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Seed Germination and Seedling Growth Performance of *Terminalia arjuna* (Roxb.) at Nursery Stage

MS THESIS

BY

Samir Kumar Mondol

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This project thesis has been prepared and submitted to the Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh for the partial fulfillment of professional degree of MS in Forestry .

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DECLARATION

I, hereby, declare that this project thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Khulna University or other institutions.

Samir Mondol

(Samir Kumar Mondol)

Dedicated
To My
Beloved Parents

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ABSTRACT

Terminalia arjuna (Roxb.) is an important medicinal tree species in the Asian countries. Large scale planting program for the species is often difficult due to its limited seed germination capacity and longer germination period in the natural conditions. The study describes various pre-sowing treatments attributed to the seed germination and seedling growth of *T. arjuna* at nursery stage in Bangladesh. The study was conducted in the nursery of Forestry and Wood Technology Discipline, Khulna University, Khulna over a period of eight months. A total of 1200 seeds were subjected to four treatments e.g. control (T_1), 24 hours soaking in normal water (T_2), 48 hours soaking in normal water (T_3) and soaking in 65-70^{0}C hot water for 5 minutes(T_4). Seeds were sown in polybags. External morphology of seeds was studied. The average length and diameter of the seeds were 4.69cm and 2.61cm respectively. The effects of different treatments on seed germination and seedling growth performance were explored. Seed germination started 10 days after sowing and continued up to 34 days. The fastest seed germination and highest germination percentage (77.33%) was observed in T_3 and delayed germination with lowest percentage was in T_1 (45.33%). There was significant difference in seed germination of all the treatments. The highest height growth, diameter growth and leaf formation were also found in T_3 (105.3cm, 11.55 mm and 55.7 respectively. The lowest height growth and leaf formation were observed in T_1 (90.76cm and 50.63 respectively); while the lowest diameter growth was observed in T_2 (8.48mm). The treatment T_4 also showed good growth performance which was always near about the treatment T_3. There were observed significant difference for height growth and diameter growth, but no significant difference was observed for leaf number. There were observed highly strong positive correlations among height growth, diameter growth and leaf formation of the four treatments. On the other hand, the seedlings showed sharp growth during June-August and showed poor growth during later period (September-November). Therefore, pre-sowing treatment, seeds soaking in normal water for 48 hours (T_3) was more effective in germination and production of quality seedling of *T. arjuna* in the nursery. This findings provide important information for genetic resource conservation for future research.

CHAPTER ONE: INTRODUCTION

1.1: General description of the species

Terminalia arjuna (Roxb.) is a deciduous large-sized fluted tree to 30 m tall and 2-2.5 m dbh, with an often buttressed trunk. Its superficial, shallow root system spreads radially along stream banks. The large, spreading crown produces drooping branches. Bark grey or pinkish-green, thick, smooth and exfoliating in thin irregular sheets (Troup, 1921).

Leaves simple, opposite to sub-opposite, 5–25 × 4–9 cm, oblong or elliptic oblong, glabrous, hard, often inequilateral, margin often crenulate, apex obtuse or sub-acute, base rounded or sometimes cordate. The petiole is short (2-4 cm long), sericeous, with 2 (or 1) prominent two glands at petiole apex.Inflorescences are short axillary spikes or small terminal panicles, 9-13 cm long with 2.5-6 cm long branches. The rachis short, white and pubescent. Lower receptacle 0.8-1.5 mm long, short sericeous, upper receptacle 1.5-1.75 mm long, glabrous except at base where slightly pubescent (Orwa et al.2009).

Flowers are small, cup-shaped, regular, sessile, polygamous, white, creamy or greenish-white and strongly honey-scented. Fruit 2.5-6 x 1.8-2.8 cm long, obovoid-oblong, dark brown to reddish-brown fibrous woody, indehiscent drupe, glabrous with 5-7 equal thick narrow stiff-wings and striated with numerous upwards-curved veins (Orwa et al.2009).

T. arjuna is usually an evergreen tree with new leaves appearing in the hot season (February to April) before leaf fall. Trees sometimes may be leafless for a very short period before flowering. Fruit bearing begins 6-7 years after planting (Troup, 1921).

Flowering begins in April and extends to May with the fruit ripening the following February-May, nearly a year after the appearance of the flowers. Generally, every third year is a good seed year. The pattern of flowering and fruiting is not markedly different in different regions (Kramer & Kozlowki, 1979).

Arjun is propagated by seed. One kg contains 775-800 Nos of seed. Seed are hard; need soaking in water for about 36 hours for germination. Seeds collected from previous season are directly sown (dibbled at 7.5 cm X 8.5 cm on well-prepared raised beds, regularly watered and weeded. Germination takes about 50-70 days with 50-60% germination and within 2-3months gets ready for transplanting in the main field. Seedlings can be prepared in poly bags also (Hartmann et al., 1997).

Seedlings are planted during rainy season (May-June) in rows. Stumps of 2 cm from one-year old seedlings after the first showers in April are best to regenerate the areas likely to be waterlogged. A moderate shade-bearer, but does not tolerate dense overhead shade. Seedlings are sensitive to drought and frost but grow well if moisture is available. It produces root suckers. Coppicing is satisfactory and pollards well. Not suitable for open and dry hillsides (Luna, 1996).

During rainy season incidence of powdery mildew disease appears in the early stages of growth,which is maximum during September. This can be controlled by spraying sulphur containing fungicide like Karathane (wet suphur) @ 0.1 % 500 g- 700 g in 500 – 700 litre water. Some leaf-eating insects appear but it is advisable not to use synthetic pesticides particularly when bark harvesting is undertaken. Neem based pesticides may be used.

Although flowering and fruiting starts after 6-7 years of planting, bark is removed not before 15 years of growth to get quality product. Only thick bark is cut away. The harvesting is done during dry period before the spring (April - May). Generally from ground about 3 m (10ft) height depending upon the girth of the bole is considered for bark harvesting. Bark of the old branches also can be harvested after about 30 years onwards. About 10 cm wide bark strip is removed alternately to the upward direction all around the trunk. The equal portion of bark that is left will be harvested in the next year. This alternate removal will help the tree in maintenance of translocation of organic solutes. To avoid quick drying, the cut surface may be plustered with a mixture of mud and cowdung immediately after bark removal. Collected bark is cut into pieces and dried under sun and shade (Chander, 2004).

1.2: Geographic distribution of the species

The tree is common throughout the greater part of Indian peninsula along rivers, streams, ravines and dry watercourses. It is native to both India and Sri Lanka; but exotic to Bangladesh. It is basically a tropical species. It grows almost in all types of soils but it prefers humid, fertile loam and red lateritic soils. It grows in low land to hilly areas and it can tolerate half submergence for a few weeks. It is also planted for shade and decoration in avenues or parks (Orwa et al.2009).

1.3: Background of the study

Plants have been playing an important role in the health care from the time immemorial. At present, more than 10,000 plant species are being used for medicinal purposes. Bangladesh is a country reported as storehouse of plants; about 37% of which have medicinal uses. Although Bangladesh Forest Research Institute (BFRI) enlisted 220 species of medicinal plants in Bangladesh. Yusuf et al. (1994) reported that the number was 546. Among the species, *Terminalia arjuna* (Roxb.) is considered as an important medicinal plant in the country. *T. arjuna* is a deciduous tree species of combretaceae family. The combretaceae is a family of flowering plants in the order Myrtales (Wikipedia, 2013). The family comprising about 20 genera and 500 species of trees, shrubs and lianas, widespread in tropical and subtropical regions of the world. *T. arjuna* is native to India and Sri Lanka. The tree is common in almost every part of India. It is grows well along bank of streams, rivers, ravines, dry water courses, reaching very large sizes on fertile alluvial loam (Troup, 1921).

Terminalia arjuna is an important medicinal plant in Bangladesh. It is mostly known for its medicinal values. Bark is used in about 12 Ayurvedic preparations (Scassellati, 1999). Every parts useful medicinal properties arjun holds a reputed position in both Ayurvedic and Yunani Systems of medicine. It is also recommended for reclamation of saline, alkaline soils and deep ravines. Used for agro and social forestry. Timber is locally used for carts, agricultural implements, water troughs, traps, boat building, house building, electric poles, tool-handles, jetty- piles and plywood. It is one of the major tannin yielding trees (Oudhia, 2002). So, the species has great economic value. But, due to tremendous population pressure, poverty, absence of appropriate government policy, and unsustainable utilization of forest resources, the population of this valuable tree species is declining rapidly. However, large scale planting program for the species is often difficult due to its limited seed germination capacity and longer germination period in the natural conditions. So different pre-sowing treatments of seeds can be helpful to increase seed germinations and for better growth of *T.*

arjuna seedlings at nursery stage. Conservation and sustainable use of genetic resource depends upon the knowledge of the extent and pattern of intra-specific variation, seed germination and clonal propagation. Characterization of natural resource is important for a better understanding of genetic resource conservation. For these reasons the species has been chosen. It will be helpful for widening the plantations programme in agro and social forestry. But there has very few studies conducted on seed germination and seedlings growth performance of *T. arjuna*. So, further study is essential regarding this issue. This study describes various pre-sowing treatments attributed to the seed germination and seedling growth of *T. arjuna*.

