EARLY GROWTH OF COMMON BEAN CROPPED OVER RUZIGRASS RESIDUES[1]

Crescimento Inicial do Feijoeiro Cultivado sobre Resíduos de Braquiária

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ABSTRACT - Ruzigrass (*Brachiaria ruziziensis*, syn. *Urochloa ruziziensis*) is used as a cover crop in tropical regions because it has a high yield potential, is widely adapted and has a vigorous root system. However, it may affect early growth of the next crop due to allelopathy and competition for soil nitrate. A greenhouse experiment was conducted in glass-walled pots with soil to determine the effect of ruzigrass residues on the initial growth and mineral nutrition of common bean (*Phaseolus vulgaris*). Ruzigrass was grown in the pots for 50 days and chemically desiccated. Then, common bean was grown: without ruzigrass residues; with ruzigrass shoots placed on the soil surface; with ruzigrass roots left in the soil; and with ruzigrass shoots and roots left undisturbed. Root growth of common bean was decreased by ruzigrass residues, but shoot biomass was not affected when it was grown in the presence of ruzigrass shoots or roots alone. In pots where ruzigrass residues were undisturbed, common bean biomass yield was decreased. Nitrogen concentration in common bean shoot was not affected by ruzigrass shoot on the soil surface, an evidence that the observed decrease in common bean growth probably was due to allelopathic effects rather than competition for nitrogen.

Keywords: *Phaseolus vulgaris*, *Urochloa ruziziensis*, no-tillage, allelopathy.

*RESUMO - A braquiária ruziziensis (**Brachiaria ruziziensis**, syn. **Urochloa ruziziensis**) é amplamente adaptada às regiões tropicais e tem sido empregada como cobertura do solo, por apresentar sistema radicular vigoroso e alta capacidade de produção de biomassa. No entanto, pode haver prejuízo ao crescimento da cultura subsequente, devido à alelopatia e competição por nitrato do solo. Um experimento foi conduzido em casa de vegetação para determinar o efeito dos resíduos de **Urochloa ruziziensis** sobre o crescimento inicial e a nutrição mineral do feijoeiro (**Phaseolus vulgaris**). A braquiária ruziziensis foi cultivada em vasos por 50 dias e dessecada. Em seguida, o feijoeiro foi cultivado: sem resíduos de braquiária; com resíduos da parte aérea deixados sobre o solo; com as raízes da braquiária no solo; e com resíduos da parte aérea sobre o solo e das raízes no solo. O desenvolvimento das raízes do feijoeiro diminuiu quando cultivado na presença dos resíduos de braquiária, porém a matéria seca da parte aérea não foi prejudicada quando cultivada na presença de resíduos da parte aérea ou das raízes de braquiária isoladamente. No tratamento com a presença da parte aérea e raízes de braquiária, verificou-se diminuição da matéria seca da parte aérea do feijoeiro. O teor de nitrogênio na parte aérea do feijoeiro não foi afetado pelos resíduos da parte aérea da braquiária, evidenciando que a redução no desenvolvimento do feijoeiro ocorreu devido aos efeitos alelopáticos e não por competição por nitrogênio.*

Palavras-chave: *Phaseolus vulgaris*, *Urochloa ruziziensis*, plantio direto, alelopatia.

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INTRODUCTION

Common bean (*Phaseolus vulgaris*) is among the most important species cropped under no-till. Along with other agricultural techniques, the use of grass forages as cover crops in common bean production systems has resulted in yields above the national average (Bernardes et al., 2010). However, depending of the species and on the amount of straw left on the soil surface, brachiarias may impair the growth and development of the next crop due to the release of allelopathic compounds (Gomes Júnior & Christoffoleti, 2008) and/or competition for soil nitrate (Echer et al., 2012; Rosolem et al., 2012). Allelopathy differs from competition for nutrients because it depends on the natural release of inhibitory substances that can interfere with plant growth in a shared environment (Chou, 2006).

Initial common bean growth is decreased by allelopathic compounds from several species, such as millet, sorghum, soybean, pine, velvet bean (Faria et al., 2009), and brachiaria. Growth of several plants, including common bean (root and shoots) is decreased when *Urochloa decumbens* residues are incorporated into the soil (Souza et al., 2006).

