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Technical Note

Allelopathic influence of maize crop residues on the development of maize and bean plants

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Abstract

The maize plant (*Zea mays* L.) belongs to the Poaceae family, and it is cultivated in large scale all over Brazil, the third biggest corn producer. The present study was aimed to test in a greenhouse the allelopathic effects of maize crop residues over its own development as well ason bean plants (*Phaseolus vulgaris* L.). The handlings were constituted by 0, 2, 4, 6 and 8 t ha^{-1} of maize crop residues, under coverage, in 3 L plastic vessels, filled with topsoil, on which the maize and bean seeds were planted, in a total of 5 handlings with 4 repetitions to each species. Under the conditions of the tests, the results showed that the maize crop residues did not induce significant statisticalvariation on the development of the maize plant. Meanwhile, the use of 8 t ha^{-1} on the bean plant provided greater shoot growth compared to control. There was no interference on the root growth by the concentrations tested, and a smaller development in the number of leaves was noticed at higher concentrations (4, 6 and 8 t ha^{-1}) compared to control. Based on these results, it is evidenced that maize crop residues can be used as topsoil for the sowing of corn and bean plants.

Keywords: allelopathy; *Zea mays* L.; *Phaseolus vulgaris* L.; greenhouse.

Influência alelopática dos restos culturais de milho no desenvolvimento de plantas de milho e feijão

Resumo

O milho (*Zea mays* L.) é uma planta da família Poaceae, cultivada em grande escala em todo Brasil, sendo este o seu terceiro maior produtor. O presente trabalho teve como objetivo testar em casa de vegetação os efeitos alelopáticos dos restos culturais de milho sobre seu próprio desenvolvimento e sobre o feijão (*Phaseolus vulgaris* L.). Os tratamentos foram constituídos de 0, 2, 4, 6 e 8 t ha^{-1} de restos culturais de milho, em cobertura, em vasos plásticos de 3L, preenchidos com terra vegetal, nos quais as sementes de milho ou feijão foram plantadas, totalizando 5 tratamentos com 4 repetições para cada espécie. Nas condições testadas, os resultados mostraram que os restos culturais do milho não induziram diferença estatística significativa no desenvolvimento do próprio milho. Para o feijão, o uso de 8 t ha^{-1} proporcionou maior crescimento da parte aérea comparado a testemunha. No crescimento da raiz não ocorreu interferência das concentrações testadas. Houve um menor desenvolvimento no número de folhas nas maiores concentrações (4, 6 e 8 t ha^{-1}) quando comparadas a testemunha. Com base nestes resultados, pode-se dizer que os restos culturais de milho pode ser utilizado na agricultura como cobertura vegetal para semeadura de milho e feijão.

Palavras-chave: alelopatia; *Zea mays* L.; *Phaseolus vulgaris* L.; casa de vegetação.

Influencia alelopático de rastrojo de maíz en el desarrollo de las plantas de maíz y frijol

Resumen

El maíz (*Zea mays* L.) es una planta de la familia Poaceae, que se cultiva a gran escala en todo el Brasil, siendo este el tercer mayor productor. El presente estudio tuvo como objetivo probar en un invernadero los efectos alelopáticos de rastrojo de maíz en su propio desarrollo y del frijol (*Phaseolus vulgaris* L.). Los tratamientos consistieron en 0, 2, 4, 6 y 8 t ha^{-1} de

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rastrojo de maíz en cobertura, en contenedores de plástico de 3L, con suelo donde se plantaron las semillas de maíz y frijol, totalizando 5 tratamientos con 4 repeticiones para cada especie. Bajo las condiciones ensayadas, los resultados mostraron que lo residuo del maíz no indujo una diferencia estadísticamente significativa en el desarrollo de la propia maíz. Para los frijoles, el uso de 8 t ha^{-1} proporciona mayor crecimiento de brotes en comparación con el control. En el crecimiento de la raíz no se produjeran interferencias en las concentraciones probadas. Hubo un desarrollo menor en el número de hojas en concentraciones más altas (4, 6 y 8 t ha^{-1}) en comparación con el control. Con base en estos resultados, se puede decir que se pueden utilizar los residuos de los cultivos de maíz en la agricultura como cobertura del suelo para la siembra de maíz y frijol.

