Does plant species composition vary beneath *Cinnamomum camphora* plantation trees, compared to natural forest in Amani Nature Reserve?

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Abstract

Plantations of introduced species can alter the species richness and composition of understorey plant communities relative to natural forest, by changing the biological and physical environment. In this study, the plant species beneath a *Cinnamomum camphora* plantation were compared with an adjacent natural forest. Species richness was lower in the *C. camphora* plantation than in natural forest. Samples from the two communities were 2.5 times more dissimilar than samples from within the same area. Climbers and ferns were significantly more abundant in natural forest than in the plantation. Potential reasons for species composition differences are discussed.

INTRODUCTION

There is increasing interest in the effects of introduced plant species on local and global species diversity (Sax and Gaines, 2003), and on ecological processes and ecosystem functioning (Richardson and van Wilgen, 2004; Standish et al., 2004). Trees in particular can alter their environment by affecting light and water availability, soil nutrient availability due to uptake, and by their inputs into soils through leaf litter and woody debris (Wardle, 2002). These alterations can then affect what other plant species are found in the community. Monospecific plantations of introduced species therefore have the potential to change the species richness and composition of understorey plant communities relative to natural or semi-natural intact forest, via their biological and physical effects on the environment.

Introduced tree species, particularly in plantations, can impact the regeneration of native tree species (Chapman and Chapman, 1996). In the East Usambaras, only the effects of *Maesopsis eminii* have been investigated in detail. However, many other species have been introduced into the area, including Japanese Camphor (*Cinnamomum camphora L.*) (Iversen, 1991). There has been little to no investigation of plant species richness and composition under *C. camphora* plantations. Thus, in this study, the plant species beneath a *C. camphora* plantation were compared with an adjacent natural forest block. Species richness was predicted to be less in the plantation than in natural forest. Plant communities were expected to be more dissimilar between plantation and

natural forest than within the same area of forest. In addition, canopy cover and thickness of leaf litter layer were measured, as they could be potential co-varying factors that may affect plant species richness and composition.

METHODS

Study Site

The *C. camphora* plantation surveyed was planted in 1904/05 as part of the Botanical Garden plantations established under German administration for experimental commercial use (East Usambara Catchment Forest Project, 1995). The plantation is situated on the Mbomole hill trail in Amani Nature Reserve at approximately 950 m altitude. Adjacent natural forest further up the trail was selected for comparison. The plantation is on a negligible slope, whereas the natural forest is on a steeper slope. About 50% of the *C. camphora* plantation is interplanted with *Melaleuca leucodendron* and *Podocarpus usambarensis*.

Sampling procedure

The understorey of the area was assessed using 10 randomly placed quadrats of 5 m x 5 m within the plantation and adjacent natural forest. Care was taken to ensure that all quadrats were at least 5m away from edges and each other. Most quadrats in the plantation fell within the monospecific areas of *C. camphora*. The species, life form and size of all plant individuals at ground and understorey level (below 10 m) were recorded. For tree species, individuals less than 1 m high were recorded as seedlings and those above 1 m as saplings. Trees were identified with assistance from Mr. A Mndolwa, and according to the guide to *Trees of Amani Nature Reserve* (Schulman et al., 1999). Percentage canopy cover was estimated using a densiometer, with the mean average of four measurements been taken for each quadrat. Thickness of leaf litter was also measured at five points in each quadrat and the mean was taken.

Analysis

Cumulative species richness curves were constructed to compare the accumulation and total species richness of quadrats in the plantation with those in natural forest. Differences in species composition between the two areas were assessed by randomly splitting the 10 quadrats of each site into two sets of five quadrats. The total abundance of each species in each set was then determined. Average Euclidean distances were then calculated between sets from the plantation and natural forest and between sets from within the same area for comparison (Krebs, 1999).

To investigate differences in life form abundance between the two sites, a two-way ANOVA was performed on percentage life form abundance per quadrat (as number of individuals). Plant individuals were categorised into the following life forms:

- Tree seedlings
- Tree saplings
- Shrubs
- Climbers/Lianas
- Herbs
- Graminoids

The data were arcsine square root transformed prior to analysis. Differences in leaf litter thickness and canopy cover between the two sites were analysed using a two sample t-test. Again percentage canopy cover data were arcsine square root transformed prior to analysis.

