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CONTROL OF LATERAL ROOT EXTENSION OF FAST-GROWING TIMBER SPECIES USING GRASSES AS BIOLOGICAL BARRIERS

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Resumen

Se investigó el potencial de cinco especies de gramíneas como barreras biológicas para reducir la competencia radicular en asociaciones agroforestales con árboles maderables de crecimiento rápido como *Eucalyptus deglupta* y *Cordia alliodora*. Las raíces de *C. alliodora* de seis meses crecieron hacia el lado contrario de las barreras, mientras que las de *E. deglupta*, aunque mostraron diferentes tipos de interacción, generalmente cruzaron la barrera. El crecimiento de ambas especies de árboles en asociación con las gramíneas fue menor que en el control. Es probable que el efecto barrera de las gramíneas sea mejorado mediante el establecimiento de varias hileras en lugar de una, o reduciendo la distancia de siembra dentro de la hilera.

Key words: agroforestry, *Cordia alliodora*, Costa Rica, *Eucalyptus deglupta*, root competition.

Introduction

Root competition is a major obstacle to the development of agroforestry systems. In order to address this problem, the root system of the tree component can be manipulated to reduce overlap with the root system of the associated crop, an approach that has been termed "root management" (Schroth, 1995; 1999). One possibility is to force the tree roots into greater soil depths by restricting lateral tree root development. Yocum (1937) demonstrated that the presence of the relatively competitive root system of maize restricted the lateral and increased the vertical development of apple tree (*Malus domesticus*) roots. The effect of grasses on tree root distribution was also demonstrated by Atkinson et al. (1978). Based on these results, we hypothesized that strips of competitive grass species could be used to separate the rooting zones of trees and crops in agroforestry associations by restricting the lateral tree root development. If the lateral root extension of the grasses is less than that of the trees, total root competition with the crops could thus be reduced. In this study, we evaluate the potential of five useful grass species, of differing competitiveness, for controlling the lateral root development of two fast-growing timber trees, *E. deglupta* and *C. alliodora*, in Costa Rica.

Materials and Methods

In December 1997, a field trial was established in the experimental area "La Montaña" of CATIE in Turrialba, Costa Rica (9°53' N.; 83°38' W.; 602 m.a.s.l.). The climate is tropical humid with 2684 mm of annual rainfall, usually with only one dry month (March) and average annual temperature of 21.7 °C. The soil, an Andic Eutropept according to the USDA/SCS Soil Taxonomy (Kass et al., 1995), developed from alluvial deposits, is clay- and nutrient-rich, has no rocks and was well drained by an adjacent 2 m ditch. The plots consisted of single rows of three trees of either *E. deglupta* or *C. alliodora*, at 30 cm spacing within the row and 1.5 m between neighboring rows. On one side of the tree rows, at 30 cm distance, either no grass (control) or one of the following five grass species was planted at the same time: *Saccharum* sp. (sugar cane), *Cymbopogon nardus* or *Vetiveria zizanioides* (vetiver), two grasses frequently used for erosion control; and *Brachiaria brizantha* or *Panicum maximum* (guinea grass), two productive fodder bunch grasses of high nutritive value. The grasses were planted by vegetative propagation with 12 cm spacing within the row for *V. zizanioides*, *C. nardus* and *B. brizantha*, and 30 cm for the larger species *Saccharum* sp. and *P. maximum*. Bagged nursery seedlings were used to establish the trees. The 12 combinations of tree and grass species were replicated three times. The *E. deglupta* and *C. alliodora* plots were evaluated four and eight months after planting, respectively, because of the much slower initial shoot and root growth of the *C. alliodora*. Tree and grass roots were excavated manually by carefully removing the superficial soil-layers until the lateral tree root system was exposed. The position of the roots was recorded with the help of a 10 x 10 cm grid.

Results

Interactions between C. alliodora and grasses

The root system of the young *C. alliodora* trees explored the soil relatively extensively and consisted of a few fine roots only. The primary lateral roots radiated from the stem at a depth of 10-20 cm, deepening slightly with increasing distance from the stem (Figure 1). The root systems of neighboring trees clearly avoided each other, resulting in little overlap of their rooting space. In the presence of grass barriers, most of the tree roots grew in the opposite direction to the barriers, avoiding contact with the grass roots. This behavior led to strongly asymmetric root systems (Figure 2). The degree of avoidance of the grass roots by the tree roots depended on the competitiveness of the respective grass species: the aggressive, fast-growing guinea grass had the strongest barrier effect on the tree roots with no *C. alliodora* roots passing through the grass lines. The root systems of the *V. zizanoides* and the *C. nardus* were less dense and their barrier effect was less pronounced. Both *B. brizantha* and *Saccharum* sp. also had a very clear effect on tree root distribution.