There are some studies which examined the germination percentage of *Terminalia species* through different pre-sowing treatments like depulping the fruits, soaking the seeds in hot or cold water for hours, scarifications, H_2SO_4 treatment etc. For example, Ara et al. (1997) and Hossain et al. (2005) found positive correlation between seed germination and different pre-sowing treatments of *T. chebula* and *T. belerica*. They also found positive correlation between growth performance and different pre-sowing treatments of these species. However, acid treatment is risky and difficult to apply, costly and general people are reluctant to use this treatment. On the other hand, cold and hot water treatments are most preferable by general people, cheap and easily applicable. Moreover, although water treatment (hot and cold) was applied for seed germination of *T. chebula* and *T. belerica*, no water treatment were applied for seed germination of *T. arjuna*. Hence, different water treatments has been used that can be helpful to find the better treatment which will enhance both seed germination and growth performance of *T. arjuna*. But, very few studies have been conducted on seed germination and growth performance of *T. arjuna*. This study is an effort to investigate the effects of seed treatments on germination status and growth performance of *T. arjuna* seedlings at nursery stage in Bangladesh.

1.4: Importance of *Terminalia arjuna*

PRODUCTS

Fuel: It makes excellent charcoal and firewood with calorific values of 5030 Kcal/kg and 5128 Kcal/kg for the sapwood and heartwood respectively.

Medicine: *T. arjuna* has been widely used in Ayurvedic medicine for the treatment of cancer, dermatological and gynaecological complaints, heart diseases (Dwivedi & Udupa, 1989) and urinary disorders. The bark is acrid, an astringent and tonic, and is useful in treatment of high blood pressure and ulcers. The cancer cell growth inhibitory constituent (luteolin) has been isolated from bark, stem and leaves of *T. arjuna* (Pettit et al., 1996). Luteolin has also been shown to have specific anti-bacterial activity against Neisseria gonorrhoea. It can also be used as alexiteric, styptic, tonic and anthelmintic and it is useful in fractures, inflammation and wounds and ulcers (Kumar & Prabhakar, 1987).

Timber: The sapwood is pinkish-white and the heartwood is brown to dark-brown, very hard, lustrous, strong and heavy (specific gravity 0.74; weight 816-865 kg/mn). The odourless, coarse-textured wood is streaked with dark lines and has irregularly inter-locked grains. Timber is locally used for carts, agricultural implements, water troughs, traps, boat building, house building, electric poles, tool-handles and jetty-piles. It also provides satisfactory rayon-grade pulp in mixture with other woods.

Fodder: It is widely planted for raising tassar silkworm and livestock fodder in India where leaves are heavily lopped. The leaves contain 9-11% crude protein and 14-20% crude fibre.

Tannin or dyestuff: The bark (22–24%), primarily, and fruit (7–20%) are used as tanning and dyeing material. The tannage can be used for making fine upper leather and excellent sole leather of light-brown or buff color with a red tint. It yields up to 45 kg dry bark chips on a three-year cycle without injury, as it is reproduced after 2 rainy seasons (Avula et al., 2013).

Silk production: The arjun is one of the species whose leaves are fed on by the *Antheraea paphia* moth which produces the tassar silk (tussah), a wild silk of commercial importance (Prasad et al., 1996).

Other products: The bark, containing large amount of lime (calcium carbonate), is often burnt to produce lime for chewing with betel. The bark is also used to assist precipitation of mud from turbid water.

SERVICES

Erosion control: The species is commonly found and planted along the banks of rivers, streams, old irrigation channels, edges of tank bunds and alluvial bars in seasonally dry water courses, helping to reduce soil erosion on the banks through its root-mass.

Shade: It is planted for shade or ornament in avenues and parks.

Intercropping: *T. arjuna* is an agroforestry species, often intercropped with coconut and citrus. It is also an excellent shade tree, especially in coffee plantations (World Agro forestry Centre, 2007).

Ornamental: This tree is often planted on roadsides and is also used for ornamentation.

Reclamation: Arjun is usually used in agro and social forestry for reclamation of saline, alkaline soils and deep ravines as well as in sand dune afforestation programmes with Casuarina species (Oudhia, 2002).

Pollution control: It is also planted near wells as roots of *T. arjuna* are believed to purify and cool the water in the wells.

Other services: The leaves or flowers have sacred value in India. The astrologers associate the plant with constellation Swati whose presiding deity is Vayu.

1.5: Objectives of the study

The specific objectives of the study were:-

- To find out suitable pre-sowing treatment for better germination success
- To know the seedling growth performance (height, diameter and leaf number) at nursery stage.

CHAPTER TWO: LITERATURE REVIEW

2.1 Germination

Seed germination is the resumption of metabolic activity after a period of dormancy. Water and oxygen are taken through the seed coat and the embryo begins to enlarge. The seed coat then breaks open and the radicle emerges followed by the shoot which contains leaves and the stem (Stack, 2008). Yet, germination is not the same thing as plant growth. When a plant seed is exposed to proper conditions germination occurs. The proper conditions for seed germination include the right amount of water, oxygen and a proper temperature. There are other factors that affect seed germination. They include light, the depth at which you plant your seed, and pH levels (Stack, 2008).

Seeds in freshly collected and well-treated fruit germinate at high level. Germination percentage varies widely from as low as 13% to as high as 90%, plant percent from 30% to 56%. Sometimes seed lies dormant for a year and germinate later on. Troup (1921) states 90%, Pattanath and Gupta (1976) report 187% potential in the laboratory. However, the germination is much dependent on condition in the germination bed, both temperature and light seems to affect germination. Pattanath and Gupta (1976) found the maximum germination at a constant $30^{0}C$ whereas altering day (-) night temperature at 30^{0} (-) $20^{0}C$ resulted in zero germination. The seed need partial shade appear to lose germination potential, whereas the seed buried in the soil under forest canopy for upto 6 months retain their germination potential, in full, further when placed under full light, started germination immediately (Luna, 1996).

Rapid germination of seeds is very desirable because the shorter the time required the less opportunity there is for injury by insects, fungi or unfavorable weather condition or for seeds to be eaten by birds or rodents. Many environmental factors can affect seed germination. Light intensity, day length, night length, light color, water, water quality, gravity, cowdung, temperature, chemical agents, genetics, oxygen availability, seed condition, seed age, seed coat condition, seed size and other environmental conditions have strong effects on seed germination and seedling growth at nursery stage. The most important environmental factors controlling seed germination and seedlings growth are water, temperature, light and radiation, aeration, oxygen and various chemicals. Non-dormant seeds must imbibe certain amount water before they resume the physiological processes involved in germination. For example, seed respiration increases greatly with an increase in hydration above some critical level. The absolute amount of water required to initiate germination are relatively small, usually not more than two to three times the weight of the seed (Kramer and Koztowski, 1979).

At temperature near 38^0C, moisture stress was critical early in germination of mesquite seeds. However, at 29^0C embryo growth was largely influenced by temperature and soil moisture stress was not a limiting factor until later in the germination process (Morris et al., 2000).

Seed germination of *Terminalia spp.* is epigeous. The hard endocarp of the fruit opens slightly and the radical emerges. The hypocotyls elongate by arching, and the large foliaceous cotyledons, which are convolute in the seed, extricate themselves and unroll. The hypocotyls straightness and still farther elongates, varying the cotyledons above ground; at the same time the young shoot emerges from between the two cotyledonary petiols (Troup, 1921).

Allelopathic performance of the aqueous extract of bark of *Terminalia arjuna* on *Cassia sophera* was evaluated under laboratory conditions. Aqueous extract of bark were prepared at different concentrations of 2, 4, 6, 8 and 10%. Ten seeds of test plant were kept for germination in sterilized Petri dishes of 9 cm diameter lined double with double layer of blotting paper moistened with different concentrations of aqueous extract (2 to 10%) and distilled water. Each treatment had three replicates. The experiment was recorded for 15 days. It was observed that aqueous extract reduced the germination, plumule and radicle length. Phytotoxicity of extract depends upon concentration. However, extract at higher concentration (10%) had strong inhibitory effect on germination and seedling growth of test species. From this we can suggest that *T. arjuna* may be a source of natural weedicide and can be used for controlling invasive plants (Gulzar and Siddiqui, 2013).

2.2 Factors affecting the seed germination

Seeds are living organisms held in a state of suspended animation or dormancy. There are many factors that can affect the viability of seeds, including moisture, air, temperature, and light. In an ideal situation and environment, every single seed we planted would grow into a seedling, but as we all know, that doesn't normally happen. Although dormant, seeds are still slowly respiring and using food reserves within. When the right environmental cues wake the seeds up they begin to germinate and emerge from their hard seed coat. There are four major factors that are affect germination:

Moisture: A dormant seed only contains 10-15% of water and is essentially dehydrated. The seed has to absorb water in order to become active. It is imbibed by the seed coat and enzymes within the seed become active and functional, metabolizing stored food reserves. The embryo then begins to swell. The softened seed coat ruptures as the seed grows too big for its encasement and germination has commenced. The seed leaves or cotyledons are now apparent. Photosynthesis does not begin until the true leaves are developed and at this point in development the seedling is still surviving on its own food reserves. Seedlings of *T. arjuna* are sensitive to drought and frost but grow well if moisture is available. Matin and Khan (1999) found sharp growth performance during wet and semi-dry season in seven species of *Albizia* seedlings due to optimum moisture, while found slower growth in dry season due to scarcity of moisture. Matin and Rashid (2000) also found same trend of results in rain tree, ipil-ipil and mandar seedlings.

Air: In the dormant condition the seeds respiratory rate is very low and so oxygen is required in very small quantities. But for germination, oxygen is needed in large quantities. The seeds obtain oxygen that is dissolved in water and from the air contained in the soil. If soil conditions are too wet, an anaerobic condition persists, and seeds may not be able to germinate.

