SOIL NUTRIENT AVAILABILITY AND COMPETITIVE PERFORMANCE OF SEVEN PIONEER SPECIES

HARDY SEMUI

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Abstract

The competitive and physiological growth performance of seven pioneer species was evaluated in the nursery of Universiti Malaysia Sarawak. In contrast to the single plant plots, each species in the competition stands were arranged in hexagonal arrays with each individual seedling surrounded by 6 equidistant neighbors. Nutrient treatment was administered to evaluate its importance to species growth performance in the experiment. Mortality was higher in the competition stands compared to the single plant plots. The total biomass, relative growth rate, height and diameter of Melastoma was higher compared to the other six species suggested nutrient is not limited to this species. The LMR were significantly different among species in different nutrient treatment in single and competitive stands. The leaf area of the species in competition stands differed among nutrient treatments in contrast to the single plant plots. The competitive interaction of the plant in the competitive stands affected the leaf area for photosynthesis of the species. Low NAR affect photosynthesis rate that decrease growth performance of the plant species. Resulted in lower biomass were observed in the competition stands. The NAR of all the species were higher in the single plant plots compared to the competition stands. The competitive effect of the species affected the RGR and LMR that contribute to the low NAR. Melastoma has the highest photosynthesis rates, biomass production, phosphorus use efficiency, lower ZNGI which conclude that Melastoma was the best competitors compared to the other species. The combination of nitrogen and phosphorus nutrient treatment suggested a better biomass growth for all species. Generally, the experiment concluded that the competitive ability of the pioneer species ranked from the weakest to the strongest are Ficus, Trema, Duabanga, Nauclea, Dillenia, Vitex and Melastoma. The understanding of the relationships among the physiological, whole plant allocation patterns and demographic characteristics of different species is essential to understand the distribution pattern of the plants species in the natural habitat.
Abstrak

Chapter One

Introduction

Tropical rain forests are the most species rich and complex terrestrial ecosystems in the world. The forests provide several important ecological functions including maintenance of hydrological and nutrient cycles, support of food chains, regulation of heat and energy balance, and carbon storage. However, the landscape of tropical rain forest is changing due to extensive human intervention, such as ranching, agriculture plantation and shifting cultivation. Mature forest on a large scale is being converted to early successional forest dominated by fast growing pioneer species. Like many of the tropical rainforest, the forest of Sarawak has been subjected to many disturbances from human activities. According to Bruenig (1993), Sarawak has a total of 8.7 million ha of forest area and it is declining by the rate of 60 000 ha annually as a result of shifting cultivation and logging. Pioneer species have invaded these secondary forest sites and now dominate the regrowing forests. Irrespective of the causes and the intensity of change, forest ecosystems are often naturally able to recover most of their attributes through natural succession (Bazzaz, 1996). Tropical secondary forests have a rapid turnover of floristic composition (Whitmore, 1984). In the long term, this successional forest may be replaced by mature forest dominated by climax species. Studies of forest succession will play a major role in ecosystem preservation, management, rehabilitation, and restoration (Bazzaz, 1996).

Early successional or secondary forest consists mainly of pioneer species. Pioneer species often have seeds with long dormancy buried in the soil. Seed germination may be enhanced by light quantity and/or quality, by temperature fluctuations, or by physical disturbance at the soil surface. Most pioneer species have epigeal germination and photosynthetic cotyledons. Pioneer species also typically
have high leaf nitrogen concentrations. Most pioneer species have continuous leaf production fast leaf turnover rates, leaves arranged in flat crowns without multiple layers, early reproductive maturity, high fecundity, and high growth and mortality rates (Bazzaz, 1991). A combination of some or all of these traits may enable a species to successfully colonize open microsites. Pioneer species can be divided into different categories depending on the time that they appear in succession, early successional species (e.g., Melastoma sp., Trema sp., Nauclea sp.), and middle or later successional species which have larger mature stem diameters and live longer in secondary forest (e.g., Duabanga sp. and Ficus sp.).

Secondary forests appear to accumulate woody plant species at a rapid rate but the mechanisms driving succession are complex and poorly understood. Site age, climate and soil properties all have a strong influence on patterns of succession (Brown and Lugo, 1990). Early successional communities differ in structure and floristic composition depending on various site features. In Sarawak, disturbed habitats, which have an open canopy and degraded soil, may initially be colonized by species such as, Dicranopteris linearis, Macaranga sp., Mallotus, Melastoma and Dillenia. Colonization by early successional species will affect nutrient availability in the soil and light levels in these sites. Tilman (1982) explains succession in terms of resource ratios, especially between nitrogen and light. Secondary forest species respond rapidly to changes in resource levels (Bazzaz, 1991).

