UNDERSTOREY PLANT DIVERSITY UNDER SEVEN TROPICAL AND SUBTROPICAL PLANTATION SPECIES

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OTUBA M & JOHANSSON KE. 2016. Understorey plant diversity under seven tropical and subtropical plantation species. The aim of this study was to determine if the number of understorey species in *Eucalyptus* plantation was less compared with that in plantations of other common tropical and subtropical species. Meta study was used to collect information for assessing the differences in the number of understorey plant species. The number of understorey plant species in the *Eucalyptus* plantation was in higher compared with that of the six other species. Thus, it could be concluded that the generally-held perception of fewer understorey species in *Eucalyptus* plantation was not applicable.

Keywords: Stands, nitrogen-fixing, non-nitrogen fixing, exotic, trees

INTRODUCTION

While the area of natural forests is shrinking, that of plantation forests is expanding rapidly and dominates the landscape in some regions of the world. The global area of planted forests and trees has increased by 264 million ha between 2005 and 2010 (FAO 2010). Most of these forests were established through afforestation, i.e. planting non-forested areas. China had the largest total area of plantation forests with approximately 77 million ha in 2010, followed by United States (25 million ha), Russia (17 million ha), Japan (10 million ha) and Canada (9 million ha) (FAO, 2010).

The establishment and expansion of plantation forests in the tropics and subtropics is based mainly on exotic tree species, for example *Eucalyptus* and pine managed in short rotations (7–30 years). During harvest, large quantities of nutrients are removed, gradually exhausting the soil of plant nutrients particularly in areas with high rainfall or poor soil conditions (Nambiar 2008, Laclau et al. 2010).

Since most silvicultural practices lead to disturbances to the ecosystem, assessment of sustainability and biodiversity in fast-growing tree plantations has become an important issue of ecosystems study. Fast-growing forest tree plantations, in particular those of *Eucalyptus* species, are considered less dense and have low diversity in understorey vegetation compared with other plantation species or other kinds of vegetation cover. This disadvantage has been attributed to the allelopathetic effect, root competition, tree canopy cover and intensive site preparation prior to stand establishment (Bernaldez et al. 1989, Alves et al. 1990, Fabião et al. 2002). Tree canopy cover exerts direct effect on the quantity and quality of light reaching the understorey vegetation (Zobrist et al. 2005), decreasing the number of understorey vegetation species, especially those which are less tolerant to shade and low soil moisture levels. On the other hand, some intensive forest plantations have improved species diversity of understorey and, thus, monoculture plantations have been recommended for restoration of forest vegetation on degraded land as they allow colonisation of native species (Lugo 1997, Carnus et al. 2003).

Understorey vegetation protects the soil against erosion when the stand canopy is not closed, contributing to nutrient cycling as well as increased soil carbon content and stability of soil aggregation. Although environmental effects of eucalypt on native plant species are well

documented, data on the comparison of number of understorey species in *Eucalyptus* stands with that of other commonly used plantation species, nitrogen-fixing and non-nitrogen fixing tree species are sparse. In order to bridge these gaps, this study was aimed at analysing the difference in the number of understorey species in *Eucalyptus* stands to that of six other commonly used plantation species, nitrogen-fixing and non-nitrogen fixing. This comparison will contribute to the on-going debate on the controversy of whether *Eucalyptus* plantation suppresses or facilitates species diversity in the understorey.

MATERIALS AND METHODS

Data collection and data analysis

Meta analysis was applied to compare the undergrowth in *Eucalyptus* stands with that in other commonly used plantation species in the tropical and subtropical areas. The table of contents of high profile forestry and sustainable development electronic journals were surveyed using Swedish University of Agricultural Sciences library databases, mainly Google Scholar, AGRIS and Web of Knowledge. The Center for International Forestry Research online library also used to find scientific studies where the undergrowth in the *Eucalyptus* stand was compared with that of another commonly used plantation species established within the same experiment.