Palabras clave: alelopatía; *Zea mays* L.; *Phaseolus vulgaris* L.; invernadero.

Introduction

The beneficial and negative effects of the rotation and succession system has been explained, in part by the allelopathic phenomenon, which refers to the biochemical interactions between the organisms of a same community. The interference among plants, in this case, proceeds by the compounds (allelochemicals) elaborated and liberated on the environment by its living tissues or by the decomposing of dead tissues (RICE, 1984; ALMEIDA, 1991).

There is a very elevated variety of organic compounds identified as allelochemicals (ALMEIDA, 1991; TAIZ and ZEIGER, 2009). The allelochemicals modify the growth standards, changing metabolic and cellular patterns, including modifications on the membrane function, on the nutrients absorption, (RICE, 1984; REIGOSA et al., 1999), also affecting growth, photosynthesis, respiration, protein synthesis and enzymatic activity.

The same substance can affect several physiological functions as well as various substances can affect just one function in the organism (ALMEIDA, 1988; MALHEIROS and PERES, 2001). The productivity decrease caused by invasive plants or by residues of the previous cultivation may, in some cases, be the result of the allelopathy (TAIZ and ZEIGER, 2009).

The allelochemicals activity has been used as an alternative to the use of herbicide, insecticide and nematicide (FERREIRA and AQUILA, 2000). The allelopathy is recognized as an important ecologic mechanism on natural and manipulated ecosystems. It's a phenomenon that influences on the primary and secondary vegetal succession, encompassing all later stages (REIGOSA et al., 1999). When plants are cultivated, the allelopathy can be a determining factor on the success or failure of the crop. Some allelochemicals that can be used as pesticides are substances that appear and are preserved on the plants evolution and represents some advantage against microorganism action, virus, insects, pathogen and herbivores, either by inhibiting their actions, or by stimulating the plant growth or even by offering advantages to the individual amidst the competition with other vegetables (FERREIRA and AQUILA, 2000).

It is common on the agricultural tillage to cultivate the main plantation over the residues of the previous crop due to the direct planting system These soil residues can present influence over the main plantation through the liberation of organic compounds that can perform allelopathy on the plants (SPIASSI et al., 2011). Based on that, the allelopathy has been attracting interest as a result of its application on the agriculture, since productivity decrease caused by invasive plants or by residues of previous crops, in some cases, result from allelopathy (NEPOMUCENO, 2011).

The maize plant (*Zea mays* L.) is among the most important gramineous in Brazil's agricultural production, both for human and animal consumption. It is the product the stands out in production volume of the total production of cereals and oilseeds, since in every 3 kg of harvested grains, more than 1 kg is maize (PINAZZA, 1993). In terms of modernization of the Brazilian agriculture, the use of the direct planting system is an unquestionable reality and the participation of maize cultivation, in rotation and succession planting, in order to assure the direct planting system sustainability, is fundamental (CRUZ et al., 2006). The bean plant is the most important legume for the world population, mainly to Latin America, India and Africa, to whom animal protein is limited due to economic, religious and cultural matters. It's a species originated from the high regions of Central America (FARIA, 2009).

Considering the great amount of maize residues left on the environment, the present study aimed to test in a greenhouse the allelopathic effects of maize (*Zea mays* L.) crop residues on the development of maize and bean (*Phaseolus vulgaris* L.) plants.

Material and Methods

The research was conducted in a greenhouse, on the farming school of FAG (Faculdade Assis Gurgacz), on the city of Cascavel, Parana State, located on latitude 24º 56′ 09″ and longitude 53º 30′ 01′′, with 700 m altitude.

The CD321 maize (*Zea mays* L.) seeds variety was donated by the COODETEC – Central Cooperative of Agricultural Research. Bean cultivar (*Phaseolus vulgaris* L.) (variety colibri IAPAR carioca). The seeds were treated with Orthocide fungicide. On the handlings it was used maize (30F93 Pionner variety) residues collected in field and placed in a greenhouse for 72 hours by the temperature of 35° C for its complete drying. After this period, it was withdrawn and shredded in approximately one centimeter long fragments.

