EFFECT OF LEAF EXTRACTS OF *Swietenia mahagoni* L. ON THREE AGRICULTURAL CROPS

A THESIS

BY

RUMNAZ SHAMIMA NASRIN RIMA

Registration No. 1805165

Thesis Semester: January-June, 2019

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY AND ENVIRONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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June 2019

Dedicated

To

My Beloved Parents,

Husband and

Honorable Teachers

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EFFECT OF LEAF EXTRACTS OF *Swietenia mahagoni* L. ON THREE AGRICULTURAL CROPS

ABSTRACT

A study was conducted at the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh during May to September 2018.There were two experiments in the study. Experiment one was conducted to find out the effect of leaf extracts of *Swietenia mahagoni* on the three agricultural crops in laboratory condition. There were three concentrations of leaf extracts viz., 1%, 2%, 3% along with a control (only water). Experiment two was conducted with 1%, 2%, 3% concentration of leaf extracts with control (only water) in the pot. In both experiments, three agricultural crops namely Chilli, (*Capcicum annum*), Brinjal (*Solanum melangona)* and Okra (*Abelomoschus esculentas)* were taken as test crops to satisfy the objectives of the study. Designs of laboratory and pot experiments were CRD with three replications. Results of laboratory experiment showed that 3% concentration of leaf extracts of *S. mahagoni* inhibited more germination of all the three tested crops compared to other concentrations. Three percentage concentrations leaf extracts of *Swietenia mahagoni* showed that the germination percentage were 59.10% in Chilli, 56.28% in Brinjal, and 49.20% in Okra over control. The results indicated that inhibition increases with the increase of concentration. In case of pot experiments, leaf extracts of *S. mahagoni* also inhibited the germination of the three tested crop. Three percentage concentrations leaf extracts of *Swietenia mahagoni* showed germination percentage 55.69% in Chilli, 48.26% in Brinjal, and 50.23% in Okra over control. Morphological parameters like plant height (cm) showed significantly better performance in control over leaf extracts in all the tested crops at both laboratory and pot experiments. Similar results were recorded for biomass allocation like total dry weight (g). Among the three tested crops, Chilli performed the best compared to other two crops. From the overall result it can be concluded that the allelopathic effect of leaf and root of *S. mahagoni* on the agricultural crops which inhibited more in laboratory compared to pot condition. This effect may be minimized through proper management of the agroforestry field by removing the fallen leaf residues.

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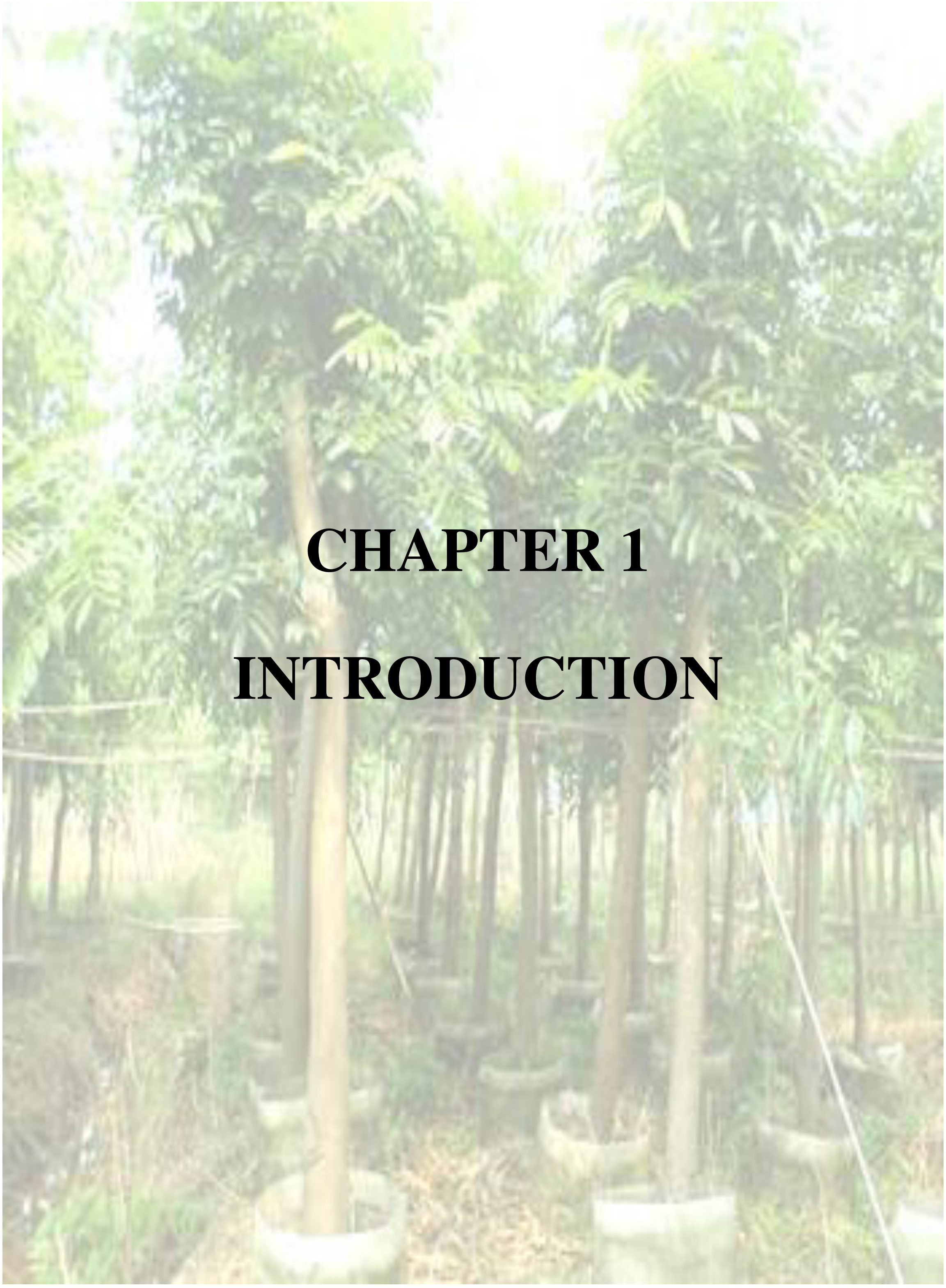
ACRONYM AND ELABORATIONS

AEZ	=	Agro-ecological zone
BADC	=	Bangladesh Agriculture Development Corporation
CRD	=	Complete Randomized Design
e.g.	=	For example
HSTU	=	Hajee Mohammad Danesh Science and Technology University
i.e.	=	That is
MS Excel	=	Microsoft Excel



CHAPTER 1

INTRODUCTION

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INTRODUCTION

Agroforestry has attracted a great attention in recent years because of its potential to reduce poverty, improve food security, reduce land degradation and mitigate climate change (Luedeling *et al.,* 2016). It can also provide a more even income for landowners since all of their income is not tied to a few crops or a single season. In agroforestry system as trees grow in close proximate to crops, interaction takes place and this interaction between trees and crops are common phenomena. The spatial root distribution of plants to be important for inter specific interactions in agricultural intercropping, few experimental studies have quantified patterns of root distribution and their impacts on inter specific interactions in agroforestry systems (Zhang *et al.,* 2013), competitive interactions between trees and crop causes decrease in productivity and the economic yield of intercropping system (Cao *et al.*, 2012). Besides this positive and negative interaction or above and below ground interaction (Ong *et al.,* 1991), many researchers found the allelopathic effect of trees on crops (Zhang and Fu, 2010). Some trees are considered of having allelochemicals and volatile compounds in all parts. These chemicals (allelochemicals) have harmful effects on the crops in the ecosystem resulting in the reduction and delaying of germination, mortality of seedling and reduction in growth and yield (Ghafar *et al*., 2000) and this effect is called allelopathic effect.

The term allelopathy is a Greek word meaning to suffer from each other. The allelopathic study has become a major issue nowadays. The effect of these allelochemicals has traditionally been considered as negative on other organisms. Allelochemicals inhibit seed germination by blocking hydrolysis of nutrients reserve and cell division and cause significant reductions in the growth of plumule and radical of various crops (Kayode and Ayeni, 2009). Some studies focus that allelochemicals are present in many organs, including leaves, flowers, fruits and buds (Inderjit, 1996; Ashrafi *et al.,* 2007). The allelochemicals have diverse applications in agriculture, especially in weed management in crop systems as growth regulator, weed management and as pesticides etc. Most of the studies asserted the inhibitory action of allelochemicals as well explored known dimension of allelopathy on the weed and pest management with the use of allelochemicals (Rizwan *et al.,* 2017).

Allelochemicals are present in practically all plant tissues. Modern research suggests that allelopathic effects can be both positive and negative, depending upon the dose and organism affected (Rice, 1984). Allelopathic interactions might lead to either stimulation or inhibition of growth. Allelopathy has the active or passive effects which influence the releaser itself or other organisms. Besides trees weeds also have allelopathic effect. Decline in crop yields in cropping and agroforestry system in recent years has been attributed to allelopathic effects (Oyun, 2006). Willis (1991) and Luo (2005) stated that less vegetation exists under *Eucalyptus* canopy than indigenous trees. Study by Lin *et al.,* (2003) showed that water, ethanol, or acetone extracts from *Eucalyptus* also have allelopathic effect on *Pisolithu stinctorius,* a common fungus in South China.

Several studies focused on the allelopathic effects caused by forest trees (Blanco, 2007). The forest trees, *mahogoni* spp were tested for their allelopathic effects on different plant species (Del Moral and Muller, 1970, Sasikumar *et al.,* 2001, Zhang and Fu, 2009, Kikuchi *et al.,* 2009).

The name mahagoni was initially associated only with those islands in the West Indies under British control (French colonists used the term *acajou*, while in the Spanish territories it was called *caoba*). The indigenous Arawak name for the tree is not known. In 1671 the word mahogany appeared in print for the first time, in John Ogilby's *America*. Among botanists and naturalists, however, the tree was considered a type of cedar and in 1759 was classified by Carl Linnaeus (1707–1778) as *Cedrela mahagoni*. The following year it was assigned to a new genus by Nicholas Joseph Jacquin (1727–1817), and named *Swietenia mahagoni*.