A few tropical grasses such as *U. humidicola* and *U. brizanta* can release braquialactona in the rizosphere, which may decrease or even stop nitrification in the soil (Subbarao et al., 2009). However, inhibition of nitrification by *U. brizantha* is limited to the rhizospheric area, and does not interfere with NO_3^- and NH_4^+ concentration in bulk soil (Fernandes et al., 2011). In addition to inhibition of nitrification, cover crops with high C/N ratio such as ruzigrass (*Brachiaria ruziziensis*, syn. *Urochloa ruziziensis*) may affect the initial growth of the next crop due a temporary N immobilization by the soil microbial biomass (Perin et al., 2006; Rosolem et al., 2012).

Therefore, the choice of species to be introduced in the crop rotation may be limited by allelopathy or high competition for soil nitrate. Indeed, common bean yield under no-tillage was decreased (Farinelli et al., 2006), particularly when ruzigrass was introduced in the rotation as a cover crop (Bernardes et al., 2010). Although there is evidence that ruzigrass can interfere with the growth and nutrition of the next species in the system, little is known about its effect on early growth of common bean, and if the effect is due to allelopathy or soil nitrate competition. This is important because if the impairment is caused by an induced N deficiency, it could be overcome by using higher N fertilizer rates. Thus, the objective of this work was to study the effect of ruzigrass residues on initial root and shoot growth and mineral nutrition of common bean (*Phaseolus vulgaris*).

MATERIALS AND METHODS

A greenhouse experiment was carried out in Botucatu, São Paulo, Brazil in glass-walled pots (rhizotrons) with soil. The soil was collected from the topsoil layer (0-20 cm) of a Rhodic Hapludox (Soil Survey Staff, 2006), or dystroferric Red Latosol (Embrapa, 2006), sandy clay loam (636 g kg^{-1} sand, 141 g kg^{-1} silt, and 223 g kg^{-1} clay), and passed through a 4 mm sieve. The soil chemical characteristics before liming (Raij et al., 2001) were as follows: 23.0 g dm^{-3} of organic matter (OM); pH ($CaCl_2$) 3.8; 10.0 mg dm^{-3} of P (resin); 1.1, 0.0, 86.3 and 87.7 $mmol_c$ dm^{-3} of K, Ca, Mg and H+Al, respectively, with base saturation of 2%. Liming was done to increase base saturation to 60%. The soil was fertilized with 100, 150, and 100 mg dm^{-3} of N, P, and K respectively, as urea, superphosphate, and potassium chloride. The rhizotrons were built from 0.26 m diameter, 0.60 high PVC tubes cut longitudinally in the middle, where a glass window was attached. A wooden lid was adapted over the glass window to avoid light from reaching the roots. Pots were filled with 16 dm^{-3} of soil.

Twelve seeds of ruzigrass (*Brachiaria ruziziensis,* syn. *Urochloa ruziziensis*) were planted, and thinned to four plants per rhizotron seven days after seedling emergence. Soil water content was monitored every two days by weighting the rhizotrons, and kept around 80% of the soil water retention capacity. Forty days after emergence, the plants were chemically desiccated with glyphosate and cut close to soil surface six days after herbicide application. The residues on the soil surface were sampled for macronutrient analysis as in Malavolta et al. (1997). The amount of

residues on the soil surface of each rhizotron was adjusted to the equivalent to 9,000 kg ha^{-1}. Shoot residues were chopped into pieces 3 to 5 cm long and accommodated on the soil surface. In pots without ruzigrass residues, the soil surface was covered with gray styrofoam flakes to avoid excessive temperatures and water loss. The treatments were then installed: control (common bean grown in pots with no previous ruzigrass cultivation); ruzigrass shoot (common bean grown in the presence of ruzigrass shoot residues); ruzigrass root (common bean grown in the presence of ruzigrass root residues); and ruzigrass shoot + root (common bean grown in the presence of ruzigrass shoot and root residues). Six pre-germinated seeds of common bean (*Phaseolys vulgaris*, cv. IAC Alvorada) were planted five days after grass cutting and, after thinning, two plants were grown per pot. The rhizotrons were inclined to 15^{o} from the vertical direction, so the root system would grow facing the glass. The experiment was carried out in a completely randomized design with five replications. Each replication was represented by one rhizotron.

