CV (%)	12.07

Means followed by the same letter do not differ by the Tukey test (P>0.05).

the changes in the competitive process altered the soil microbiota, depending on the combinations of plants. Thus, the microbiota associated with the crop and weed rhizosphere was also modified, which can assist in understanding the behavior of these species and in some cases, explaining the species competitive skills. In a study with maize conducted by Matos et al. (2019), in plants cultivated in competition with *Bidens pilosa* and *Amaranthus viridis*, it was observed that the intensity of maize growth depends on weed species and on the way that coexisting plants affect the microbial communities of the soil.

Biomass, microbial activity, inorganic phosphorus solubilization and acid phosphatase activity were altered by plant species, competing weed and soybean combinations and, in some cases, by root contact. The soybean treatments in competition with weeds had a lower metabolic quotient compared to soybeans in monoculture. In monoculture, soybeans experienced less oxidation of organic matter per unit of microbial biomass, showing greater energy efficiency. Weeds are more dependent on associations with soil microorganisms than crops to increase their growth (Massenssini et al., 2014). For example, *B. pilosa* has physiological characteristics, photosynthetic rate, transpiration and stomatal conductance similar to the soybean crop (Ferreira et al., 2015) and it is likely that *B. pilosa* competitive ability is related to the greater capacity of this species to handle soil microbiota and access nutrient sources unavailable to the crop. *Bidens pilosa* and other weed plants can alter the structure of the soil microbial community and select microorganisms that establish positive interactions, increasing their ability to survive over time (Cui and He, 2009; Emam et al., 2014).

According to the results, it is expected that the adaptability characteristics of weeds are directly influenced by soil microorganisms and thus, there is a greater capacity for adaptation and plant development in environments that allow association with soil microorganisms. The contact of soybean roots and the species *B. pilosa*, *B. decumbens* and *E. indica* had a strong influence on the increase in microbial activity and Pi solubilization, verifying different strategies for the acquisition of phosphorus.

Based on the results, soil microorganisms are crucial for making phosphorus available to the plants, influencing their competitive ability. Therefore, the microbial activity of the soil must be considered in the weed management in agricultural production systems.

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