Temperature: Temperature affects both germination percentage and germination rate. Germination rate is invariably low at low temperatures but increases gradually as temperature rises. Germination percentage, unlike the germination rate may remain relatively constant, at least over middle part of the temperature range, if sufficient time is allowed for germination to occur. Three temperature points varying with the species are usually designated for seed germination. Minimum is the lowest temperature for effective germination maximum is the highest temperature at which germination occurs. Optimum temperatures for seed germination fall within the range at which the largest percentages of seedlings are produced at the highest rate (Hartmann et al., 1997). Temperature also greatly influenced the growth and development of tropical species. For growth and development *T. arjuna* requires a mean annual temperature of 20-30°C (Orwa et al., 2009).

Light: Light of a relatively high intensity is desirable to produce sturdy, vigorous plants; particularly if transplanting is involved. Low light intensity results in etiolating and reduced photosynthesis and poor seedlings survival if transplanted. High light intensity, on the otherhand often results in high temperatures that produce heat injury to the seedling, particularly at the soil level, in a manner resembling 'damping-off' fungi attacks. Shading is desirable for many kinds of plants during their early seedling growth out-of-doors to avoid heat injury (Hartmann et al., 1997). *T. arjuna* is a moderate shade-bearer, but does not tolerate dense overhead shade.

2.3 Description of the species *(T. arjuna)*

Phenology: *T. arjuna* is usually an evergreen tree with new leaves appearing in the hot season (February to April) before leaf fall. Trees sometimes may be leafless for a very short period before flowering. Fruit bearing begins 6-7 years after planting. Flowering begins in April and extends to May with the fruit ripening the following February-May, nearly a year after the appearance of the flowers. Generally, every third year is a good seed year. The pattern of flowering and fruiting is not markedly different in different regions. Pollination in *Terminalia spp.* is entomorphillous (Srivastava et al., 1993).

Seed Morpholology: Fruit is drupe, 2.5 cm long, ovate, thick with 5 rigid, longitudinal wing, 0.6 cm broad, the fruit is often notched near the top, marked with oblique upward curving striations. Cotyledons petiole 0.3"-0.6" long, flattened above, tomentose, lamina 0.7-0.9"× 1.4-2.2", foliaceous, somewhat fleshy, reniform, much broader than long, apex broadly truneate, decurrent, entire, green, with three conspicuous and two minor veins from the base (Troup, 1921). The number of seeds is about 775 per kilogram (Siddique and Ali, 1994).

Seed Collection and Storage:

At the age of 6-7 years trees start bearing fruit. Every third year is a good seed year. Fruits ripen from following February to May when they can be collected either by lopping the branches or from the ground previously swept clean. Then they are dried in open sunlight. The seeds are viable for at least one year when stored in sealed tins, but it is preferable to sow them in the same year. Seed weight varies considerably depending upon the source and the time of collection. About 175 to 450 fruits weight to one kg. Germination of untreated seeds is about 50-60% and that of hot water treated ones about 90%. There is a direct correlation between seed the weight and germination. Heavier seed show the highest germination because of the large amount of reserved food material for growing embryo. Stored seed from the middle layer of open and closed containers have showed belier germination than the upper and basal layers (Athaya, 1985).

Pre-sowing Treatments:

Pretreatment is a kind of treatment applied to seed to overcome seed dormancy and hasten germination (Bonner, 1987). Pretreatment of seeds are intended to improve the survival or germination of seed after sowing. The term is often shortened to "seed pretreatment", which is really a misnomer, since what we are concerned with here is treatment before seed sowing, not some action before seed treatment (Willan,1990). Azad et al., (2006) and Hossain et al., (2005a, 2005b) found positive effects of pre-sowing treatments on seed germination and seedlings growth of lohakath and horitoki and, bohera. . Matin and Rashid (2000) also found same trend of results in rain tree, ipil-ipil and mandar seedlings.

The fruits of *Terminalia arjuna* is hard; have impermeable seed coat and thick fleshy Pulp which leads to longer germination period (up to 2-3 months). It is the major constraints of raising seedling and establishing plantations of the species. However, this problem of seed germination can be overcome by different pre-sowing treatments like soaking the seeds in cold water (for 24 hours or 48 hours), soaking the seeds in hot water (for few minutes), depulping the fruits, scarifications, H2SO4 treatment etc. (Ara et al., 1997).

Generally untreated seeds of *T. arjuna* show erratic germination and it may continue for two months. Seeds soaked in hot water may give 74% germination with initial period of germination extended for 11 days. The seeds pre-treated in cow dung shiny and sown also hasten germination the probable cause being that such seeds attract termites which eat up the fibrous seed coat, enabling the seed to imbibe water resulting in quick germination. Such beds however have to be treated with insecticide such as Ekalux 0.02% after 5 days of sowing or when the radicles emerge (Date, 1987).

Growth Performance:

Growth is the biological phenomenon of size increase over time, and is measured in diameter, height, basal area, and volume (Kyaw, 2003). Information on diameter increments and growth patterns of individual trees is an important tool for forest management, primarily to: (i) select tree species for logging; (ii) select tree species for protection; (iii) estimate cutting cycles; and (iv) prescribe silvicultural treatments. In addition, dbh growth rate varies significantly between and within tree species, and also in relation to ages, seasons, and microclimatic conditions (Silva et al. 2002). Furthermore, the increment of the trees strongly depends on environmental site conditions, stocking of the stand, silvicultural treatments, and endogenous growth characteristics of the species (Pancel, 1993). Increment of diameter and height is a significant index in order to determine the growth ability of a species. This index can be applied to identify the best technical measurements in the forest, as well as to select the best species to improve the yield and quality of a forest plantation (Hung, 2013).

However, the study on growth performance of a species at nursery stage is very much important as it ensure the suitability of larger plantation program of the species. For larger plantation program of a species it is inevitable to know its growth performance at initial stage to reduce any risk and for better management. The success of plantation programs largely depends on germination of seeds and growth of seedlings in the nursery. The nursery technique should be efficient enough to produce adequate number of quality seedlings within a reasonable period of time. Moreover the technology should be cost effective (Hossain et al., 2005). On the other hand, the study of growth performance of a species at nursery stage is necessary for any types of cutting practices of the species. From the study of growth performance at nursery stage the suitable time of cutting practice of a species can be known which is very important.

It was observed in various studies of tropical and sub-tropical species that the species showed sharply increased height growth, diameter growth and leaf formation during wet and semi-dry season; while it showed very lower growth of height, diameter and leaf formation during dry season (Matin and Khan, 1999).

A study was conducted over a period of six months from January to June 2004 to explore the effects of different seed treatments on germination and seedling growth attributes of a *Terminalia species*, Horitoki (*Terminalia chebula* Retz) in the nursery of Chittagong University, Bangladesh. Seeds were subjected to six pre-sowing treatments e.g. control (T_0), depulped (T_1), depulped and soaked in cold water for 12 hours (T_2), depulped and soaked in cold water for 24 hours (T_3), depulped and soaked in cold water for 48 hours (T_4) and depulped and soaked in hot water for 2 minutes (T_5). The study revealed that depulping the fruits and soaking in water for various periods significantly enhanced seed germination and seedling growth. Seed germination started 29 days after sowing and continued up to 86 days. The highest germination percentage (66.7%) was observed in the fruit depulped and soaked in cold water for 48 hours (T_4) followed by 60% in the depulped 4 seeds soaked in cold water for 24 hours (T_3). The lowest germination percentage (48.9%) was obtained from 3 controlled seeds (T_0). The highest germination value (4.41), germination energy (58.9) and vigor index (5291) was also obtained in T_4, which was significantly ($p<0.05$) different from the control and other treatments. Shoot length, root length, collar diameter and leaf number followed the same trend of higher value for T_4, T_5 and T_3 respectively. Similar trend was also observed in shoot, root and total seedling dry weight. Therefore, pre-sowing treatment, T_4 (depulped seeds soaking in cold water for 48 hours) was more effective in germination and production of quality seedling of *T. chebula* in the nursery (Hossain et al., 2005a).

A study was undertaken to determine the optimum conditions for germination and seedling growth of *Terminalia spp.* (bohera) by using four different manures mixed with soil viz. celrich (bio-organic soil enricher), farmyard manure (FYM), goat and poultry manures, three types of nursery beds viz. sunken, flat and raised, three types of containers (having different volumes) and three types of soil viz. silt loam, sandy loam and sandy. Seedlings raised in different treatments in nursery for 12 months were planted in field to assess field growth.

Experiments revealed maximum seed germination percent in the FYM and minimum in the poultry manure treatment. Maximum germination percent was recorded in sunken beds as compared to flat and raised nursery beds. Among different types of containers, 4000 ml-plastic pots showed maximum germination whereas the minimum was recorded in 350 ml-root trainers and 1600 ml-polybags. Survival percent was higher for seedlings raised in FYM, sunken beds, silt loam soil and 4000 ml-plastic pots compared to other treatments. The best combination for optimum germination and growth in nursery for Terminalia was silt loam soil + FYM + sunken beds or 4000 ml-plastic pots. After 12 months of growth, height was greater in seedlings raised in soil mixed with FYM, sunken beds, silt loam soil and 4000 ml-plastic pots as compared to other treatments. Compared to other treatments collar diameter was higher in seedlings raised in goat manure, sunken bed, and silt loam soil and root trainer. Survival percent under field conditions was higher in seedlings raised in FYM and Celrich (bio-organic soil enricher) compared to other treatments (goat and poultry manures), whereas maximum height and collar diameter were recorded in seedlings raised in plastic pots (Bali et al., 2013).

