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Interference of weeds on seedlings of four neotropical tree species

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ABSTRACT. Seasonal semideciduous forests in southeastern Brazil have experienced intensive fragmentation, and the interference of weeds may affect the dynamics of restored communities. The purpose of this study was to determine if there were specific densities of the weeds *Urochloa decumbens* and *Ipomoea grandifolia* at which the growth of seedlings of four Neotropical tree species – *Senegalia polyphylla* and *Enterolobium contortisiliquum* (Fabaceae) and *Ceiba speciosa* and *Luehea divaricata* (Malvaceae) – would be negatively affected. A randomized experimental design was conducted in a greenhouse, with five treatments to each tree species (different weed densities per pot per tree species) and four replicates per treatment. After the weeds flowered, the height and stem diameter of seedlings were quantified, including the aboveground dry biomass and the percentages of macro and micronutrients contents in the leaves. The growth of the tree seedlings was affected by the lowest weed density (two weeds per pot) when interacting with *U. decumbens* or *I. grandifolia*. In general, significant decreases in the percentage of macro and micronutrients in the leaves were observed, especially at eight weeds/pot. Such results could warrant experimental practices in chemical control in conjunction with alternative methods to control of these two weeds in restored areas.

Keywords: competition, management, seasonal semideciduous forest, restoration.

Interferência de plantas daninhas em mudas de quatro espécies arbóreas neotropicais

RESUMO. As florestas estacionais semideciduais do sudeste do Brasil têm experimentado intensa fragmentação e a interferência de plantas daninhas influencia a dinâmica das comunidades restauradas. O objetivo deste estudo foi testar se o aumento das densidades de plantas daninhas (*Urochloa decumbens* e *Ipomoea grandifolia*) afetava o crescimento de mudas de quatro espécies de árvores neotropicais - *Senegalia polyphylla* e *Enterolobium contortisiliquum* (Fabaceae), *Ceiba speciosa* e *Luehea divaricata* (Malvaceae). O delineamento experimental foi inteiramente casualizado: cinco tratamentos por espécie (diferentes densidades de plantas daninhas por vaso, por espécie de árvore) e quatro repetições por tratamento. Após o florescimento das plantas daninhas, quantificaram-se a altura, o diâmetro do caule, a biomassa aérea seca e as porcentagens de conteúdo de macro e micronutrientes nas folhas das espécies arbóreas. Verificou-se que a menor densidade de *U. decumbens* e de *I. grandifolia* afetou de negativamente, o crescimento das mudas das espécies nativas. No geral, observou-se diminuição do conteúdo de macro e micronutrientes nas folhas das mudas das quatro espécies arbóreas, principalmente na densidade de oito plantas daninhas/vaso. Os resultados obtidos podem embasar práticas experimentais sobre o controle químico em conjunto com métodos alternativos no controle de *I. grandifolia* e *U. decumbens* em áreas de restauração ecológica.

Palavras-chave: competição, manejo, floresta estacional semidecidual, restauração.

Introduction

Due to the high level of human interaction and the fragmentation of the seasonal semideciduous forests in southeastern Brazil, there has been a significant change in plant diversity (FREITAS et al., 2010; MARTINI et al., 2008; METZGER 2000) and forest structure, which disrupts the functioning of the forest and the complex biological interactions (FAVERI et al., 2008). The fragmentation of these forests also generates restrictions on gene flow and species migration (DALE et al., 1994; FARIA et al., 2009).

Although attempts are currently being made to restore these forests, the restoration of functional diversity is particularly challenging. The presence of weeds in the system further affects the dynamics of the forest and makes the process of restoration more difficult (RIBEIRO et al., 2010; VELDMAN et al., 2009). In fact, high densities of invasive species could affect the dynamics of restored communities at some level (DOUST et al., 2008; DUNCAN, 2006; HOLL et al., 2000; VELDMAN et al., 2009). It is therefore important to implement effective weed control methods while simultaneously protecting the native species.

Because theoretical models for ecological restoration are aimed at self-sustainability in the long-term (GUARIGUATA; OSTERTAG, 2001), we propose the theory of "successional management" (PICKETT et al., 1987) as a conceptual basis for developing field practices to increase the efficiency of weed control. Successional management takes into account the ecological processes that drive secondary succession (variables implied in the disturbances, competition, species composition before the disturbance and their ecological performances) to have successful weed control in areas of restoration in the long-term (KRUEGER-MANGOLD et al., 2006). The goal of successional management is to understand competitive interactions by relating the individual performances between pairs of species to their life histories based on the hypothesis that evolution has selected for different strategies of growth and survivorship, which are expressed in species-specific combinations of characteristics related to competition, stress tolerance, and disturbance (GRIME, 1979). In practical terms, experimentation investigating successional management could generate efficient alternatives for weed control in restored areas.

In this sense, the effect of density of two weed species - the invasive grass, *Urochloa decumbens* Stapf (Poaceae) and the invasive vine, *Ipomoea grandifolia* (Dammer) O'Donnel (Convolvulaceae) - was tested on four native tree species: two leguminous tree species, *Senegalia polyphylla* (DC.) Britton Rose and *Enterolobium contortisiliquum* (Vell.) Morong., and two Malvaceae tree species, *Ceiba speciosa* (A. St.-Hil.) Ravenna and *Luehea divaricata* Mart. These four native species are widely distributed throughout the tropical forests of South America and have been used broadly in the initial recovery phase of restored areas in southeastern Brazil (RODRIGUES et al., 2009).

I. grandifolia has been researched extensively in Brazil, in an attempt to find ways to reduce its adverse affects in both agricultural (MONQUERO et al., 2009; RAMIRES et al., 2010) and forestry plantations (CARBONARI et al., 2010). *U. decumbens* negatively affected both the growth of annual (CHIOVATO et al., 2007; DIAS et al., 2004) and perennial agricultural crops (BIFFE et al., 2010) and the growth in forestry plantations (CHEUNG et al., 2009; HOLANDA et al., 2010; LEAL et al., 2009; SOUZA et al., 2010b).

The following question was answered: "Was there a specific density of *U. decumbens* and *I. grandifolia* at which the biomass and macro and micronutrient accumulation of the four native tree seedlings were negatively affected?" It was hypothesized that both weed species would have better competitive performances than the woody species (GRIME, 1979); additionally, as the weed abundance increases, there would be a greater interference on the growth and nutrient accumulation of the native seedlings.

Material and methods

The experiment was conducted in Araras, São Paulo State - southeastern Brazil. The mean annual temperature is 21.4°C, and the mean annual rainfall is approximately 1,428.1 mm. The summers are hot and rainy (September – March), and the winters are dry (April – August). The dystrophic red latosol ("oxisols") soil type predominates in this area.

