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Germination dynamics and inter-specific competition between A. lebbeck (L.) Benth. and A. Saman (F.Muell.) at the seedling stage

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DECLARATION

I, Md. Nazmul Hossain, hereby declares that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree, except where due acknowledgement had been made in the text.

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Dedication

Dedicated

To

My beloved Family

Acknowledgements

All praises are due to almighty Allah who has enabled me to complete this thesis paper.

Many people helped me in reaching this thesis paper in final shape. All of them cannot be mentioned on this page, if more omitted than explicitly written here, let, all take thanks. Firstly, it is a great opportunity for me to express my heartiest gratitude to my honorable teacher and supervisor Md. Sharif Hasan Limon, Associate Professor, Forestry and Wood Technology Discipline, Khulna University, Khulna, for his regular supervision, continuous guidance and suggestion, advice during the nursery work and preparation of my thesis work. Secondly, I would like to express my solemn gratefulness to my beloved parents, who brought me to this earth. Special thanks for their suggestion, cooperation and encouragement for my thesis work and finally help me to finish the work to lead it in completion. I am really grateful to my other two thesis mates Bristi Jhara Biplob and Tama Ray for helping me cordially during nursery work.

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Abstract

A. saman and *A. lebbeck* are two common species of Bangladesh and found both in forest and plantation Intra and interspecific interactions are common when two or more species are grown together. Interaction may be positive (facilitation) or negative (competition). Competition is considered an important factor in structuring plant communities and start at the early stage of a plant life. Competition at the seedling stage is important because seedlings appear to be more sensitive to competition than adult plants. *A. saman* and *A. lebbeck* seedlings were studied at different density mixtures (*A. saman%*: *A. lebbeck%* = 100:0, 75:25, 50:50 and 25:75, 0:100) in a RCBD. Germination indices and height growth were investigated. The study showed significant variation ($p<0.05$) in germination between two species. No significant variation ($p>0.05$) was observed either at species or mixture level in the case of height growth. *A. saman* at its lowest density mixture showed a significant mortality among the mixtures, but no significant variation between species. These two species have different strategies to avoid competition at seedling stage.

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Chapter One: Introduction

1.1 Background of the study

Albizia lebbeck and *Albizia saman* are two common species grow in Bangladesh and found in both natural forest and plantation. Both of the species are from the same genus and have allelopathic effect and affect negatively on the growth and survival of the neighboring species (Noor and Khan, 1994; Parvin *et al.*, 2011; Ghosh *et al.*, 2013). Sometimes these species are grown together and with other species. When two or more species grow together, they affect each other due induced resource completion (Sewia, 1998).

Competition is a very common interaction among the plants and it is very exceptional to find a plant that is not affected by its neighboring plants (Weiner, 1991). Competition among the plant communities indicates that the supply of light, water, or nutrients to plants is reduced by the coexistence of neighbors and the proximity of plants to plants of either the same or different species (Harper, 1977; Tilman, 1982). At the developmental state, competition for the recourses, light and space does not take place between all plants in a population, rather competition occurs among the plants immediately surrounding the individual (Harper, 1977; Antonovics & Levin, 1980; Florentine & Fox, 2003). Plants competitive capability can be evaluated between species in two different ways; in their competitive effect or capability to restrain other individuals and in their competitive response or capacity to keep away from being suppressed (Goldberg & Werner, 1983). So, the information on interspecific competition of two species grown together is vital for planning and managing both natural and plantation forest.

Competition is an important factor in structuring plant communities (Tilman 1988; Grime 2001). However, ecologists find that it's hard to predict accurately about the outcome of competitive interactions in many plant communities (Connell, 1983; Connor and Simberloff, 1979; Gilpin and Diamond, 1984). Competition takes place not only within the species but also within and between stages of different species when plants go through various physiological stages as their development progresses (Connell, 1983; Schoener, 1983; Cameron *et al.*, 2007). Competition starts and affects from the very beginning of a plant's life. Seedling growth, initial root shoot ratio, emergence even germination may be particularly sensitive to competition (Foster & Gross, 1997, 1998; Foster, 1999). It is more important to investigate the compete potentiality of the seedling stage of a species because it was seen that seedlings appear to be more susceptible to competition than adult plants (Foster, 1999; Nash-Suding & Goldberg, 1999) and intra- and interspecies competition at the seedling stage is significant in formatting the structure of the succeeding plant community (Segelquist *et al.*, 1993; Stromberg, 1997). Even though some other studies indicated that competition is relatively rare at the very early stage of plant life, but it may have impacts in determining the final biomass of the plants (Goldberg *et al.*, 2001).

Small variations in growth rate and size between species at the early stage can potentially determine long-term developmental patterns. Because, is assumable that if any plant can dominate at the early stage it will keep dominating throughout its life as it will be capable of taking more recourse (light, water and nutrient) and space. So, investigation starting from germination and specially growth and survival at seedling stage is important for interspecific competition.

1.2 Objectives

1. To study the germination pattern of *A. saman* and *A. lebbeck.*

2. To study the inter-specific completion between *A. saman* and *A. lebbeck* through survival and growth at seedling stage.