Terminalia species (Arjun, Hritoki, Bohera etc.) is important medicinal tree species in the Asian countries. Large scale planting program for these species is often difficult due to its limited seed germination capacity and longer germination period in the natural conditions. The study describes various pre-sowing treatments attributed to the seed germination and seedling growth of *Terminalia chebula*. A total of 1200 fruits were subjected to various treatments of which 600 were depulped by rotting the fleshy pulp in water while rests were kept intact and dried followed by their storage in airtight containers until setting up for the experiments. The effects of depulping and soaking period (0, 24, 48 and 72h) on seed germination and seedling growth performance were explored. The fastest seed germination and highest germination percentage (73.8%) was observed in depulped seeds soaked in cold water for 48 h followed by 72h and delayed germination with lowest percentage was in intact fruits without treatment. Growth parameters including shoot length, root length, total height, leaf number, leaf area, collar diameter, dry mass and vigor index were also maximum and significantly higher in the same treatment compared to others. Considering the practicability of the nursery raising technique for the species, the best treatment option obtained in this study was depulping thefruits and soaking the seeds in cold water for 48h which could be useful for large scale plantation programs (Hossain et al., 2013).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

The study was carried out in the nursery of Forestry and Wood Technology Discipline, Khulna University, Bangladesh. The geographic distribution of this area lies between 22°48' N and 89° 31' E. The elevation is 4m above mean sea level. The study area is situated in the south-western part of Bangladesh and it is the part of the Sundarbans delta. The nursery enjoys typically tropical climate with hot humid summer and cool dry winter. There are mainly three seasons winter, summer, monsoon which affects the climatic condition of the study area. The winter season start from November and ended in February when the temperature is fluctuated. The temperature during this period ranges from 7°C to 12 °C. The summer is continuing during March to June when the general temperature is 25-32 ° C but sometimes the temperature is raised up to 36-40 ° C. The monsoon season is continuing from July to October (BBS 1993, Alam et al 2005). The recorded average air temperature was 27-32° C and the average soil temperature was 23-27° C in polybags. The average relative humidity was 75% that is suitable for the experiment.

3.2 Seed collection and Processing

Fresh and mature seeds of *Terminalia arjua* were collected in early March, 2013 from a mature tree of Khulna University campus. The seeds were collected manually from the standing tree. The mother tree was 12-15 years old and it was healthy, straight bole and spreading crown. A total of 1200 (3×4×100) seeds were collected for the study. After collection, all seeds were dried in open sunlight for 3 days to reduce the moisture and then stored it in cool and dry condition till the treatments were applied. Uniform seeds were used for the treatments to reduce non-treatments variation. Measurement of the fruits and seeds were taken in unopened condition and before putting them into the germination test respectively. The extracted seeds were tested to eliminate the stained, discolored and damaged seed.

3.3 Experimental design and treatment combinations

There were four treatments including control and 3 replications for each treatment. The pre-sowing treatments used in the experiment were as follows:

T_1: Control (no treatment)

T_2: Immersion in normal water for 24 hours

T_3: Immersion in normal water for 48 hours and

T_4: Immersion in hot water (65-70^{0}C) for 5 minutes.

For the purpose, 100 seeds were tested for each replication to explore the effect of pre-sowing treatments on germination. So, a total of 300 seeds were used in each treatment. Therefore, a total of 1200 seeds (100×3×4) were used for 4 treatments in polybags (15cm × 10cm). One seed were used in each polybag. The seeds were sown manually in polybag. The poly bag was filled with the mixture of topsoil and decomposed cow dung in the ratio of 3:1. Soils were sieved well. The polybags were kept in shade until the germination occurs. Watering was made to the polybags every alternative day other than wet season. Complete Randomized Design (CRD) was used for the experiment.

The effects of pre-sowing treatments were assessed periodically by counting germinated seeds. The germination was recorded daily from the date of sowing and continued till the germination ceased. The starting and finishing dates of germination were also recorded. After germination, 30 healthy seedlings for each treatment were separated. Then, a total of 120 seedlings (30×4) were allowed for growing altogether under same environmental condition to assess initial growth performance. Every treatment was divided into tree replications (design one, design two and design three) according to germination design. Height growth was measured by a wooden scale keeping just above the polybag at the base of seedlings. Collar diameter was measured by an Electronic Digital Caliper at the collar zone and number of leaves was counted manually for each seedling individually. The duration of the growth performance was six months. Data were collected on the same date for each treatment.

3.4 Seed germination

The number of seeds germinated on every day was recorded for each treatment in polybag. The starting and finishing dates of germination were also recorded. At the end of the germination period, the germination percentage and rates of germination were obtained using the following equations (Azad et al., 2012), which was modified from Maguire (1962):

$$G_p = N_g/N_t \times 100 \qquad (1)$$

$$G_r = \sum \frac{Ng}{\text{Days of count}} \qquad (2)$$

i.e.,

$$G_r = \sum \frac{Ng}{\text{Days to first count}} + \ldots\ldots + \sum \frac{Ng}{\text{Days to final count}} \qquad (3)$$

where G_p is the germination percentage, N_g the number of germinated seeds, N_t the total number of seeds planted and G_r the rate of germination.

3.5 Data analysis

Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) were carried out to analyze the data. Data were analyzed using MS Excel and SAS software to explore possible treatment variation. Analysis of variance was carried out to determine the treatment effect on germination starting and closing date after seed sowing, length of germination period, seed germination percentage and germination rate and growth performance (height, diameter and leaf number) of *Terminalia arjuna*. Data transformation was done by using Arcsine transformation. Many biological variables do not meet the assumptions of parametric statistical tests: they are not normally distributed, the variances are not homogeneous, or both. Using a parametric statistical test (such as an anova or linear regression) on such data may give a misleading result. Transforming the data will make it fit the assumptions better. So, data transformations are an important tool for the proper statistical analysis of biological data.

DMRT was conducted to compare mean germination starting and closing date after seed sowing, length of germination period, seed germination percentage and germination rate and growth performance (height, diameter and leaf number) of different pre-sowing effect of *Terminalia arjuna*.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1: Morphological characteristics of *Terminalia arjuna* fruits

It was observed that the color of the fruit of *Terminalia arjuna* were dark brown to reddish-brown. The fruit is 1-seeded, drupe and often flattened. The average length and diameter per fruit were (4.69±0.897) cm and (2.61±0.67) cm respectively. The average weight (dry) per fruit was (1.509±0.108) gm. One kg contains 500-700 dry fruits of *T. arjuna.*

4.1.2: Effect of treatments on seed germination in polybag

In all treatments, germination was completed within 10-34 days after sowing the seed in polybags. The highest germination success (77.33%) was observed in T_3 (immersion in normal water for 48 hours) and lowest (45.33%) in T_1 (control). The second and third germination success were obtained in T_4 (60.67%) and in T_2 (55.67%) respectively. Analysis of variance (ANOVA) showed significant differences ($P<0.05$) in germination closing days, germination period and germination percentage among the treatments; but ANOVA for germination starting days did not show significance difference ($P>0.05$) among the treatments.

DMRT showed significant difference on seed germination among all treatments. The seed germination in T_3 was significantly higher than that of other treatments, while the seed germination in T_1 was significantly lower than that of other treatments.

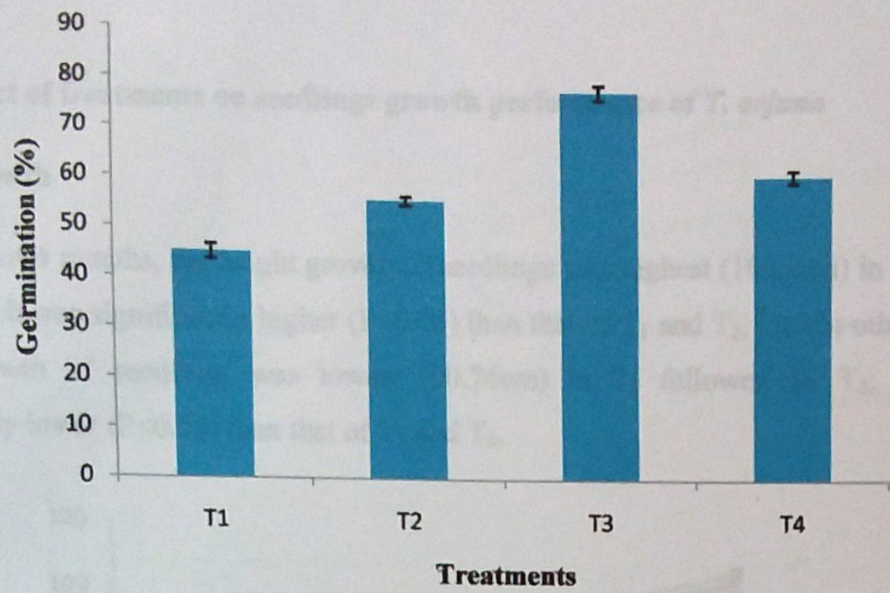

Fig-1: Effect of pre-sowing treatments on seed germination of *Terminalia arjuna.* Bars show 95% confidence limit.