Until the 19th century all of the mahogany was regarded as one species, although varying in quality and character according to soil and climate. In 1836 the German botanist Joseph Gerhard Zuccarini (1797–1848) identified a second species while working on specimens collected on the Pacific coast of Mexico, and named it *Swietenia humilis*. In 1886 a third species, *Swietenia mahagoni*, was named by Sir George King (1840–1909) after studying specimens of Honduras mahogany planted in the Botanic Gardens in Calcutta, India. Today, all species of *Swietenia* grown in their native locations are listed by CITES, and are therefore protected. Both *Swietenia macrophylla* and *Swietenia mahagoni* were introduced into several Asian countries at the time of the restrictions imposed on American mahogany in the late 1990s and both are now successfully grown and harvested in plantations in those countries. A small percentage of global supply of genuine mahogany comes from these Asian plantations, notably from India, Bangladesh, Indonesia and from Fiji, in Oceania. For *Swietenia mahagoni*, the trees in these plantations are still relatively young compared to the trees being harvested from old growth forests in South America. Thus, the illegal trade of big leaf mahogany continues apace.

Mahagoni is a cropland agroforestry tree species planted along with various annual crops like paddy, wheat, and cereals and other cash crops in farmers' lands either in scattered or in bund (Raj *et al.,* 2016). *Swietenia mahagoni i*s one of the most important plants used to prevent soil erosion and to recover the plant cover. This plant also used in farmland as windbreak and medical plant (Saberi *et al.,* 2013).

Many studies have evaluated the allelopathic effects of and confirmed the strong inhibitory effects of Mahagoni extracts on some crops (Zhang and Fu, 2010). Leaf extract of Mahagoni inhibited seed germination and reduced root and shoot lengths of cucumber and maximum inhibition was observed in higher concentrations of extract (Allolli and Narayanareddy, 2000). The leaf leachate of *E. globulus* inhibited germination and growth of rice, sorghum and blackgram (Djanaguiraman *et al.,* 2005). Moreover, the extract of *E. globulus* inhibited germination and seedling growth of greengram and cowpea (Djanaguiraman*et al.,* 2002) and blackgram (Sasikumar *et al.,* 2002). El-khawas and Shehata (2005) found that leaf extract of *E. globulus* inhibited germination of maize and kidney-bean. The allelopathic effect of extract from S. *mahagoni* was tested on tomato; the extract significantly inhibited germination and growth of this plant (Fikreyesus *et al.,* 2011).

Swietenia mahagoni have been introduced into many countries, owing to their fast growth and their rising demand for paper and plywood (Cossalter and Pye-Smith, 2003). Mahagoni is widely grown in the tropics and subtropics and thus is of great commercial importance. At present, Mahagoni is grown on more than 20 million ha of plantations around the world (Booth, 2013). In Bangladesh, like many other developing countries, Mahagoni was introduced in the 19^{th} century (Hossain and Hoque, 2013).

Mahagoni species effect on the environment, on undergrowth vegetation and soil fertility may vary within different geographical areas, rainfall regimes and between species. So to discourage or promote the planting of Mahagoni and to use them for agroforestry purposes, sufficient scientific evidences on the ecological impact, on undergrowth vegetation, soil fertility, and the quality of the product should be further investigated (Kumar *et al*., 2008).

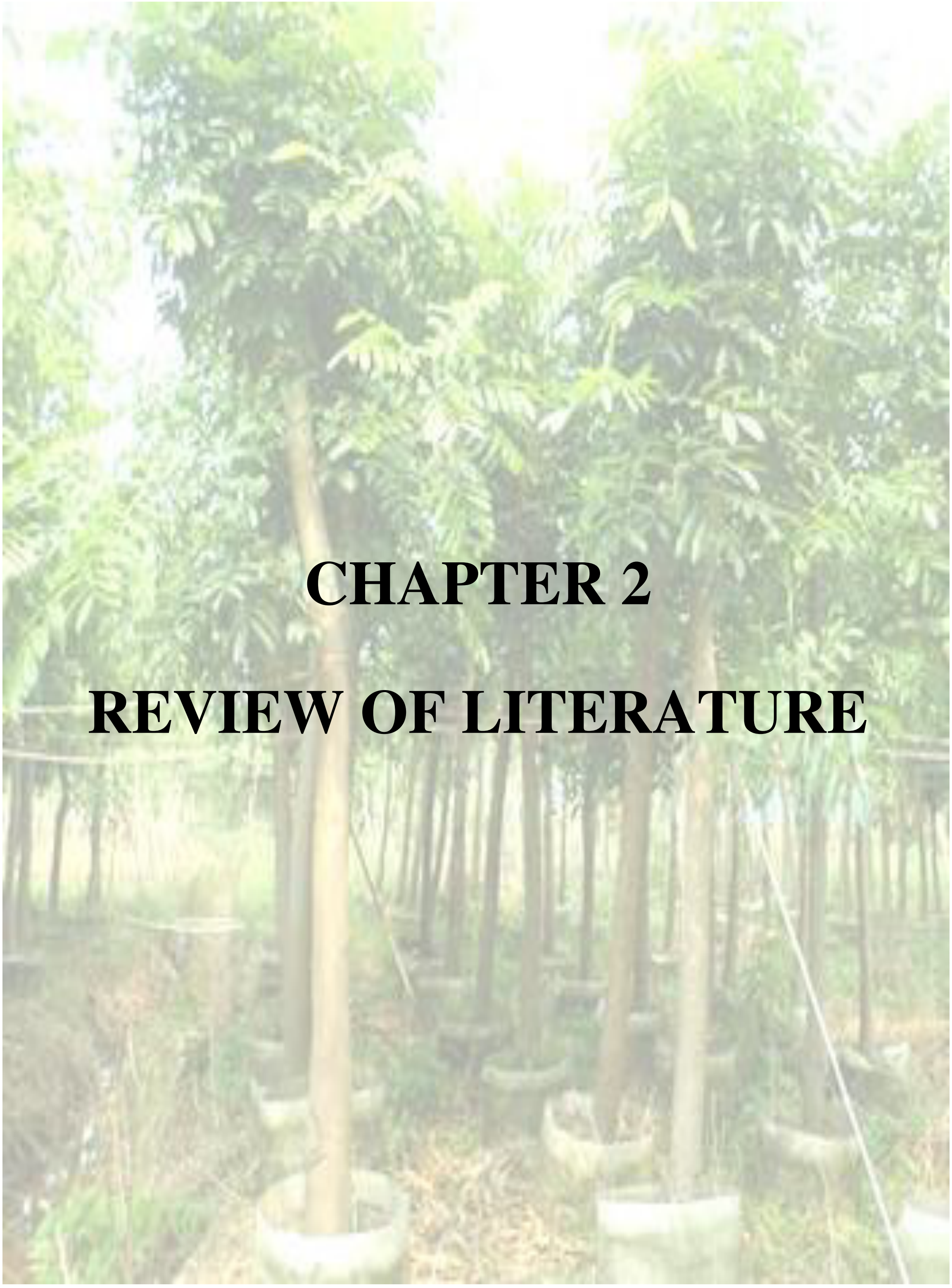
In the traditional agroforestry system, people are growing several tree species in or around the agricultural fields as a boundary or woodlot. Among these are *S. mycrophylla* and *S. mahagoni* are very common forest tree and due to their adverse effects some of the farmers are now reluctant to grow these tree species in their agricultural fields (CNST, 1997).

Very few researches have yet been undertaken to verify the impact of *S. mahagoni* leaf litter on land cropsunder Bangladesh conditions. In some cases, it is assumed that the effects in Bangladesh are the same as those in India (Hossain and Hoque, 2013). Certain phenolic acids and volatile oils released from the leaves, bark, stem and roots of certain Mahagoni species act as allelopathic agents and are harmful to other plant species (Florentine and Fox, 2003). The allelopathic effects have been mostly studied of leaf litter and root extracts and least of live leaf (Zhang and Fu, 2010). As *S. mahagoni* is now an integral part of our agroforestry system. Therefore this study will be an attempt to assess the effect of leaf extracts of *S. mahagoni* on germination and growth of three agricultural crops in different concentrations.

Objectives:

The study was carried out with the following objectives:

1. To assess the effects of leaf extracts of *Swietenia mahagoni* on germination and seedling growth of three crops namely Chilli, Brinjal and Okra.
2. To find out above ground biomass allocation of the tested crops due to the influence of extracts.



CHAPTER 2

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

Agroforestry is relatively a new area of research. A lot of studies have been conducted on allelopathic effect of agroforestry tree species on vegetable crops but very few research projects have been done to observe the effects of *Swietenia mahagoni* under Bangladesh conditions (Hossain and Hoque, 2013). Therefore, the research was carried out to observe the effects of *Swietenia mahagoni* on some agricultural crops like Chilli, Brinjal and Okra. Literatures some way linking to the subject of interest from home and abroad are reviewed and outlined below the following headings:

2.1 Concept of Agroforestry

The word agroforestry is derived from the combination of two words that is agro, meaning "agriculture crops," and forestry, meaning "forest trees”. It is a farming method that allows trees and shrubs to grow along with agriculture crops and/or livestock that means blending agriculture and forestry in the same production system.

Agroforestry is a system which is not only ecologically rational but also economically sound. In recent years, agroforestry is developed as a science for improving the productivity, profitability and sustainability of production of available lands, and soil conservation.

Agroforestry has three components that are forestry (trees), agriculture (crops) and livestock (animals)/fodder and forage. The combination of these components is known as agroforestry. However, the definitions of agroforestry given by various scientists and institutions are as follows:

"Agroforestry is a sustainable management system for land that increases overall production, combines agriculture crops, tree crops, and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population" (Bene *et al.*, 1977).

Nair (1977) defined Agroforestry is a land use system that integrates trees, crops and animals in a way, which is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers.

"Agroforestry has been defined as a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially, on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population" (King and Chandler, 1978).

King (1978) explain the concepts of agroforestry, and to delineate various sub-divisions of the subject. Agroforestry should be considered to be a generic term which embraces the following specific components:

Agri-silviculture - the conscious and deliberate use of land for the concurrent production of agricultural crops (including tree crops) and forest crops.