Twenty-four such comparisons were made. The *Eucalyptus* species were *Eucalyptus urophylla, E. camaldulensis, E. saligna, E. globulus, E. grandis* and *E. robusta*. The other commonly used tropical and subtropical plantation species included were nitrogen-fixing (*Casuarina equisetifolia* and *Leucaena leucocphala*) and non-nitrogen fixing (*Juniperus procera, Pinus patula, Cupressus lusitania* and *Cordia africana*) tree species. Excel spreadsheet was used to compute quantitative data (Jensen et al. 1997).To test the difference in the number of undergrowth between *Eucalyptus* stand (μ_e) and that of other species (μ_o), a test of difference between population means of matched pairs (Newbold 1991) was used. Thus, the 24 comparisons were considered as matched pairs. Sample mean of the difference was calculated as

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y \quad (1)$$

where y = difference in the number of understorey species in *Eucalyptus* plantations and that of other plantation species and n = number of samples. Null hypothesis (H_0) was that the difference (Y in the population) in the number of understorey plant species in *Eucalyptus* stands were equal or lower than that of other commonly used plantation species.

$$H_0 = \mu_{es} - \mu_{os} = Y_0 \quad \text{or} \quad (2)$$

$$H_0 = \mu_{es} - \mu_{os} \leq Y_0 \quad (3)$$

where μ_{es} = mean of understorey plant species in *Eucalyptus* plantation, μ_{os} = mean of understorey plant species in other plantation species, Y_0 = hypothesised mean and H_0 = null hypothesis. H_0 was tested against the H_1 hypothesis whereby the number of understorey species in the *Eucalyptus* stand was higher:

$$H_1 = \mu_{es} - \mu_{os} \geq Y_0 \quad (4)$$

where H_1 = alternative hypothesis using the student *t*-test. The decision rule, H_0 was rejected if

$$\frac{\bar{y} - y_o}{S_\mu \sqrt{n}} > t_{n\ -\ 0.005,\ \alpha} \quad (5)$$

where t_n = test statistics of sample number, α = significance level or probability of rejecting the null hypothesis when it was true, y_o = intercept, i.e. estimate for the mean outcome and S_μ= sample standard deviation. Sample variance was calculated using equation 6.

$$S_\mu^{\,2} = \frac{1}{n-1}\sum_{i=1}^{n} y_i^{\,2} - n\bar{y}^{\,2} \quad (6)$$

where $S_\mu^{\,2}$ = sample variance and y_i = individual score of difference in the number of understorey plant species in *Eucalyptus* and that of other plantation species.

Table 1 Comparison of understorey species between plantations of *Eucalyptus* and six common species

Altitude (m asl)	Rainfall (mm)	*Eucalyptus* spp.	Number of understorey species (μ_e)	Plantation spesies	Number of understorey species (μ_o)	y	y^2	Reference
1200–2200	600–900	*E. saligna*	27	*Pinus patula*	18	9	81	1
		E. globulus	19	*P. patula*	18	1	1	1
		E. saligna	27	*Cupressus lusitanica*	16	11	121	1
		E. globulus	19	*C. lusitanica*	16	3	9	1
		E. saligna	23	*P. patula*	21	2	4	2
		E. grandis	26	*C. lusitanica*	11	15	225	3
		E. globulus	24	*P. patula*	21	3	9	3
		E. saligna	23	*C. lusitanica*	11	12	144	3
		E. grandis	26	*P. patula*	21	5	25	3
		E. globulus	24	*C. lusitanica*	11	13	169	3
2200–2700	> 900	*E. globulus*	46	*C. lusitanica*	68	-22	484	4
		E. saligna	66	*P. patula*	49	17	289	4
		E. globulus	46	*P. patula*	49	-3	9	4
		E. saligna	66	*C. lusitanica*	68	-2	4	4
		E. saligna	63	*Cordia africana*	51	12	144	5
		E. saligna	63	*C. lusitanica*	28	35	1225	5
		E. saligna	63	*P. patula*	32	31	961	5
		E. globulus	30	*C. lusitanica*	10	20	400	6
		E. globulus	57	*C. lusitanica*	21	36	1296	7
		E. globulus	57	*Juniperus procera*	31	26	676	7
		E. globulus	57	*C. lusitanica*	21	36	1296	8
		E. globulus	57	*J. procera*	31	26	676	8
		E. robusta	20	*Casuarina equisetifolia*	9	11	121	9
		E. robusta	20	*Leucaena leucocephala*	20	0	0	9