Table 1: Summary of different pre-sowing treatments effect on germination starting days, closing days, germination period and germination percentage of *Terminalia arjuna* seedlings in polybag at nursery stage. Same letter in the same row show no significance difference and ± indicates 95% confidence limit

Particulates	Treatment (T_1)	Treatment (T_2)	Treatment (T_3)	Treatment (T_4)
Germination starting days	13.67 ±1.2a	11.33 ±0.88ab	10±0.58b	10.33 ±0.88b
Germination closing days	33.67 ±1.2a	32.33 ±1.45a	24.67±0.88b	30.33±0.88a
Germination period	20 ±0.58a	21.33 ±0.88a	15 ±0.58b	19.33 ±0.88a
Germination percentage	45.33 ±1.45d	55.67 ±0.88c	77.33 ±1.45a	60.67 ±1.2b
Germination rate	1.70±0.06d	2.69±0.02c	3.93±0.03a	2.85±0.04b

Note: T_1: Control, **T_2**: Immersion in normal water for 24 hours, **T_3**: Immersion in normal water for 48 hours, **T_4**: Immersion in hot water (65-70^{0}C) for 5 minutes.

4.1.3: Effect of treatments on seedlings growth performance of *T. arjuna*

Height growth

At the end of 6 months, the height growth of seedlings was highest (105.3cm) in T_3 followed by T_4; which was significantly higher ($P<0.05$) than that of T_1 and T_2. On the other hand, the height growth of seedlings was lowest (90.76cm) in T_1 followed by T_2; which was significantly lower ($P<0.05$) than that of T_3 and T_4.

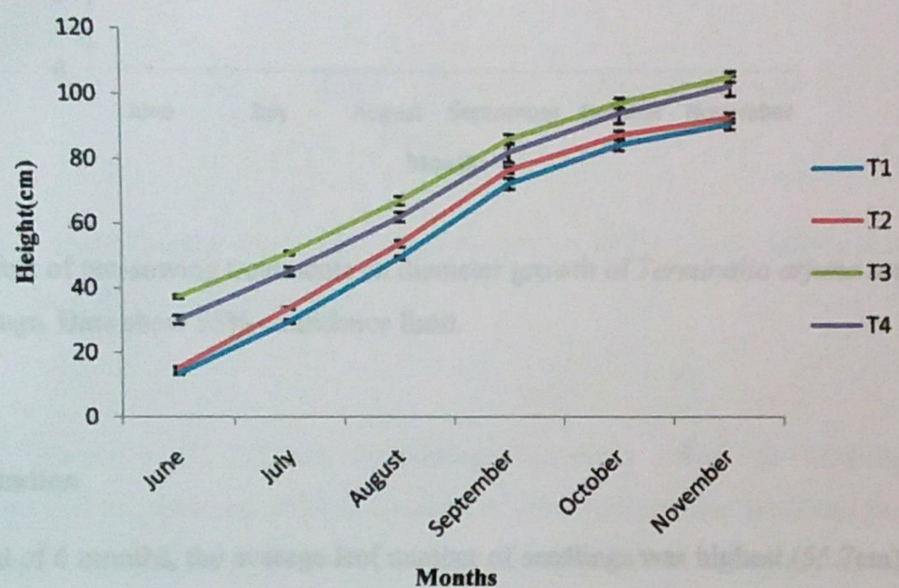

Fig-2: Effect of pre-sowing treatments on height growth of *Terminalia arjuna* at nursery stage. Bars show 95% confidence limit.

Diameter growth

At the end of 6 months, the diameter growth of seedlings was highest (11.55mm) in T_3 followed by T4; which was significantly higher ($P<0.05$) than that of T_1 and T_2. The diameter growth of seedlings was lowest (8.48mm) in T_2 followed by T_1; which was significantly lower ($P<0.05$) than that of T_3 and T_4.

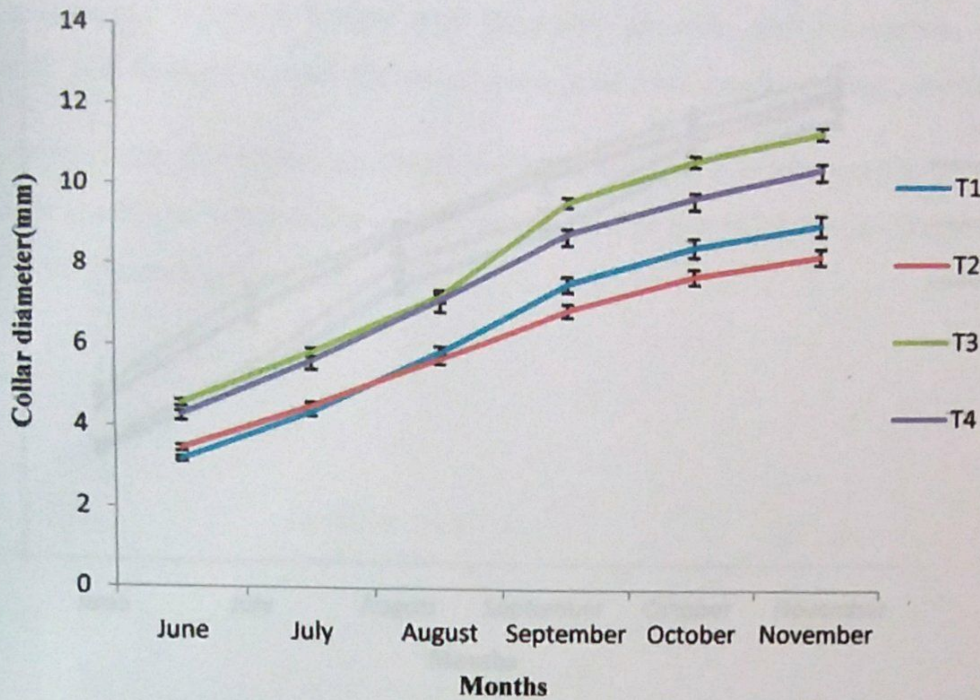

Fig-3: Effect of pre-sowing treatments on diameter growth of *Terminalia arjuna* seedlings at nursery stage. Bars show 95% confidence limit.

Leaf formation

At the end of 6 months, the average leaf number of seedlings was highest (55.7cm) in T_3 and the lowest (50.63) in T_1. The second and third higher collar diameter growth was found in T_4 and T_2 respectively. Analysis of variance (ANOVA) did not show significant difference ($P<0.05$) in leaf number among the four treatments.

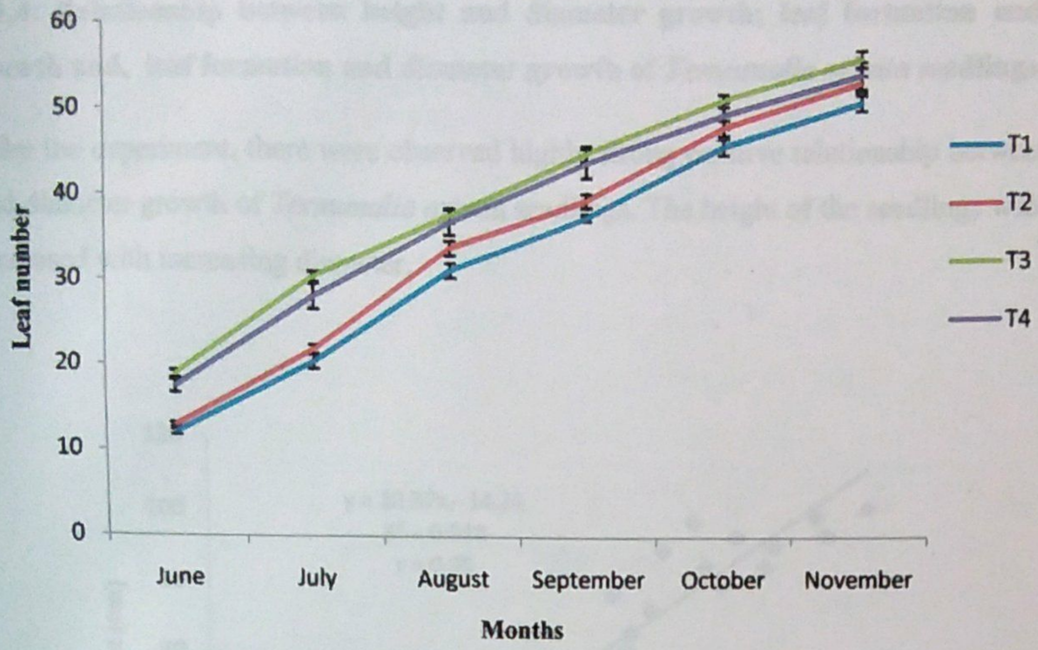

Fig-4: Effect of pre-sowing treatments on leaf production of *Terminalia arjuna* at nursery stage. Bars show 95% confidence limit.

Table 2: Summary of different pre-sowing treatments effect on seedlings growth performance (height, diameter and leaf number) of *Terminalia arjuna* seedlings in polybag at nursery stages. Same letter in the same row show no significance difference and ± indicates 95% confidence limit.

Particulates	**T_1**	**T_2**	**T_3**	**T_4**
Collar diameter(mm)	9.25±0.26b	8.48±0.2b	11.55±0.15a	10.66±0.27a
Height growth(cm)	90.76±1.72c	92.66±1.41bc	105.3±1.54a	102.38±2.96ab
Leaf number	50.63±0.9a	52.9±0.93a	55.7±0.95a	53.83±1.58a

Note: T_1: Control, **T_2**: Immersion in normal water for 24 hours, **T_3**: Immersion in normal water for 48 hours, **T_4**: Immersion in hot water (65-70^{0}C) for 5 minutes.

4.1.4: Relationship between height and diameter growth; leaf formation and height growth and, leaf formation and diameter growth of *Termunalia arjuna* seedlings

After the experiment, there were observed highly strong positive relationship between height and diameter growth of *Termunalia arjuna* seedlings. The height of the seedlings was sharply increased with increasing diameter.