Sylvo-pastoral systems - land management systems in which forests are managed for the production of wood as well as for the rearing of domesticated animals.

Agro-sylvo-pastoral systems - in which land is managed for the concurrent production of agricultural and forest crops and for the rearing of domesticated animals. This system is, in effect, a combination of agri-silviculture and the sylvo-pastoral system.

Multi-purpose forest tree production systems - here forest tree species are regenerated and managed for their ability to produce not only wood, but leaves and/or fruit that are suitable for food and/or fodder.

Agroforestry is a land use practice in which farmers deliberately integrate woody perennial plants—trees and shrubs—with crops or livestock on the same tract of land. Agroforestry systems, (whereby there is a deliberate planting of trees in combination with food/forage crops for the benefit of people and the environment) have been reported to be potentially productive in degraded and marginal soils. The trees and shrubs in agroforestry systems can be selectively protected and regenerated, or planted and managed. Agroforestry systems can include native species as well as introduced non-native species. As farmers include woody species that produce wood, fodder, edible leaves, and other products, agroforestry systems evolve into more complex production systems that can provide a broader range of benefits and more resilient farming systems than those relying on simplified annual crop production. There are numerous definitions of agroforestry which stress different aspects of and expectations about the integration of trees in farming landscapes. Following the predominant definition over the past two decades, agroforestryis a set of land use practices that involve the deliberate combination of woody perennials including trees, shrubs, palms and bamboos, with agricultural crops and/or animals on the same land management unit in some form of spatial arrangement or temporal sequence such that there are significant ecological and economic interactions among the woody and non woody components (Sinclair, 1999).

Agroforestry practices offer practical ways of applying various specialized knowledge and skills to the development of sustainable rural production systems. Agroforestry is recognized as a land use option in which trees provide both products and environmental services. In agroforestry systems, the trees grown on different farmlands in the same locality when aggregated can bring about improved wooded situation thereby enhancing environmental protection (Otegbeye, 2002).

World Agroforestry Center (ICRAF, 2000), agroforestry is defined here as a dynamic, ecologically based natural resource management practices that, through the integration of trees and other tall woody plants on farms and in the agricultural landscape, diversifies production for increased social, economic and environmental benefits.

Agroforestry has been defined as a dynamic, ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Leakey, 1996).

Saxena (1984) pointed out that agroforestry utilizes the inter space between tree rows for intercropping agricultural crops and that does not impair the growth and development of the trees but enables farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

The International Centre for Research in Agroforestry (ICRAF, 1997) defines agroforestry as a dynamic, ecologically based, natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for all land users at all levels.

Agroforestry include the optimal use of land for both agricultural and forestry production on a sustainable basis including the improvement of the quality of soil. This is in addition to the socio-economic benefits that are accruable from agroforestry. Indeed the advantage of agroforestry is all encompassing and germinates to a sustainable production system and livelihood. (Alao and Shuaibu, 2013)

Saka *et al*. (1990) stated that an agroforestry system can provide a sound ecological basis for increased crop and animal productivities, more dependable economic returns and greater diversities in social benefits on a sustained basis.

Agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Verma *et al.,* 2016).

Lundgren and Raintree (1983) defines agroforestry is a collective name for land use systems and technologies where woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals, in either a spatial arrangement or a temporal sequence, there being both ecological and economical interactions between the different components.

Whether on marginal or high-potential lands, diversified agroforestry systems may be the most appropriate form of land use where land tenure constraints, lack of marketing infrastructure or an unfavourable political economy make it imperative for small landholders in trying to reduce risks, to try to satisfy most of their basic needs directly from the land resources under their control (Lundgren and Raintree, 1983).

2.2 Tree Crop Interaction

The integration of agriculture and/or farming with forestry on the land can simultaneously be used for more than one purpose. This practice is meant to have both environmental and financial benefits.

In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree, 1982).

When promoting agroforestry one should then stress the potential of it to achieve certain aims, not only by making theoretical and qualitative remarks about the benefits of trees, but also, and more importantly, by providing quantitative information (Lundgren, 1982).

Whenever tree-crop combination is tried as an agroforestry intervention, there can be strong above-ground and below-ground interaction for critical and limited resources. In general, trees have been found to improve soil physical and chemical properties by various means (Nair, 1984; Lai, 1989).

Trees act as nutrient pumps i.e. exploiting the nutrients from the deeper depths and in the process of recycling make it accessible to the companion shallow rooted ground crop (Kellman, 1979; Yamoah *et al.,* 1986). This situation although is not applicable where "cut and carry" practice is a common feature which depletes the soil nutrients year after year and may result into unsustainable proposition (Nair, 1993). The intensity and severity of interaction for nutrients between the trees and crops will depend on the planting geometry and density of each component. However, direct evidence as to where, and how severely, nutrient competition occurs is limited due to the difficulties of separating nutrient competition from competition for light, water and from allelochemical interactions (Young, 1989). Imo and Timmer (2000) concluded that tree-crop interactions are not constant, and may be affected by several factors, including total planting densities, component combinations, climatic and soil conditions, and management regimes.

Tree-crop combination competes for available moisture in the soil, more severely under rainfed agroforestry system. So, inadequate moisture will become the limiting factor which will deleteriously affect the growth and yield of the components (Singh *et al.,* 1989; Corlett *et al.,* 1989).

Progress in promoting agroforestry is held back because decision-makers lack reliable tools to accurately predict yields from tree-crop mixtures. Amongst the key challenges faced in developing such tools are the complexity of agroforestry, including interactions between various system components, and the large spatial domains and timescales over which trees and crops interact. A model that is flexible enough to simulate any agroforestry system globally should be able to address competition and complementarity above and below ground between trees and crops for light, water and nutrients. Most agroforestry practices produce multiple products including food, fiber and fuel, as well as income, shade and other ecosystem services, all of which need to be simulated for a comprehensive understanding of the overall system to emerge. Several agroforestry models and model families have been developed, but as of 2015 their use has remained limited for reasons including insufficient flexibility, restricted ability to simulate interactions, extensive parameterization needs or lack of model maintenance. An efficient approach to improving the flexibility and durability of agroforestry models is needed. Various types of agroforestry systems are currently being promoted in many contexts, and the impacts of these innovations are often unclear. Rapid progress in reliable modeling of tree and crop performance for such systems is needed to ensure that agroforestry fulfills its potential to contribute to reducing poverty, improving food security and fostering sustainability (Luedeling *et al.,* 2016).

Modeling competition and complementarily in capture of light, water and nutrients must often be considered in attempts to predict yield of tree-crop mixtures. The impact of trees on crop microclimate can be of key importance (Ong *et al.,* 2015). In all crop models, crop growth is simulated as a response to available water and ambient temperature, often also to light capture. All of these are substantially altered by trees, and the impact will depend on tree canopy structure and, for water, on rooting patterns (Anderson and Sinclair, 1993). Accurate simulation of these interactions is one of the major challenges in agroforestry modeling, since they are central for verifying one of the primary pathways through which agroforestry is expected to contribute to climate change adaptation in hot climates. Likewise, competition and complementarily below-ground is an area for model development. How water and nutrients are partitioned between different parts of the tree, as well as between trees and crops is one of the more complex questions in agroforestry modeling. To what level of detail these processes should be simulated is amongst the central decisions that an agroforestry modeler has to take. There are certainly arguments for simulating many nutrient and water acquisition processes at the root level, including hydraulic lift, but the complexity that this might add to a model, its parameterization needs and processing time during simulation runs may often not be desirable.

Incorporation of tree hedges along contours has been proposed as a means of reducing soil erosion and increasing soil fertility of tea (*Camellia sinensis* L.) plantations on sloping terrain in high-rainfall zones of Srilanka. Tea yields in these hedgerow intercrops are determined by the balance between the positive (i.e., increased soil fertility) and negative (i.e., resource competition) effects of hedgerows. Tea yields, measured over one complete pruning cycle from October 1998 to September 2001, showed reductions relative to a sole tea crop under all hedgerow species except *Euphatorium*. The yield reductions ranged from 22 to 40%. Tea yields under *Euphatorium* showed increases up to 23% relative to the sole crop control. Addition of hedgerow prunings as mulch increased tea yields in all hedgerow intercrops. The yield increases ranged from 11 to 20%, with the highest being under *Euphatorium*. Tea yields showed a negative relationship (R^2=0.38) with the pruned biomass of hedgerows. Limitation of environmental resources (e.g., water and light) and hedgerow characters which intensified resource competition (i.e., greater canopy lateral spread and height and greater root length densities, especially in the top soil layer) were responsible for observed tea yield reductions in hedgerow intercrops (De Costa and Surenthran, 2005).

Integration of trees in agroforestry system results in positive or negative interactions between trees and crops. Micro-climate amelioration and maintenance or improvements in soil productivity are the major positive interactions while competition for light, water and nutrients, and allelopathy are the major negative interactions in agroforestry systems. The balance between negative and positive interactions determines the overall effect of interactions in a given agroforestry system. Selection of suitable tree species for agroforestry is important, however many a times it is not possible to select tree species having all the desirable characters for agroforestry because of different production or protection goals. In such situations agroforestry systems have to be managed through planting optimum density of trees, proper spatial arrangement and pruning and thinning of tree crowns and roots to reduce the negative effects of trees (Basavaraju and Rao, 2000).

In recent decades, integrating trees with crops for food and wood production has received considerable attention in both tropical (Garrity *et al.,* 2010) and temperate regions (Palma *et al.*, 2007). Agroforestry has shown potential to increase and sustain food production per unit area in systems like the parklands of the Sahel (Bayala *et al.*, 2012), through the use of 'fertilizer trees' intercropped or in fallow rotations with crops throughout sub-Saharan Africa (Sileshi *et al.*, 2008) and through integrating trees with crops on sloping land (Tiwari *et al.*, 2009). It is increasingly seen as a promising approach to improving food security (Glover *et al.,* 2012), largely because the trees are associated with enhancing and sustaining soil health and hence crop yield (Barrios *et al.,* 2012). Trees also produce fodder, fuel and construction materials, which are in high demand in many rural areas and if produced on farm may reduce the costs of obtaining them off-farm. Through production of high value timber, farmers can often generate substantial additional revenue in both temperate (Dupraz *et al.*, 1997) and tropical contexts (Dupraz *et al.*, 1997; Bertomeu, 2006; Santos-Martin and Van Noordwijk, 2009). Fruits obtained from trees can enhance both income (Luedeling and Buerkert, 2008) and human nutrition (Kehlenbeck *et al*., 2013).