Every three days, a transparent plastic film was positioned over the glass of each rhizotron, and new root growth was drawn with pens of different colors for each evaluation. At 18 days after plant emergence, the plants were cut close to the soil surface, oven dried (65 ^{o}C) for three days and weighted. A sample was ground for macronutrient analysis as in Malavolta et al. (1997). A soil sample was taken from each rhizotron and analyzed for pH, and nutrients (Raij et al., 2001). Soil from the rhizotrons was washed in tap water over a 1 mm mesh sieve to separate common bean roots, which were stored in ethanol (30%). Roots were digitalized using an optical scanner (Scanjet 4C/T, HP) with the resolution of 250 dpi and analyzed with "Win Rhizo" version 3.8-b (Regent Instrument Inc., Quebec, Canada). Then, the roots were dried and weighted to determine root biomass yields. The plastic films with root growth annotations were evaluated according to Tennant (1975) taking into consideration root growth in each time interval. Equations were fit to accumulated root growth, and root growth rate was calculated as the first derivative of the accumulated root growth equations. Nutrient uptake efficiency was calculated by dividing the amount of nutrients accumulated in the common bean shoot by the root surface area.

Results were subjected to ANOVA. All statistical analyses were performed using the SAS/STAT software package (SAS, 2000). Means were compared using the protected LSD test.

RESULTS AND DISCUSSION

At harvest, ruzigrass had accumulated the equivalent to 228 kg ha^{-1} of N, 21 kg ha^{-1} of P, 125 kg ha^{-1} of K, 65 kg ha^{-1} of Ca, and 52 kg ha^{-1} of Mg in shoots. Over time, these nutrients, mainly N and K, could be washed back to the soil and impact positively common bean growth, but only K concentration was increased in soil (Table 1). The release of N, P, Ca and Mg from ruzigrass desiccated with herbicide is slow (Crusciol et al., 2009). Moreover, at least part of the N may be lost by NH_3 volatilization (Damin et al., 2008) or

Table 1 - Soil chemical characteristics after common bean cropped over ruzigrass residues

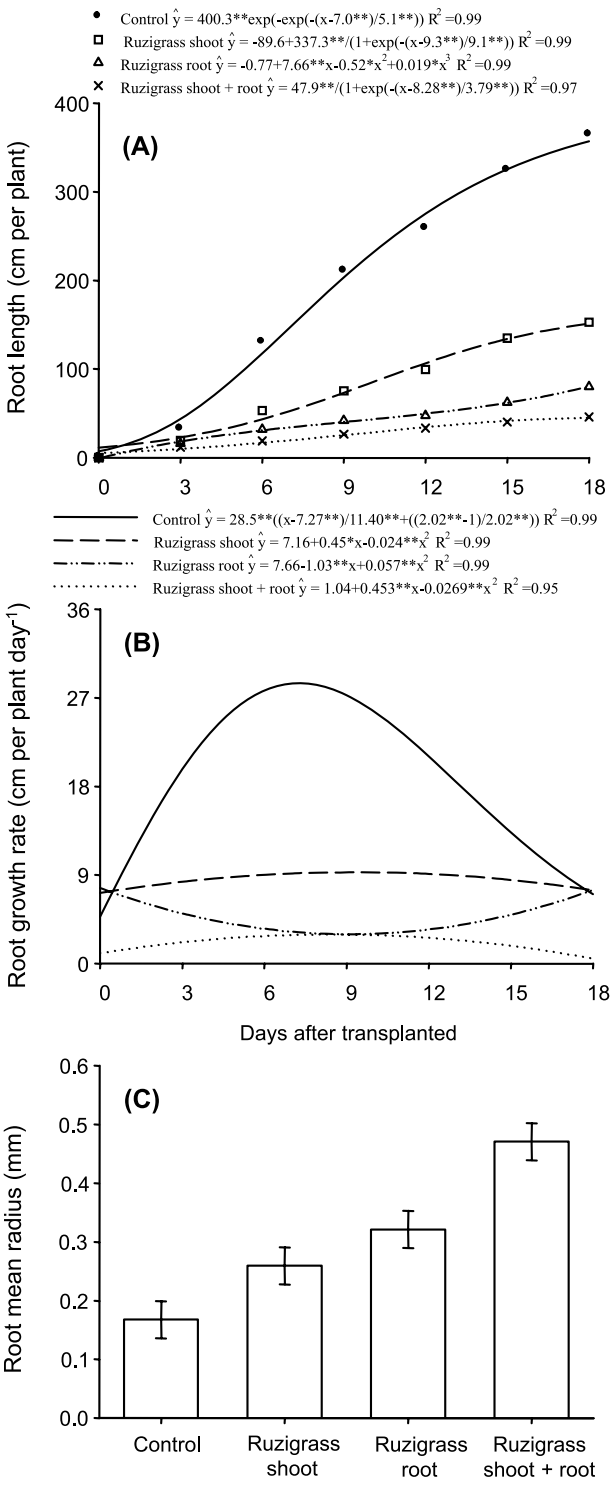
Treatment	pH	O.M.	P[1/]	H+Al	K	Ca	Mg	CEC	V[2/]
	($CaCl_2$)	(g dm^{-3})	(mg dm^{-3})	(mmol$_c$ dm^{-3})					(%)
Control	5.4	11	63	31	1.6	46	13	90	66
Ruzigrass shoot	5.6	18	67	30	3.9	39	13	86	65
Ruzigrass root	5.2	11	54	36	1.5	36	9	88	59
Ruzigrass shoot + root	5.2	12	52	36	3.4	31	12	82	56
LSD	0.14	2.2	10.5	2.4	0.62	3.4	2.2	12	5.4
	ANOVA								
Treatment	**	**	NS	**	**	**	**	NS	**
CV (%)	2.0	12.7	13.3	5.4	17.9	6.7	14.0	10.4	6.6