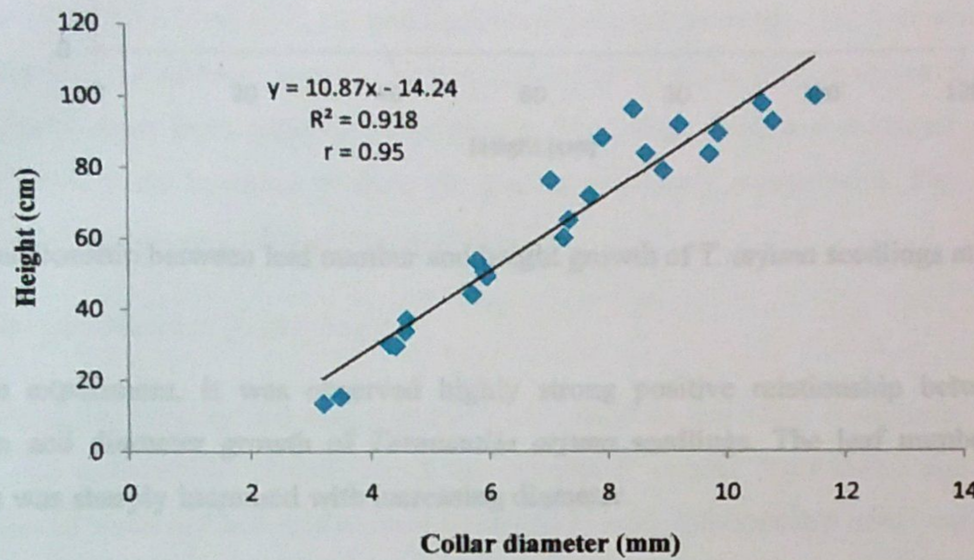

Fig-5: Relationship between height and diameter growth of *T. arjuna* seedlings at nursery stage.

There was also a highly strong positive relationship between leaf formation and height growth of *Termunalia arjuna* seedlings. The leaf number of the seedlings was gradually increased with increasing height.

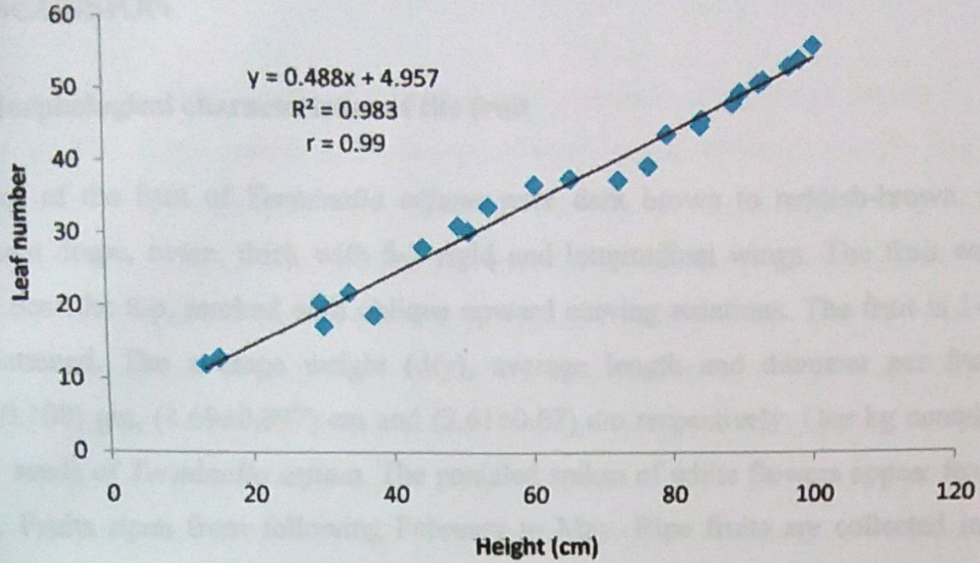

Fig-6: Relationship between leaf number and height growth of *T. arjuna* seedlings at nursery stage.

After the experiment, it was observed highly strong positive relationship between leaf formation and diameter growth of *Termunalia arjuna* seedlings. The leaf number of the seedlings was sharply increased with increasing diameter.

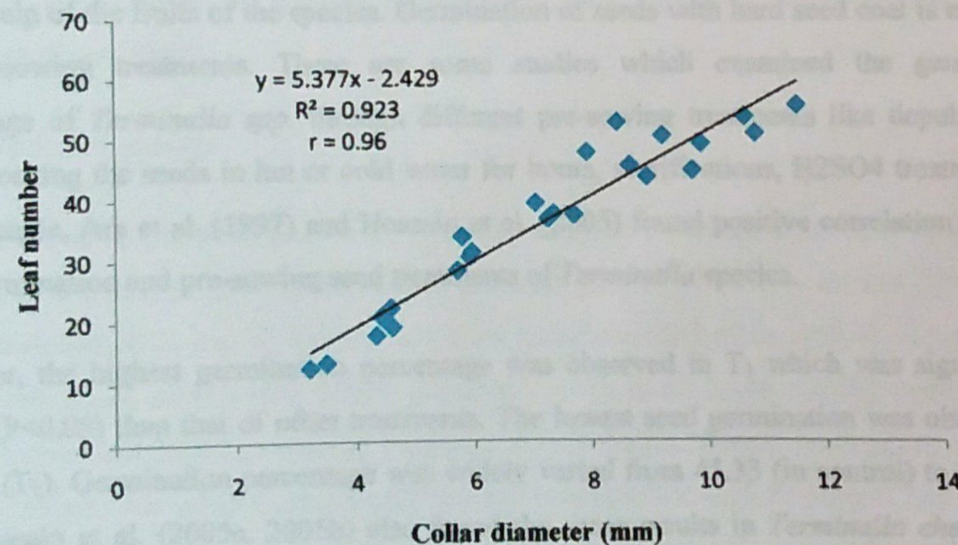

Fig-7: Relationship between leaf number and diameter growth of *T. arjuna* seedlings at nursery stage.

4.2 DISCUSSION

4.2.1: Morphological characteristics of the fruit

The color of the fruit of *Terminalia arjuna* were dark brown to reddish-brown. Fruit is indehiscent drupe, ovate, thick with 5-7 rigid and longitudinal wings. The fruit was often notched near the top, marked with oblique upward curving striations. The fruit is 1-seeded, often flattened. The average weight (dry), average length and diameter per fruit were (1.509±0.108) gm, (4.69±0.897) cm and (2.61±0.67) cm respectively. One kg contains 500-700 dry seeds of *Terminalia arjuna.* The panicled spikes of white flowers appear from April to July. Fruits ripen from following February to May. Ripe fruits are collected in March either by lopping the branches or from the ground previously swept clean. The seeds are viable for at least one year when stored in sealed tins.

4.2.2: Seed germination in polybag

Poor germination capacity and longer germination period are the major constraints of raising seedling and establishing plantations of the species *T. arjuna*. This delay and irregular germination of seeds are believed to have attributed to hard, impermeable seed coat and thick fleshy pulp of the fruits of the species. Germination of seeds with hard seed coat is enhanced by pre-sowing treatments. There are some studies which examined the germination percentage of *Terminalia spp.* through different pre-sowing treatments like depulping the fruits, soaking the seeds in hot or cold water for hours, scarifications, H2SO4 treatment etc. For example, Ara et al. (1997) and Hossain et al. (2005) found positive correlation between seed germination and pre-sowing seed treatments of *Terminalia* species.

However, the highest germination percentage was observed in T_3 which was significantly higher ($P<0.05$) than that of other treatments. The lowest seed germination was observed in control (T_1). Germination percentage was widely varied from 45.33 (in control) to 77.33 (in T_3). Hossain et al. (2005a, 2005b) also found the same results in *Terminalia chebula* and *Terminalia belerica.* DMRT showed significant differences ($P<0.05$) among the four treatments. The difference of germination percentages might be due to the difference of immersion time. Immersion in water made the seeds soften in different level which helps in seed germination.

4.2.3: Height growth

From results it was observed that the highest height growth of seedlings was in T_3 and the lowest in T_1. The height growth of T_3 was significantly higher ($P<0.05$) than T_1 and T_2. The height growth of T_3 was also higher than T_4 but did not show significance difference ($P>0.05$). Hossain et al. (2005a, 2005b) also found same results in *Terminalia chebula* and *Terminalia belerica* at the age of six months among five treatments. During June- August there was a sharp rise in height growth of the species. But after that time (September-November) the species showed slower growth in height than previous period. The increase in height growth during first three month might be due to high rainfall in this period that increased soil moisture in the polybags of the seedlings. Similar observations were also found during the growth study of some forest tree seedlings by Matin and Banik (1993); and by Matin and Khan (1999). Matin et al. (2000) also reported better height growth of seedlings of some multipurpose tree species at nursery stages in the same period (April -July) than latter period (August-March). On the other hand, the causes of poor height growth in latter period (September-November) might be due to water stress (Loomis, 1934 and, Matin and Banik, 1993). During September-November the leaf number per plant became less than in June-August. This reduction of photosynthetic surface decreased the relative amount of carbohydrates available for growth, as compared with unstressed plants (Kramer, 1969; Matin and Khan, 2000).