The maize crop residues were incorporated in coverage on 3 L plastic vessels, filled with topsoil, calculating the vessel area circumference in order to add to crop residues on the concentrations of 0, 2, 4, 6 and 8 t ha^{-1}, without soil incorporation, whereas the zero concentration was equivalent to the treatment without residues, as control. Subsequently, the plantation was made. After the germination (approximately 10 days), a thinning was conducted, leaving 5 plants for repetition, conditioned within a greenhouse for 30 days by room temperature, moistening the substratum every 48 hours.

The experimental outline was entirely casualized, with 5 treatments and 4 repetitions with 5 seeds, totaling 20 seeds per treatment for each tested species. Thirty days after the plantation, the maize and bean plants were evaluated in relation with the variables: number of leaves, stem length (cm) and major root length (cm) for the maize plant and main root length for the bean plant, whose roots were scooped and washed.

The statistical analyses were conducted through the JMP statistical program (Statistical Analysis System SAS Institute Inc. EUA, 1989 – 2000 4.0.0. version). The comparison between the treatments average was performed by the application of the Tukey test, at 5% probability level.

Results and Discussion

The maize (*Zea mays* L.) crop residues did not induce significant statistical difference on the development of all variables of the maize plant (shoot and root length and number of leaves), when compared to the treatment without crop residues, 30 days after the plantation (Table 1). In a similar work, testing maize crop residues over the development of the maize plant on laboratory conditions, VIECELLI and FIORESE (2008) found that, on the proportion of 2 t ha^{-1}, the germination of maize varieties DKB 214 and P32R21 are sensitive to maize crop residues, when compared to control. However, the shoot and root development of the tested varieties were increased by the presence of maize crop residues.

Although the 8 t ha^{-1} concentration has not presented difference from the control treatment, it differed from the other concentrations (2, 4 and 6 t ha^{-1}), which stimulated the shoot growth of maize plants developed on this maize crop residues concentration.

Depending on the species used as crop residues or extracts donor, the effect can be presented differently. SONEGO et al. (2012) verified that the maize root and seedlings growth were decreased by the Tanzania grass extracts produced by green dry culms and leaves, whereas the stem growth was lower when it was used the extract produced by green material of the grass in study.

Differently from what stated in this work, SANTOS et al. (2003) verified that the AG1051 maize crop residues caused negative effect over coffee plants growth, when incorporated. Whilst the use of maize crop residues under coverage promoted growth of all studied characteristics, except of the chlorophyll content.

ALMEZORI et al. (1999) noted the effect of phenolic acids from decomposing maize crop residues, which inhibited the wheat (*Triticum aestivum*L.) and maize seedlings shoot growth. The maize root exudates interfered on the soybean (*Glycine max* L. Mer.) seeds germination, but with a low percentage when compared to control, in field these results would be of little relevance (BORTOLINI and FORTES, 2005).

According to DURIGAN and ALMEIDA (1993), when in coverage, the crop residues release slow and continuously sufficient quantities of allelochemicals that interfere negatively over the plants. It is important to remember that the beneficial effects of a plant over another shouldn't be detached

Table 1. Effects of the maize crop residues on the development of maize.

Concentration	Shoot length (cm)	Root length (cm)^{ns}	Number of leaves ^{ns}
0 t ha^{-1}	9.6 ab ± 2.17	35.5 ± 6.79	4.5 ± 0.72
2 t ha^{-1}	8.5 a ± 1.78	37.0 ± 6.50	4.2 ± 0.71
4 t ha^{-1}	8.8 a ± 0.65	34.2 ± 8.12	4.4 ± 0.60
6 t ha^{-1}	8.6 a ± 1.58	32.0 ± 6.42	4.4 ± 0.51
8 t ha^{-1}	10.4 b ± 2.01	32.4 ± 7.56	4.9 ± 0.62

Averages followed by different letters on the columns statistically differ between them, at 5% provability level, by the Tukey test. Values followed by the average indicate the standard deviation. Ns: non-significant.

from the allelopathy concept, since a given chemical compound can have inhibitory or stimulating effect, depending on its concentration on the environment. The allelochemicals can also cause beneficial effects when liberated in small amounts, stimulating the plant growth (GOLDFARB et al., 2009).

