COMPETITION WITH GRASSES AND POSITIVE EFFECTS OF INITIAL SEED DENSITY ON THE ESTABLISHMENT OF *MYRACRODRUON URUNDEUVA* (ANACARDIACEAE) IN A TROPICAL PASTURE

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INTRODUCTION

In the last decades, pasture development has been one of the main causes of deforestation and degradation in Latin America, and there is currently a demand to restore these environments to a minimum level of productivity and preservation of species diversity (Holl *et al.*, 2000). However, information on germination rates and seedling establishment of native species in pasture areas are very scarce in tropical regions (Camargo *et al.*, 2002).

Seeds of tree species that invade abandoned pasture areas are subject to high post - dispersal predation rates and water and temperature stresses, and thus have lower chances to germinate than in forest habitats (Holl, 1999; Holl *et al., ,* 2000; Zimmerman *et al.,* 2000). After germination, the growth and survival of seedlings can be negatively affected by unfavorable environmental conditions, high herbivore and pathogen attack rates, intraspecific competition due to high aggregation levels of seeds, and interspecific competition with exotic grasses (Harper, 1977; Matos *et al., ,* 1999; Gilbert *et al.*, 2001; Meiners *et al.,* 2002; Peters, 2003; Russo, 2005).

Thus, pastures are more stressful environments than forest habitats, and several studies suggested that soil coverage by the surrounding vegetation at sites of seed deposition can facilitate the establishment of tree species, by providing a more favorable microclimate for seed germination and seedling establishment (Maestre, 2005; Malkinson & Jetsch, 2007). Bruno *et al.*, (2003) suggested that the mechanisms of facilitative processes can strongly influence population growth rates and the distribution of populations, by ameliorating extreme conditions in more severe environments. Spatial and temporal variation in environmental conditions could change the outcome of biotic interactions among plants (Pugnaire & Luque, 2001; Maestre, 2005), so that the effect of density can change along biotic and abiotic gradients (Bruno *et al.*, 2003,; Malkinson & Jetsch, 2007).

We previously observed high levels of seed aggregation of *Myracrodruon urundeuva* Fr. Allemão (Anacardiaceae) in pastures in central Mato Grosso do Sul state, mid - western Brazil. The spatial distribution of seeds after dispersal is generally aggregated nearby the parent trees, following a pattern consistent with the Janzen - Connell model (Nathan & Casagrandi, 2004).

OBJECTIVES

The aim of this study was to evaluate the effects of an exotic grass and seed initial density on rates of *M. urundeuva* seed germination and survival in the field. We also evaluate the effect of seed density on rates of *M. urundeuva* germination and survival under favorable conditions.

MATERIAL AND METHODS

Study species

Myracrodruon urundeuva, is a wind - dispersed, deciduous tree that grows up to 20m high (Carvalho, 2003). The complete maturation of the fruits begins in late September and extends until October, followed by fast germination in the field. Adult individuals produce large numbers of small seeds (about 0.018g each seed; Carvalho, 2003). It is a recommended species for restoration of degraded areas because it is a light - demanding species (Pinto & Oliveira - Filho, 1999) and can potentially grow in the presence of grasses (Carvalho, 2003). This species was classified as a vulnerable species in the official list of Brazilian species threatened by extinction (Brasil 1992), because it is highly explored for timber and medicinal uses (Paula & Alves, 1997).

Study site

This study was carried out in Campo Grande district, Mato Grosso do Sul state (mid - western Brazil), in an area of abandoned pasture ($20^0$41'27"S, $54^0$34'26"W). Mean annual rainfall varies between 1,300 and 1,700 mm, and relative humidity is generally low, rarely reaching 80%. Mean annual temperatures vary between 20 and 22^0C (Köppen, 1931). Soils in the region are classified as red latosoil.

Field Experiment

We carried out a 2x2 factorial experiment to evaluate the effects of exotic grass (*Brachiaria* sp. - Poaceae) and seed initial density on rates of *M. urundeuva* seed germination and survival in the field. The factor "density" consisted of sowing high and low densities of seeds. Previous observations in another area of abandoned pasture where several individuals of *M. urundeuva* occurred indicated that seed densities on the soil could reach up to 185 seeds per $0.25m^2$, under the crown of adults (Pereira, 2007). Thus, we sowed a density of 200 seeds per $0.25m^2$ in high seed density plots, and a density of 20 seeds/$0.25m^2$ in low seed density ones. The factor "grass" also consisted of two levels: in the first, all plants inside the plots were removed together with their roots, whereas in the second (Control) the vegetation was maintained intact. Thus, four treatment combinations were obtained, 1) high seed density in the presence of grasses, 2) low seed density in the presence of grasses, 3) high seed density with grasses removed, and 4) low seed density with grasses removed. There were five replicates of each combination in the field. The experiment was conducted during the wet season, from 21 October 2006 to 13 January 2007. After the germination peak (about 30 days after sowing), seedling survival was monitored every two weeks until the end of the experiment.