Values are reported as means at $p \leq 0.005$ (student t-test); Reference 1 = Feyera et al.(2002), 2 = Kindu et al. (2006), 3 = Michelsen et al. (1996), 4 = Senbeta et al.(2002), 5 = Lemenih et al. (2004), 6 = Abiyu et al.(2011), 7 = Michelsen et al.(1993) and Lisanework and Michelsen (1994), 8 = Lisanework and Michelsen (1994) and Michelsen et al. (1993) and 9 = Parrotta (1995); y = difference in the number of understorey species in *Eucalyptus* plantations and that of other plantation species

RESULTS AND DISCUSSIONS

Understorey biodiversity under *Eucalyptus* and other plantation species

The understorey in the *Eucalyptus* plantation had on average 12.3 more species compared with that in the plantation of the rest of the species studied (Table 1). The calculated test value was 4.244 against $t_n - 0.005\alpha = 2.807$. Hence, the null hypothesis of equal or lower number of understorey species in *Eucalyptus* stands compared with the rest of the commonly used plantation species was rejected at the 0.005 significance level. At 2200–2700 m above sea level, the largest positive difference (36) in *Eucalyptus* was found between *E. globulus* and *Cupressus lusitanica* (Table 1). The largest negative difference (-22) was also found between these two species (Table 1). At 1200–2200 m above sea level, the largest difference in *Eucalyptus* was found between *E. grandis* and *C. lusitanica* (15), followed by *E. globulus* and *C. lusitanica* (13). The smallest difference was found between *E. globulus* and *Pinus patula* (1) and *E. saligna* and *P. patula* (2) (Table 1). This indicated that, at higher altitudes, species differences and diversity of understorey flora were generally larger compared with those at lower altitudes.

This comparison suggested that, generally, environmental conditions on the forest floor supported understorey establishment and growth in *Eucalyptus* plantations species, similar to the rest of the species in the study. These results are in contrast to findings stating that *Eucalyptus* species inhibit growth of understorey herbaceous and woody species (Basanta et al. 1989, Madeira et al. 1989). High rainfall reduces competition between trees and understorey plants for water and nutrients with low mobility. Allelopathic effects are reduced by leaching of toxic compounds (Michelsen et al. 1996). The choice of tree species may affect the number of understorey woody colonisation in terms of their attractiveness as roosting habitat for seed-dispersing birds and bats (Mitra & Sheldon 1993).

The difference in the number of understorey plant species between the *Eucalyptus* and the rest of the plantation species also varied depending on the location, indicating the importance of site conditions. The variation may also be attributed to the management systems employed, for example conifers are managed for timber production on long rotation while *Eucalyptus* is managed on shorter rotation. The nature of crown and extent of litter accumulation differ in the plantation stands. Coniferous stands produce thick crown and more litter accumulation than *Eucalyptus* that reduces germination and growth of understorey species. Species richness, density and growth characteristics of colonising woody species vary considerably between different plantation species, even among closely located stands (Fimbel & Fimbel 1996).

CONCLUSIONS

Results of this meta study indicated that the impact of *Eucalyptus* on the understorey plant diversity was more favourable compared with the rest of the commonly used plantation trees in the tropics and subtropics. Therefore, it could be concluded that the notion of fewer understorey species in *Eucalyptus* plantations was not generally applicable.

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