Chapter Two: Literature review

2.1 Seed germination

Through the germination process, seeds develop into plants. It is the starting of plant life. International Seed Testing Association (ISTA) defined germination as the emergence and development of the seedling to a phase where the feature of its necessary structures denotes whether or not it is capable to develop further into a satisfactory plant under suitable conditions in the soil. Bewley and Black (1994) defined germination as "germination includes those facts that start with up taking of moisture by the inactive dry seed along with ending with the expansion of the embryonic axis. The penetration of the structures surrounding the embryo by the radical is called as visible germination which is the visible sign that germination is completed. The following events, including the recruitment of the main storage reserves are connected with the seedling growth. Practically, all of the metabolic and cellular events also happen in imbibed dormant seeds that are known to occur before the completion of germination of non-dormant seeds. Further metabolic activities are regularly only delicately varied from those of the previous. Hence, practically, all the metabolic steps needed to complete germination are achieved by a dormant seed (Bewley, 1997).

2.1.1 Factors affecting seed germination

Germination and emergence are the two main significant phases in plants' life cycle, which determine the optimum utilization of the water and nutrient recourses obtainable to plants as well as can vie for an ecological niche (Gan *et al.*, 1996; Forcella *et al.*, 2000). Light, temperature and moisture are the main environmental factors which affect seed germination (Martins *et al.*, 2000; Canossa *et al.*, 2008; Ikeda *et al.*, 2008; Rizzardi *et al.*, 2009). Along with these factors, seed size, pH, seed viability and dormancy, and planting depth also affect seed germination (Lu *et al.*, 2006; Norsworthy & Oliveira, 2006).

2.1.1.1 Temperature and Light

Many individual reactions and phases are involved with the complex germination process and each of which is affected by temperature. Germination is regulated by temperature in three ways i.e. (i) it determines the capacity and rate of germination, (ii) remove the primary and/or secondary dormancy, and (iii) induces the secondary dormancy. Both the capacity for germination and the rate of germination are affected by the temperature. In terms of cardinal temperature, the consequences of germination can be expressed. That means maximum, minimum and optimum temperatures at which germination will take place (Bewley & Black, 1994).

Sometimes, it is difficult to define the minimum temperature as germination is continuing but such a sluggish rate that confirmation of germination is frequently made before actual germination is finished. The temperature, which gives the maximum percentage of germination in the shortest period of time is defined as the optimum germination temperature (Bewley & Black, 1994).The maximum and the optimum temperature for most of the seeds are 30-40°C and 15-30°C respectively. Germination has a cardinal temperature in its each stage and due to the intricacy of germination the temperature response may change during the germination period (McDonald, 1998).

Andrade (1995) mentioned that among many factors, temperature and light are the two important factors play significant roles in promoting germination in soil with sufficient water availability. With modulating germination of non dormant seed's temperature may also determine the number of dormant seeds in population (Benech- Arnold & Sánchez, 1995). In arid environments, alternating temperatures may alternate the essentiality of light for seed germination (Benítez-Rodrígues *et al.*, 2004). Germination may be induced by the fluctuation of temperature in the dark and the fluctuation may have influence on producing phytochrome (Pons, 2000; Probert, 2000). According to Smith (1975), in light sensitive seeds the phytochrome is accountable for germination.

2.1.1.2 Water

Water is a basic prerequisite for seed germination seed germination. Again, it is necessary for enzyme activation, breakdown, translocation and use of reserve storage material. Usually, seeds contain less moisture content and comparatively metabolically inactive in their inactive state. It indicates they are in a state of quiescence. Consequently, quiescent seeds are capable of maintaining a minimum level of metabolic activity which confirms their long lasting survival in the soil and at the time of storage. Imbibation is an important requirement of seed germination when a dry seed goes into the soil. The adjacent water potential and the resistance to movement of water in the soil may govern the extent and rate. Hegarty (1978) showed that the air dried seed's water potential is very low (less than 100 Mpa). As a result, there is no shortage of driving potential and some seeds are capable of germinating in soil at beneath the permanent wilting point (Doneen & MacGillivray, 1943; Manohar & Heydecker, 1964).

Both the rate and percentage of germination and emergence can be reduced by water stress. There is a wide response range among the species, i.e., from resistance to very sensitive. Resistance seeds get an advantage, i.e., they can easily establish plants in areas in which drought sensitive seeds cannot do so. Water stress is often used in the laboratory and sometimes in horticulture to delay germination ((Bewley & Black, 1994).

2.1.1.3 Seed size

Plant life can be affected by the size of the seeds in various ways. For example, seed size influences the water relations and seed dispersal and emergence, germination, establishment, survival and growth of seedlings (Milberg & Lamont 1997). Large seeds have a larger amount of reserves to encourage germination, growth and seedling survival (Milberg & Lamont 1997).

2.1.1.4 Genetic variability

Several Indian dry tropical species such as *Albizia lebbeck* (Rao, 1985), *Prosopis cineraria* (Arya *et al.*, 1995), *Acacia nilotica* (Krishnan & Toky 1995) and *Lagerstroemia parviflora* (Prasad *et al.*, 1988) vary in germination percentage and seedling growth rate among the provinces. Some characteristics which indicate the amount of seed reserve (i.e., pod length and seed weight) also varied among the prominence in *Albizia lebbeck* (Kumar & Toky 1993), *Tecomellaun dulata* (Arya *et al.*, 1993), *Acacia mangium* (Salazar, 1989) and *Prunella vulgaris* (Bagchi & Dobriyal, 1990). Seeds of *Albizia lebbeck* from Cochin and Madurai, compared to those from other places had the amount greatest carbohydrate content which amplified the seedling survival and growth under stress from frost and drought, (Kumar & Toky 1994).