A randomized experimental design was conducted in a greenhouse. Five treatments were applied to each of the four tree species, consisting of different densities of *I. grandifolia* or *U. decumbens* seeds interacting with one tree seedling - zero (control), two, four, six, and eight weeds per pot. Each treatment for each tree species had four replicates. Once the seedlings reached a height of 10 cm (*C. speciosa* and *E. contortisiliquum*) and 15 cm (*S. polyphylla* and *L. divaricata*), they were transplanted from polypropylene tubes to 20 L plastic bags containing soil that was collected from a topsoil stratum on a dystrophic red latosol clay textural class (Table 1).

Seeds of *U. decumbens* and *I. grandifolia* were sowed into the pots 20 days after the transplantation of the seedlings. To maintain the experimental weed densities for each treatment type, thinning was applied through manual method. The period of interaction between the native seedlings and the weeds was determined from the time of weed emergence to weed flowering. This interval lasted 110 days for *U. decumbens* and 100 days for *I. grandifolia*. Thereafter, measurements of stem diameter and height of the native plants were taken. The aerial portion of each native seedling was harvested and dried in an oven (60°C) to a constant weight; they were then weighed to determine the aboveground dry biomass. The leaves of each seedling were triturated in a Wiley type mill, and each sample was homogenized to quantify the percentages of macro and micronutrients in the leaves - phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe), in accordance with the protocols of Bremner (1965), Wolf (1974), Braga and Defelipo (1974) and Blanchar et al. (1965).

Table 1. Chemical-physical characteristics of the soil used in the interference experiment (SB: sum of bases; CEC: cation exchange capacity; PBS: percent base saturation).

Sample	pH $CaCl_2$	OM	P	K	Ca	Mg	H + Al	SB	CEC	PBS	Clay	Silt	Sand
		g dm^{-3}	mg dm^{-3}			mmol$_c$ dm^{-3}				%		g kg^{-1}	
0-20	5.3	22	12	2.3	28	11	0	40.9	68.9	63	510	170	320

Linear regression analyses were performed to verify the effects of the weeds on the aboveground growth of the tree species. Polynomial curve fitting to compare macro and micronutrients in the different weed densities was performed. The data analyses were performed using Sigmaplot 11 (Systat Software Inc.).

Results and discussion

The height, the aboveground biomass and stem diameter of the four native seedlings were negatively affected by the densities of both weed species, starting at the lowest weed density treatment of two weeds per pot (Figures 1 and 2), confirming our prediction. A previous experiment has shown that annual weeds (*Bromus rubens*, *Schismus* spp. and *Erodium cicutarium*) could affect the density and biomass of some native annual species in a negative way (BROOKS et al., 2000). Similar patterns were verified in forestry plantations when weeds coexisted with native species, including *U. decumbens*, *Eucalyptus* spp. (ADAMS et al., 2003; PEREIRA et al., 2012; SOUZA et al., 2010a), *Pinus patula* (LIPHADZI et al., 2006), and *P. radiata* (KIRONGO et al., 2002) or *Carya illinoinensis* (SMITH et al., 2005).

Changes in the percentages of macro and micronutrient content in the leaves of the seedlings varied among the native species and the treatments; in general, the nutrient content decreased significantly with increasing densities of both weed species (Figures 3 to 6). The interactions with *S. polyphylla* and both weed species promoted a significantly negative effect in all macronutrient content, with the exception of Ca and Mg. When interacting with *I. grandifolia*, the native species decreased their leaf macronutrient content when the highest weed density treatment was applied: 8 weeds/pot (Figure 3). When *S. polyphylla* coexisted with the two weed species, the micronutrient leaf content percentages of B and Mn did not differ significantly between the treatments (Figure 5).

There were no differences in the level of P at any density for the interaction of the *E. contortisiliquum* seedling with *I. grandifolia* or *U. decumbens*, but the leaves revealed a decrease in content of all of the macronutrients (Figure 3). There was a significant effect of the *I. grandifolia* density on the content of all of the micronutrients in the leaves, with the exception of Cu. However, we observed a significant decrease in the levels of Cu and Fe when *U. decumbens* interacted with the *E. contortisiliquum* seedlings (Figure 5).

The coexistence of *C. speciosa* seedlings with *I. grandifolia* did not show any significant differences in content of P and Mg in the leaves, even when considering all weed densities. There were significant reductions in the content of Ca, K, N, Mg and S in the leaves with increasing densities of *U. decumbens* (Figure 4). The content of all leaf micronutrients decreased with the interaction with *I. grandifolia* and *U. decumbens*, with the exception of Cu (Figure 6). Fernandes et al. (2000) has shown that the growth of *C. speciosa* is not affected by varying the concentration of P. Conversely, Sorreano et al. (2011) found that decreasing the concentration of Ca has a negative effect on the height and stem diameter of *C. speciosa,* and the omission of N has a negative effect on the production of leaves. Both P and N accumulate more consistently in broadleaf weeds (PEDRINHO-JUNIOR et al., 2004); however, Duarte et al. (2008) found that concentrations of macronutrients in *Ipomoea nil* were organized as follows: K > N > Ca > Mg > P > S. From these results, we predict that *I. grandifolia* will eventually follow a similar pattern.

The interaction of *L. divaricata* seedlings with *I. grandifolia* reveals that the content of all leaf macronutrients significantly decreased (Figure 4). The leaf P or S content when *L. divaricata* was interacting with *U. decumbens* did not change in any treatment; however, the levels of Ca, K, and N reduced significantly. Increasing densities of both weed species promoted significant decreases in content of all the micronutrients in the leaves (Figure 6).

