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Ground Vegetation Response to Fertilization in an *Azadirachta excelsa* Stand in Johore, Malaysia

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Abstract: The aim of this study is to investigate the effects of N additions (50, 100 and 150 kg ha^{-1}) on ground vegetation 12 months after field experimental establishment. The experiment consists of a control and three levels of N applications in four replicates. Nitrogen was provided as urea and all N treated plots were given 75 kg ha^{-1} of P. In each plot of 64 m^2, two systematically quadrats (2×2 m) were examined. All ground floras in the plot were identified and the percentage covered were estimated. Ground vegetation composition and species richness were not affected by N application. The cover of *Ageratum conyzoides* increased on fertilized plots while the cover of *Borreria latifolia* and *Asystasia intrusa* decreased. Results of this study showed that N addition could influence ground vegetation by improving nutrient availability in the tree stand thus changing light penetration to the forest floor.

Key words: *Azadirachta excelsa* plantation, ground vegetation, nitrogen fertilization, nutrient availability

INTRODUCTION

As natural forests decline rapidly, current wood production is depending greatly on plantations and area designated for forest plantation is rapidly increasing (FAO, 2005). Enhancing biodiversity especially flora in plantation systems as a part of sustainable forestry management is promoted by the United Nations Forum on Forests (UNEP, 2002) and the international certification process (Nussbaum and Simula, 2005). The occurrence of ground flora in plantations could be affected by management (Lindgren and Sullivan, 2001; Decocq *et al*., 2004), edaphic factors (Wallace and Good, 1995; Watkinson *et al*., 2001) and land-use history (Honnay *et al*., 2002; Chase, 2003). Life history of species and its dispersal attributes determined their colonization and persistence within a disturbed landscape (Tilman, 1988; Schippers *et al*., 2001).

Industrial forest plantations have been established extensively in Malaysia since 1980s, covering an estimated area of 500,000 ha and consisting mainly of *Acacia mangium*. Other species such as *Falcataria moluccana*, *Gmelina arborea*, *Eucalyptus* sp. and *Azadirachta excelsa* have also been planted. These plantations are characterised by low plant species diversity, as existing plants were eliminated during the site preparation and by the thicket stage, as dense shade becomes limiting (Wallace and Good, 1995; Ferris *et al*., 2000). The ability of ground vegetation to persist through the various stages of the management cycle and disperse can determine plant existence, even for a relatively short time.

Most sites available for establishment of forest plantation in Malaysia are characterised by high acidity, low Cation Exchange Capacity (CEC), low base saturation and high level of exchangeable Al (Tessens and Shamsuddin, 1983). The loss of nutrients and organic matter and physical degradation during harvesting and site preparation operations may create the need for mineral fertilizer additions to sustain rapid growth of plantations. Under repeated short rotations of fast-growing species, N and P are the two most important nutrient elements determining the productivity of most tropical plantations as base cations are important in highly acid soils (Fölster and Khanna, 1997). Many studies have assessed the effects of fertilization on the concentration of nutrients in the soil and plant, the nutrient fluxes, the crown condition and the tree growth (Laclau *et al*., 2008; Van Den Driessche *et al*., 2008).

The response of ground vegetation to fertilization has received less attention especially in the tropics although their contribution to the annual nutrients cycling is great (Rokenkirchen, 1995). Nitrogen addition at high doses caused changes in ground layer vegetation

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(Van Dobben *et al*., 1999; Nordin *et al*., 2005), with the strongest effect observed in the least fertile sites (Gilliam, 2006). In contrast, weak responses of forest floor species were observed when moderate rates of N were applied (Kellner and Redbo-Torstensson, 1995). Fertilization has often been found to cause a reduction in plant species diversity (Rajaniemi, 2002). Meanwhile, a decrease in plant species density of about 30% following addition of N in sites across a wide range of productivities has been reported by Gough *et al*. (2000). Rarer species were more likely to be lost than abundant species as productivity increased (Suding *et al*., 2005). Davis *et al*. (1993) found that species intolerant of competition tend to decrease after fertilization. Similarly, Rajaniemi (2002) and Rajaniemi *et al*. (2003) indicated that below-ground competition cause plant diversity to drop when plots are fertilized.

In Malaysia, fertilization studies mainly focused on improving tree growth while fewer studies focused on the effect of fertilizers on forest floor vegetation. As to further understand its effect thus this study was designed to determine whether N application affect the occurrence of established ground vegetation species in an *A. excelsa* stand.

MATERIALS AND METHODS

Azadirachta excelsa plantation is located in Kampung Usaha Jaya, Sungai Karas, 9 kilometer from Labis town (2°22'N, 130°3'E), Johore, Peninsular Malaysia. The average annual temperature varies from 25.0 to 26.9°C while the mean annual precipitation is 1,882 mm with mean humidity ranging from 83.0 to 88.6%. *Azadirachta excelsa* plantation is a third rotation stand after two rotations of rubber and was established in March 1998. The site is undulating with slopes ranging from 1 to 25 %. Trees were planted in a spacing of 2×2 m distance.