2.1.1.5 Oxygen and Carbon Dioxide

According to McDonald (1998), Seeds require oxygen for its germinating metabolism. If the seed contains oxygen concentration less than in air then it may delay the seed germination of most of the species with a few exception, i.e, seeds of aquatic plants (i.e, *Typha latifolia*) are actually inhibited by air. High carbon dioxide concentrations (e.g., 4%) can prevent germination of several species (e.g., CapseUa bursa-pastoris). Low concentrations of oxygen affect germination adversely are rarely found in the terrestrial habitat. The air in the soil, for example, contains about 19% oxygen and no more than 1% carbon dioxide; the latter is not likely to inhibit germination (Bewley & Black, 1994).

2.2 Factors affecting Seedling growth and survival

2.2.1 Water

Excess or shortage of water can affect the seedling growth and survival (Kozlowski *et al*., 1991). It is important to maintain the drainage system where the rainfall is medium to high as water logging conduction can reduce growth and increase mortality of the plants as a result of oxygen deficit in the root zone (Davis & Langer, 1994; Kozlowski *et al.*, 1991). Water logging can also guide to the death of roots as a result of increased Phytophthora fungi activity (Kozlowski *et al.*, 1991). Seedlings are comparatively more susceptible to water stress than adult plants and seedling grows with much slower rate when the soil moisture goes below the field capacity (Zahner in Kozlowski *et al.*, 1991). If the soil's water potential is below about -1500kPa then plants generally become permanently wilted (McLaren & Cameron, 1993). So, it is better to plant in winter or autumn to overcome the possibility of water stress (Porteous, 1993).

2.2.2 Soil Nutrients

Shortage of vital nutrients adversely affects plant growth and survival; this can be developed by the eased application of fertilizers (During, 1980; Kozlowski *et al.*, 1991; McLaren & Cameron, 1993). The influence of various levels of essential nutrients in soils has been widely investigated on economically important species growth and survival. Species vary significantly in their capability to absorb essential nutrients and in their tolerance of limited supplies of essential nutrients (Kozlowski *et al.*, 1991).

In India, due to nitrogen application, the Increase in the growth of tree seedlings have been reported for most species observed, including, *Populus ciliate* (Deol & Khosla, 1983), *Eucalyptus tereticornis*, *Eucalyptuscamaldulensis*, *Eucalyptus grandis* and *Eucalyptus citriodora* (Prasad & Rawat, 1994), *Acacia mollisima* (Rao, 1985), *Acacia catechu* (Prasad & Rawat, 1992), *Bauhinia variegata* (Koul *et al*., 1995) and *Leucaenaleucocephala* (Sivasupiramanium *et al.*, 1988). Rachmawali *et al*., (1996) reported urea induced increases in most of the growth variables in the seedling stage of some Indonesian species, such as *Albizia lebbeck*, *A. procera*, *Dalbergia latifolia* and *A. sinensis*. Though, the amount of nitrogen application for increasing the seedling growth has a limit. For example, sorted dosages of N increased the biomass of *Eucalyptus tereticornis* seedlings from control to 100 ppm N per pot and thereafter the biomass decreased with further application of the N level (Prasad & Rawat 1994). An incompatible effect of N at higher dosages may also cause the lesser uptake of P and K by the seedlings (Koul*et al*. 1995).

2.2.3 pH

Water culture experiments have revealed that plants can tolerate a varied range of pH. However, there are secondary effects in soil that can impede plant growth and survival, i.e. nutrients may be unavailable or toxic chemicals are released into the soil solution (Bradshaw and Chadwick, 1980; Russel, 1988). Optimal pH levels for plants fluctuate between and within species (Bradshaw & Chadwick, 1980; McLaren & Cameron, 1993).

Aluminium and manganese when become soluble then can have toxic effects below pH 4 to 5 (McLaren & Cameron, 1993). Micronutrients become very soluble and may be toxic when adequate amounts are present at low pH (McLaren & Cameron, 1993). For plants, iron, manganese and boron become tough to absorb and phosphorus becomes unavailable above nearly pH 8 (Bradshaw & Chadwick, 1980). By applying lime in soil, acidity can be reduced (During, 1980); but excess alkalinity can be decreased by applying nutrients in soil (Bradshaw & Chadwick, 1980).

There are so many species which need acidic pH for their growth; on the other hand, there are also some plant species which are intolerant of soil acidity. In some cases, the toxic properties of aluminium ions are responsible for this because of soil hydrolytic acidity (Lima de & Copeland, 1990, Samuels *et al.*, 1997, Deska & Jankowski, 2001, Alamgir & Sufia 2009). Though, sometimes the presence of H+ ions has a negative effect on plant development only (Slootmaker, 1974; Mayer & Poljakoff-Mayber, 1989; Carver & Ownby, 1995; Jankowski *et al.*, 2000).

Marschner (1991) shown that it is possible to grow in acid soil for some plant species, but seed germination should be germinated in lower acidic environment. The availability of macro and micro elements which is necessary for plant growth also affected by soil pH (Kabata-Pendias and Pendias 1999). This signifies generally to initial stages of plant development, i.e. seed germination and seedling development (Mayer & Poljakoff-Mayber, 1989, Carver and Ownby, 1995, Jankowski*et al.*, 2000).