FONTANÉTTI ET AL. (2007) verified that on the first year of the organic direct planting system implantation for maize cultivation, the use of legumes such as the jack bean (*Canavali aensiformis* (L.) DC.), sunn hemp (*Crotalaria juncea* L.) and millet (*Pennisetum americanum* (L.) Leeke) as coverage plants provided better results, which suggest that itshould be included on the rotation plan.

NOCE et al. (2008) verified that for the initial maize seedlings development there was a significant growth decrease for plants subjected to signal grass coverage, in relation to sorghum (*Sorghum bicolor* (L.) Moench) and millet coverage, which do not differ between them. Many factors determined the allelochemical toxicity, such as: concentration, flow rate, age and metabolic stage of the plant, environmental conditions. The production varies in quality and quantity with age, cultivation, plant organ and season (SINGH et al., 2003).

Besides, the allelopathic activity is species-specific, which implies that different plant species may be sensitive or tolerant to potential allelochemicals liberated on the environment (ALBUQUERQUE et al., 2009), that is, to respond in different ways, which can be noticed on maize and bean plants subjected to maize crop residues in this experiment. Due to the fact of density dependence of phytotoxic effects, it is assumed that if the donor species is allelopathic, the recipient plant shall have a greater development in an intermediary density, having a reduced size in both low (in result of a higher phytotoxicity) and high (higher competition for resources) density (KRUSE et al., 2000).

In this study it was found that the higher concentration of crop residues (8 t ha^{-1}) presented better average for stem length and number of maize leaves. These data, along with the inhibition absence compared to the control treatment, suggest that maize crop residues can be used on the crop rotation of maize itself.

The handling with vegetation coverage can result in an increase of the subsequent cultivation; ROSA et al. (2011) found that treatments with velvet bean (*Mucuna deeringiana* (Bort.) Merr) and pigeon pea (*Cajanus cajan* L.) resulted in larger length of maize plants. On the other analyzed parameters, the treatments did not differ, showing that it doesn't interfere over the maize cultivation, as an alternative for the integrated handling of species on the practice of summer green fertilization and crop rotation on the direct planting system. The same was found by OLIVEIRA et al. (2012) on the maize varieties (AG9010 YG and CD 308) subjected to the extract of soybean plant remains, where concentrations higher than 5% caused positive effect on the root length, keeping this effect up to 20% concentration, whereas the other variables weren't influenced by the extract.

SPIASSI et al. (2011) testing the effect of plant remains on the initial maize development found that crop residues of *Crambe abyssinica* (*Crambe abyssinica* Hochst. Ex RE Fries) provided reduction on the root and shoot development. Whilst safflower (*Carthamus tinctorius* L.) residues provided positive effect on the shoot development, inhibiting the root growth, and the treatment with canola (*Brassica napus* L.) did not present negative effect on maize cultivation, which indicates that it can be used as vegetation coverage on the soil before the maize sowing, since it stimulated growth with a consequent increase of the shoot dry mass.

When evaluated the effect of maize crop residues over the bean plant development, it is noticed that there was increase on the shoot development under the 6 and 8 t ha^{-1} crop residues concentrations, which significantly differed from the other concentrations, from the treatment without crop residues and between itself. The concentration of 8 t ha^{-1} promoted a better shoot development, followed by the 6 t ha^{-1} concentration, with 16.1 cm and 14.6 cm, respectively. There was no significant influence on the root development under the concentrations tested (Table 2).

With similar results, VANIN et al. (2008) verified that, in greenhouse tests, there was allelopathic effect of the maize crop residues over the bean cultivation, which stimulated the shoot growth and did not interfere on the root system development. The same was found by CARVALHO et al. (2012) on the bean cultivation, where the residues from the consortium between sunn hemp and sorghum had beneficial effect on the initial growth of common bean seedlings, when used as mulch or when applied as aqueous extracts.