RESULTS

Species richness

Species richness was lower in the *C. camphora* plantation compared to natural forest and accumulated with sample size at a slower rate. The total number of species in all 10 quadrats was 58 for the plantation and 71 for the natural forest (Fig. 1).

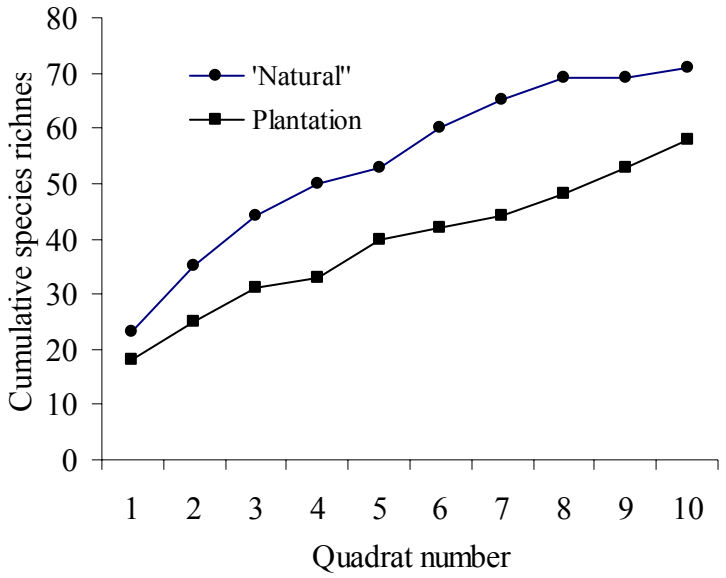

Figure 1. Cumulative species richness in *C. camphora* plantation and adjacent natural forest, with increasing sample size (n=1-10, quadrat area=25m^2).

Species composition

The average Euclidean distance ranged from 23.98 to 27.21 for comparisons between plantation and natural forest (Table 1). This distance was approximately 2.5 times greater than those for comparison within the same area (Table 1).

Table 1. Average Euclidean distances comparing plant species composition between two random sets of five quadrats per forest area (to 2 d.p.). Comparison: Plantation against plantation; natural against natural; and plantation against natural.

Comparison	Average Euclidean distance
Plantation a-Plantation a	10.65
Natural a-Natural b	9.57
Plantation a-Natural a	26.32
Plantation a-Natural b	23.98
Plantation b-Natural a	27.21
Plantation b-Natural b	25.25
Mean Plantation-Natural	25.69

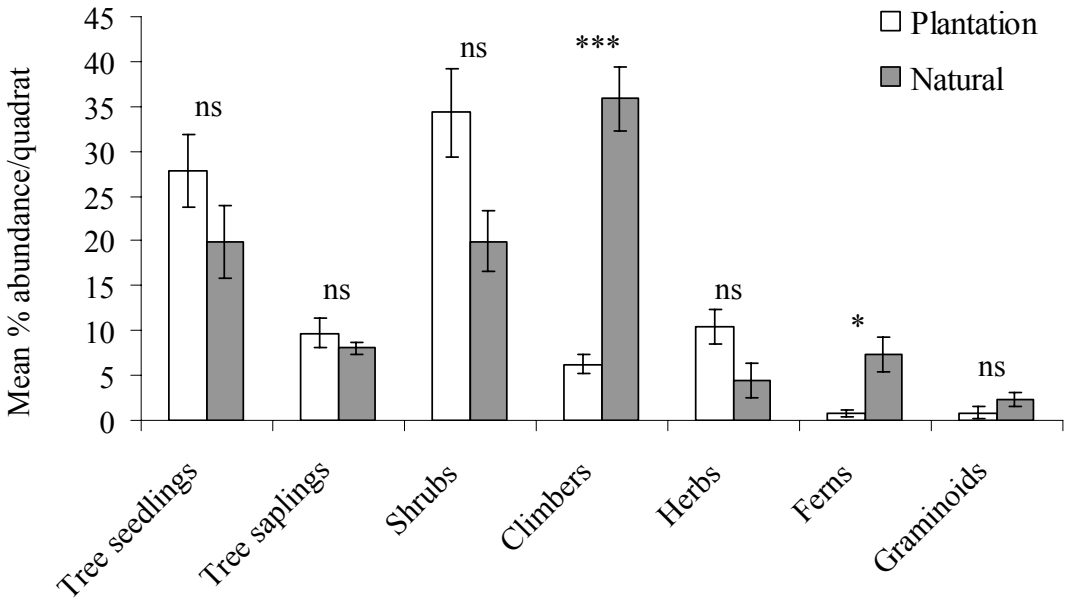

Figure 2. Comparison of mean percentage abundance of life forms (calculated as percentage of all individuals) in *C. camphora* plantation and natural forest. Results of two way ANOVA are indicated by; ns = non-significant result; * = significant ($0.01 \leq p \leq 0.05$); and *** = highly significant ($p < 0.001$). Errors bars are ± 1S.E.