Plant nursery experiment

To evaluate the effect of density under favorable conditions, another experiment was set up in the nursery of Universidade Federal de Mato Grosso do Sul, also in Campo Grande. The same high seed (200 seeds/$0.25m^2$) and low seed densities (20 seeds/$0.25m^2$) were tested in the field and in the plant nursery. The seeds were sown in plastic trays with a nutritive substrate and wetted twice a day. There were five randomized replicates of each treatment in the nursery. The experiment was monitored weekly during the same period of the field experiment, and the number of seedlings was recorded. Seeds used in both experiments (field and nursery) were collected from ten trees in the region, located at a minimum distance of 100m from each other to increase the genetic representation of the population.

Data Analyses

The nursery experiment evaluating the effect of seed density on rates of germination was analyzed with a 1 - way ANOVA, considering seed density as a fixed factor. Seed germination in the field experiment was analyzed with a 2 - way ANOVA, with both factors (density and grasses) considered fixed. Proportion data were arcsine - square root transformed to obtain homogeneous variances (Sokal & Rohlf, 1995). Residuals were graphically checked to evaluate the effectiveness of the transformations and data normality. The significance level considered was $p = 0.05$.

After germination, we used a survival analysis (accelerated failure time analysis) to evaluate the effects of density and grasses in the field experiment and the density in the nursery experiment on the proportion of individuals surviving along time (Fox, 1993). As we expected that deaths (failure) of the individuals decreased continuality along time, we used a Weibull distribution. This statistical approach compares the predicted time when 50% of the population have died (median survival values) among the treatments. This analysis was performed using the LIFEREG procedure (SAS, 1990).

RESULTS AND DISCUSSION

In high seed density plots, germination rates were 0.10 ± 0.01 (mean $\pm$ 1 SE) and 0.07 ± 0.02 in bare soil and in the presence of grass, respectively, whereas in low seed density plots the corresponding values were 0.06 ± 0.02 and 0.10 ± 0.04. The germination of seeds of *M. urundeuva* in the field was not influenced by the presence of grass ($F_{1,16} = 0.024$; $P = 0.880$), differences in seed density ($F_{1,16} = 0.347$; $P = 0.564$), nor by the interaction of both factors ($F_{1,16} = 1.873$; $P = 0.190$).

The germination rate in the nursery was much higher than in the field. However, there was also no influence of seed density on the germination of *M. urundeuva* seeds ($F_{1,8} = 0.009$; $P = 0.928$). Mean germination rates were 0.49 ± 0.05 and 0.50 ± 0.16 in the high and low seed density treatments, respectively.

These experiments showed that neither grass nor initial seed density influenced seed germination of *M. urundeuva* in the field; however general germination rates were much higher in the nursery than in the field. This difference can be due to seed predation in the field or higher water supply in the nursery, important causes that should be evaluated using other experiments.

The effect of seed density on seedling survival in the field depended on the presence of exotic grass (interaction grass vs. density, $P < 0.001$). In bare soil plots, higher survival of seedlings was observed in the high seed density treatments when compared to low density ones. In the presence of grass, however, there was a higher survival of *M. urundeuva* seedlings in low density plots. There was a high proportion of seedlings surviving under high densities until 38 days after sowing, but afterwards this value decreased to 0.17 and did not vary until the end of experiment, whereas the proportion of seedlings surviving in low density quickly stabilized in higher levels. Thus, the lowest proportion of surviving individuals was recorded in plots where grass was removed with a low initial density of seeds, whereas the highest proportion was recorded in plots with high initial density of seeds and removal of grass.

There was no significant effect of seed density on seedling survival in the nursery ($P = 0.220$). We only recorded a weak trend for an increase in seedling survival in the low seed density treatment, since only one seedling died along the experiment.

The effect of initial seed density on survival of *M. urundeuva* seedlings varied both between nursery and field, and between plots with or without exotic grass. In the nursery, the higher density of co - specific plants exerted no significant influence on seedling survival. Nevertheless, only one individual (2%) died under conditions of low density against a mortality of 6.9% under high density. It is possible that the density used as high density treatment was not high enough to limit any resource. In contrast, the results found under field conditions showed that density effects on seedling survival rates were either positive in grass removal plots or negative in plots with grasses.