The maize crop residues reduced the number of leaves under 4 and 6 t ha^{-1} concentrations, significantly differing from treatments without residues and from the 2 t ha^{-1} concentration. However, the highest concentration (8 t ha^{-1}) remained similar to the control treatment.

ARAUJO et al. (2011) verified that the bean plant presented bigger susceptibility to the *Crotalaria juncea* L. extract when compared to the maize plant, suggesting that the bean plant is more sensitive to vegetation coverage. Indeed, as verified in this study, the bean plant had its stem growth stimulated by the crop residues, while to the maize plant it didn't had influence.

According to FERREIRA and AQUILA (2000) many compounds that are potentially allelochemical vary in concentration, localization and composition, being able to be excreted on the soil or in the air in active form or just leached. The resistance time, persistence and transformation can increase, decrease or cease its allelopathic effect, by the action of microorganisms in the soil. The allelochemical production may vary in quality and quantity from species to species, on metabolite quantity from one place of occurrence (or cultivation cycle) to another, as many of them have syntheses triggered by occasional vicissitudes to which they are exposed.

Apart from the benefits of allelopathy, such as the stimulation of plant growth depending on the species and concentration, the crop residues can be used on the conservationist handling, aiming the grain productivity growth, improving and preserving the natural characteristics of the environment and the production sustainability. Studies have shown that by using crop residues as vegetation coverage, there's a reduction of soil erosion; calcium, magnesium, phosphorus and potassium lost as well as decrease of organic matter lost up to eight times more than the conventional system, and the soil temperature became 5º C lower than a prepared soil and the water availability was also superior when compared to a prepared soil (LEAL et al., 2005).

The crop residues are widely used on agriculture, in order to maintain soil nutrients, since the cultivation of a same plant repeatedly may reduce or even extinguish the soil nutritional properties. According to ALMEIDA (1991), this practice aims the soil conservation, from organic matter, temperature and water retention to erosion prevention.

According to TOKURA and NÓBREGA (2006) the conducting of researches that study the allelopathic potential between cultivated plants allows cost reduction of agricultural production, as well as environmental impact reduction caused by the cluttered and crescent use of agrochemicals. VIDAL (2010) relates that the vegetation coverage also lowers invasive plants infestations, preventing seed

Table 2. Effects of maize crop residues over bean plant development.

Concentration	Shoot length (cm)	Root length (cm)^{ns}	Number of leaves
0 t ha^{-1}	13.4 c ± 2.17	21.4 ± 6.79	7.6 a ± 0.72
2 t ha^{-1}	13.3 c ± 1.78	22.5 ± 6.50	7.3 a ± 0.71
4 t ha^{-1}	13.8 c ± 0.65	20.7 ± 8.12	5.2 b ± 0.60
6 t ha^{-1}	14.6 b ± 1.58	23.2 ± 6.42	5.2 b ± 0.51
8 t ha^{-1}	16.1 a ± 2.01	20.2 ± 7.56	6.1 ab ± 0.62

Averages followed by different letters on the columns statistically differ between them, at 5% probability level, by the Tukey test. Values followed by the average indicate the standard deviation. Ns: non-significant.

germination and weed emergence through all sorts of mechanisms such as: physical barrier, reduction of temperature fluctuation, increase of population of seed predator organisms, release of allelopathic compounds, among others. FARIA (2009) found that the mulch used (sorghum, millet and soybean) reduced the incidence of invasive plants over the evaluated cultures (maize, soy and bean).

Thereby, the use of maize crop residues as vegetation coverage can be an alternative before the sowing of bean and maize itself, since the practice did not interfere negatively on the development of those cultivations.

Conclusions

Under the conditions that the present study was developed, it is concluded that there was no allelopathical effect from the different maize crop residues concentrations over its own development. Whilst, to the bean plant, the increase of maize crop residues concentrations induced shoot development growth.

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