There was a significant interaction between site and life-form abundance (F_{18}=14.86, p<0.001).This was largely explained by greater abundance of ferns and climbers in natural forest than the plantation, whereas other life-form abundances did not differ significantly between sites (Fig. 2).

Canopy cover and leaf litter layer

Leaf litter thickness was significantly less under the plantation quadrats compared to natural forest (Fig. 3a). Canopy cover was also significantly greater in natural forest quadrats compared to the *C. camphora* plantation (Fig. 3b).

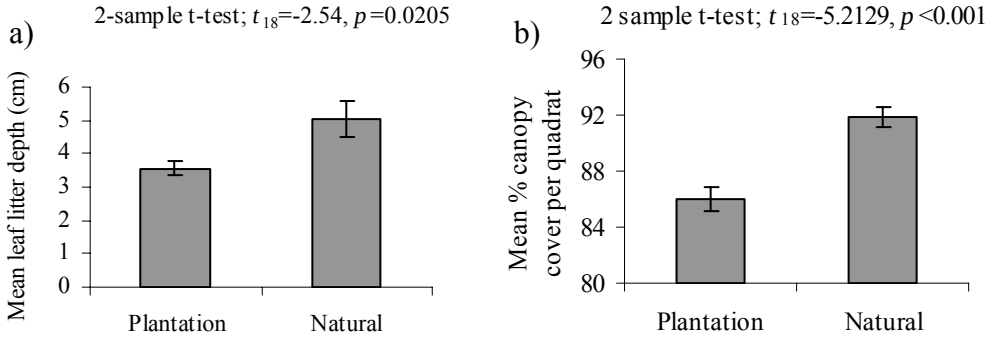

Figure 3. Physical properties of plantation and forest sites; a) comparison of mean leaf litter thickness, and b), comparison of mean percentage canopy cover per quadrat. Error bars are ± 1 S.E., two sample t-test results shown.

DISCUSSION

Plant species richness is lower under *C. camphora* plantations than in natural forest. Species composition also differs, potentially due to lower habitat heterogeneity. Growth of liana, climber and fern species may be more favoured by the higher shade of natural forest, but this is conjectural, and the finding here may not be causal. In addition, this result of greater climber abundance could be an artefact of greater *Culcasia orientalis* abundance in the natural forest than in the plantation. Apart from ferns and climbers, however, the abundances of other life forms were fairly comparable between the two sites.

Dissimilarity in species composition is greater between sites than within the same area of forest according to Euclidean distances. Therefore, species differ, but life forms generally stay the same between the two communities. This could be related to other plant traits, such as dispersal. In Kibale National Park, Uganda, Chapman and Chapman, (1996) found that tree species under plantations largely possessed animal-dispersed seeds. In a study on regeneration of native species under *Maesopsis eminii*, Viisteensaari et al. (2001) concluded that frugivorous birds and monkeys

were responsible for seed dispersal under *M. eminii* from outside areas. In this study, the most abundant tree species present in the plantation were *Allanblackia stuhlmanii*, *Maesopsis eminii, Parinari excelsa, C. camphora* and*, Cephalosphaera usambarensis,* (Appendix I). With the exception of *C. camphora*, and *Parinari excelsa*, the fruits of the above species are animal-dispersed (Schulman et al., 1999), which may explain their high abundance in the plantation despite the absence of adult trees. However, the gradient of slope was much greater in the natural forest than the plantation, which could have a confounding effect on plant species composition.