Agroforestry practices are often part of strategies to improve natural resource management (Ong and Kho, 2015), and they are often more effective than other land uses in providing regulating, supporting and cultural ecosystem services (Pagella and Sinclair, 2014), such as microclimatic buffering, amelioration of soil structure and water infiltration, reduction of overland flow, regulation of the water cycle and provision of habitat for wild species (Bayala *et al.,* 2014). The potential of agroforestry practices to sequester carbon in wood and soil has been widely demonstrated (Luedeling *et al*., 2011;). Agroforestry may also affect emissions of other greenhouse gases either positively or negatively (Rosenstock *et al*., 2014) and is expected to help farmers adapt to climate change through the risk-mitigating effects of additional farm products derived from trees, positive microclimatic effects through shading and enhanced farm productivity through tighter nutrient and water cycles (Garrity *et al.,* 2010).

Agroforestry interventions are envisaged in many places, including locations where they have never been tested. In a number of cases, substantial positive contributions of agroforestry to food security, natural resource management, and climate change mitigation and adaptation have been demonstrated, but it is clear that not all these successes can be replicated everywhere. The magnitude of all documented or assumed benefits of agroforestry depends on site-specific responses by trees, crops or other components of the system, with strong variation between locations and farming contexts (Coe *et al.,* 2014). Benefits also vary over time, because many effects of trees on soils are slow to materialize (Barrios *et al*., 2012). For instance, the beneficial effects of *Faidherbia albida* on crop yields have been reported to start only after the trees reach 20 to 40 years of age (Ong and Kho, 2015).

The long life span of trees, and the large number of potential tree species means that it often takes a long time to establish the viability and relative merits of alternative agroforestry practices in new environments through empirical approaches. This makes recommendation domains for particular technologies difficult to delineate. Tools are needed for faster ex-ante assessment of performance potentials. Since planted trees can remain in place for decades, such tools need to consider the impacts of climate change (Luedeling *et al*., 2014). Process-based modeling has been identified as a viable approach to making such projections (Bayala *et al.*, 2015), but a number of obstacles must be overcome for agroforestry models to successfully meet this challenge.

Many farming systems in developing countries are complex assemblages of several species, and they often include trees or other woody elements, that exhibit competitive as well as complementary interactions with field crops (Bayala *et al.,* 2015). Trees can affect crop production in a number of ways, negatively through competition for light, nutrients and water, as well as positively through increased input of biomass from leaves and roots that often enhance nutrient cycling (Rao *et al.,* 1998). Positive effects on crops may also arise through improved water relations (Bayala *et al.*, 2008) and microclimate (Muthuri *et al.*, 2014). Modeling approaches for capture of water, nutrients and light that produce reliable predictions in monocultures may not suffice in more complex situations, because they do not consider critical competitive and facilitative interactions between trees and crops. In monocultures, accurate prediction of the timing and location of water uptake, nutrient uptake and light interception, is less critical than in mixtures, because all modeled plants are similar in their uptake and interception characteristics. Resource availability dynamics in different soil layers and over a sequence of days can be thus simulated relatively easily. In mixed cropping situations, this may be true for aggregated plant growth, but not for growth of competing components (Van Noordwijk *et al.*, 1998). The wide range of existing empirical and mechanistic tree models that operates from leaf to stand scales, while capable of modeling discrete trees and, in principle, their interaction with crops, have rarely been successfully coupled with crop models (Van Oijen *et al.,* 2010). Similarly to monoculture crop models, most tree models are designed to simulate single trees or single-species forests or plantations. More complex arrangements, such as mixed-tree stands or seedling development in forests, have been modeled (Lopez-Serrano *et al.,* 2015), but such models remain limited to situations that are much simpler than most agroforestry settings (Porte and Bartelink, 2002).

Zhang *et al.* (2013) a field experiment was conducted to investigate the relationship between root distribution and interspecific interactions between intercropped jujube tree (*Zizyphus jujuba* Mill.) and wheat (*Triticum aestivum* Linn.) in Hetian, south Xinjiang province, northwest China. They found that the interspecific competition effects in jujube tree/wheat agroforestry systems.

In agro-ecosystems, several weeds, crops, agroforestry trees and fruits trees can interact negatively with crops by exerting an allelopathic influence on crops, thus, affecting their germination and growth adversely (Kohli *et al.,* 1998).

2.3 Allelopathy of different multipurpose trees /crops

Literature reveals that higher plant (tree-crops) releases some phytotoxins into soil, which adversely affect the germination and yield of crops. This type of tree-crop interactions was named phytochemical ecology/ecological biochemistry (Harborne, 1977).

Neem (*Azadiracta indica)* is an evergreen tree native to Southeast Asia. All parts of the tree have been used medicinally for centuries. It is widely used in toothpastes, soaps and lotion today, as well as biological insecticide. Neem (*Azadiracta indica*) is a versatile tree native to South and Southeast Asia, Japan, tropical USA, South America, Australia and Africa (Bokhari and Aslam, 1985; Von Maydell, 1986).

Amalraj and Shankarnarayan (1986) investigated that the aqueous extracts of *Balanites roxburghii* leaf fruit have inhibitory effects on germination of *Pennisetum typhoides, Sesamum indicum, Vigna radiate* and *Vigna aconitifolia.* At 10% concentration of extract, the germination percentage was reduced in all, but the effect was statistically significant only in the case of *Pennisetum typhoides.*

The allelopathic effect of three tree species (*Azardiracta indica, Vitellaria paradoxa, and Parkia biglobosa*) on germination and growth of cowpea was investigated in the Southern Guinea Savannah agro ecological zone of Nigeria. Results showed that the tree species brought about considerable inhibition in the germination of cowpea seeds and in its growth parameters. The statistical germination value of the cowpea seeds under the tree species had decreased value thus indicating that growth inhibitions were seriously felt. It was apparent that *Parkia biglobosa* (53.33) and *Vitellaria paradoxa* (60.00) had more inhibitory effect on cowpea seeds germinability than that of *Azardiracta indica.* (63.33) while all the treatments are lower than that of control (100). The tree species had similar inhibition capability in the cowpea plant height, stem circumference, number of leaves, above grand biomass and below grand biomass. (Aleem *et al.,* 2014).

Gulzar and Siddiqui (2015) conduct research to investigate the effect of aqueous extract from *Calotropis procera* on the growth of *Brassica oleracea var botrytis.* They found that higher concentrations of extract (60% and 80%) significantly reduced germination percentage, radicle length, plumule length, dry matter accumulation, and relative water content of the brassica seedlings as compared to control. The retardatory effect increases with the increase in the concentration of three types of extract used, with more pronounced effect noticed by leaf extract followed by fruit and flower extract. There were significant interactions among the different concentrations of extracts used, type of extract with respect to gemination percentage, seedling length, dry biomass, and relative water content. The effect of pot based assay in relation to chlorophyll content was significantly reduced and antioxidant enzymes [superoxide dismutase (SOD), peroxidase (POD), and catalase (CAT) activities] show both significant and non-significant effect on antioxidant enzymes based on concentrations of extract and extract type used. The antioxidant enzymes show the significant decrease in its activity at low concentrations (20% and 40%) and non-significant increase at higher concentration (60% and 80%) of extracts in contrast to control.

Albuquerque *et al.* (2010) observed thatthe phenomenon of allelopathy has recently received greater attention from researchers and farmers worldwide crop failures and low yields caused by the reseeding, over seeding, crop rotation and replanting of fruit trees in orchards are believed to be caused by allelopathic activity. Moreover, the expensive and environmentally impacting herbicides for weed control have motivated studies directed at developing cheaper, environmentally-friendly alternatives. The release and dynamics of allelochemicals in the soil are discussed herein. Examples of allelopathic crops, the allelochemicals produced and their uses in cropping systems are also presented along with current research trends regarding allelopathy.

Adhikary (2017) conducted a research to evaluate the allelopathic effect of *Xanthium indicum L.* on seedling growth and total chlorophyll content in green gram (*Phaseolus radiatus* L.). The results showed that different concentrations of various types of aqueous leachate of test weed (5, 10, 15, 20 and 25%) were reduced seedling growth and total chlorophyll content. The findings reveals that there might have diversified group of allelochemicals present in test weed which leached to soil medium and there after absorbed by crop plant where they reduced or inhibited the intermediate metabolic pathways as a result seedling growth and total chlorophyll content reduced.

Mubeen *et al*. (2012) conducted a study to evaluate the allelopathic effects of water extracts of sorghum and sunflower alone and in combination on the germination and seedling growth of rice and weeds *viz., Trianthema portulacastrum, Dactyloctenium aegyptium* and *Eleusine indica*. Distilled water treatment was included as control. Sorghum and sunflower water extracts when applied in combination caused maximum inhibitory effects on time taken to 50% germination, mean germination time of *E. indica* seeds and germination index of *T. portulacastrum* seeds as compared to the sole application of these water extracts. Water extracts of sorghum and sunflower when applied alone or in combination increased the root, shoot length and the seedling biomass of rice over control. Combined application of sorghum and sunflower water extracts has overall more inhibitory effects on the germination of rice, *T. portulacastrum*, *D. aegyptium* and *E. indica* when compared to their sole application.

Manimegalai *et al.* (2012) worked out aspects of allelopathy in natural, managed and manipulated ecosystems are the role in agriculture. Extract were prepared from dried leaves using distilled water. The sterilized fifty seeds were placed in petridishes containing different concentrations of *Tectona grandis* leaf extract (5, 10, 25, 50, 75 and 100%). Seeds with distilled water were maintained as control. The emergence of radicle was taken as criteria for germination from 2nd day after sowing. Germination percentage was maximum in 5% extract treatment and the percentage of germination was gradually decreased as the concentration of extract increased. A low percentage of germination was observed in 100% concentration of leaf extract. The 5% extract alone showed a promontory effect, while the other concentrations exhibited inhibitory effect. The intensity of inhibition increased as the concentration of the leaf extract increased.