In successional forests on soil of low nutrient content and high light levels, pioneer species tend to have small leathery, long-lived leaves (Chapin, 1980, Vitousek, 1982). The root systems of pioneer species tolerant of low soil nutrients often have high root:shoot ratios (Crawley, 1986). Nutrient use efficiency is expected to be higher in low nutrient environments due to the overall lower availability of soil
nutrients. Higher nutrient use efficiency may involve a lower rate of loss of nutrients from live foliage, and reabsorption of a large proportion of foliar nutrients prior to leaf fall (Vitousek, 1984).

A range of soil factors influence species composition in the forest including P availability, Al toxicity, drainage, water holding capacity and availability of K, Ca and Mg (Sollins, 1998). Secondary forest biomass growth in the tropics appears to respond more to P than other elements because P is generally more deficient in tropical soil (Sollins, 1998). Nitrogen availability may also be a constraint on productivity at tropical montane sites. Soil pH influences Al toxicity and cation availability, especially below a pH of 5.3. A strong relationship has been found between pH and various plant processes (Sollins, 1998). Soil chemical factors have a strong influence on species composition. Ashton and Hall (1992), found that a guild of fast-growing tree species is more common on higher P- and cation-rich soils than on soil of lower nutrient status. The distribution of primary forest species, including the Dipterocapaceae, has been shown to be strongly influenced by variation in soil fertility (Ashton and Hall, 1992, Davies and Becker, 1996).

Competitive interactions among plant species may affect the species composition within forests (Silvertown and Doust, 1993). Forest composition and structure are influenced by resource availability and the ability of the plant species to capture these resources. Competition for limiting resources may strongly influence succession from early open forest communities to mature tropical rain forest. Competitive interactions among pioneer species in early succession may have a significant impact on the rate of regeneration and the floristic composition of early successional forest. The importance of plant competition has been illustrated in a wide range of other plant communities but rarely has the importance of competition been

The possible role of plant competition and their effect of competitive interactions among seven pioneer species in early successional rain forest communities in Sarawak was investigated in this study. Study on the growth performance of pioneer species is numerous but study of pioneer species in Sarawak is lacking and is essential due to many degraded lands left after shifting cultivation. The competitive and physiological growth performance of tropical pioneer species in relation to nutrient availability is essential in the understanding of basic plant growth. The response of different plant species variation in a wide range of environmental factors contributes to species diversity, composition and species dominance among plant communities. Colonization by the tropical pioneer species and the process of succession merits further investigation as to enhance our knowledge on basic plant biology.

It is hypothesize that performance of individual pioneer species is influenced by interactions with other plant species in the community. This experiment hypothesizes that the outcome of competitive interactions in the community will depend on soil nutrient availability and the competitiveness of each plant species. To test these hypotheses, single plants and mixtures of seven pioneer species were grown in four nutrient treatments: nitrogen alone, nitrogen and phosphorus, phosphorus alone and without nutrient application. The following specific questions were addressed by the experiment:-
1) Do pioneer species differ in competitive ability in different nutrient treatments?

2) Did the outcome of the competition change under different nutrient treatments?

3) Does nutrient availability affect overall biomass growth in the competitive stands?

4) Which species performed better in the different nutrient treatments?

5) Which nutrient had the most significant influence on the growth of the seven pioneer species?
Chapter Two

Literature Review

2.0 Introduction

The growth of forest trees depends on environmental factors such as soil nutrient availability, soil moisture, light levels, and carbon dioxide which vary spatially in forest communities (Bazzaz, 1996). Other factors influencing plant growth include the plant’s genetic identity, plant-plant interactions, pathogens and insect herbivores. The response of different plant species to variation in a wide range of environmental factors contributes to species diversity, species composition and species dominance among plant communities (Tilman, 1986). The interactions among species are mediated through resources in the environment.

Plant-plant interactions for resources consist of intra- and inter-species interactions. Individual organisms interact most strongly with neighboring organisms rather than with more distant organisms (Pacala and Silander, 1990). Although larger individuals might be expected to have stronger interactions than smaller individuals of any given species. The effect of interactions among organisms is not always negative, however some competitive interactions are negative interactions. Neighborhood interactions involve a change in resource availability for a neighbor leading to direct or indirect competitive interactions. Direct competition is an interaction between immediate neighbors. Indirect competition results from other species in the same tropic level changing the shared pool of nutrient resources. A positive interaction between species is facilitation, and a negative interaction causes either mortality of neighbors or a decrease of neighbor biomass.