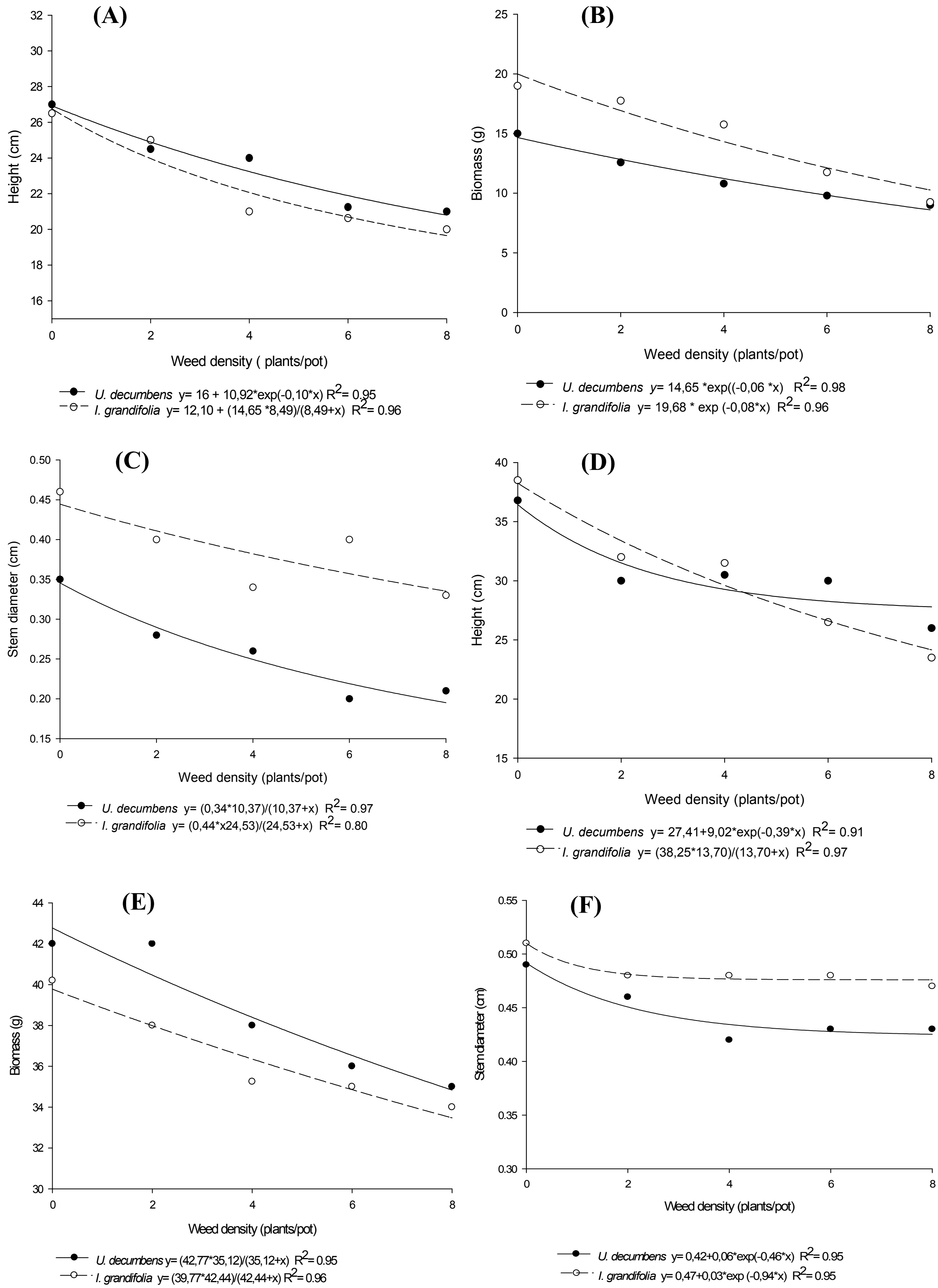


Figure 1. Interference of different densities of U. decumbens (110 days) and I. grandifolia (100 days) on the height, aboveground biomass and stem diameter of L. divaricata (A-C) and C. speciosa (D-E).

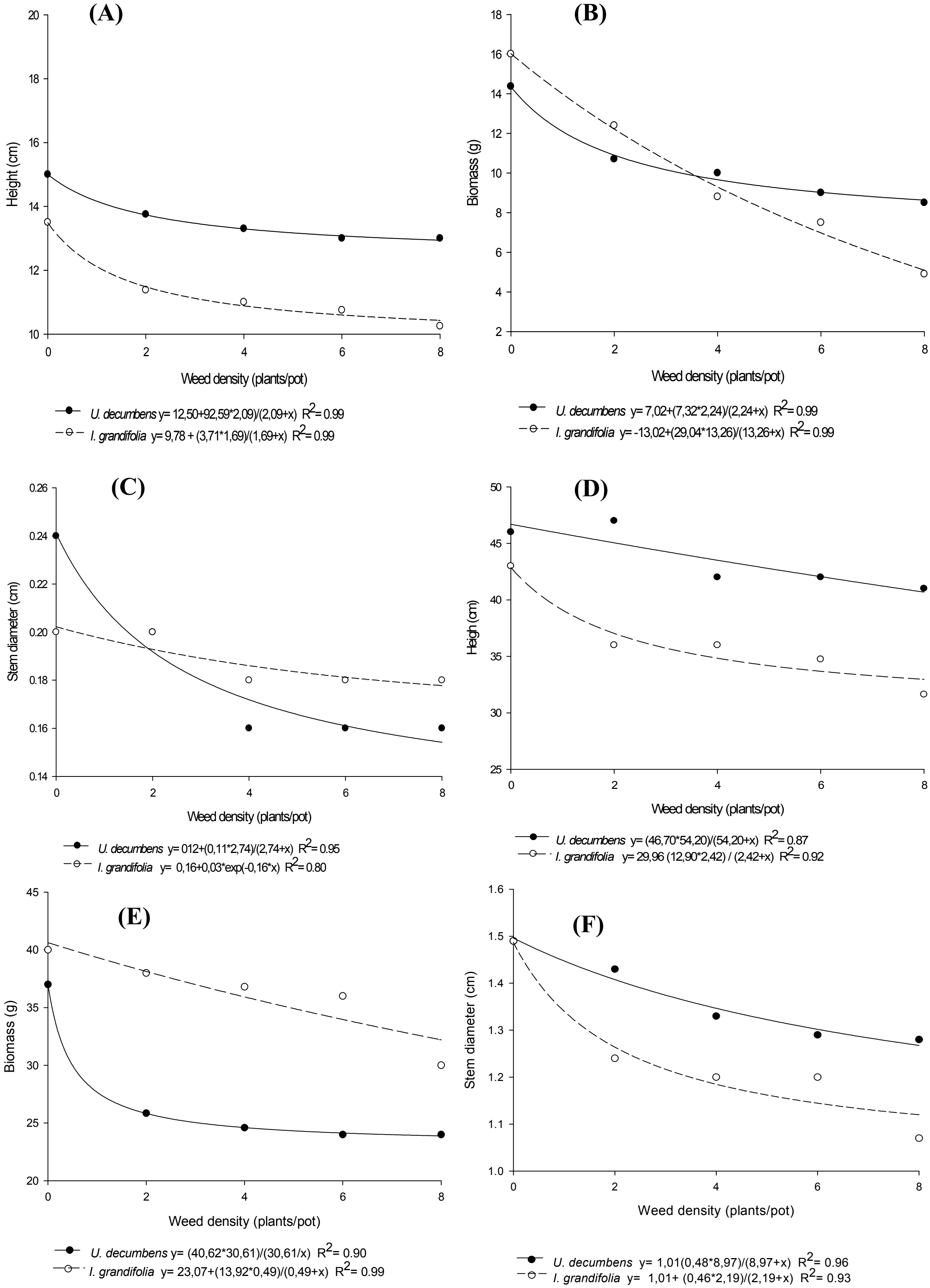
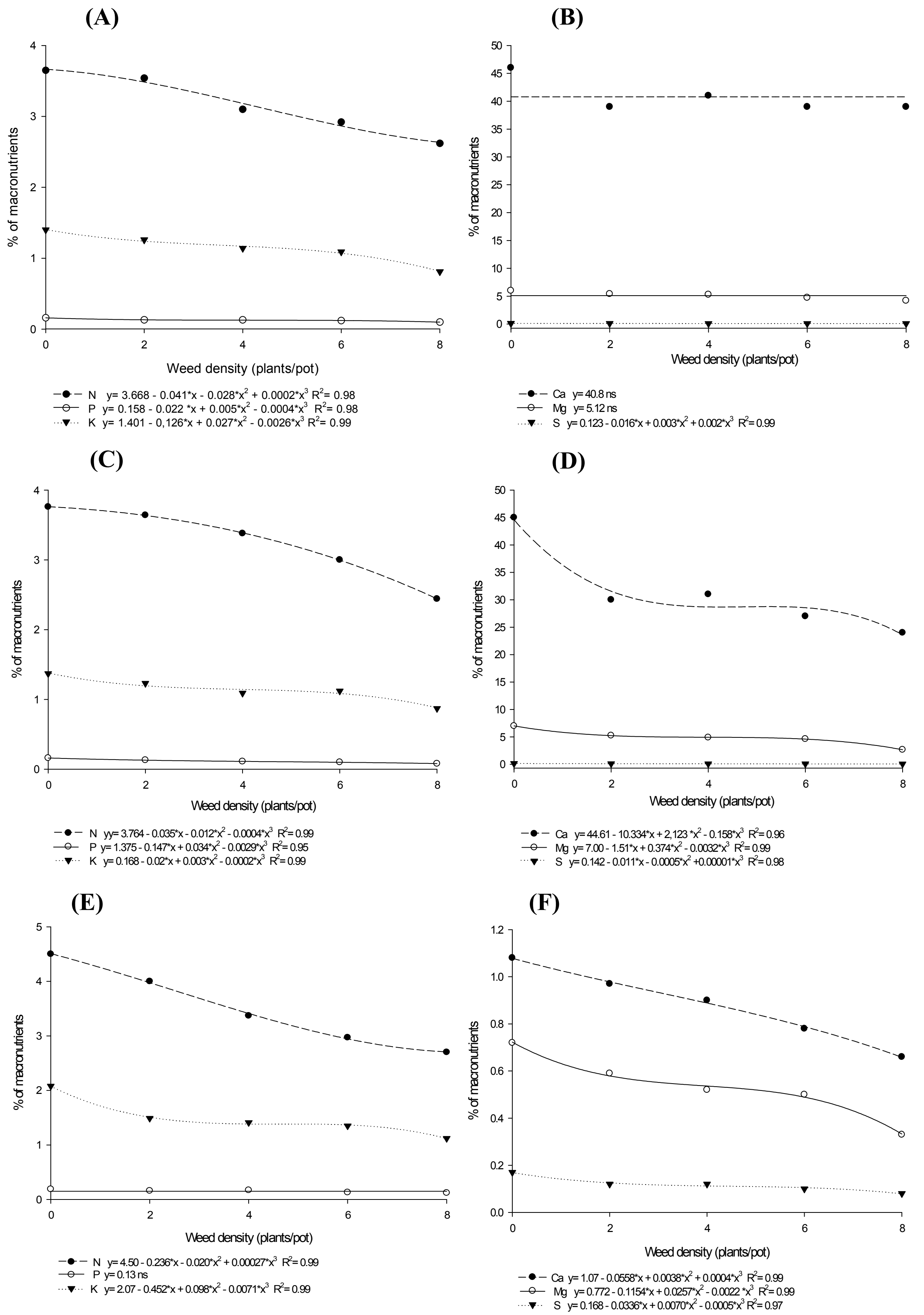