Primary development stages of some species are enhanced by acid soil pH. These happen to the plants having thick seed coats (Turner *et al.*, 1988; Vleeshouwers*et al.*, 1995; Yost, 2000). The effect of acid pH may be direct, revealing itself in dissolving of the seed coat. Sometimes the effect is indirect, which includes stimulating conditions for the development of fungi of some species whose action creates perforation in the seed coats (Vleeshouwers *et al.*, 1995).

2.2.4 Ambient CO_2

Seedling growth is affected strongly by doubling up the concentration of CO2 as well as its associated procedure (Eamus & Jarvis, 1989; Ceulmans & Mousseau, 1994). Different psychological process of plants like plant growth, water use efficiency and photosysnthesis etc are being changed due to the elevation of CO2 (Johnson & Major 1998; Drake *et al.*, 1997).

2.2.5 Soil Physical Factors

There are some soil physical distinctiveness that have an effect on the growth and survival of plant. They affect on moisture and root penetration, aeration and drainage (Glinski & Lipiec, 1990). These physical characteristics can be determined through measuring hydraulic conductivity, aeration and bulk density of the soil. There is a measurement when bulk density exceeds 1.7 to 1.8 glcm3 in a heavy soil or 1.5 to 1.6 glcm3 in a light soil, roots will enter a soil rarely (Russel, 1988; and Bowen in Glinski & Lipiec, 1990). So, plants grown in mechanically impeding soil possess lower nutrient uptake, water uptake, reduced root size, and vesicular arbuscularmycorrhizacolonization; but in case of assimilation of root, lateral branching, oxygen per unit of roots, and root thickness is increased (Glinski & Lipiec, 1990). Poor aeration means air filled in porosity is less than 10% which limits the growth of plants (Glinski and Stepeniewski in Glinski & Lipiec, 1990; Vomicil & Flocker in Resinger *et at.*,1988).

2.2.6 Seed Size

Seed size is very important in plant life as it is responsible for plant growth and survival. Young seedlings grown from large seeded species take nutrients for their establishment and survival. Early seedlings originated from cotyledons grow more than from the soil. As, nutrient uptake from the soil is very important early seedling growth, small seeded species with small cotyledons grew poorly in nutrient deficient soil. If any disturbance happens during regeneration, small seed size will be produced. Seedlings of *Terminaliaivorensis* and *Albizia saman* originated from larger seeds showed enhanced performance on growth than that of from smaller seeds (Oni & Bada, 1992).

2.2.7 Competition

Competition has a great influence on plants. It is almost impossible to find a plant which has never affected in a negative way by its neighboring plants. There is a lot of research work on competition between populations and individuals, but in the nature the role of it still a mystery.

Different ecologists consider competition in different meaning. Plant growth, survival as well as their competition occurs not only within species, but also between and within of different species. So, they have to pass different physiological stages in their lives (Connell 1983; Schoener 1983; Cameron *et al.*, 2007).

Plants have different stages sensitive to competition in their growth lives, particularly germination, root and shoot development stages (Foster & Gross 1997, 1998; Foster 1999). Adult seedlings are more sensitive to competition than small seedlings (Foster1999; Suding & Goldberg 1999).

In order to discuss interactions between plants a terminology was developed (Harper, 1977). It helps to explain the relations between plants. Plants interact with nearby individuals only because they are sessile. Neighbor effects refer to all the effects of plants do on one another and it is the sum of numerous positive and negative interactions where negative effect is referred to as interference.

Negative effects of neighboring plants include:

i. Discharging harmful chemicals (allelopathy)
ii. Scarcity of light, water or mineral nutrients
iii. Epidemic disease or other hazards (e.g. grazing) susceptibility
iv. Susceptibility to lodging
v. Decreasing pollinators availability
vi. Changing capability of the environment in order to provide particular triggering system (e.g. for breaking dormancy).

Positive effects of neighbors include:

i. Epidemic disease,grazing, wind or lodging protection
ii. An over-abundant resources reduction that is very harmful
iii. Availability of specific resources(e.g. Nitrogen-fixing symbionts who provide nitrogen may become available to neighbors) increment

2.2.7.1 **Competition within populations**

Positive effects may be significant in particular situations, but neighboring plants usually compete in a negative way. Most of the time, it happens due to resource limitation and utilization. That's why, competitive interactions are centered for most of the cases.

In single species populations the study of competition in plants starts with the analysis of density dependence. Actually, three possible reactions of a plant have been found to interfere (Harper, 1977).

A plant may:

1) Die or fail to germinate and develop while retaining viability

2) Grow and survive to a certain level or for a certain time because of limitation of the environment and it also includes its neighbors

There are different types of experiment. Among them, a density/yield experiment is very important. Regeneration rate can be decreased as well as death rate of plant's parts like leaves, buds or branches can be increased due to competition. Competition also decreases the rate of growth. If one plant grows in high densities, it will grow in low densities after a certain time if it exists. In this case, yield increases in a linear way with density at low yield continuum. But smaller increment in yield will be occurred if the density is higher (Weiner, 1991).

Many studies have been developed to show the relation between mean plant size and density as well as density and total yield within a crop population. The relationship between density and yield has also been developed (Willey and Heath. 1969). One of them is "reciprocal yield" relationship that is widely applicable (Bleasdale & Nelder, 1960; Holliday, 1960).