Hossain *et al*. (2012) carried out a study to examine the allelopathic effect of different concentrations of leaf, root, bark, fruit kernel and seed aqueous extracts of *Moringa oleifera* on the germination of *Vigna radiata* cv. The rate of germination of *V. radiata* decreased with the increase of aqueous extract concentration, irrespective of plant parts. The rate of germination was found to suffer more when treated with 10.0, 12.5 and 15.0% extracts. Among the plant parts root and bark aqueous extract were found to inhibit mungbean germination more than the other plant parts used. The inhibitory effect of leaf, fruit kernel and seed aqueous extracts were almost similar, while those were relatively less than bark and root extracts. The allelochemicals released from different plant parts of *M. oleifera* impeded the rate of germination in laboratory condition.

Hassan *et al.* (2012) studied the allelopathic potential of the aqueous extracts and powder of Khella (*Ammi majus*), Ghobaish (*Guiera senegalensis*) and Safsaf (*Salix spp.*) on germination and seedling growth of two *Sorghum bicolor* L. cultivars. Khella extract sustained the maximum reduction in germination percentage and mean germination time. Botanical extracts exhibited extra inhibitory effects on radical emergence than on plumule growth. Pot experiment indicted variations in seedlings germination and post-germination growth between the two cultivars in response to different botanical residues. Fatarita seedling emergence improved by Khella and decreased with Ghobaish and Safsaf. While, Hybrid seedling emergence improved with Ghobaish and Safsaf and reduced by Khella as compared to control. The higher MGT was recorded in Fatarita in some treatments as compared to control. Hybrid exposes a constant MGT in all treatments. Botanical extracts stimulated some growth parameters and reserve others in both cultivars. The results suggest that allelopathic potentials of these plants may entitle them to control specific weeds especially in non-sequential crops by preparing them as natural herbicides.

Gupta and Mittal (2012) studied the allelopathic effects of some selected weeds (*Phalaris minor* L.*, Chenopodium murale* L.*, Sonchus oleraceus* L.*, Cyanodon dactylon* L. and *Convolvulus arvensis* L.*)* of Ajmer district on seed germination and seedling growth of wheat (*Triticum aestivum* L.). Root, stem and leaf aqueous extracts of weeds at 2, 4, 6, 8, 10% concentrations were applied on test plant under laboratory conditions. The aqueous extracts of all the weeds under study caused inhibitory effects on seed germination; seedling length and seedling dry weight of crop, which increased progressively on increasing the concentration of weed plant part extracts. The leaf extract of *Phalaris minor* have more inhibitory effect on the germination percentage of crop as compared to other weeds under study. The inhibition caused by the leaf extract of *Phalaris minor* was found to be more than stem and root extracts of all the weeds under study.

Evangeline *et al*. (2012) studied the allelopathic impact of *Tectona grandis* L. on the germination and seedling growth of *Vigna mungo* (L.). Seed germination and seedling growth of *V. mungo* were inhibited. In addition, the reduction of seed germination was found to be up to 48% at 10% concentration. At this concentration, the epicotyls showed 67.30% reduction in length when compared to the control. Consequently, the hypocotyl demonstrated 64.70% reduction in length. In pot culture experiments, a 4% aqueous extract of the leaves was found to inhibit seed germination and the growth of the seedlings. This concentration of leaf extracts reduced seed germination percentage to the tune of 70.00%. There was reduction in shoot length to about 33.30% and the root length about 54.30%. Higher concentration of aqueous extracts of the leaves prevented seed germination. As for the biomass of *V. mungo* is concerned, aqueous extracts of the leaves of *T. grandis* caused a corresponding reduction.

Ashafa *et al.* (2012) carried out an investigation on the allelopathic effects of dry and fresh aqueous leaf extracts of *Mangifera indica* at 5, 10, 15 and 20% on the seed germination percentage and seedling growth rate of C*assia occidentalis* seeds in a greenhouse. Both dry and fresh leaf extracts exhibited different degrees of inhibition in *C. occidentalis* germination percentage and growth rate of seedlings at varying concentration. Dry leaf extract at 15 and 20% completely inhibited the emergence of *C. occidentalis* while the aqueous fresh leaf extract at these concentrations yielded some degree of seed germination and growth rate. The seedling radicle and plumule length were adversely affected as the treatment level increases in both extracts. The concentration dependent responses of *C. occidentalis* to both dry and fresh leaf extracts confirmed that both extracts contain allelochemicals which are likely to be phenolic compounds. On the basis of overall toxicity potency of *M. indica* leaves, result showed that 15 and 20% dry leaf extract exerted the highest germination percentage and growth inhibition on *C. occidentalis* seeds. The compounds from *M. indica* leaves especially the dry ones possess a strong phytotoxic potential and can serve as lead molecules for the synthesis of bioherbicides**.**

Shapla *et al.* (2011) revealed that inhibition of germination and growth parameters of mungbean and soybean were varied according to different parts of plants and soil from different place. *Melia azedarach*: T2 (root zone soil) >T3 (soil mulched dry leaf) >T4 (soil watered with aqueous leaf extract T1 (top soil T5 control / fresh garden soil).

Alagesaboopathi (2011) reported that leaves stem and root extracts of *Andrographis paniculata* significantly decreased germination and seedling growth in *Sesamum indicum*.

Alagesaboopathi and Deivannai (2011) stated that the plumule and radicle length of *Cajanuscajan* var. Vamban 2 and var. Vamban 3 seedlings with increase of *S. grandiflora* extracts concentration. The result revealed that the inhibitory and stimulatory effect may be due to the presence of these allelochemicals like sterols, saponins, phenols and tannins.

Mehar (2011) reported that mesquite (*Prosopis juliflora* (Sw.) DC.), which is widespread in Saudi Arabia, United States of America and India, inhibits the germination or growth of many plant species growing in its vicinity, through by releasing allelopathic substances into the environment. Due to this, it has not been put to good use despite of enormous biomass production. The present study was attempted to observe the effect of aqueous extract of mesquite tree on the growth of rice seedlings. For this two different concentrations of an aqueous extract (0.1 and 1%) were used as treatments. The results indicated that except for some treatments, both at low concentrations; most of the treatments had led to comparable or better growth of seedlings than the control treatment. Even when there was less reserve mobilization from seeds during germination; seedlings were able to make up the loss in due course of time and showed better growth than control.

Rebecca and Sahoo (2011) studied the effects of aqueous leaf extracts of *Tectona grandis* L. and *Mikania micrantha* L. on germination and growth of *Zea mays* L. (maize) and *Oryza sativa* L. (paddy) during 2009-2010. The extracts suppressed the germination of paddy to an extent of 10-30% under high extract concentration and 40-50% suppression in maize under similar concentration. The growth of root and shoot of both the test crops also got suppressed under high extract concentration. Similar was also the case with *M. micrantha* where germination of paddy was suppressed to an extent of 10-35% and 45-65% suppression in maize under high extract concentrations. As the concentration increased from 30-100% the aqueous leaf extract of *M. micrantha* has detrimental effect on the root and shoot growth of both the test crops.

Dhole *et al.* (2011) investigated the allelopathic effect of five weed species *viz., Ameranthus tricolor* L., *Euphorbia heterophylla* L., *Physalis angulata* L., *Alternanthera sessilis* L. and *Portulaca oleracea* L. collected from Jawar fields from Nanded District. The aqueous extract of *Portulaca oleracea* L. was found to be stimulatory effect towards seed germination root length, shoot length and seedling growth of Jawar. The *Physalis angulata* L. had shown inhibitory effect while *Ameranthus tricolor* L., *Alternanthera sessilis* L. and *Euphorbia heterophylla* L. having moderate inhibitory effect. Further the allelopathic potential of five different weeds in same Jawar field and suggested that those weeds may affect Jawar seed germination and seedling growth due to inhibitory or stimulatory effect of allelochemicals which are present in the aqueous extract of weeds.

Salam and Kato (2010) studied allelopathic potential of aqueous methanol extract of Neem leaves on seed germination and seedling growth of different plants *viz.,* Cress (*Lepidum sativum* L.), Lettuce (*Lactuca sativa* L.), Alfalfa (*Medicago sativa* L.), Wild Buckwheat (*Eriogonum compositum*), Sand Fescue (*Festuca myuros* L.), Timothy (*Phleum pratense* L.), Barnyard grass (*Echinochloa crusgalli*) and *Echinochloa colonum* .Neem leaves may contain growth inhibitory substances and may possess allelopathic potential. Therefore, Neem leaves may be a possible candidate for the isolation and identification of allelopathic substances and for the development of natural herbicides for sustainable agricultural production.

Hossain and Alam (2010) revealed that different concentrations of *Lantana camara* leaf extracts caused significant inhibitory effect on germination, root and shoot elongation and development of lateral roots of the *Oryza sativa* L., *Triticum aestivum* L., *Vigna sinensis* (L.) Hassk.*Cucurbita pepo* L., *Abelmoschus esculentus* (L.) Moench, *Amaranthus tricolor* L.) and forest crops (*Acacia auriculiformis* A. Cunn. ex Benth. and Hook, *Paraserianthes falcataria* (L.) Nielson, *Albizia procera* (Roxb.) Benth.

Sahoo *et al.* (2010) used aqueous leaf extract of different concentrations of *Mangifera indica* L. to investigate their effects on germination, shoot and root lengths and dry matter yield of 5 food crops *viz*., *Capsicum annum* L. (Chilli)*, Glycine max* (L.) Merr. (Soybean)*, Zea mays* L. (Maize)*, Oryza sativa* L. (Rice) and *Abelmoschus esculentus* (L.) Moench (Lady’s finger). Both bioassays and pot culture indicated that the inhibitory effect was much more pronounced at higher concentrations, while the lowest concentration showed stimulatory effect in some cases. The most affected crop was lady’s finger among the test crops. The inhibitory effect was much pronounced ($P<0.001$) in shoot and root lengths as compared with the germination of the receptor crops.