Figure 2. Interference of different densities of *U. decumbens* (110 days) and *I. grandifolia* (100 days) on the height, aboveground biomass and stem diameter of *S. polyphylla* (A-C) and *E. contortisiliquum* (D-F).


(A)
% of macronutrients
Weed density (plants/pot)
N $y= 3.668 - 0.041*x - 0.028*x^2 + 0.0002*x^3$ R^2= 0.98
P $y= 0.158 - 0.022 *x + 0.005*x^2 - 0.0004*x^3$ R^2= 0.98
K $y= 1.401 - 0,126*x + 0.027*x^2 - 0.0026*x^3$ R^2= 0.99
(B)
% of macronutrients
Weed density (plants/pot)
Ca y= 40.8 ns
Mg y= 5.12 ns
S $y= 0.123 - 0.016*x + 0.003*x^2 + 0.002*x^3$ R^2= 0.99
(C)
% of macronutrients
Weed density (plants/pot)
N $yy= 3.764 - 0.035*x - 0.012*x^2 - 0.0004*x^3$ R^2= 0.99
P $y= 1.375 - 0.147*x + 0.034*x^2 - 0.0029*x^3$ R^2= 0.95
K $y= 0.168 - 0.02*x + 0.003*x^2 - 0.0002*x^3$ R^2= 0.99
(D)
% of macronutrients
Weed density (plants/pot)
Ca $y= 44.61 - 10.334*x + 2,123 *x^2 - 0.158*x^3$ R^2= 0.96
Mg $y= 7.00 - 1.51*x + 0.374*x^2 - 0.0032*x^3$ R^2= 0.99
S $y= 0.142 - 0.011*x - 0.0005*x^2 +0.00001*x^3$ R^2= 0.98
(E)
% of macronutrients
Weed density (plants/pot)
N $y= 4.50 - 0.236*x - 0.020*x^2 + 0.00027*x^3$ R^2= 0.99
P y= 0.13 ns
K $y= 2.07 - 0.452*x + 0.098*x^2 - 0.0071*x^3$ R^2= 0.99
(F)
% of macronutrients
Weed density (plants/pot)
Ca $y= 1.07 - 0.0558*x + 0.0038*x^2 + 0.0004*x^3$ R^2= 0.99
Mg $y= 0.772 - 0.1154*x + 0.0257*x^2 - 0.0022 *x^3$ R^2= 0.99
S $y= 0.168 - 0.0336*x + 0.0070*x^2 - 0.0005*x^3$ R^2= 0.97