The experiment was set up in March 2001. The treatments consisted of a control and three different levels of N applications (50, 100 and 150 kg ha^{-1}) in four replicates. Nitrogen was provided in the form of urea and all N treated plots were also supplied with 75 kg ha^{-1} of P. These fertilizers were broadcasted between the rows of trees. Some physical and chemical properties of the soil in the plantation had been determined and reported by Ong *et al*. (2005) where the soil is of clay loam with low pH and exchangeable K and Mg. Meanwhile, the organic C, N and P are found to be moderate.

A year after application of fertilizer (March 2002), two systematically quadrats (2×2 m) were examined in each plot of 64 m^2. All ground floras within the plot were identified and the ground cover percentage was estimated for each species. All ground vegetation in the quadrat was harvested for biomass determination. Leaf Area Index (LAI) for the tree stand in each plot was measured using a LAI-2000 plant canopy analyzer (LI-COR Inc.). Diameters for all trees in the plot were measured at the beginning and the end of the experiment using a diameter tape. Soil samples and fresh leaves from the trees were also collected.

In each sampling site, soil sample was collected from the upper 10 cm soil layer. Samples were air-dried and sieved to a size of 2 mm before analysis. Young and fully expanded leaves were sampled from the upper level of the tree crowns. Foliar samples were ground after oven-drying (70°C, 48 h). Total N was determined using the Kjeldahl method (Forster, 1995), while available P was determined colorimetrically using the molybdenum-blue method on a Mehlich III extract (John, 1970).

Data on the ground flora was sorted out by plots, species and cover of the plants and the mean cover of different species was calculated. Data in the form of percentage was arcsine transformed before analysis. Species richness was determined by the number of species present in the plot. Shannon-Wiener Diversity Index was used to determine species diversity. The cover, species richness and species diversity were analysed using a one-way ANOVA at a 5% level of significance. The association between parameters was analyzed by the Pearson's correlation coefficient.

RESULTS AND DISCUSSION

No effect of treatments on the ground vegetation cover, vegetation biomass, species richness, species diversity, total soil N (soil N), available soil P concentration (soil P), foliar N, stand diameter increment and stand LAI were observed (Table 1). Only foliar P showed significant response to the treatment (Table 1). Although insignificant, fertilization application increased soil N, soil P, foliar N and LAI while reducing total covers of ground vegetation. This result is in contradiction with that of Dalling and Tanner (1995), Holmes (2001) and Rowe *et al*. (2006) where fertilization increased ground cover.

The lower total cover and biomass of ground vegetation in the treated plots (Table 1) suggests that some other environmental factors might have influenced the changes. These changes maybe related to LAI which influence light penetration to the forest floor (Sang *et al*., 2008). As trees increased in diameter growth, more leaves and branches developed and resulted in higher LAI ($r = 0.90$, $p<0.01$). Thus, the decrease of vegetation cover is more in line with an increase of shading (Table 2).

Table 1: Ground vegetation cover, biomass and richness, soil and foliar nutrients and stand leaf area index of *Azadirachta excelsa* stand.

Parameters	Control	50 kg ha^{-1} N	100 kg ha^{-1} N	150 kg ha^{-1} N
Species cover (%)	97.5 (2.7)	85.0 (4.3)	76.0 (2.2)	80.0 (6.6)
Ageratum conyzoides	40.0 (2.4)	65.0 (4.7)	55.0 (2.3)	55.0 (4.9)
Asystasia intrusa	30.0 (2.5)^a	5.0 (1.0)^b	5.0 (0.7)^b	2.5 (0.6)^b
Borreria latifolia	20.0 (1.2)	10.0 (1.4)	7.5 (1.4)	10.0 (1.3)
Centotheca lappacea	0.0	0.0	1.0 (0.3)	0.0
Cleome rutidosperma	5.0 (0.5)^a	0.0^b	2.5 (0.7)^a	7.5 (0.5)^a
Cyrtococcum accresceus	0.0^b	5.0 (0.9)^a	2.5 (0.4)^b	0.0^b
Phyllanthus amarus	0.0^b	0.0^b	0.0^b	2.5 (0.8)^a
Unidentified	2.5 (0.3)	0.0	2.5 (0.7)	2.5 (0.6)
Biomass (g)	42.2 (1.0)	37.2 (1.3)	30.2 (0.9)	33.3 (2.2)
Ageratum conyzoides	14.3 (0.8)	23.2 (1.3)	14.6 (0.8)	18.3 (1.5)
Asystasia intrusa	16.2 (1.1)^a	4.4 (0.5)^b	4.9 (0.4)^b	2.8 (0.3)^b
Borreria latifolia	9.1 (0.5)	6.4 (0.6)	5.5 (0.6)	6.8 (0.6)
Centotheca lappacea	0.0	0.0	0.7 (0.2)	0.0
Cleome rutidosperma	1.6 (0.2)^a	0.0^b	1.8 (0.2)^a	1.9 (0.2)^a
Cyrtococcum accresceus	0.0^b	2.2 (0.4)^a	1.0 (0.2)^b	0.0^b
Phyllanthus amarus	0.0^b	0.0^b	0.0^b	1.9 (0.3)^a
Unidentified	1.1 (0.2)	0.0	1.9 (0.3)	1.6 (0.3)
Species richness	4	3	5	4
Shannon-Wiener Diversity Index	1.2847	1.0592	1.4914	1.3393
Soil nutrient				
N (%)	0.16 (0.02)	0.22 (0.03)	0.28 (0.06)	0.23 (0.04)
P (mg kg^{-1})	2.56 (0.29)	12.66 (0.71)	26.04 (1.01)	10.24 (0.70)
Tree stand				
Foliar N (mg g^{-1})	15.4 (5.9)	18.4 (6.3)	19.6 (6.0)	25.7 (11.2)
Foliar P (mg g^{-1})	1.4 (0.4)^b	1.7 (0.4)^b	2.0 (0.4)^b	3.2 (0.4)^a
Diameter increment (cm)	0.98 (0.32)	1.06 (0.34)	1.09 (0.36)	1.16 (0.30)
Leaf area index	0.46 (0.02)	0.64 (0.05)	0.82 (0.02)	0.80 (0.06)