Competitive neighborhoods may differ in patterns of resource acquisition. Neighborhood competitiveness is classified into symmetrical, size-symmetrical and
asymmetrical (Bazzaz, 1996). Symmetrical interactions in neighboring plants occur when the plants have equal influence on each other regardless of their size, architecture or physiological characteristics. In size-symmetrical interactions, plants are influenced by the size of their neighbors. Resource acquisition of a plant occurs in proportion to their biomass or size (Thomas and Weiner, 1989). Asymmetric competition occurs when there is an unequal competitive effect by a species on its neighbors (Keddy, 1989). In asymmetrical interactions, the larger individual acquires a disproportionately large amount of resource relative to its size (Weiner, 1990). In tropical rainforest, sun-loving species will compete for light in the forest. Asymmetric interactions among species for light enables a species to become dominant in a community. The tallest plants acquire more light and become strongly dominant in the competitive hierarchy (Keddy and Shipley, 1989, Wilson and Keddy, 1986).

2.1 Pioneer Plant Species

The pioneer plant species for this competition experiment are commonly found in fallow areas following shifting cultivation and in abandoned open areas with high light availability. These pioneer species can be found throughout Borneo. The fruits of Vitex, Dillenia, Trema, Melastoma and Ficus are eaten by small mammals and birds which disperse the seeds. The seeds of Duabanga and Nauclea are extremely small and light, and are dispersed by wind.

Vitex pubescens Vahl. (Verbenaceae) is known as Kepapa or Leban in Sarawak. This species is a common tree of secondary forest and is often found at the edge of forest reserves or in the thickets that border rice-fields or road-sides. This genus is medium-sized tree of up to 24 m tall and 120 cm girth (Corner, 1988, Kochummen, 1978). Kochummen & Ng (1977) found that the number of Vitex
individuals decreased from 124 to 10 individuals over in 29 years of forest succession in Kepong. *Vitex* is a relatively long-lived pioneer species.

*Duabanga moluccana* Blume (Sonneratiaceae) is known locally as Sawih. It is found in Java, Borneo, Sulawesi, the Moluccas and New Guinea. In Sabah and Sarawak, it is widely distributed up to 750 m above sea level, on fertile clay-rich soils. It is found in high-light intensity areas such as river banks, forest edges, logged over forest, road sides, abandoned cultivation sites and also on limestone hills. This species is able to live for more than 50 years (Ashton, 1988, Othman, 1995). It is a long-lived late successional species.

*Dillenia suffruticosa* (Griff.) Martelli (Dilleniaceae) is known as Simpoh or Buan or Da’un Kayo’ Urip (Kayan) in Sarawak. The local people use the leaves of this species to wrap rice. This pioneer species is found in forest edges and belukar. It is very common in swampy ground and one of the most conspicuous pioneer species in abandoned lowland areas of Sarawak (Corner, 1988, Kochummen, 1983).

*Nauclea maingayi* Hk. (Rubiaceae) is known locally as Empitap. It is very common along roadsides throughout Sarawak. This pioneer species is found in swampy ground or well-drained clay soils. The mature seeds persist in the ground until the area is opened by forest clearing. The species has large leaves, which is a common feature of species that invade open areas. Some areas may be dominated by this species especially in mid- to later successional stages.

*Trema cannabina* Lour. (Ulmaceae) is known locally as Murieng (Bidayuh) and Kereneong (Iban). *Trema* is a pioneer shrub or medium-sized tree common in the lowlands and hills from sea level to 1500 m in newly cleared areas, young secondary vegetation, and in all types of soil, including limestone (Soepadmo and Edi Hamli, 1996). This species is very widespread, occurring in Myanmar, Thailand, Indo-
China, China, and throughout Malesia to Australia. In the study of Kochummen (1966), *Trema* sp. increased in numbers followed by a rapid decline in frequency during forest succession in an abandoned farm in Peninsular Malaysia. A tree inventory conducted in an abandoned farm in 1947 and 1949 in Peninsular Malaysia, found that *Trema* died out within two years of establishment of successional forest (Kochummen and Ng, 1977). *Trema* is relatively a short-lived pioneer species compared to the other species.

*Melastoma malabathricum* Linn. (Melastomataceae) is known locally as Kemunting or Senduduk. This species is very common in open areas throughout Malaysia especially in the lowlands. It may be found in the forest, at the edge of streams and in open areas on various types of soil. Individual plants flower continuously once they reach reproductive maturity (Corner, 1988). In the study of Kochummen and Ng (1977) the abundance of *Melastoma* decreased from 2652 individuals to 2 individuals from 1947 to 1976 as the successional forest matured.

*Ficus grossularioides* Burm.f. (Moraceae) is known locally as pokok Ara. All *Ficus* species are protected in Sarawak as their fruits are eaten by small mammals and birds. This species is a very common small tree that can be found at the edge of the forest. The seeds of this species germinate freely in shade (Raich and Gong, 1990) but this species establishes in open micro-sites and is common in secondary forest (Grubb, 1996; Sim et al., 1992).

2.2 Competitive Effect and Response

In the context of exploitation competition, the competitive effect of plants can be mechanistically defined as the influence of plants in a neighborhood on resource