Now, Reciprocal yield $1/w=ad+b$

Here, w is the mean yield per plant,

d is the density and

a and b are constants.

Another formulation has been developed by Vandermeer(1984):

$$w = w_m / (1+cd^{-e})$$

w is the mean yield of isolated plants,

c is a measurement of competition that includes its intensity and the area within which it operates, and

e is a measurement of the rate where the effect of competition decays when function of the density is occurred between plants.

2.2.7.2 **Interspecific competition**

In many ways, Interspecific competition is similar to competition within a species. All plants have the same general requirements. So, neighboring plant's effect can be determined by its size than by its species (Goldberg and Werner, 1983). The modeling of interspecific competition is more problematic while the analysis and qualification of intraspecific interference at the population level is relatively successful. So, analysis is complex in case of more than one species because of the performance of each component as they are influenced by the density of both components (Weiner, 1991).

Chapter three: Materials and Methods

3.1 Site chatracteristics

The study was conducted at the forest nursery of Khulna University, Khulna (22.81°N 89.56°E). Khulna is influenced by tropical climate and characterized by hot summer, a distinct rainy season and short winter. The average annual temperature in Khulna is 26.1°C. The average annual rainfall is 1736mm.

(https://www.meteoblue.com/en/weather/forecast/modelclimate/khulna_bangladesh_1336135)

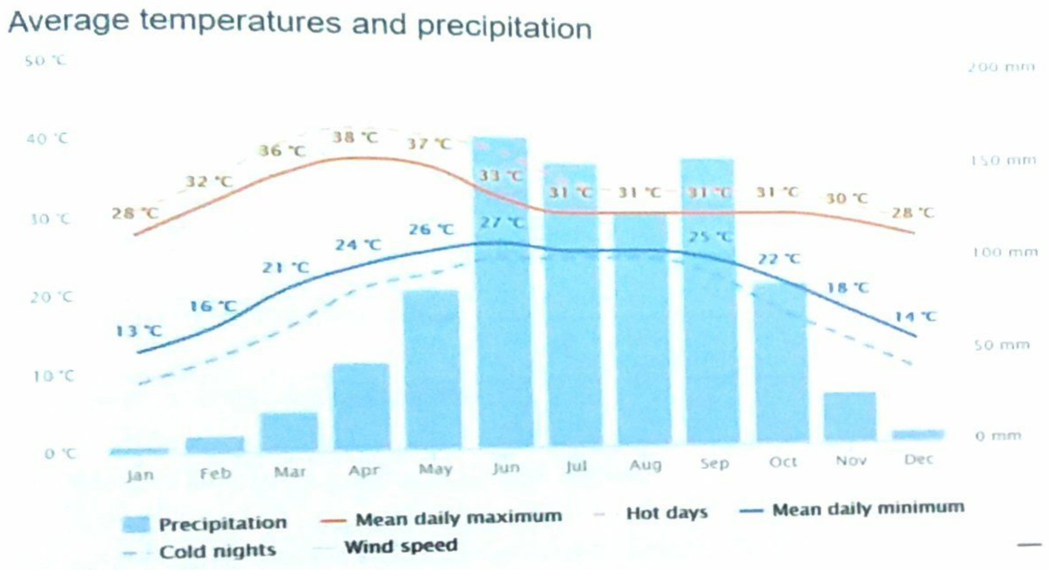

Fig 3.1: Climatic map of Khulna (https://www.meteoblue.com/en/weather/forecast/modelclimate/khulna_bangladesh_133613)

3.2 Seed collection

Seed pods of both *Albizia lebbeck* and *Albizia saman* were collected from Khulna University campus in February, 2016. The pods were collected directly by climbing the tree and by shaking the branches. The mother trees of *Albizia lebbeck* and *Albizia saman* were straight bole, well formed, healthy and spreading crown.

3.4 Seed preparation and storing

Proper seed extraction, preparation and storage are very important for germination and growth experiment in a controlled environment. After collecting the pods from the trees, seeds were extracted from pods gently. After separation, the seeds were washed with flowing water and dried in the open sun. After drying the seeds were stored at room temperature until sowing.

3.5 Experimental Design

The experiment was carried out using the Randomized Complete Block Design (RCBD) to measure the species mixture effect on germination, survival and growth of *Albizia lebbeck* and *Albizia saman* at seedling stage. For each treatment three replications were used. For germination and growth test, three treatments were used.

Treatment one: 75% *Albizia saman* and 25% *Albizia lebbeck*

Treatment two: 50% *Albizia saman* and 50% *Albizia lebbeck*

Treatment three*:* 25% *Albizia saman* and 75% *Albizia lebbeck*

Control condition:

Control one: 100% *Albizia saman*

Control two: 100% *Albizia lebbeck*

3.6. Nursery bed preparation and seed sowing

The experimental lay out was Randomised Complete Block Design. At first, about 20''x12'' nursery bed was prepared. Then the bed was devided into 3 large blocks and each block contains five 4'x2'' sub plot. The controls (100% of *Albizia saman* and *Albizia lebbeck)* and treatments with *Albizia saman* and *Albizia lebbeck* in ratios of 75:25, 50:50 and 25:75 (i.e., 75% *Albizia saman* and 25% *Albizia lebbeck* seeds, 50% *Albizia saman* and 50% *Albizia lebbeck* seeds, 25% A. saman and 75% *Albizia lebbeck* seeds) were distributed all over the blocks randomly. Seeds were soaked into water for 24 hours before sowing.