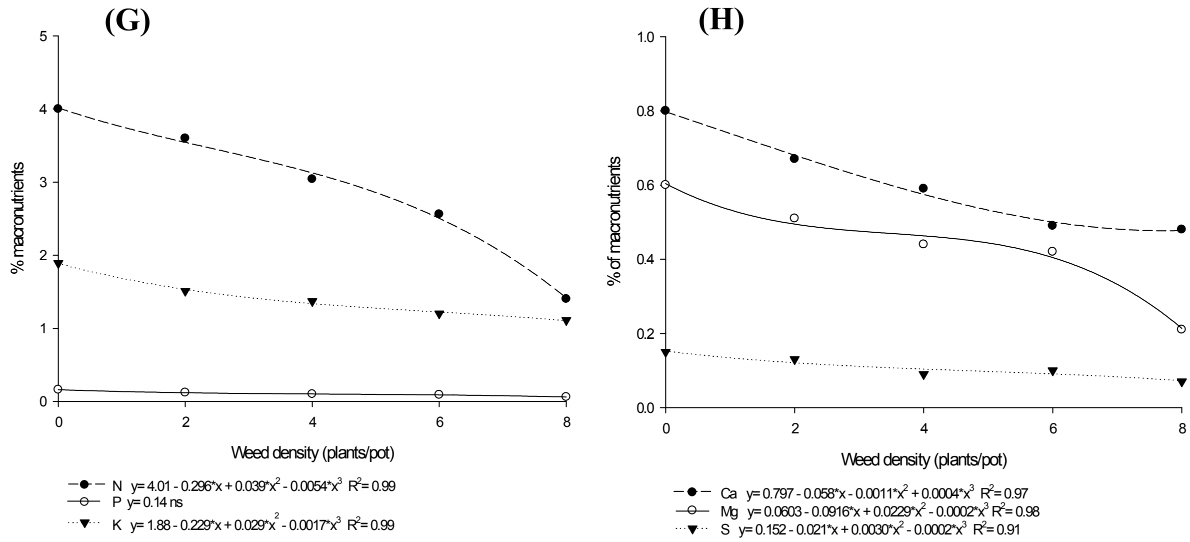
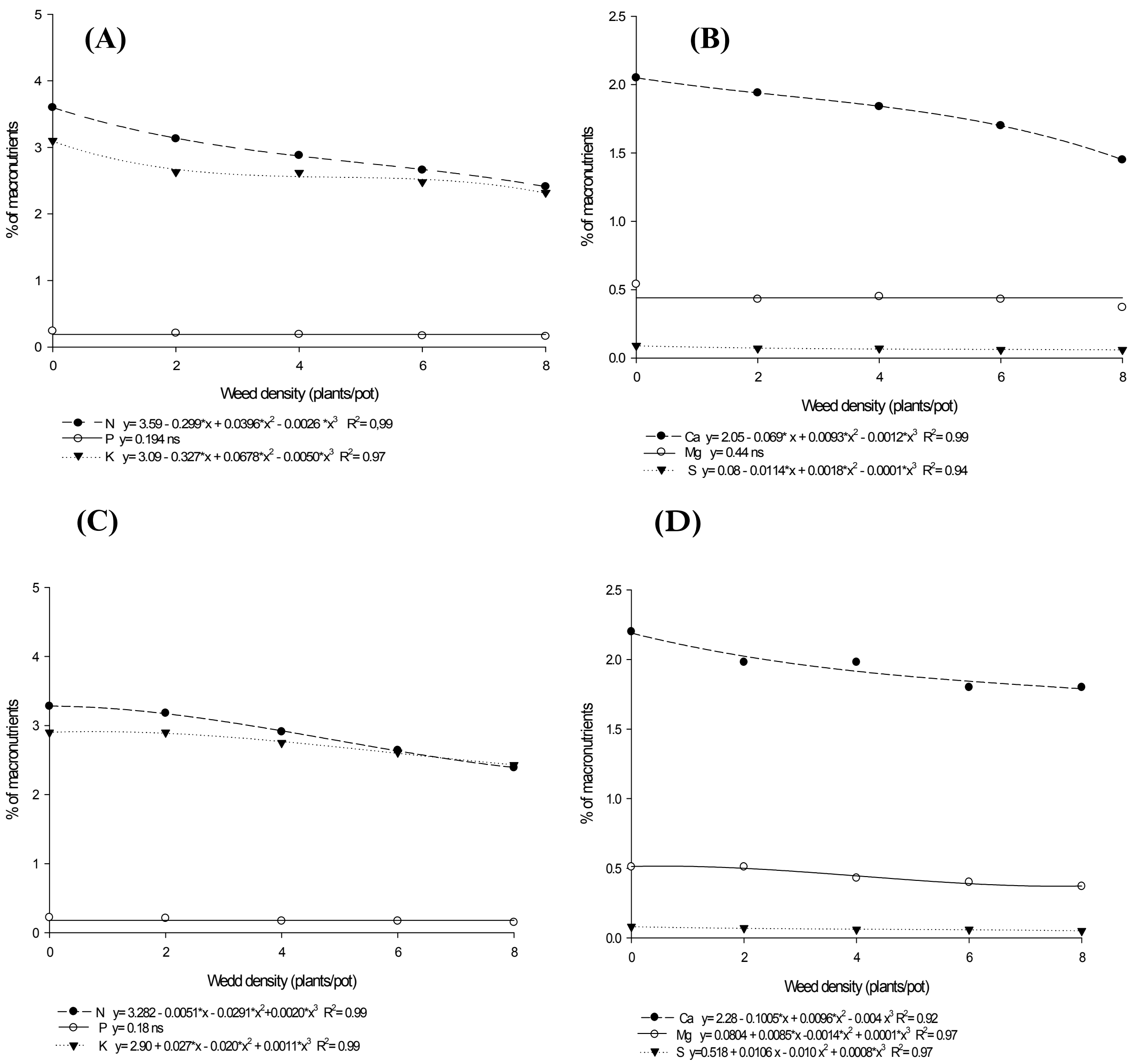


Figure 3. Percentages of leaf macronutrients of *S. polyphylla* interacting with different densities of *I. grandifolia* (A–B) and *U. decumbens* (C-D); and *E. contortisiliquum* interacting with different densities of *I. grandifolia* (E-F) and *U. decumbens* (G-H).