[1/] Resin; [2/] Soil base saturation. NS and **: not significant and significant at p≤0.01 by the F-test.

immobilized (Rosolem et al., 2012). Conversely, ruzigrass can take up soil non-exchangeable K (Garcia et al., 2008) and easily release it back to the soil (Rosolem et al., 2003). Soil organic matter and pH were higher when ruzigrass shoots were in the soil surface, probably because mineralization was impaired by a given mechanism in this management. In the presence of ruzigrass roots, soil pH was lower, resulting in higher H+Al and low Ca and Mg concentrations, and consequently a low base saturation (Table 1).

Ruzigrass residues decreased common bean root length, from the third day after transplanted (Figure 1A). Roots of bean plants grown in the presence of ruzigrass roots were shorter than in presence of only ruzigrass shoots on the soil surface, showing that the ruzigrass shoot residues have a lower effect on common bean root growth than root residues (Figure 1A and Table 2). High inhibition of common bean root growth rates was observed up to 15 days, and the presence of ruzigrass residues resulted in thicker roots, with a lower surface area (Figure 1B, C and Table 2). This was not expected because it has been shown that soybean roots can grow through biopores left by grain sorghum as the previous crop (Olibone et al., 2006). However, *p*-coumaric acid has been found in two *Urochloa* species (Souza Filho et al., 2005), in addition to the previously identified ferulic acid, 2,4-dihydroxybenzoic, vanillic acid, *p*-hydroxybenzoic acid and *p*-hydroxyphenylacetic (Chou, 2006). Ruzigrass root mineralization immobilizes soil N mainly from the first to the seventh week (Abiven et al., 2005), which corresponds to the initial bean development, and a decreased cotton early growth after ruzigrass was attributed to N deficiency caused by immobilization of soil N (Echer et al., 2012).

In the present experiment, common bean root growth was most affected by ruzigrass only during the first two weeks (Figure 1A, B). If the main inhibitor was N deficiency, the root growth rate should have remained lower for a longer period, because the deficiency was not alleviated. Hence, it can be inferred that competition for N was not the main factor leading to a lower common bean root growth. The occurrence of thicker roots supports this inference, because N deficiency would result



* p ≤0.05 and ** p ≤0.01. Vertical bars in Figure 1C represent the LSD at p ≤0.05.

Figure 1 - Root length (A), root growth rate (B) and root mean radius (C) of common bean cropped over ruzigrass residues by 18 days.

in longer and thinner roots. Nitrogen deficiency increases root length and root surface area in wheat (Shangguan et al., 2004), and decreases root diameter in potato (Sattelmacher et al., 1990). However, common bean growth may also have been indirectly affected by other biological soil properties that may be affected by the presence of cover crops (Silva et al., 2007), which were not evaluated in this study.

Root biomass and shoot biomass of common bean were both decreased when cropped after ruzigrass, and the effect was higher on roots of common bean, as shown by the higher shoot/root surface ratio in the treatments with ruzigrass residues (Table 2). However, shoot biomass was similar in treatments with the presence of ruzigrass shoots or roots alone. It has been shown that brachiaria shoot is the most important source of allelopathic substances (Souza Filho et al., 2005) because plants of this genre have 4 to 5 folds more polyphenols in the leaves than in the roots (Abiven et al., 2005). However, deleterious effects of ruzigrass roots on root growth and biomass yield of common bean were also significant (Figure 1 and Table 2).