Romman *et al.* (2010) carriedout an investigation on effect of *Euphorbia hierosolymitana* in Wheat (*Triticum durum* local var. Hourani), in both laboratory and glasshouse. Higher concentration of aqueous leachate of *E. hierosolymitana* reduced the germination rate. On the other hand, the radicle and coleoptile length of the germinated seeds of Wheat were significantly inhibited by the leachate. Also, the aqueous leaf leachate of *E. hierosolymitana* was found to inhibit significantly the growth of Wheat seedlings. Allelochemicals caused significant reduction in root and shoot length, fresh, dry weights and decreased the amount of total chlorophyll and protein contents.

Rokiek *et al*. (2010) studied the effect of mango leaves on growth and propagative capacity of purple nutsedge. Two experiments were carried out include soil treatments with mango leaf extract(weekly for one month) at concentrations, 0, 5, 10, 15 and 25%. The second experiment included soil treatments with mango leaf powder at the rate of, 0, 20, 40, 60, 80 and 100g/kg soil. Maximum inhibition was recorded by 25% leaf extract. Moreover, soil treatment with mango leaf powder showed significant reduction in dry weight of foliage and underground organs. The highest inhibitions were observed by using 80 and 100 g/kg soil of mango leaf powder. In general, non significant differences were found between inhibitions caused by 80 and 100g/kg soil. The total phenols in foliage and underground organs of purple nutsedge revealed that the inhibitory effects were concomitant with the accumulation of total phenols compared to controls.

Mahmood *et al.* (2010) conducted an experiment to test the potentiality of sorghum (*Sorghum bicolor*), sunflower (*Helianthus annuus*), brassica (*Brassica napus*), maize (*Zea mays*), rice (*Oryza sativa*) and mulberry (*Morus Alba*) water extract on growth of horse purslane. In the laboratory bioassay, sorghum + sunflower water extract combination at higher concentration (100%) completely inhibited germination of horse purslane. In pot experiment, the foliar application of sorghum + sunflower water extract combination at higher concentration (100%) greatly suppressed growth traits (shoot and root length) of horse purslane seedling and this combination reduced shoot dry weight by 66% over control. Inhibitory effect was proportional to the concentrations of the extracts and higher concentration had the stronger inhibitory effect. In crux, combination of sorghum + sunflower water extracts may be used as natural herbicide to control horse purslane.

Soyeymani and Shahrajabian (2012) studied allelopathic effects of sesame (*Sesamum indicum*) on canola (*Brassica napus*) growth and germination. Treatments include leaf, root, stem and flower extract. Each extract includes 4 levels 0, 25, 50 and 100%. The *Brassica napus* sensitized to exuding allelochemical materials form sesame and the rate of germination, percentage of germination, seedling weight, coleoptile length, radical length decreased by increasing density of extracts.

Sahoo *et al.* (2007) reported that teak has a potentials harmful allelopathic chemicals and the toxic effect of teak followed the order: leaf litter > crushed seeds > soil root zone in maize.

Maharjan *et al.* (2007) studied allelopathic effects of aqueous extract of leaves of *Parthenium hysterophorus* on seed germination and seedling growth of three cereal crops (*Oryza sativa* L., *Zea mays* L. and *Triticum aestivum* L.), three cultivated crucifers (*Raphanus sativus* L., *Brassica campestris* L. and *Brassica oleracea* L.) and two wild species of family Asteraceae (*Artemisia dubia* Wall ex. Besser and *Ageratina adenophora* (Spreng) King and HE Robins). Seed germination of all crucifer species was completely inhibited at >2% leaf extract of *Parthenium hysterophorus* but in other species, except maize, complete failure of seed germination was recorded only at >6% in *Triticum aestivum* and *Ageratina adenophora;* at 10% in *Oryza sativa* and *Artemisia dubia*. Seed germination of *Zea mays* was not completely inhibited but it was low at high concentration of the extract. The extract had strong inhibitory effect to root elongation of seedling in cereals and to shoot elongation in crucifers and wild Asteraceae. Leaves of *Parthenium* hysterophorusmay be a source of natural weedicide against *Ageratina adenophora* which will help to control invasive plants.

Hiwale *et al.* (2007) carried out a study on allelopathic effect of leaf leachate of four species *viz.,* Custard apple (*Annona squamosa*), Aonla (*Emblica officials*), Neem (*Azadirachta indica*) and Subabool *(Leucaena leucocephala)* on Soybean (*Glycin max*), Maize (*Zea mays*), Okra (*Abelmoschus esculentus*), Sunhemp (*Crotolaria juntia*), Green gram (*Phaseolus aurus),* Pigeon pea (*Cajanus cajan)*, Fodder jowar (*Sorgham vulgar*), Sesamum *(Seasamum indicum)* and Moth bean *(Phaseolus aconitifolius*). Seed germination was suppressed by leaf leachate of all tree species as compared to control (seed treatment with distilled water). The shoot and root length was significantly influenced by the leaf leachates of the tree species. Root length was highly influenced as compared to shoot length. Custard apple, Aonla and Subabool were found to have beneficial effect on Soya bean, Green gram, Pigeon pea and Sesamum and suppressing effect on Okra, fodder Jowar, Sunhemp, Maize and Moth bean.

Sharma *et al.* (2005) conducted an experiment on effect of leaf leachate of *Terminalia chebula* and *Sapindus mukorossi* on germination and growth of commonly cereals, pulses and vegetable crop under laboratory condition. The tested crops *viz.,* Wheat, Maize, Gram, Peas, Lentil and Brinjal responded differently to aqueous leaf extracts of *T. chebula* and *S. mukorossi* indicating the presence of different phyto active compound which are either phyototoxic or promoters. Some strains had synergistic or no adverse effect on germination and growth of tested field crops where other had antagonistic effect.

The allelopathic extracts from *Tectona grandis* leaves significantly inhibited germination and growth of tomato *(Lycopersium esculentum*), eggplant (*Solanum melongena*) and *Capsicum annum*. The allelopathic extract from *Tectona grandis* has also shown high allelopathic activity on *Triticum aestivum* (Krishna *et al.*, 2003).

Macias *et al.* (2000) reported the phytotoxicity activity of extracts from bark and leaves of *Tectona grandis* between 1000-1250 ppm, on the germination, root and shoot length of *Lepidium sativum* L., *Lactuca sativa*, *Lycopersicum*, *Allium cepa* and *Triticum astivum* L. Bioassary results showed that bark extract of *T. grandis* had higher phytotoxicity. The most affected parameters were root length of tomato, onion and wheat.

Mathela (1994) reported that the secondary metabolites (glycosides, steroids, flavonoids and diterpenoids) of some medicinal and aromatic plants accounted for allelopathic activity.

Gaynar and Jadhav (1992) observed the decrease in germination of rice and cowpea under the influence of leaf leachates of *Terminalia tomentosa,* after 3 days of sowing but it was non-significant after 5 days of sowing. They also reported the decrease in germination percentage of rice and cowpea under the influence of leaf leachates of *Acacia auriculiformis.*

Horticultural tree crops for cash purposes are extensively planted by small landholders as an outgrowth of shifting cultivation in many parts of the world, notably the oil palm, cacao, coffee and cola nut plantations of West Africa, covering as much as 67 percent of the land in southern Nigeria (Getahun *et al*., 1982) and the coconut, rubber, oil-palm, cacao and coffee plantations of smallholders in Southeast Asia (Pelzer, 1978; Liyanage *et al*., 1984 and Dove, 1983).

The transition to tree-crop-based systems is not equally feasible from all stages in the main sequence of intensification in tropical land use. There are few ecological constraints in stages 1 and 2 to the planting of extensive areas to tree crops, although the economic incentives will generally have to be rather attractive since leisure time is likely to be highly valued in integral swidden societies at this stage of development. Nevertheless, as Dove (1983) has pointed out, extensive cash cropping of trees is a common feature of many relatively long-fallow Sweden systems. At stages 3 to 5, however, the transition to tree crops is less easily achieved, because of the commitment of land to other uses and the relatively long lag between planting and first harvest. Here *taungya* practices can ease the burden of the establishment phase by providing early returns of interplanted field crops.

Thakur (2014) tested the allelopathic effects of three agroforestry tree species viz mulberry, plum and pomegranate by growing soybean crop for 30 days in pots containing field soil either mulched with leaves or irrigated with aqueous leaf extracts of the woody species. The maximum adverse effect on seed germination, germination relative index, vigor index, root length, shoot length and dry matter production of soybean was caused by leaf leachate after Hollis *et al.* (1982) followed by leaf leachate obtained after Tukey and Mecklenberg (1964) and minimum by foliage mulched at the soil surface.

The allelopathic effects of aqueous extracts from sorghum stem and rice husks were examined on the germination and growth of maize. The extracts brought about considerable inhibitions in the germination of maize seeds and in the growth of radical and plumule. In both extracts, the degree of inhibition increased with the increase in the concentrations of the extracts thus suggesting that the effects of the extracts were concentration dependent. However, the results obtained also tend to suggest that the degree of retardation might be more pronounced in the extracts derived from the sorghum stem than those from the rice husks. In the sorghum extract-treated seeds, no growth of the plumule was obtained until the 72-hour period of the experiments whereas plumule growths were recorded at the lower extract concentrations of the rice-husk derived extracts (Kayode and Ayeni, 2009).

The pace of evaluating allelochemicals released from higher plants in nature has greatly accelerated, with promising results in field screening (Khan *et al.*, 2005). In Agriculture, the inhibitory effect of weed species on germination and growth of crops has been attributed to phytotoxic chemicals released from the leaf litter and roots. Further, Rice

(1974) observed that many species of weeds produce toxins that are inhibitory to other weeds and often to themselves. *Lantana camara*, one of the world's 10 worst weeds was introduced in the Indian subcontinent during the early part of the nineteenth century (Bansal, 1998). Frequently allelopathy caused decrease in plant growth more than what caused by competition in plants on sunlight, water and nutrition (Rice, 1984). Allelopathic compounds restrict plant growth through negative interactions with important physiological processes such as changes in cell wall structure, prevention of cell division and activity of some enzymes. These compounds can also affect the equilibrium of plant hormones, pollen tube germination, absorption of nutrient elements, displacement of stomata, photosynthesis, respiration, protein synthesis, pigment, and changes in DNA and RNA structures (Glass ADM, 1974). Alellopthic effect of Umbelliferae family on lotus was verified by (Lydon *et al.,* 1997; Ghorbanli *et al.*, 2008) investigated the allelopathic effect of *Artemisia annua* on redroot pigweed (*Amarantus retroflexus*), common lambsquarters (*chenopodium album*), soybean (*Glycine max*) and corn (*Zea mays*).