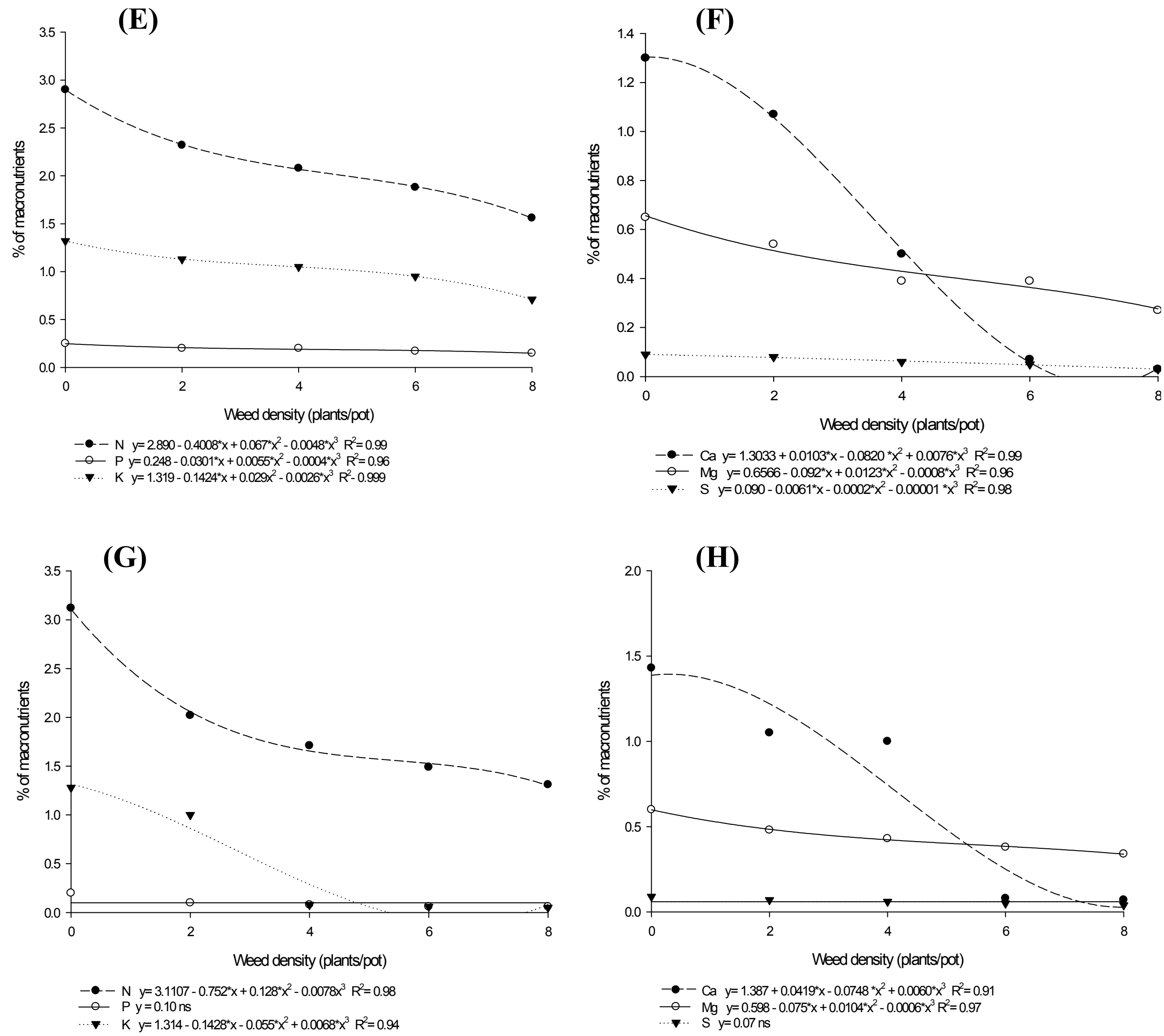
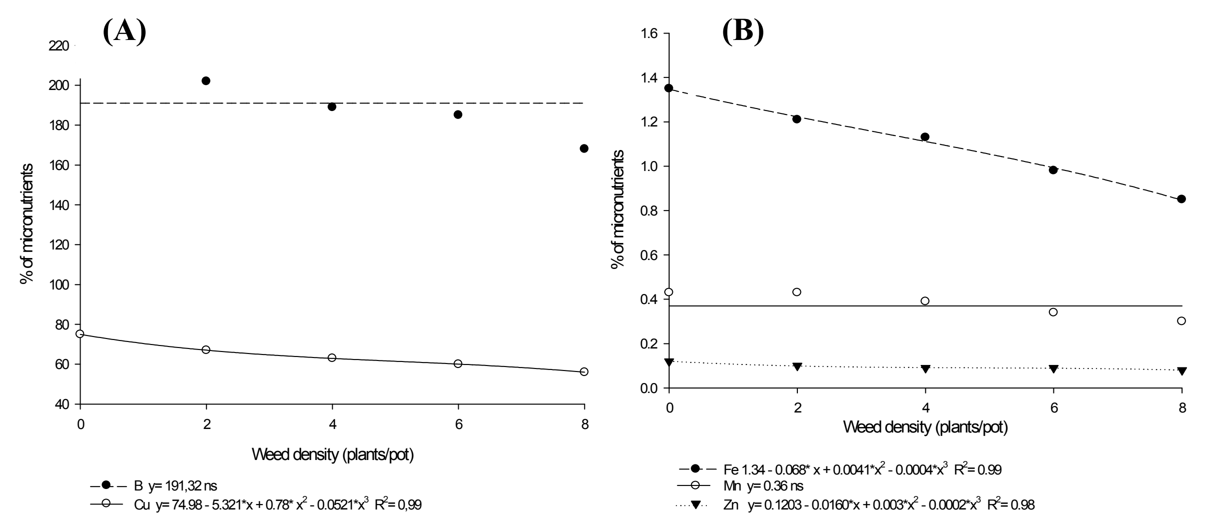


Figure 4. Percentages of leaf macronutrients of *C. speciosa* interacting with different densities of *I. grandifolia* (A–B) and *U. decumbens* (C-D); and *L. divaricata* interacting with different densities of *I. grandifolia* (E-F) and *U. decumbens* (G-H); (ns: no significant differences).