Interactions between E. deglupta and grasses

The root system of *E. deglupta* is characterized by lateral roots radiating very superficially from the stem. It is a very opportunistic root system with the capacity to develop locally a dense fine root system where conditions are favorable (e.g. sites with litter accumulation, fertilizer or lime; pers. obs.). In general, the *E. deglupta* roots passed through the grass barriers. They were nevertheless influenced by the presence of the grass roots. Five types of interactions could be distinguished, depending on the grass species involved: 1) The tree roots passed through the barrier at "weak points", especially between two neighboring grass bunches. This probably was favored by the fast growth of the tree roots, which arrived at the grass lines before these had formed a dense root barrier. In order to reach these "weak points", the tree roots often changed their direction of growth. 2) The tree roots turned slightly downwards and passed below the grass barrier. 3) The tree roots divided into several smaller diameter roots which then passed through the barrier by growing around individual grass bunches (observed in particular with vetiver). This reaction could lead to a reduced extension of the tree roots and thus reduced interaction with a crop growing behind the barriers. 4) The tree roots, when reaching the grass barrier at a low angle, changed their direction and grew parallel to the grass strip without traversing it. This was only observed with *P. maximum.* 5) In two cases, tree roots meeting with *B. brizantha* roots turned by approximately 90 degrees and grew away from the barrier.

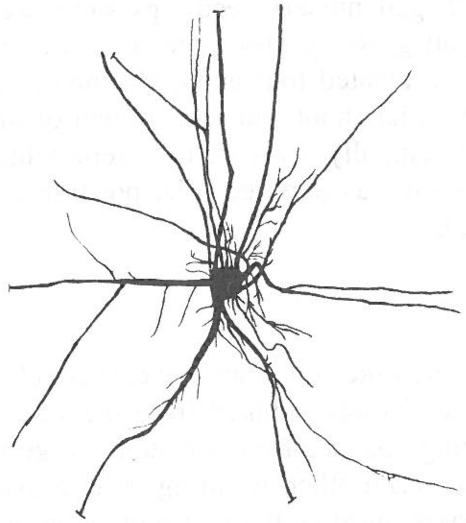
Fig. 1. Root system of an individual *Cordia alliodora* tree

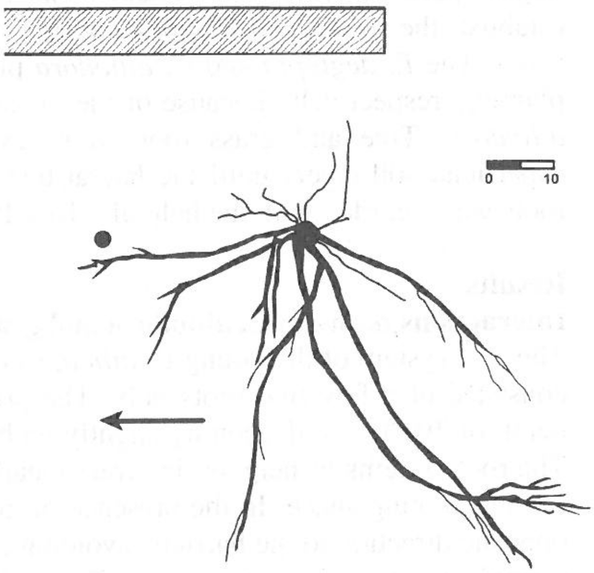

Fig. 2. Root system of a *Cordia alliodora* tree in association with a barrier of *Panicum maximum*; arrow indicates direction of tree line

Discussion

The root system of the slower-growing, less aggressive tree species, *C. alliodora,* followed a strategy of avoiding the root systems of competitors, including both neighbors from the same species and the adjacent grass barriers. Root systems of this type seem to be particularly suitable for management with biological barriers, as even a single grass row forced the *C. alliodora* roots into the opposite direction and prevented them effectively from exploring the soil beyond the grass barrier. A crop species growing here would not have experienced tree root competition at this early development stage, and depending on lateral grass root extension and competitiveness, total root competition with the crops could be reduced. In contrast, strong reactions of the *E. deglupta* roots to grass competition were rare and apparently limited to the associations with the more competitive grass species, *B. brizantha* and *P. maximum.* Less pronounced interactions, which did not result in a significant change in the growth direction of the *E. deglupta* roots, were more common and also occurred in the associations with the less aggressive grass species.

The fact that the *E. deglupta* roots were clearly influenced by the presence of the grasses indicates that the development of more efficient biological root barriers should be worthwhile. These options include: 1) choosing a competitive grass species (below-ground); 2) planting multiple, instead of single grass barriers; 3) planting the trees after the grasses so that the grass root systems would be denser at the time of the contact with the tree roots; and 4) using directed fertilizer placement within the tree line to reinforce the barrier effect. More efficient grass barriers would probably not only have a stronger effect on tree root distribution, but also on tree growth. In this experiment, the growth of both tree species was reduced by the grasses, either because of root competition or because of shading. Obviously, the development of biological root barriers can not simply aim at maximum efficiency of the barriers for controlling tree root development, but has to look for an optimum balance between costs and benefits of the technique. This would also have to take into account additional uses of the barrier plants, e.g. for fodder or erosion control when planted along the contour on sloping land.

Conclusions

It has been demonstrated that the lateral root development of relatively fast-growing trees such as *C. alliodora* can be manipulated at an early stage with simple grass strips. Controlling root development of more aggressive tree species such as *E. deglupta* would require more efficient barriers. The results of this study can be taken as preliminary evidence for the potential of biological root barriers for the management of root interactions between trees and crops in agroforestry. Further work should concentrate on the identification of efficient grass species and planting designs for the barriers, taking the balance of costs and benefits of barriers of differing competitiveness into account. The efficiency of the barriers for older trees also needs to be studied.

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