Melkania (1984) recorded allelopathic potential in non-forest tree species of Himalayan region in the order: *Celtis australis > Juglans regia > Grewia optiva > Bauhinia retusa > Meliaazedarach.* Among the agro-crops studied as phytomer species, the inhibitory effects varied. Germination of *Glycine soja* seed was inhibited by 51.57 and 53.13 per cent when treated with *Celtis australis* and *Melia azedarach,* respectively.

Bhardwaj (1993) conducted laboratory studies to notice the effect of leaf leachates of *Robinia pseudoacacia* on maize, wheat, mustard, soybean and urd and observed reduced germination per cent, root shoot length and vigour index as compared to control.

Srinivasan *et al.* (1990) conducted a pot experiment where in *Vigna mungo, Vigna radiata,* cowpeas, pigeon peas and soybeans were grown for 30 days in top soil taken from under *Eucalyptus tereticornis, Casuarina equisetifolia, Leucaena leucocephala* and *Acaciaholosericea.* Top soil from under all 4 tree species reduced crop germination and growth. *E. tereticornis* had the greatest inhibitory effect. Soybeans were the most sensitive crop. Soybean germination in top soil under *E. tereticornis* was 69 per cent of germination in control plants and dry matter production was reduced by 10 per cent.

Bhatt and Todaria (1990) studied the allelopathic effect of *Adina cordifolia, Alnus nepalensis, Celtis australis* and *Prunus cerasoides* by growingcrops of *Eleusine* *coracana, Glycine max* and *Hordeum Vulgare* on top soil, rhizosphere soil from the plantation of these trees and on field soil either mulched with dry leaves or irrigated with aqueous leaf extracts of the tree species. Maximum reduction in germination percentage, root-shoot length and dry matter production was obtained with experimental garden soil mulched with dry leaves of trees and by the effect of *A. cordifolia* followed by *P. cerasoides. H. vulgare* proved most susceptible and *E. coracana* highly resistant to these tree-cropinteractions.

Aleem *et al.* (2014) investigated the allelopathic effect of three tree species (*Azardiracta indica*, *Vitellaria paradoxa* and *Parkia biglobosa*) on germination and growth of cowpea in the Southern Guinea Savannahagro ecological zone of Nigeria. They found that the tree species brought about considerable inhibition in the germination of cowpea seeds and in its growth parameters. The statistical germination value of the cowpea seeds under the tree species had decreased value thus indicating that growth inhibitions were seriously felt. *Parkia biglobosa* (53.33) and *Vitellaria paradoxa* (60.00) had more inhibitory effect on cowpea seeds germinability than that of *Azardiracta indica*. (63.33) while all the treatments are lower than that of control (100). The tree species had similar inhibition capability in the cowpea plant height, stem circumference, number of leaves, above grand biomass and below grand biomass.

Tree species selection to inter-cultivate with food crops has often been made on the basis of traditional knowledge by farmers in Ghana. Lately, Taungya system has been introduced to enable farmers produce food and at the same time retain the forest cover in communities bordering forest reserves. Fresh matured leaves and roots extracts of ten tree species were examined for their allelopathic effects on four agricultural crops to explore the allelopathic potential of the tree species and to recommend the appropriate tree species to be used under the Modified Taungya System in Ghana. Germination of *Hibiscus esculentus* seeds was significantly reduced in all the root and leaf extracts while germination of *Zea mays* seed sincreased in the entire root extracts except in that of *Terminalia superba*. Roots extract of *Sennasiamea* promoted germination of both *Zea mays* and *Lycopersicon esculentum* seeds. Plumuleand radicle extension of seedlings of the four crops were significantly reduced by all the rootand leaf extracts with the exception of *Zea mays* whose plumule and radicle development was increased by *Eucalyptus grandis* leaf extracts. On the basis of the results obtained in this studythe following tree species (*Senna siamea*, *Albizzia lebbeck and Jatropha curcas*) could be recommended for planting (Abugre *et al.,* 2011).

Einhelling (2002) reported that individual compounds can have multiple phytotoxic effects on a plant. There was a reduction in radicle growth of the germinating seeds because the extracts might have contained allelochemicals that affected the enzymes responsible for plant hormone synthesis, in addition to nutrient and ion absorption by affecting the plasma membrane permeability of the roots (Fujii *et al*., 1991). There is an inhibitory effect on root elongation when the roots come into contact with the extract and for that matter with inhibitory chemicals as described in early works with various crops and weeds (Bhowmik and Doll, 1984; Qasem, 1995).

An experiment was carried out by Hiwale *et al.* (2007) to study allelopathic effect of leaf leachate of four tree species viz., Custard apple (*Annona squamosa*), Anola (*Emblica officials*), Neem (*Azadirachta indica*) and Subabool (*Leucaena leucocephala*) on Soyabean (*Glycine max*), Maize (*Zea mays*), Okra (*Abelmoschus esculentus*), Sunhemp (*Crotolaria juntia*), Green gram (*Phaseolus aurus*), Pigeon pea (*Cajanus cajan*), Fodder jowar (*Sorghum vulgar*), Seasum (*Seasamum indicum*) and moth bean (*Phaseolus aconitifolius*). Leaf leachates of all trees suppressed seed germination compared to control (only water). Root length was highly influenced compared to shoot length. Custard apple, Anola and Subabool were found to have beneficial effect on Soyabean, Green gram, Pigeon pea and Sesamum and suppressing effect on Okra, Fodder jowar, Sunhemp, Maize and Moth bean. Neem was found to suppress most of the growth parameters, whereas Custard apple, Anola and Subabool promoted them.

Devaranavadgi *et al.* (2003) noted that in existing agrosilvicultural systems involving different tree species (*Acacia nilotica, Albizia lebbeck, Azadiracta indica, Cassia siamea, Dalbergia sissoo, Hardwickia binata* and *Leucaena leucocephala*) to assess the allelopathic effects of different tree crops on rabi Sorghum. They observed that the control treatment produced the maximum grain and Stover yield. Plant height was highest with *Leucaena leucocephala* while *Hardwickia binata* produced plants with the least height. The highest diameter at breast height (dbh) and crown diameter was recorded in *Acacia nilotica* while the lowest values for dbh crown diameter were recorded in *Dalbergia sissoo* and *Hardwickia binata*, respectively. Total biomass was maximum in *Acacia nilotica* and was minimum in *Hardwickia binata.* The performance of robi Sorghum in terms of Stover and grain yield was inversely proportional to the silvicultural parameters of tree species and as well as the total dry matter produced by them. Germination of Sorghum with *Hardwickia binata* was 85% and a similar superiority was observed for root length, shoot length and dry weight of seedlings. Lower values were located in *Acacia nilotica.* The results indicate that among the tree species studied, *Hardwickia binata* had the minimum allelopathic effect on robi Sorghum.

An experiment was carried out by Ashutosh *et al.* (2009) and studied that *Grewia optiva, Bauhinia variegata and Albizia lebbeck* are the suited tree species for plantations in the sub-tropical region of Garhwal Himalayas due to their high biomass production.

Silva *et al.* (2007) found that *Azadirachta indica* has inhibitory effects of its extract on *Phaseolus vulgaris* germination percentage and growth was evaluated, although Neem (*Azadirachta indica)* is well known for its biological activities in many countries. Both seed germination and radical growth were affected in a concentration dependent manner.

An experiment was established by Devaranavadgi *et al.* (2004) to assess the allelopathic effects of different tree species (*Acacia nilotica, Albizia lebbeck, Azadiracta indica, Cassia siamea, Dalbergia sissoo, Hardwickia binata* and *Leucaena leucocephala*) on Chickpea. Among the tree species, *Hardwickia binata* had significantly less allelopathic effect on Chickpea compared to other tree species. The germination percentage (80%), root length (18.65cm), shoot length (31.32 cm) and seedling dry weight at 10 days were least affected by *Hardwickia binata* as compared to other tree species. The maximum harmful effect was observed with *Acacia nilotica* which had higher total biomass production (3688kg/ha) and crown spread (8.2m).

Ahmed El-Shabasy (2017) found that allelopathy of *Prosopis juliflora* on *Acacia ehrenbergiana* through mineralanalysis of both leaf extract and rhizoshere soil for both species. All mineral contentdecreased in combined soil and certain elements increased only in leaf extract of *Prosopis juliflora* as Fe^{+2} and Na^{+} whereas other elements decreased in leaf extract for two species as Mg^{+2} and Mn^{+2}. The study reported that macro and microelements might be responsible for dominance of *Prosopis juliflora.*

An experiment was conducted by Nguyen *et al.* (2003) to assess the allelopathic effects of *Galactia pendula, Leucaena glauca, Melia azedarach* and other four species including *Desmodium rezone, Euphobia hirta, Manihot esculenta* and *Morus alba*. *Galactia pendula, Leucaena glauca, Melia azedarach* were assessed the greatest allelopathic potential and the other four were second most suppressive to Radish germination and growth. Findings also indicated inhibitory exhibition of allelopathic plants were species dependent. Moreover, inhibitory effects varied among plant parts such as the leaves, stem and root.

Choudhary *et al.* (2016) evaluated the performance of two rhizomatous crops *i.e.*, turmeric (*Curcuma longa*) and ginger (*Zingibar officinale*) under rainfed conditions as Nautiyal, sole crops and with 15-year old well established stands of forest tree species located at the research farm of ICAR Research Complex for NEH Region, Research Centre, Basar, Arunachal Pradesh. The average illumination below the canopies varied from 72.0 to 79.2% of incident radiation on turmeric and 71.7 to 78.8% of incident radiation on ginger. Turmeric and ginger were cultivated in the inter row spaces of 24 and 12 Multipurpose trees (MPTs), respectively. Turmeric and ginger did not perform well under as many as 18 and 5 MPTs, respectively. Turmeric, in association with nitrogen fixing tree species *Alnus nepalensis* and *Parkia roxburghii* did not significantly reduce its productivity. Leaf area and leaf area index (LAI) significantly higher under *A. nepalensis* than the sole turmeric crop. MPTs had significantly negative effect on the growth and yield attributes of ginger crop. The reduction in yield of ginger ranged from 11.3 to 31.3%. They found that turmeric cultivation more profitable than the ginger under *A. nepalensis* based agroforestry systems in comparison to the other MPT based agroforestry systems.