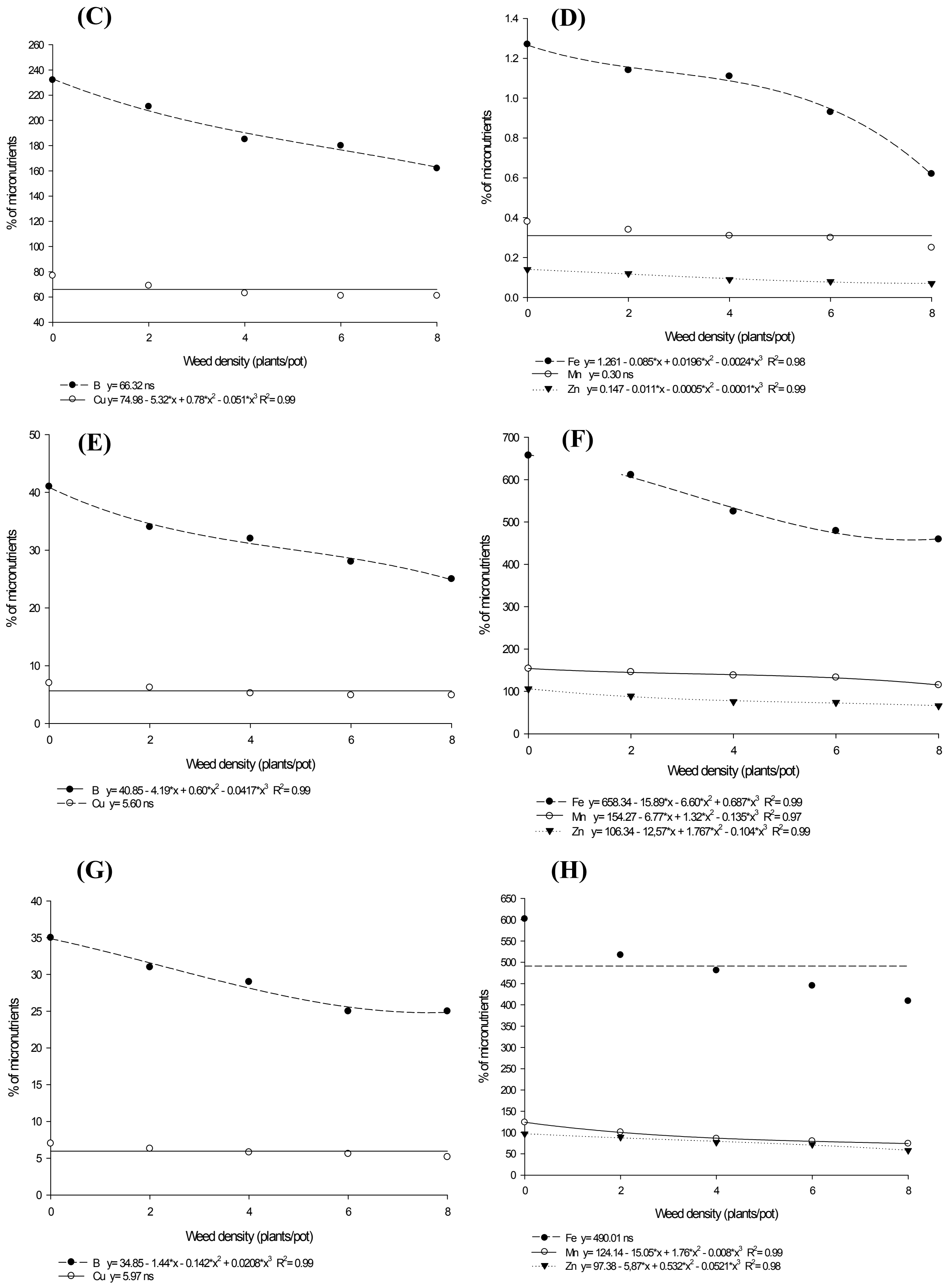
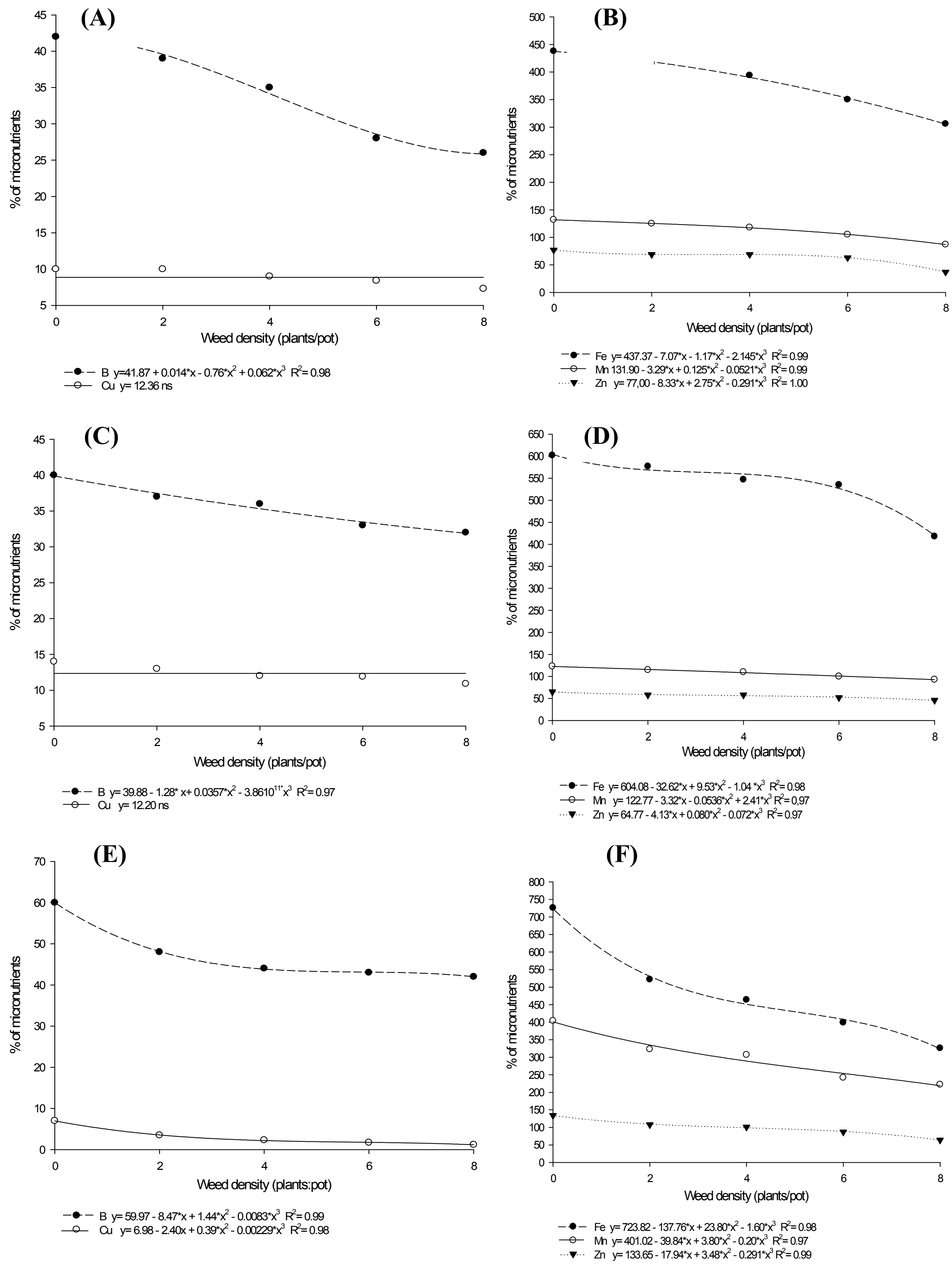


Figure 5. Percentage of leaf micronutrients of *S. polyphylla* interacting with different densities of *I. grandifolia* (A –B) and *U. decumbens* (C-D) and *E. contortisiliquum* interacting with different densities of *I. grandifolia* (E-F) and *U. decumbens* (G-H); (ns: no significant differences).