The presence of ruzigrass roots in soil decreased nutrient concentrations in common bean, with the exception of P and Fe (Table 3). In rhizotrons where only the ruzigrass shoot was left on the soil surface, the concentrations of N, P and Fe in the shoot of common bean were not affected, while K concentration was increased. However, nutrient concentrations found in common bean shoot are within or very close to the adequate range (Rosolem & Boaretto, 1989), except for S, wich was low in the presence of ruzigrass roots and ruzigrass roots and shoots. In the presence of ruzigrass residues, nutrient uptake efficiency was generally increased (Table 3), but this was not enough to overcome the decrease observed in root length and root surface area (Table 2).

Therefore, the decreased biomass yields observed in the presence of ruzigrass residues cannot be attributed to N deficiency, as it was observed for cotton (Echer et al., 2012). Ruzigrass shoot residues resulted in higher K concentration in the soil and higher K uptake by common bean. It has been demonstrated that K remains in plant tissues as an ion, free to be washed out when the cells die, or even before that, and up to 0.26 kg ha^{-1} t^{-1} of K may be washed by rains per day from plant residues left on the soil surface (Calonego et al., 2005), which would be enough to explain the higher soil and plant K concentrations observed in the present experiment.

Common bean root growth was decreased by ruzigrass residues, but shoot biomass was not affected when it was grown in presence of ruzigrass shoots or roots alone. In pots where ruzigrass residues were undisturbed, common bean biomass yield was decreased. Nitrogen concentration in common bean shoot was not affected by ruzigrass shoots left on the soil surface, which is evidence that the observed growth decrease is probably due to allelopathic effects rather than competition for nitrogen.

Table 2 - Biomass of root, shoot and total plant, root length, root surface area and shoot/root surface area ratio of common bean cropped over ruzigrass residues

Treatment	Root	Shoot	Plant	Root length	Root surface area	Shoot/Root surface ratio
	(mg per plant)			(cm per plant)	(cm^2 per plant)	(mg cm^{-2})
Control	690	1,520	2,210	1,992	392	3.9
Ruzigrass shoot	360	1,210	1,570	1,217	256	4.7
Ruzigrass root	410	1,270	1,680	1,384	275	4.6
Ruzigrass shoot + root	206	920	1,126	861	188	4.9
LSD	48	372	387	266	47	1.65
	ANOVA					
Treatment	**	*	**	**	**	-
CV (%)	8.5	22.6	17.5	14.6	12.6	-

NS, * and **: not significant and significant at $p \leq 0.01$ and $p \leq 0.05$ by the F-test.

Table 3 - Shoot plant nutrient concentration and nutrient uptake efficiency by common bean cropped over ruzigrass residues

Treatment	N	P	K	Ca	Mg	S	Zn	Mn	Fe
	Nutrient concentration								
	($g\ kg^{-1}$)						($mg\ kg^{-1}$)		
Control	32	3.3	36	35	6.6	3.4	52	76	137
Ruzigrass shoot	30	3.3	45	22	4.1	2.3	57	45	67
Ruzigrass root	26	2.8	24	22	3.2	1.4	53	25	54
Ruzigrass shoot + root	22	2.5	32	15	2.8	1.4	53	18	105
LSD	4.6	0.9	4.9	2.8	0.8	0.5	5.0	5.8	75
	ANOVA								
Treatment	**	NS	**	**	**	**	NS	**	NS
CV (%)	12.7	22.1	10.8	8.9	13.4	16.9	6.9	10.6	18.4
Treatment	Nutrient uptake efficiency								
	($mg\ m^{-1}\ day^{-1}$)						($\mu g\ m^{-1}\ day^{-1}$)		
Control	4.4	0.5	5.1	4.9	0.9	0.5	7	10	30
Ruzigrass shoot	7.7	0.9	11.2	5.9	1.1	0.6	5	11	21
Ruzigrass root	10.4	1.5	12.8	11.7	1.7	0.8	28	11	12
Ruzigrass shoot + root	16.7	1.6	20.9	9.4	1.7	0.9	34	3	41
LSD	3.7	0.4	5.6	2.9	0.5	0.2	6	4	29
	ANOVA								
Treatment	**	**	**	**	**	**	**	NS	**
CV (%)	28.6	28.2	23.3	27.9	28.4	23.7	22.4	21.4	20.8

NS and **: not significant and significant at $p \leq 0.01$ by the F-test.

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