Interactive tree and N supply effect on root mass of two annual pasture grasses

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Introduction

A major aim of integrated crop livestock system (ICLS) with trees is to increase the overall land productivity and/or its sustainability by making best use of the environmental resources (water, light and nutrients) used by plant for growth (Jose *et al*. 2008). Consequently, research efforts have been done in order to investigate the complex animal-plant-soils interactions operating upon the biological production of these systems, and their environmental impacts. For instance, since roots return to soil as a stock of C in the soil is in general larger than shoot return, interest in describing plant root system has increased due the current debate over sequestration of C by vegetation. Therefore, an important issue of ICLS is the degree of competition or, conversely, the complementary level that exists between root development and root system activities (Gregory 2006). However, our knowledge about the mechanisms by which biomass allocation (aerial parts of the plant *vs.* root system) is regulated is poor (Poorter *et al*. 2011), mainly when considering simultaneous stresses (*e.g.* light and nutrients). In the present study we report the shoot:root ratio and root mass variation responses to N fertilization levels of two forage grass species growing in field situation under a tree canopy while grazed by beef heifers *versus* an open, treeless ICLS.

Materials and methods

A field experiment was established at the Agronomic Institute of Paraná, Ponta Grossa-PR (25°07’22’’S; 50°03’01’’W). The study was carried out in 8 paddocks (0.99±0.231 ha each) with an ICLS (production system that integrates corn or soybeans crops, during the warm season, and cattle grazing on a cool season pasture, on the same area and in the same cropping year), with or without trees. In 2006, three tree species (eucalyptus, *Eucalyptus dunnii;* pink pepper, *Schinus molle;* silver oak, *Grevillea robusta*) were planted at 3 x 14 m spacing, in 4 paddocks (237 trees/ha) of the 8 paddocks. During the winter (*i.e.* livestock phase), a black oat - ryegrass mixture (*Avena strigosa* + *Lolium multiflorum*) was sown for cattle grazing. The paddocks were managed in order to maintain a target surface sward height of 20 cm by adjusting the number of animals weekly (put and take approach). In August 2012, root cores (15 cm depth, 10 cm diameter) were collected with an auger beneath the vegetation. The core samples were washed through sieves of 1 mm and cleaned to remove soil from roots. The samples were then oven-dried (48h at 60°C) and weighed. Each sample corresponds to two sub-samples (*i.e.* core samples collected in the rows and between crop rows). Root mass, including live and dead roots, was expressed as g DM/m^2. Shoot biomass was measured at the same time and in the same place where root cores were collected. These assessments were made according to Figure 1A, in an unshaded (*i.e.* in a treeless system, see T0 Fig. 1A, with 5 samples per paddock) and in a shaded area (ICLS with trees, with two samples at each distance from trees rows, see T1 until T5, Fig. 1A). Shading percentage was estimated by differences between measures obtained with a ceptometer (Decagon LP-80 AccuPAR), placed at above the grass canopy, in both systems. In addition, the effect of two N fertilization levels (90 and 180 kg/ha, N- and N+, respectively) was also investigated. Therefore, the effect of block (GL=1), two N levels (GL=1) and six shading conditions (*i.e.* from T0 to T5, see Fig. 1A, GL = 5) were evaluated. The experimental design was a split-plot with two replications, and data were statistically analyzed using ANOVA with the Statgraphics (Magnugistics, USA) package. Prior to ANOVA, data were normalized using log transformation.

Results and discussion

The mean percentage of light reduction recorded under the trees compared to unshaded condition was 39 ± 1.45 %. The relative shade intensity decreased with increasing distance from the row, and ranged from 57 ± 3.20 (T1) to 31 ± 3.09% (T3, Fig. 1A). Both shading conditions and N fertilization level significantly affected root dry mass, explaining, respectively, 0.56 and 0.07 of the total variance. However, no significant interaction between these two factors was observed. Root biomass was lower under the higher N fertilization level (N- = 244±23.5, *vs* N+ = 186±16.9 g DM/m²), and under tree canopy (Fig. 1B). Here, root mass doubled in unshaded (+54%) compared to shaded conditions. Therefore, on average, the shading

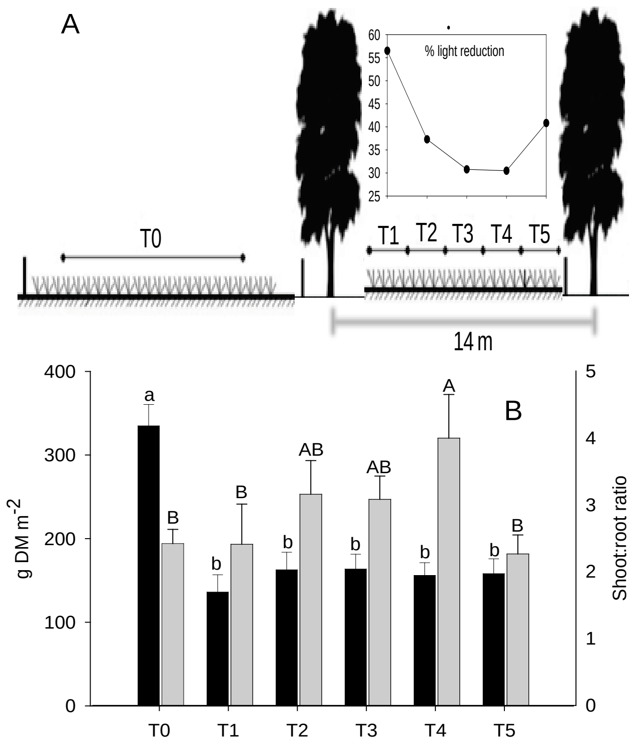

Figure 1. Trial representation showing the sampling locations, and the percentage of light reduction compared to full sunlight (A). The distance between two ranks is 14 m. Mean values of root mass (0 – 15 cm, g/m^2, black bars) and shoot:root ratio (gray bars) of two grass species (*Avena strigosa* + *Lolium multiflorum*) grown in field situation under grazing (B). Vertical bars correspond to standard error and lower (black bars) and upper (gray bars) case letters correspond to significant differences (P < 0.05) between shading conditions (B). T0 = under full sunlight; T1 until T5 = under the tree canopy.

effect on root mass was higher than the N effect. Klump *et al*. (2007) also showed that root mass increases under low N fertilization level when comparing to higher ones.

Although changes in soil resources are a key aspect of adaptive plasticity of root systems, it can be inferred that shade was the main cause for root biomass changes in the soil top 15 cm layer. Plants under shade usually modify their biomass allocation pattern, favoring the production of the aerial parts in detriment to roots, to maximize sunlight exposure under limited radiation condition (Paciullo *et al*. 2010). This statement was confirmed by shoot:root ratio, except for T1 and T5 (Fig. 1B). In these last two conditions, *i.e.* closer to the trees rows, below-ground competition can be more severe (*e.g.* by water), minimizing shading responses (*i.e.* the development of the aerial parts of the plant in detriment to the root system). More detailed studies in understory during all development of tree cycle will help us to achieve a better knowledge about the mechanisms by which allocation is regulated.

Conclusions

Forage root biomass was more sensitive to changes in light environment than N availability. However, a concern is determine if root returns from trees compensate the yearly substantial reduction in root biomass of plants growing under tree canopies, in integrated systems, in regard to carbon inputs to soils, particularly the relatively stable C.

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