3.7 Sampling and measutement

3.7.1 Gerermination Measurement

The number of germinated seeds were recorded everyday. The start and end was recorded. Different parameters of of germination were calculated in this experiemnt like germination percentage, germination speed, mean germination time, mean daily germination, peak value and germination value using the folowing methods.

Germination percentage= $\frac{\text{Number of germinated seeds}}{\text{Total Number number of seed planted}}$x100

Speed of germination= n1/d1+n2/d2+n3/d3+----------

Where, n = number of germinated seeds, d= number of days

Mean germination Time (MGT) = n1xd1 + n2xd2 + n3xd3 + --------/ Total number of days

Where, n= number of germinated seed; d = number of days

Mean daily germination (MDG) = Total number of germinated seeds/ Total number of days

Peak Value (PV) = Highest seed germinated/ Number of days

Germination Value (GV) = Mean daily germination*Peak Value

Relative Germination Ration = $\frac{\text{Germination percentage of test plant}}{\text{Germination percentage of control}}$X100

3.7.2 Inter-specific competition

Inter-specific competition between the species was measured by comparing the growth and survivability of the seedlings when they were grown in monoculture and mixture.

3.7.2.1 Height measurement

After completing germination the seedlings were selected randomly to measre the growth of the seedlng. Growth, in this case was height as it is commonly considered as good indicator of growth and competition at seedling stage. 30 seedlings from each plot were selected to study survival and growth. Height measurement was taken in cm at every 15 days interval.

3.7.2.2 Survivability

Survivability of the seedlings was measured by counting the number of seedlings at the end of the experiment.

3.9 Data analysis

Data were organised in Microsoft Excel. After that, data were tested using Two Way Anova by SPSS (trail version) to find whether the value of the data of the treatments are significanly different. Graphs were prepared using microsoft excel.

Chapter Four: Result and Discussion

4.1 Germination

Germination indices like Germination Percentage (GP), Germination Speed (GS), Mean Germination Time (MGT), Mean Daily Germination (MDG) and Peak Value (PV) and Germination Value (GV) were determined in the study. The Germination percentage (GP) for *Albizia saman* and *Albizia lebbeck* were observed as 70% and 54% respectively. Germination for *A. saman* was found higher than the value (42%) found by Alamgir and Hossain (2005). Germination percentage of *A. lebbeck* was also found higher than the value (41%) found by Azad *et al.*, (2006). The higher value of germination percentage in this study could be attributed to season of sowing, seed sources and seed bed environment (Maguire, 1962; Shaw *et al.*, 1994). Germination percentages for *A. saman* and *A. lebbeck* were significantly ($p<0.05$) different from each other. *A. lebbeck* had significantly lower ($p<0.05$) GS, MGT, and MDG than *A. saman* (Table 4.2). Poor germination percentage (<50%) was also reported by different authors (Azad *et al*, 2006; Tripathi, 1987).

Table 4.1: Different germination indices *of A. saman* and *A. lebbeck*

Species	Germination Percentage	Germination Speed	Mean Germination Time	Mean Daily Germination	Peak Value	Germination Value
A. saman	70%	7.20	43.70	3.93	1.65	6.743
A. lebbeck	54%	3.85	33.92	2.15	0.64	1.42

Table 4.2: One Way ANOVA for germination indices for *A. saman* and *A. lebbeck*

Sources		Sum of Squares	df	Mean Square	F	Sig.
Germination Percentage	Between Groups	504.167	1	504.167	21.763	.010*
	Within Groups	92.667	4	23.167		
	Total	596.833	5			
Germination Speed	Between Groups	20.291	1	20.291	33.982	.004*
	Within Groups	2.388	4	.597		
	Total	22.680	5			
Mean Germination Time	Between Groups	146.450	1	146.450	13.677	.021*
	Within Groups	42.832	4	10.708		
	Total	189.282	5			
Mean Daily Germination	Between Groups	4.953	1	4.953	32.111	.005*
	Within Groups	.617	4	.154		
	Total	5.570	5			
Peak Value	Between Groups	1.928	1	1.928	6.985	.057
	Within Groups	1.104	4	.276		
	Total	3.032	5			
Germination Value	Between Groups	52.374	1	52.374	7.712	.050
	Within Groups	27.165	4	6.791		
	Total	79.539	5			

Initiation of germination was different for *A. saman* and *A. lebbeck*. *A. saman* started germination at the 3rd day of seed sowing and was completed within 22 days (Fig .4.2). On the other hand *A. lebbeck* started germination at 6th day and completed its germination within 26th days. However, Azad *et al.* (2006) found start of germination for *A. lebbeck* at 4th day and germination period was 18 days which is shorter than this study. On the other hand, *A. saman* started its germination at day 2 and continued upto 18 days, the result corresponds to the findings of Smith *et al.* (2002). *A. saman* completed most of its germination in between 7th to 15th days of seed sowing but in case of *A. lebbeck*, germination continued without any certain peak value in comparison to *A. saman* to the last day of germination. Early germination and early peak value of germination increases competitive fitness of a species for resource acquisition which is evident for *A. saman* in this study (Seiwa, 1998).