4.2.4: Diameter growth

The highest collar diameter growth of *Termunalia arjuna* seedlings was observed in T_3 and T_2 showed the lowest growth. The collar diameter growth of T_3 was always significantly higher than that of T_1 and T_2, but did not show significant difference with T_4. Hossain et al. (2005) also found significantly higher diameter growth in 48 hours soaking treatment than that of control and 24 hours soaking treatment in *Terminalia chebula* seedlings at same age. In June- August the collar diameter was sharply increased for each treatment. The causes of the increase in diameter growth might be due to adequate supply of water and moisture in this period that helps in forming new leaves and roots which ultimately increased the total carbohydrate concentrations to the seedlings. Similar results were mentioned by Matin (1989) in *Nauclea diderrichii* cuttings. On the other hand, there was observed comparatively slower growth in diameter of *Terminalia arjuna* seedlings from September to November than previous period. It might be due to less availability of water which reduced photosynthesis and decreased translocation of carbohydrates and growth regulators, all these add to reduced turgor in reducing growth. Kramer (1969) also found reduction of diameter in same period of some multipurpose species.

4.2.5: Leaf formation

The average leaf number of seedlings was highest in T_3 than that of other treatments and the lowest in T_1. Hossain et al. (2005a, 2005b) also found highest average leaf number in 48 hours soaking seeds and lowest in control of *Terminalia chebula* and *Terminalia belerica* seedlings at the age of six months among five treatments. After six months, the average leaf number under four treatments was close to each other. Analysis of variance (ANOVA) did not show significant difference in leaf number among the four treatments. In all the treatments the species showed increased leaf number during June-July. But during August-November the seedlings showed decreased number of leaves. It might be the fact that leaf shedding was influenced by water stress. Similar result also found in seedling growth study of different *albizia* species in different seasons of the year (Matin and Khan, 2000).

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1: CONCLUSION

Among the four treatments applied in the experiment for *Terminalia arjuna*, fruit soaking in cold water for 48 hours was found more effective in respect to faster germination, higher germination percentage, seedling growth and seedling vigor in comparison to control and other treatments. Seed germination, height growth, diameter growth and leaf formation was always higher in the treatment with 48 hours soaking in normal water than control and that of other treatments. It is also easily applicable and cost effective. Fruit soaking in hot water (65-70^{0}C for 5 minutes) also showed good growth performance which was always near about the 48 hours soaking treatments in normal water. There was a strong positive relationship among height growth, diameter growth and leaf formation. On the other hand, the seedlings showed sharp growth during June-August, but showed poor growth during later period (September-November). However, for establishing nursery of a particular species for producing maximum number of quality seedlings with minimum cost, time and labor, the seed pre-treatments are required. Since the seed coat of *T. arjuna* is hard, it takes more time to germinate with lower germination percentage in nursery establishment. The present study of pre-sowing treatments of seeds would prove itself potential in the practical fields.

5.2: RECOMMENDATIONS

- Since normal water treatment for 48 hours showed best germination and growth development, easily applicable and cost effective, so normal water treatment for 48 hours is suggested for large plantation program.
- During June-August (rainy season) seedlings showed significantly higher growth performance than later period. So, it is recommended to sow seeds during rainy season.
- Although seed is viable for longer period, freshly collected seed is suggested to be sown.

REFERENCES

Alam, M.A., Matin, M.A., Hoque, M.M. and Hoque, ATMR. (2005). Seed morphology and germination of Ipil-ipil (*Leocaena leococephala* Lam.)De Wit under different condition at nursery stage in Bangladesh. Asian Journal of Plant Science, 4(2):98-101.

Ara, R., Merry, S. R. and Siddiqi, N. A. (1997). Cultivation and Uses of Twelve Medicinal Plants of Bangladesh. Bulletin 7, Minor Forest Products Series, Bangladesh Forest Research Institute, Chittagong, pp. 27-31.

Athaya, C.D. (1985). Ecological studies of some forest seeds. Indian journal of forestry, 8(2):137.

Avula, B. (2013). Simultaneous determination and characterization of tannins and triterpene saponins from the fruits of various species of *Terminalia arjuna* and *Phyllanthus emblica*. Planta Med.

Azad, M.S., Biswas R.K. and Matin, M.A. (2012). Seed germination of *Albizia procera* (Roxb.) Benth. in Bangladesh: a basis for seed source variation and pre-sowing treatment effect. For Stud China, 12(2): 124–130.

Azad, M.S., Matin, M.A., Islam, M.S. and Musa, Z.A. (2006). Effect of pre-sowing treatment on seed germination of Lohakath (*Xylia kerrii* Craib & Hutch.). *Khulna University Studies,* 7(2):33-36.

Bali, R. S., Chauhan, D. S. and Todaria, N. P. (2013). Effect of growing media, nursery beds and containers on seed germination and seedling establishment of *Terminalia bellirica* (Gaertn.) Roxb., a multipurpose tree. Tropical Ecology 54(1): 59-66.

BBS (Bangladesh Bureau of Statistics). (1993). Statistical pocket book of Bangladesh. BBS, Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka, Bangladesh.

Bonner, F.T. (1987). Importance of seed size in germination and seedling growth. In: S.K. Kamara and R.D. Ayling (eds.), Proceedings of The International Symposium on Forest Seed Problems in Africa. Harare, Zimbabwe. 53-61 pp.

Chander, R. (2004). Antidyslipidemic and antioxidant activities of different fractions of *Terminalia arjuna* stem bark. Indian J Clin Biochem.

Dwivedi, S. (2007). " *Terminalia arjuna* Wight & Arn. A useful drug for cardiovascular disorders". Journal of Ethnopharmacology 114: 114-129.

Gulzar, A. and Siddiqui, M. B. (2013). Evaluation for allelopathic impact of *Terminalia arjuna* (Roxb.) wight and arn bark against *Cassia sophera.* African Journal of Agricultural Research. Vol. 8(39), pp. 4937-4940.

Hartmann, H.T., Kester, D.E., Davis, J.F.T. and Geneve, R.L. (1997). Plant Propagation Hensleigh TE and Holway, BK.1988. Agroforestry species for the Philippines. Washinton DC: US peace Crops, 404.

Hossain, M.A., Arefin, M. K., Khan, B. M. and Rahman, M. A. (2005a). Effects of seed treatments on germination and seedling growth attributes of horitaki (*Terminalia chebula* Retz.) in the nursery. Res. J. Agric. Biol. Sci. 1(2):135-141.

Hossain, M. A., Arefin, M. K., Khan, B. M. and Rahman, M. A. (2005b). Effects of different seed treatments on germination and seedling growth attributes of a medicinal plant bohera (*Terminalia belerica* Roxb.) in nursery. Int. J. For. Usuf. Mgt. 6:28-37.

Hossain, M.A., Uddin, M.S., Rahman, M.M. and Shukor, N.A. (2013). Enhancing seed germination and seedling growth attributes of medicinal tree specie *Terminalia chebula* through depulping of fruits and soaking the seeds in water. Journal of Food, Agriculture & Environment. Vol.11 (3&4): 2573-2578.

Kozlowski, T.K. (1958). Water relation and growth of trees. *Journal of forestry*, 56:498-502.

Kramer, P.J. (1969). Water and its role in plants. In: *plant and soil water relationships*- A modern synthesis. McGraw-Hill. New York, 483pp.

Kramer, P.J. and Kozlowski, T.K. (1979). Physiology of Woody Plants. Academic Press. Inc. San Diego, California-92101. Pp502-509.

Kumar, D.S. and Prabhakar, Y.S. (1987). On the ethnomedical significance of the arjun tree, *Terminalia arjuna* (Roxb.). Journal of Ethnopharmacology. 20:2, 173-190pp.

Kyaw N N. (2003). Site Influence on Growth and Phenotype of Teak (*Tectona grandis* Linn.f.) in Natural Forest of Myanmar. Göttingen, Cuvillier Verlag Göttingen.

Loomis, W.E. (1934). Daily growth of maize. *American Journal Botany,* 21:1-6.

Luna, R.K. (1996). Plantation Trees. International book distributors, Dehra Dun, India.782-787 pp.

Maguire JD. (1962).Speed of germination in selection and evaluation for seedling vigor. Crop Sci, 2:176-177.

Matin, M.A. (1989). Carbon economy during rooting of cuttings of *Nauclea diderrichii* (de, wild and th. Dur.) Merill. *M. Phil. Thesis*, Department of Forestry and Natural Resources, University of Edinburg, U.K., 123pp.

Matin, M.A. and Banik, R.L. (1993). Effect of polybag size on growth of some forest tree seedlings of Bangladesh. *Bangladesh Journal of Forest Science.* 22 (1&2):37-43.

Matin, M.A. and Khan,M.N. (1999). Growth performance of seven species of *Albizia* seedlings at nursery stage in Bangladesh. *Khulna University studies*. 1:277-282.

Matin, M.A. and Rashid, M.H. (2000). Seed germination and seedling growth performance at nursery stage of three multipurpose tree species in Bangladesh. *Khulna University Studies.* 2(1):141-148.

Morris, M. H., Negreros-Castillo, P. and Mize, C. (2000). Sowing date, shade and irrigation affect big-leaf mahogany '*Swietenia macrophylla* (king.) Forest Ecology and Management. School of Natural resources and the Environment, University of Michigan. Ann Arbor, M 48109, Usa. 132:2-3, 173-181.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Simons, A. (2009). Agroforestree Database: a tree reference and selection guide version 4.0

Oudhia, P. (2002). Arjun or Koha [*Terminalia arjuna* (Roxb.) W. & A.]. Society for Parthenium Management, (SOPAM).

Pancel, L. (1993). Tropical Forestry Handbook. Hamburg Germany, springer - Verlag.