Several studies recorded lower rates of survival and reproduction, or growth inhibition of individual plants in the presence of individuals of the same or other species, because of competition for resources (Harper, 1977; Zimmerman *et al.*, 2000; Cahill Jr., 2002). Our results showed that seedling survival rates were very low in the presence of exotic grass, with lower values when grown in high seed density conditions. This suggests strong competitive effects, both inter - and intra - specific. Even if we assume that light is not a limiting resource in pasture areas, *M. urundeuva* has very small seeds (about 0.018g per seed), normally resulting in a strong dependence on below - ground resources such as mineral nutrients and water supplies to promote its early development.

On the other hand, in the absence of grasses (bare soil), high densities of *M. urundeuva* seedlings were not enough to limit any resource, when contrasted to areas with grasses. In this environment, seedling survival in high seed density plots was higher than in low density ones. These results suggest the occurrence of intraspecific facilitation among *M. urundeuva* seedlings, among individuals within the same age or size class. Experiments evaluating if there is a positive effect of co - specific aggregation on the chances of tree seedling survival in pastures are scarce. We found no studies describing facilitation among intraclass (age or size) individuals. Malkinson & Jetsch (2007) evaluated facilitation between two age classes of the shrub *Sarcopoterium spinosum*, because they assumed that the facilitation process would not occur among individuals within the same size class. However, our study suggested that intraspecific facilitation among intraclass individuals is possible in more severe environments, at least during early seedling development. The shading provided by the plants could result in milder temperatures or reduced water loss by evaporation from the soil, and contribute to increase the amount of water from dew condensation retained by the leaves, increasing the relative humidity on the soil superficial layer.

Interest in facilitation has increased considerably in recent years. Some authors proposed that facilitation could increase the range size distribution of some species, through the expansion of their realized niche (Bertness & Callaway, 1994; Hacker & Gaines, 1997; Bruno *et al.*, 2003), possibly influencing the structure of local communities. For example, Michalet *et al.*, (2006) proposed the inclusion of facilitation into Grime's (1973) model of species richness. In this modified model, competition would have a greater impact on the regulation of species diversity in environments with more benign conditions, whereas facilitation would be dominant in intermediate levels of environmental severity. The results of our study support this hypothesis, by showing that higher initial seed densities in bare soil environments can increase the probability of *M. urundeuva* establishment in pasture areas. However, the maximum threshold of seeds to be added per plot should be investigated. An excessive increase in density can make negative effects of competition override the positive effects of milder microclimates caused by the presence of co - specifics, as suggested by our results of the nursery experiment. In this context, field studies on the establishment of native tree species are essential for the development of techniques of direct sowing as a viable alternative for future initiatives of rehabilitation of degraded areas in the tropics.

CONCLUSION

Seed germination of *M. urundeuva* was affect by the environment conditions, but there was no influence of seed density or presence of grasses on the germination. Germination was much higher in the nursery (a favorable environment) than in the pasture (a more severe environment).

The effect of initial seed density on survival of *M. urundeuva* seedlings varied both between nursery and field and between plots with or without exotic grasses.

Our results suggest that seed aggregation on bare soil can increase the chances of seedling survival, and that facilitation among intraclass (age or size) individuals is possible, at least on stressful environments.

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REFERENCES

Bertness, M.D., Callaway, R. Positive interactions in communities. Trends Ecol. Evol. 9:191–193, 1994.

Brasil. 1992. Portaria nº. 06 - N, de 15 de janeiro de 1992. Lista oficial de espécies da flora brasileira ameaçadas de extinção. Diário Oficial da República Federativa do Brasil, 23 jan., 870–872, 1992.

Bruno, J.F., Stachowicz, J.J., Bertness, M.D. Inclusion of facilitation into ecological theory. Trends Ecol. Evol. 18:119–125, 2003.

Cahill Jr., J.F. What evidence is necessary in studies which separate root and shoot competition along productivity gradients? J. Ecol. 90: 201–205, 2002.

Camargo, J.L.C., Ferraz, I.D.K., Imakawa, A.M. Rehabilitation of degraded areas of Central Amazonia using direct sowing of forest tree seeds. Restor. Ecol. 10: 636–644, 2002.

Carvalho, P.E.R. Espécies arbóreas brasileiras. Embrapa Informação Tecnológica, Brasília, Brasil, 2003, 1039p.