Note: Values in parentheses indicate SE. Means with different superscripts differ significantly ($p<0.05$)

Table 2: Pearson correlations between soil nutrient content and stand leaf area index with ground vegetation cover, biomass and species richness

Ground vegetation	Nitrogen	Phosphorus	Leaf area index
Cover	-0.6303	-0.6681	-0.7196*
Biomass	-0.5002	-0.6386	-0.8193*
Species richness	0.4004	0.4660	0.2963

*$p<0.05$

Similar observation was reported by Köchy and Bråkenhielm (2008) in southern Sweden although it was found that increase in shading was not followed by a significant increase of tree basal area.

In the present study, plant species richness, diversity and total biomass were not affected by fertilization (Table 1). This result differed to that of Siemann (1998) and Rowe *et al.* (2006) who found that addition of N significantly increased aboveground plant biomass and total ground cover respectively but not species richness. In contrast, Gough *et al.* (2000) found that addition of N increased aboveground net primary productivity but decreased species richness in seven different ecosystems.

A total of eight species were identified in all treatments (Table 1). The three most common species observed in the plots were *Ageratum conyzoides, Borreria latifolia* and *Asystasia intrusa*. These species were also commonly found in other plantations in Malaysia such as oil palm and rubber (Dahlan *et al.*, 1993; Chee and Ahmad, 1990a). Three other species namely *Phyllanthus amarus*, *Centotheca lappacea* and *Cyrtococcuni accrescens* were only found in the N treated plots.

In the present study, the impacts of fertilizer addition on the percentage cover and biomass of individual flora species were inconsistent. Only *A. conyzoides* area cover and biomass showed some insignificant increment due to the fertilization with 50 kg ha^{-1} N but the area cover and biomass decreased with higher N application (Table 1). This is consistent with the results of Rowe *et al.* (2006), who found that only four out of eight species increased in coverage as a result of fertilization in birch and willow stands in north Wales. The increase of the light demanding *A. conyzoides* (Dahlan *et al.*, 1993) cover suggests that higher N and P availabilities might have partially compensated for the reduction in growth due to shading. The increased level of N application might have increased N mineralisation and/or processes which might have induced plant nutrient uptake (Gobran *et al.*, 1993).

The coverage of both *A. intrusa* and *B. latifolia* were reduced in N treated plots (Table 1). The significant decrease of the shade-tolerant *A. intrusa* (Chong *et al.*, 1990; Dahlan *et al.*, 1993) in the present study may be due to the direct effect of increased fertilization dosage. Apparently, *A. intrusa* could not tolerate higher N addition rates. Furthermore, competition for space in N added plots with *A. conyzoides* might have also contributed to the reduction of *A. intrusa* cover. Ng (1990) found that dry matter yield of *A. intrusa* in rubber plantation in Malaysia was reduced due to cutting pressure.

The reduction of *B. latifolia* cover could be due to the reduction in light penetration as LAI increases ($r = -0.87$, $p<0.01$) with increasing level of N application. Dahlan *et al.* (1993) found that the composition of broad leaves plants such as *B. latifolia* decreased under low light penetration to the forest floor of oil palm stand. Similarly, Chee and Ahmad (1990b) only found *B. latifolia* on 3 to 5 year old rubber plantations than in the older plantations. Chee and Ahmad (1990a) noted that low yield of *B. latifolia* under a 6 to 10 year old rubber plantation was due to the closure of the canopy which reduce light penetration to the forest floor.

Ground flora do not compete much with trees as indicated by a reduction of coverage even though the application of N increased. Increase in LAI and reduction of ground vegetation coverage would enable more nutrients to be cycle via the trees. In summary, the trade-off between the positive impact of increased nutrients availability and the negative impact of increased competition for light, water and other nutrients from the greater growth of the trees as shown by increased in LAI may probably caused lack of significant impact of N addition on the ground vegetation species.

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