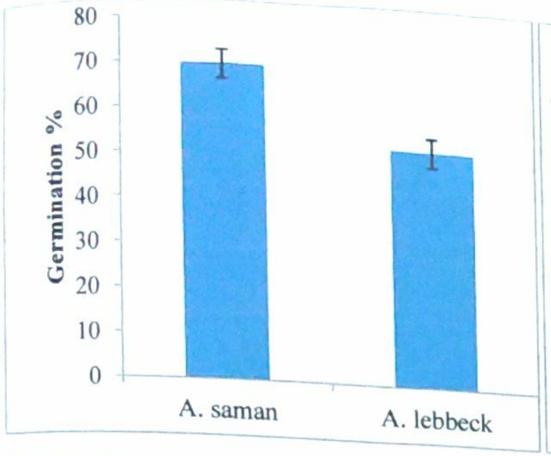

Fig 4.1: Germination percentage

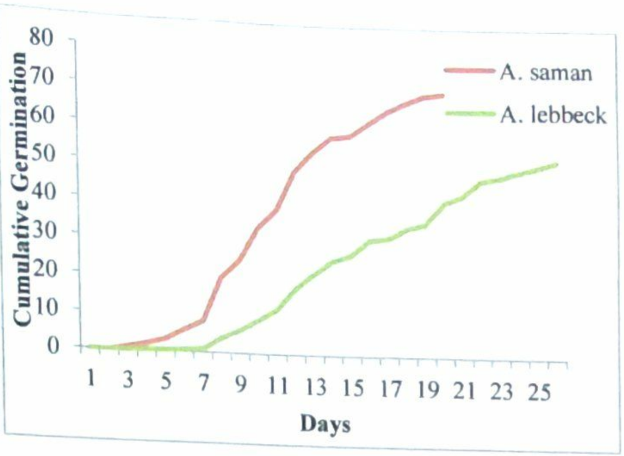

Fig 4.2: Cumulative Germination

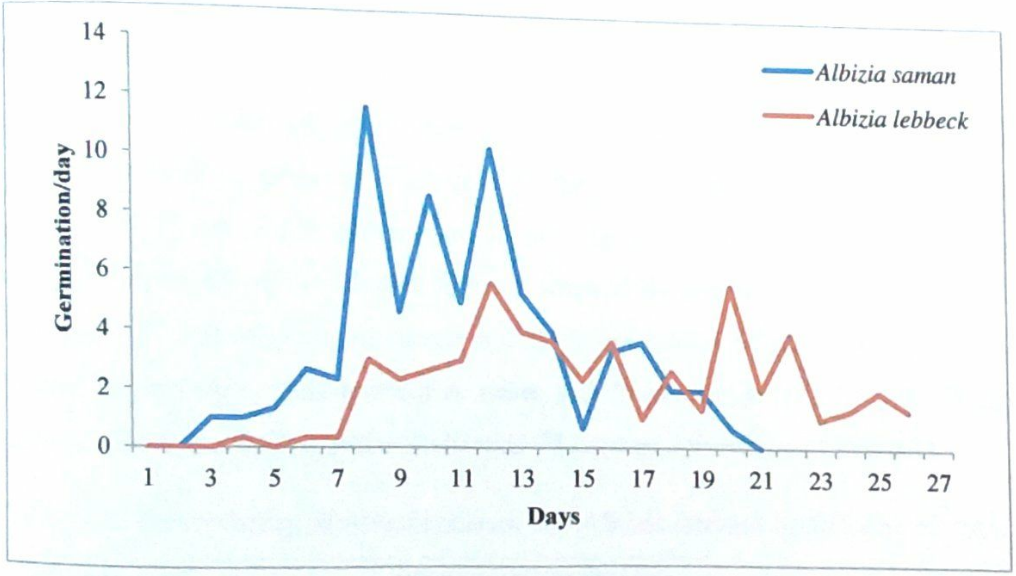

Fig. 4.3: Daily germination of *A. saman* and *A. lebbeck*

Relative germination ratio was measured to detect inhibitory tendency of species against germination. However, no significant variation (p>0.05) was found between treatment and species. Though, *A. saman* and *A. lebbeck* are known to possess allelochemicals in seed coat and seed, they did not affected germination each other significantly in this study (Noor and Azmal, 1994; Anjum *et al.*, 2010 Ghosh *et al.*, 2013).

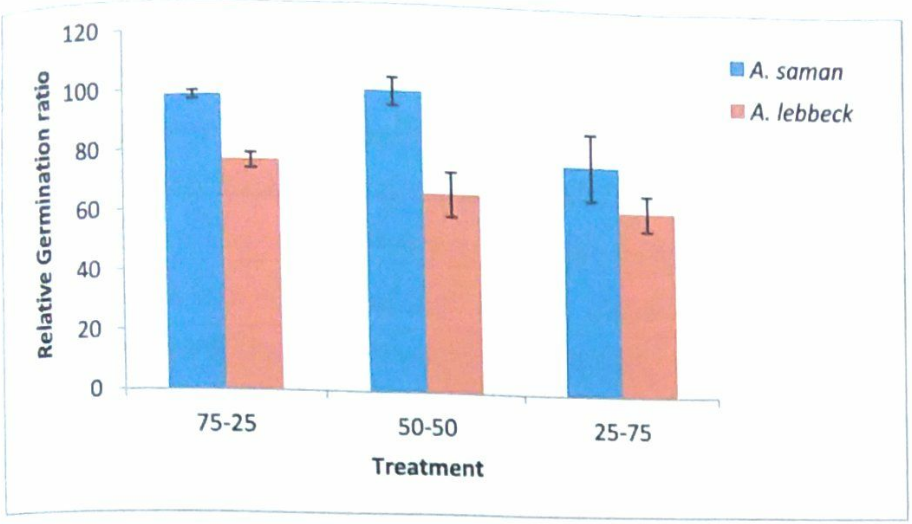

Fig. 4.4: Relative Germination Ratio for *A. saman* and *A. lebbeck* grown at different mixture