Fox, G.A. Failure - time analysis: establishment, flowering, survivorship, and other waiting times. In: Scheiner, S.M.; Gurevitch J.(eds.). Design and analysis of ecological experiments. Chapman & Hall, New York, 1993, p. 253 - 289.

Gilbert, G.S., Harms, K.E., Hamil, D.N., Hubbell S.P. Effects of seedling size, weather, seedling density, and distance to nearest conspecific adult on 6 - year survival of *Ocotea whitei* seedlings in Panamá. Oecologia 127: 509 - 516, 2001.

Grime, J.P. Competitive Exclusion in Herbaceous Vegetation. Nature 242: 344–347, 1973.

Hacker, S.D., Gaines S.D. Some Implications of Direct Positive Interactions for Community Species Diversity. Ecology 78: 1990–2003, 1997.

Harper, J.L. Population biology of plants. Academic Press, London, 1977, 892p.

Holl, K.D. Factors limiting tropical moist forest regeneration in agricultural land: soil, microclimate, vegetation and seed rain. Biotropica 31: 229–242, 1999.

Holl, K.D., Loik, M.E., Lin, E.H.V., and Samuels, I.A. Tropical montane forest restoration in Costa Rica: overcoming barriers to dispersal and establishment. Restor. Ecol. 8: 339–349, 2000.

Köppen, W. Climatologia. Fondo de Cultura Económica, Buenos Aires, Argentina, 1931.

Maestre, F., Valladares, F., Reynolds, J. Is the change of plant - plant interactions with abiotic stress predictable? A metaanalysis of field results in arid environments. J. Ecol. 93: 748–757, 2005.

Malkinson, D., Jetsch, F. Intraspecific facilitation: a missing process along increasing stress gradients-insights from simulated shrub populations. Ecography 30:339–348, 2007.

Matos, D.M.S., Freckleton, R., Watkinson, R. The role of density dependence in the population dynamics of a tropical palm. Ecology 80: 2635 - 2650, 1999.

Meiners S.J., Pickett, S.T.A., Handel, S.N. Probability of tree seedling establishment changes across a forest - old field edge gradient. Am. J. Bot. 89: 466–471, 2002.

Michalet, R., Brooker, R.W., Cavieres, L.A., Kikvidze, Z., Lortie, C.J., Pugnaire, F.I., Valiente - Banuet, A., Callaway, R.M. Do biotic interactions shape both sides of the humped - back model of species richness in plant communities? Ecol. Lett. 9: 767–773, 2006.

Nathan, R., Casagrandi R. A simple mechanistic model of seed dispersal, predation and plant establishment: Janzen - Connell and beyond. J. Ecol. 92: 733–746, 2004.

Paula, J.E., Alves, J.L. Madeiras nativas: anatomia, dendrologia, dendrometria, produção e uso. Fundação Mokiti Okada-MOA, Brasília, Brazil, 1997, 438p.

Pereira, S.R. Avaliação do modelo de Janzen - Connel em áreas degradadas: um estudo de caso com aroeira - verdadeira *Myracroduon urundeuva* M. Allemão (Anacardiaceae). M.Sc. thesis, Department of Biology, Universidade Federal de Mato Grosso do Sul, Campo Grande, MS, Brazil, 2007, 51p.

Peters, H.A. Neighbour - regulated mortality: the influence of positive and negative density dependence on tree populations in species - rich tropical forests. Ecol. Lett. 6: 757 - 765, 2003.

Pinto, J.R.R., Oliveira - Filho, A.T. Perfil florístico e estrutura da comunidade arbórea de uma floresta de vale no Parque Nacional da Chapada dos Guimarães, Mato Grosso. Rev. Bras. Bot. 22: 53–67, 1999.

Pugnaire, F.I., Luque, M.T. Changes in plant interactions along a gradient of environmental stress. Oikos 93: 42–49, 2001.

Russo, S. Linking seed fate to natural dispersal patterns: factors affecting predation and scatter - hoarding of *Virola calophylla* seeds in Peru. J. Trop. Ecol. 21: 243 - 253, 2005.

SAS/STAT. SAS user's guide, version 6, 4th edn. SAS Institute, Cary, N.C, 1990.

Sokal, R. R., F. J. Rohlf. Biometry. 3rd edn. Freeman, New York, 1995, 887p.

Zimmerman, J., Pascarella, J., Aide, M. Barriers to forest regeneration in an abandoned pasture in Puerto Rico. Restor. Ecol. 8: 328–338, 2000.