Prashad, D.N., Isha, M. and Khare R. (1996). Tasar food plants for environmental management through social forestry. Environmental assessment and management. Social forestry in tribal regions held at Birsa Age. University, Ranchi, India.

Scassellati, S.G. (1999). Antigenotoxic properties of *Terminalia arjuna* bark extracts. J Environ Pathol Toxicol Oncol.

Siddique, K. and Ali, S.S. (1994). Tree planting and Nurshing Manual. National Institute of Local Government.

Silva RP, Santos J dos, Tribuzy ES, Chambers JQ, Nakamura S and Higuchi N. (2002). "Diameter increment and growth patterns for individual tree growing in Central Amazon, Brazil." Forest Ecology and Management 166(1-3): 295-301.

Srivastava, D.P., Isa, M. and Thangavelu, K. (1993). Comperatives effects of IAA, IBA and NAA on rooting and survival of air layers of *Terminalia arjuna* Bedd. Annals of forestry. 3:1, 77-80 pp.

Troup, R.S. (1921).The silviculture of Indian Trees. Clarendon press, Oxford. Vol. II 528-553.

Verma, R.K., Khatri, P.K., Kunhikannan, C. and Totey, N.G. (1998). Advantageous effects of the tree plantation on the rehabilitation of bhata land ecosystem. Indian Journal of Forestry. 21(3): 197-203.

Willan, L.L. (1990). Seed Pretreatment. Danida Forest Seed Centre. Lecture No. C-0. Denmark.

Yusuf M., Chowdhury, J.U., Wahab, M.A. and Begum, J. (1994). Medicinal plants of Bangladesh. Bangladesh Council of Scientific and Industrial Research, Dhaka. 340 pp.

Zabala, N. Q. (1990). Silviculture of species. Development of professional education in the forestry sector, Bangladesh. Institute Chittagong University, Chittagong.

APPENDICES

Germination percentage

The SAS System 1

22:44 Friday, June 9, 2000

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
BLOCK	3	B1 B2 B3
TRTMENT	4	T1 T2 T3 T4

Number of observations in data set = 12

The SAS System 2

22:44 Friday, June 9, 2000

Analysis of Variance Procedure

Dependent Variable: GROWTH

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	1640.08333333	908.35	0.0001
Error	6	2.16666667		
Corrected Total	11	1642.25000000		

R-Square	C.V.	GROWTH Mean
0.998681	1.005733	59.7500000

Source	DF	Anova SS	F Value	Pr > F
BLOCK	2	36.50000000	50.54	0.0002
TRTMENT	3	1603.58333333	1480.23	0.0001

```
                    The SAS System                              4
                                      22:44 Friday, June 9, 2000

               Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable: GROWTH

NOTE: This test controls the type I comparisonwise error rate,
      not the experimentwise error rate

            Alpha= 0.05  df= 6  MSE= 0.361111

               Number of Means     2     3
               Critical Range  1.040 1.078

Means with the same letter are not significantly different.

      Duncan Grouping             Mean      N  BLOCK

                    A          62.0000      4  B3

                    B          59.5000      4  B2

                    C          57.7500      4  B1


                    The SAS System                              6
                                      22:44 Friday, June 9, 2000

               Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable: GROWTH

NOTE: This test controls the type I comparisonwise error rate,
      not the experimentwise error rate

            Alpha= 0.05  df= 6  MSE= 0.361111

            Number of Means     2     3     4
            Critical Range  1.201 1.244 1.266

Means with the same letter are not significantly different.

      Duncan Grouping             Mean      N  TRTMENT

                    A          77.3333      3  T3

                    B          60.6667      3  T4

                    C          55.6667      3  T2

                    D          45.3333      3  T1
```

```
                  The SAS System                          1
                                   09:05 Friday, June 2, 2000

           Analysis of Variance Procedure
               Class Level Information

           Class      Levels     Values

           TRTMENT         4     T1 T2 T3 T4

         Number of observations in data set = 12


                  The SAS System                          2
                                   09:05 Friday, June 2, 2000

           Analysis of Variance Procedure

Dependent Variable: DIA

Source                DF    Sum of Squares     F Value      Pr > F

Model                  3       17.15588333       11.72      0.0027

Error                  8        3.90373333

Corrected Total       11       21.05961667

                R-Square              C.V.                DIA Mean

                0.814634          6.994787              9.98666667

Source                DF           Anova SS    F Value      Pr > F

TRTMENT                3       17.15588333       11.72      0.0027
```

```
Analysis of Variance Procedure

T tests (LSD) for variable: DIA

NOTE: This test controls the type I comparisonwise error rate
      not the experimentwise error rate.

          Alpha= 0.05  df= 8  MSE= 0.487967
              Critical Value of T= 2.31
        Least Significant Difference= 1.3153

Means with the same letter are not significantly different.

      T Grouping           Mean       N  TRTMENT

               A         11.5550      3  T3
               A
               A         10.6583      3  T4

               B          9.2533      3  T1
               B
               B          8.4800      3  T2
```



```
Analysis of Variance Procedure

Duncan's Multiple Range Test for variable: DIA

NOTE: This test controls the type I comparisonwise error rate,
      not the experimentwise error rate

          Alpha= 0.05  df= 8  MSE= 0.487967

          Number of Means      2     3     4
          Critical Range   1.315 1.371 1.402

Means with the same letter are not significantly different.

    Duncan Grouping          Mean       N  TRTMENT

                A         11.5550      3  T3
                A
                A         10.6583      3  T4

                B          9.2533      3  T1
                B
                B          8.4800      3  T2
```

```
                The SAS System
                                         09:07 Friday, June 2, 2000  1

        Analysis of Variance Procedure
            Class Level Information

        Class      Levels    Values

        TRTMENT         4    T1 T2 T3 T4


     Number of observations in data set = 12
```

```
                The SAS System
                                         09:07 Friday, June 2, 2000  2

        Analysis of Variance Procedure

Dependent Variable: HEIGHT

Source              DF    Sum of Squares    F Value     Pr > F

Model                3      414.55562500       6.04     0.0188

Error                8      183.07166667

Corrected Total     11      597.62729167

                R-Square            C.V.            HEIGHT Mean

                0.693669        4.915410             97.3208333

Source              DF          Anova SS    F Value     Pr > F

TRTMENT              3      414.55562500       6.04     0.0188
```

```
                    The SAS System
                                                                3
                                     09:07 Friday, June 2, 2000
              Analysis of Variance Procedure

             T tests (LSD) for variable: HEIGHT

NOTE: This test controls the type I comparisonwise error rate
      not the experimentwise error rate.

              Alpha= 0.05  df= 8  MSE= 22.88396
                  Critical Value of T= 2.31
             Least Significant Difference= 9.007

Means with the same letter are not significantly different.

        T Grouping              Mean       N  TRTMENT

                 A           104.967       3  T3
                 A
        B        A           100.967       3  T4
        B
        B        C            92.833       3  T2
                 C
                 C            90.517       3  T1


                    The SAS System                              4
                                     09:07 Friday, June 2, 2000

              Analysis of Variance Procedure

     Duncan's Multiple Range Test for variable: HEIGHT

NOTE: This test controls the type I comparisonwise error rate,
      not the experimentwise error rate

              Alpha= 0.05  df= 8  MSE= 22.88396

              Number of Means     2     3     4
              Critical Range  9.007 9.386 9.598

Means with the same letter are not significantly different.

     Duncan Grouping              Mean       N  TRTMENT

                   A           104.967       3  T3
                   A
          B        A           100.967       3  T4
          B
          B        C            92.833       3  T2
                   C
                   C            90.517       3  T1
```

The SAS System 1
09:08 Friday, June 2, 2000

Analysis of Variance Procedure
Class Level Information

Class	Levels	Values
TRTMENT	4	T1 T2 T3 T4

Number of observations in data set = 12

The SAS System 2
09:08 Friday, June 2, 2000

Analysis of Variance Procedure

Dependent Variable: LEAF

Source	DF	Sum of Squares	F Value	Pr > F
Model	3	39.93333333	1.20	0.3713
Error	8	89.03333333		
Corrected Total	11	128.96666667		

R-Square	C.V.	LEAF Mean
0.309641	6.262905	53.2666667

Source	DF	Anova SS	F Value	Pr > F
TRTMENT	3	39.93333333	1.20	0.3713

```
                    The SAS System
                                    09:08 Friday, June 2, 2000   3

              Analysis of Variance Procedure

              T tests (LSD) for variable: LEAF

NOTE: This test controls the type I comparisonwise error rate
      not the experimentwise error rate.

              Alpha= 0.05  df= 8  MSE= 11.12917
                  Critical Value of T= 2.31
            Least Significant Difference= 6.2812

Means with the same letter are not significantly different.

      T Grouping          Mean       N  TRTMENT

               A
               A        55.700       3  T3
               A
               A        53.833       3  T4
               A
               A        52.900       3  T2
               A
                        50.633       3  T1
```

```
                    The SAS System                               4
                                    09:08 Friday, June 2, 2000

              Analysis of Variance Procedure

      Duncan's Multiple Range Test for variable: LEAF

NOTE: This test controls the type I comparisonwise error rate,
      not the experimentwise error rate

              Alpha= 0.05  df= 8  MSE= 11.12917

              Number of Means      2     3     4
              Critical Range   6.281 6.546 6.693

Means with the same letter are not significantly different.

     Duncan Grouping          Mean       N  TRTMENT

                   A        55.700       3  T3
                   A
                   A        53.833       3  T4
                   A
                   A        52.900       3  T2
                   A
                   A        50.633       3  T1
```