4.2 Survivability

High survival percentage was found in control. *A. saman* had 95 percent survivability and *A. lebbeck* showed 92 percent. Survivability decreased when these two species were grown in mixture. At 75 percent *A. saman* and 25 percent *A. lebbeck* (75:25) mixture, *A. saman* showed survivability of 93 percent and A lebbeck showed 81 percent, at 50% *A. saman* and 50 percent *A.lebbeck* (50:50) mixture, *A. saman* and *A. lebbeck* showed survivability of 91 percent and 79 percent respectively, at 25 percent *A. sman* and 75 percent *A. lebbeck* (25:75) mixture *A. saman* showed 78 percent and *A. lebbeck* showed 78 percent survivality (Table 4.3).

Table 4.3: survivability of *Albizia Saman* and *Albizia lebbeck* in different mixture

Treatments	Survival percentage (%)
Albizia Saman 100%	95
Albizia lebbeck 100%	92
Albizia saman 75%	93
Albizia lebbeck 75%	78
Albizia saman 50%	91
Albizia lebbeck 50%	79
Albizia saman 25%	78
Albizia lebbeck 25%	81

Significant variation ($p<0.05$) was found for survival in case of treatment (Table 4.4). Here, it is observed that 25:75 mixture that is *A. saman*: *A. lebbeck* is significantly different from control indicating survivability of *A. saman* is affected by density. Density in mixture always influence survival rate of a species (Wang and Smith, 2002) Mortality of *A. lebbeck* seedlings increased when it was grown in combination with *A. saman*. Early germination ensures early establishment which increases competitive ability of a species (Sewia, 1998). In this case *A. saman* might have enjoyed the benefit of early germination and establishment.

Table 4.4: Two Way ANOVA for the seedling survival

Source	SS	DF	MS	F	P
Treatment	768.306	3	256.102	3.689	.034
Species	265.535	1	265.535	3.825	.068
Treatment * Species	176.716	3	58.905	.848	.488
Error	1110.858	16	69.429		
Total	180936.548	24			

Table 4.5: Multiple Comparisons for survival of *A. saman* and *A. lebbeck* seedlings

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
100:0	75:25	6.5083	4.81070	.195	-3.6899	16.7066
	50:50	8.2917	4.81070	.104	-1.9066	18.4899
	25:75	15.8850*	4.81070	.005	5.6868	26.0832
75:25	100:0	-6.5083	4.81070	.195	-16.7066	3.6899
	50:50	1.7833	4.81070	.716	-8.4149	11.9816
	25:75	9.3767	4.81070	.069	-.8216	19.5749
50:50	100:0	-8.2917	4.81070	.104	-18.4899	1.9066
	75:25	-1.7833	4.81070	.716	-11.9816	8.4149
	25:75	7.5933	4.81070	.134	-2.6049	17.7916
25:75	100:0	-15.8850*	4.81070	.005	-26.0832	-5.6868
	75:25	-9.3767	4.81070	.069	-19.5749	.8216
	50:50	-7.5933	4.81070	.134	-17.7916	2.6049

Based on observed means.
The error term is Mean Square (Error) = 69.429.
*. The mean difference is significant at the .05 level.

4.2 Growth

Height was considered as growth describing parameter in this study. No significant ($p<0.05$) variation was observed between treatments and species (Table 4.6). Mean height growth for *A. saman* was found as , 42 cm , 47 cm, 49 cm and 50 cm, and for *A. lebbeck* 51 cm, 53 cm, 53 cm , 49 cm at control, 75:25, 50:50 and 25:75 mixture respectively. Though *A. saman* and *A. lebbeck* belongs to same genus and family, they might have different strategies towards growing environment to avoid competition (Khurana and Singh, 2001). Moreover, the study period was too short to find any competitive exclusion.

Table 4.6: Two Way ANOVA for the height growth

Source	DF	SS	MS	F	P
Species	1	3.670	3.6699	0.08	0.784
Treatment	3	112.079	37.3596	0.79	0.515
Interaction	3	66.225	22.0752	0.47	0.708
Error	16	752.117	47.0073		
Total	33	934.091			

Chapter five: Conclusion and Recommendation

5.1 Conclusion

A. saman and *A. lebbeck* do not show any competitive attitude. They probably follow different strategies to avoid competition atleast to stage the study carried out and factors remain unchanged. However, *A. saman* has low survivability when the share of *A. saman* goes down to 25%.

5.2 Recommendations

1. The investigation should be carried out at least upto sapling stage.
2. Number of replication should be increased
3. More factors like, soil, light and water should be incorporated.

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