Plantations can impact on natural forest regeneration. In Kibale National Park, Chapman and Chapman (1996) found that species richness and regeneration were relatively high under plantations compared to neighbouring intact forest. Viisteensaari et al. (2000) concluded that primary forest species could regenerate well under stands of *M. eminii* in the East Usambaras. Seedlings and saplings of *Allanblackia stuhlmanii*, *Parinari excelsa,* and *Cephalosphaera usambarensis* have higher abundances in the plantation than the natural forest (Appendix I). This suggests that regeneration of native forest under *C. camphora* is possible, and recruitment may be facilitated by a lower canopy cover and thinner leaf litter layer. Another difference relating to leaf litter that may exist is in rates of decomposition, and nutrient cycling and availability. A thinner leaf litter layer beneath C. camphora could indicate faster decomposition rate compared to litter of natural forest, which would increase nutrient availability for seedling and sapling growth. However, leaf retention by *C. camphora* could be longer than for native trees.

Plantations of any species, whether native or introduced, could facilitate invasion by introduced plant species. In plantations, introduced species may be released from competition with plants better adapted to natural forest conditions. The actual act of disturbance during planting may have also facilitated establishment of exotics. Higher light levels and thinner leaf litter layers could allow higher germination and growth rates of light-demanding species. Further, differences in nutrient and water availability would favour an alternative suite of species to those in natural forest. In this study, more *Clidemia hirta*, *Maesopsis eminii* seedlings, *Psidium cattleainum*, and *C. camphora* were found under plantation than in natural forest (Appendix I). This suggests that *Psidium cattleianum* and *C. camphora* in particular, do not establish well in undisturbed, natural forest. No saplings of *M. eminii* and few of *C. camphora* were present in the plantation, suggesting that recruitment from seedlings is very low.

Species richness is very high for both sites, but accumulation curves have not yet reached saturation, which suggests that a greater sample size might be required in order to fully establish how plant

species richness differs between the two sites. Plantations also affect the suite of ground and understorey plant species found. The higher abundance of invasive species such as *Clidemia hirta* and *Psidium cattleainum* suggests that plantations can facilitate the establishment and spread of alien plants.

Acknowledgments

Many thanks to Mr. A. Mndolwa, for detailed assistance in plant species identification. Thanks also to R. Trevelyan and R. Jehle for helpful advice during project planning and write-up.

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Appendix I. List of species that constitute at least 1% of the total plant abundance in 10 quadrats in each site (abundance equals number of individuals).

		Plantation		Natural	
Species	**Life form**	**Abundance**	**% of all plants**	**Abundance**	**% of all plants**
Native					
Agalaea pentagyna	Climber	24	2.32	23	2.01
Alchornea hirtella	Shrub	0	0.00	14	1.22
Allanblackia stuhlmannii	Tree	22	2.13	2	0.17
Anisophyllea obtusifolia	Shrub	13	1.26	17	1.48
Bamboo 3	Graminoid	0	0.00	19	1.66
Blotiella hieronymii	Fern	1	0.10	13	1.14
Brucea tenuifolia	Shrub	11	1.06	2	0.17
Cephalosphaera usambarensis	Tree	64	6.18	12	1.05
Culcasia orientalis	Shrub	3	0.29	393	34.32
Cynometra sp.	Tree	0	0.00	80	6.99
Dracaena sp.	Shrub	0	0.00	35	3.06
Fern 1	Fern	0	0.00	67	5.85
Leptaspis cochleata	Graminoid	1	0.10	27	2.36
Memecylon cogniauxii	Shrub	26	2.51	14	1.22
Newtonia buchananii	Tree	15	1.45	69	6.03
Herb O	Herb	13	1.26	18	1.57
Parinari excelsa	Tree	20	1.93	10	0.87
Pavetta sp.	Shrub	1	0.10	7	0.61
Psychotria brevicaulis	Herb	80	7.73	40	3.49
Psychotria capensis	Shrub	19	1.84	20	1.75
Rinorea orientalis	Herb	21	2.03	16	1.40
Rourea albido-flaveolens	Climber	25	2.42	4	0.35
Rutidea orientalis	Climber	12	1.16	0	0.00
Schefflerodendron usambarensis	Tree	0	0.00	25	2.18
Trycalisia pallens	Tree	27	2.61	8	0.70
XXVI	-	11	1.06	0	0.00
Xymalos monospora	Tree	5	0.48	58	5.07
Introduced					
Cinnamomum camphora	Tree	144	13.91	0	0.00
Clidemia hirta	Shrub	229	22.13	89	7.77
Maesopsis eminii	Tree	87	8.41	43	3.76
Psidium cattleianum	Shrub	120	11.59	7	0.61