(A)
% of micronutrients
Weed density (plants/pot)
B y=41.87 + 0.014*x - 0.76*x^2 + 0.062*x^3 R^2= 0.98
Cu y= 12.36 ns
(B)
% of micronutrients
Weed density (plants/pot)
Fe y= 437.37 - 7.07*x - 1.17*x^2 - 2.145*x^3 R^2= 0.99
Mn 131.90 - 3.29*x + 0.125*x^2 - 0.0521*x^3 R^2= 0.99
Zn y= 77,00 - 8.33*x + 2.75*x^2 - 0.291*x^3 R^2= 1.00
(C)
% of micronutrients
Weed density (plants/pot)
B y= 39.88 - 1.28* x+ 0.0357*x^2 - 3.8610^11*x^3 R^2= 0.97
Cu y= 12.20 ns
(D)
% of micronutrients
Weed density (plants/pot)
Fe y= 604.08 - 32.62*x + 9.53*x^2 - 1.04 *x^3 R^2= 0.98
Mn y= 122.77 - 3.32*x - 0.0536*x^2 + 2.41*x^3 R^2= 0,97
Zn y= 64.77 - 4.13*x + 0.080*x^2 - 0.072*x^3 R^2= 0.97
(E)
% of micronutrients
Weed density (plants:pot)
B y= 59.97 - 8.47*x + 1.44*x^2 - 0.0083*x^3 R^2= 0.99
Cu y= 6.98 - 2.40x + 0.39*x^2 - 0.00229*x^3 R^2= 0.98
(F)
% of micronutrients
Weed density (plants/pot)
Fe y= 723.82 - 137.76*x + 23.80*x^2 - 1.60*x^3 R^2= 0.98
Mn y= 401.02 - 39.84*x + 3.80*x^2 - 0.20*x^3 R^2= 0.97
Zn y= 133.65 - 17.94*x + 3.48*x^2 - 0.291*x^3 R^2= 0.99

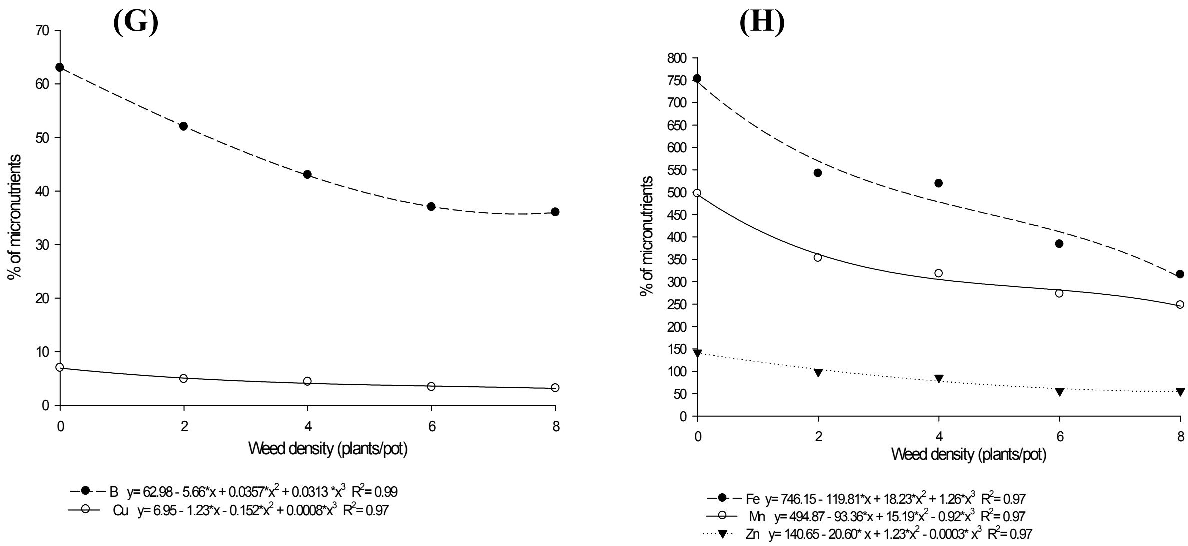


Figure 6. Percentage of leaf micronutrients of *C. speciosa* interacting with different densities of *I. grandifolia* (A –B) and *U. decumbens* (C-D) and *L. divaricata* interacting with different densities of *I. grandifolia* (E-F) and *U. decumbens* (G-H); (ns: no significant differences).

Lower availability of nutrients can affect the initial growth of seedlings. Mendonça et al. (1999) found that the growth of *Myracrodruon urundeuva* seedlings was drastically reduced in the absence of Ca and P. Other studies have shown that the omission of N could have generated a significant effect on the growth of plants. For example, Maffeis et al. (2000) found that the omission of N was the main variable contributing to the decrease in leaf production of *Corymbia citriodora*, whereas Sorreano et al. (2011) found that omitting N contributed to a decrease in the height, stem diameter, and production of leaves of *S. polyphylla*. Generally, the degree of interference depends on both the woody species and the density of the weeds: the coexistence of *Coffea* sp. seedlings with weeds of seven different species generated lower levels of relative contents of macro and micro-nutrients in coffee shoot dry matter, even at low densities (RONCHI et al., 2003).

The conventional method for controlling weeds in areas of forest restoration in southeastern Brazil has been through mechanical means (RODRIGUES et al. 2009). Therefore, based on the results, such a control strategy may not be sufficient to keep weed densities low enough, considering that the use of mechanical control may inhibit the growth and establishment of native species (SOUZA; BATISTA, 2004); furthermore, mechanical weed control does not address the rapid spread of some invasive species through vegetative propagation: U. decumbens spread aggressively through vegetation propagation (GONZÁLES; MORTON, 2005), which may contribute to their high level of interference on native plants.

Finally, the results lead to a key question: what are the best methods of weed control that will have minimal impacts on the native seedlings but will also facilitate ("theory of facilitation" - CONNELL; SLATYER, 1977) the establishment of other native plant life forms? Forest species seem to be tolerant to weed interference when coexisting with weeds in non-weeded plots; furthermore, Chapman et al. (2002) and Sweeney and Czapka (2004) found that weed control had minimal effects on native species. Perhaps these conflicting results may be related to different strategies of growth and survivorship of species (PICKET et al., 1987) and would also explain the species-specific variation observed in this study with regards to the accumulation of macro and micronutrients in response to weed density.

The legal procedures for management strategies of degraded areas in southeastern Brazil still remain subjective. In areas of restoration, the competition between weeds and native seedlings limits the development of the established forest community (DOUST et al., 2008). For this reason, when planning weed control methods, it is important to consider the trade-offs between mechanical and chemical control because there are species-specific constraints with both methods (CLAY et al., 2006; MONQUERO et al., 2011). Based on successional management, ecological managers should consider using a combination of weed control methods that minimize the impact on native species, maximize weed control, and allow for the introduction and development of functional diversity of the planted community.

It is essential to begin weed control in tropical restored areas at the initial phase of seedling planting to ensure an increase in both structural and functional complexity of the community. Weed control regarding both weed interference in tree seedlings and the restoration of large areas (hundreds of hectares) must take into account the survivorship of other native plant life forms in restored areas – arrival of seeds and development of lianas, herbs, tree lets, epiphytes, and so on. Because of the importance of weed control, experiments on herbicide use on native tree species are warranted (BRANCALION et al., 2009); these experiments should consider the chemical nature of herbicides, the selectivity on the native community, and their efficiency at controlling weeds at a dosage level that could be tolerable for the native seedlings (MYSTER, 2004; CRAVEN et al., 2009).

Conclusion

The results confirm the prediction that higher densities of *U. decumbens* and *I. grandifolia* lead to a decrease in both the aboveground biomass and leaf nutrient content of the four native tree species.

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