Most of the earlier studies had revealed that the inhibition obtained in the laboratory experiments might differ from the situations in the fields as allelopathic effects are often due to synergistic activity of allelochemicals rather than to single compound. Walnut agroforestry systems have many ecological and economic benefits when intercropped with cool-season species. Leaf litter decomposion is one of the main sources of allelochemicals in such systems. Lettuce (*Lactuca sativa* var. *angustata*) growing with walnut leaf litter shows its allelopathic activity. Lettuce growth and physiological processes were inhibited by walnut leaf litter, especially during early growth stage or with large amount of litter addition. The plants treated by small amount of leaf litter recovered their growth afterwards, while the inhibition for 180g leaf litter persisted until harvest. Twenty-eight compounds were identified in the leaf litter, and several of them were reported to be phytotoxic. (Hauser, 1993; Lisanework and Michelsen, 1993; Tian and Kang, 1994; Mehar *et al.,* 1995).

2.4 Mahagoni in Agroforestry of Bangladesh

Agroforestry involves introduction and retention of trees along with cultivation of agricultural crops on a parcel of land. This land management system satisfies the socio-economic needs of people in a sustainable way. Cropland agroforestry is an important production system in the southwest region of Bangladesh. *Swietenia macrophylla* was the most prevalent species (relative prevalence 20.83) followed by *Mangifera indica* (relative prevalence 15.57) and *Cocos nucifera* (relative prevalence 7.08). Mahagoni is very important tree for forest sector in Bangladesh. It is mostly used as timber tree.

2.5 Factors that make Mahagoni preferable by farmers

Mahagoni gives superior and versatile benefits compared to many other tree species due to this fact often farmers choose to plant Mahagoni, particularly smallholders in tropical and subtropical regions.

2.5.1 Botany

Swietenia mahagoni is is a tall tree, up to 30 m high, with a short, buttressing base, up to 1 m in diameter and a large, spherical crown, many heavy branches and dense shade. The bark is smooth grey on young trees, turning to scaly dark reddish-brown on large trees. The tree is deciduous in areas where it is subject to drought. Leaves even pinnate, 10-18 cm long and bearing 4-10 pairs of leaflets that are shiny, dark green, lance-shaped, 2.5-5 cm long by 0.7-2 cm broad. Flowers greenish-yellow, 6-8 mm across in axillary panicles; panicles glabrous, shorter than the leaves. The light brown seed capsule stands upright, about 6-10 cm long by 4-5cm diameter, with 5 valves splitting upward from the base. Each valve releases about 20 flat, brown, winged seeds, 4-6 cm long. *Swietenia* commemorates Gerard von Swieten (1700-1772), botanist and physician to Maria Theresa of Austria.

The trunk is straight and cylindrical, slightly grooved, with well-developed spurs. The crown of young trees is narrow, but old trees have a broad, dense and highly branched crown. The open, rounded crown has thick, rising branches and thick, dense foliage. The outer bark of older trees is scaly, shaggy, deeply longitudinally furrowed and brownish-grey to reddish-brown, and the inner bark is red-brown or pinkish-red. The leaves are usually paripinnate, sometimes imparipinnate, 12–45 cm long, and are made up of 3–6 pairs of lanceolate or ovate leaflets. The leaflets are asymmetrical, 5–12 cm long and 2–5 cm wide, with a whole margin and an acute or acuminate apex (Soerianegara and Lemmens 1993; Schmidt and Jøker 2000). The flowers are unisexual, 0.5–1.0 cm in length, and are borne in large, branched inflorescences including both male and female. The fruits are capsular, oblong or ovoid, 11.6–38.7 cm in length, 6.7–12.0 cm in diameter and light grey to brown with 4–5 valves. Each fruit contains 22–71 developed seeds. The seeds are samaroid, bulky at their base, 7–12 cm long and 2–2.5 cm wide including the wing (Soerianegara and Lemmens, 1993).

2.5.2 Biology

Flowering and fruiting are regular and annual, varying according to climate but taking place shortly before the rainy season. Development from flower to mature fruit takes about 8-10 months. Flowers are unisexual and the tree is monoecious. Pollination is by insects. Hybridization is frequent, especially with *Swietenia mahagoni*, wherever the species grow together. Usually 1 flower of the inflorescence develops into a fruit; the other flowers are aborted even if fertilization takes place. The tree fruits well and produces fertile seeds, sometimes as early as at 20 years of age, although usually it does not seed until it is 30-40 years old. Seed production varies according to site and year.

2.5.3 Distribution

Swietenia mahagoni grows naturally in Bahamas, Cuba, Haiti, Jamaica, Netherlands Antilles, United States of America Bangladesh, Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Fiji, Gambia, Ghana, Guinea, Guinea-Bissau, India, Indonesia, Liberia, Malaysia, Mali, Mauritania, Niger, Nigeria, Philippines, Puerto Rico, Senegal, Sierra Leone, Sri Lanka, Togo.

2.5.4 Establishment

Accessibility of seeds from the mother tree (seed collection) is simple, locally available and do not require special treatment to keep (store) for long time (Getahun, 2002). Without any special treatment, seeds lose much of their viability in 3 months and almost entirely in 6 months. Dried in the sun and sealed in airtight containers, they remain fairly viable for over 6 months. The seeds were provisionally classified as recalcitrant because of widespread reports of their short life span, but to the contrary, their viability can be maintained in hermetic air-dry storage at room temperature for 1 year. There are 3350-3500 seeds/kg.

2.5.5 Ecological range

In its original habitat, the climate is warm and equable, with temperatures ranging from 16 to 32ºC; rainfall varies from 1250 to 2500 mm, coming mostly in summer but spreading almost through the whole year. Best developments have been observed in areas receiving lower rainfall of 1000-1500 mm, in localities not far from the sea, and at elevations near sea level.

It thrives best on deep, rich soil and avoids stiff, heavy soils and well-drained sandy soils are best. It is a complete failure in dry localities and poor soils.

Swietenia mahagoni can tolerate a wide range of soils and environmental conditions. Within its natural range, it has been found on alluvial soils, volcanic soils, heavy clays, lateritic soils and soil derived from limestone, granite and other sedimentary, igneous or metamorphic rock formations (Whitmore, 1992). In tropical America, *Swietenia mahagoni* is amongst the pioneer species reoccupying degraded agricultural land (Mayhew and Newton, 1998). In the Philippines, this species is reported to be very wind firm (resistant to cyclones) (Soerianegara and Lemmens, 1993). In plantations in Java, trees can grow on very poor soils but perform best on deep, fertile, well-drained soils with a pH of 6.5–7.5. At present, *S. macrophylla* is widespread throughout the tropics, found naturally in both tropical dry and tropical wet forest types. Within its ecological range, the optimum annual rainfall is between 1000 and 2500 mm with a dry period of 0–4 months (Lamb, 1966). In Amazonian Ecuador and Peru, annual rainfall in this species' area has been reported at 3800 mm (Whitmore, 1983). The reported optimum natural development for this species is under tropical dry forest conditions with an annual precipitation of 1000–2000 mm, a mean annual temperature of 24 °C and a potential evapotranspiration ratio of 1–2 (Lamb 1966). In Indonesia, *S. macrophylla* grows at elevations of 0–1500 m above sea level, in areas with a mean annual temperature of 20–28 °C, with the range in the coldest and warmest months being 11–22 °C and 22–30 °C, respectively (Soerianegara and Lemmens, 1993).

2.5.6 Survival

Another important reason contributing to the popularity of Mahagoni is its good survival rate. Leaves and barks of Mahagoni are not/less palatable to most browsers such as cattle or livestock and wild animals it can be established and grows without any physical damage (Getahun, 2002; Atkinson *et al.*, 1992; Pohjonen and Pukkala, 1990) weighed against other woody species, such as *Olea African, Cuprusus lustinica, Juniperus procera, Cordia African, Acacia albida, Gravilia robusta* that are browsed by different grazers starting from their seedling stage but Mahagoni not compared to most other commonly used exotic tree species Throughout the Greater Antilles, the mahogany web worm (*Macalla thyrsisalis*) causes defoliation and webbing. In the Caribbean, the mahogany shoot borer (*Hypsipyla grandella*) bores into the buds, shoots and stems; in Asia, H. robusta attacks the tree. The coffee tree borer (*Apate monachus*) attacks both live and dead trees, penetrating deeply into branches, deforming trunks and making them susceptible to breakage in high winds. In Haiti an unidentified shoot borer, a caterpillar and the snout beetle (*Pachnaeus litus*) attack the tree. This beetle attacks the seed capsules. In Puerto Rico, wet-wood termites (*Nasutitermes costalis*) consume dead branches and occasionally the tree trunks. Heart and butt rots are common in older trees, apparently entering through basal scars and branch stubs. In Puerto Rico, leaf blight (*Phyllosticta swietenia*) results in defoliation under humid nursery conditions. Diseases of seedling nurseries in Haiti include leaf spot, anthracnose, leaf blister, damping off and stem blight.

2.5.7 Wood characteristics

Swietenia mahagoni is a rather soft, medium-weight timber. The heartwood is reddish or pinkish, the colour darkening with age to a deep red or brown; the sapwood is usually yellowish. It has an attractive appearance, can be worked easily with hand tools and has excellent finishing qualities and dimensional stability (Martawijaya *et al*. 2005). It polishes well and does not crack or bend, making it valuable for the manufacture of quality furniture. The timber is valued particularly for its colour and workability. The wood density is in the range of 485–850 kg/m^3 at 15% moisture content. The grain of the wood is interlocked, sometimes straight, with a fine to moderately coarse texture (Soerianegara and Lemmens 1993). The surface is glossy, and the timber is often nicely figured because of the irregular grain.

2.5.8 Multiple uses

Small scale farmers consider Mahagoni as a Nature's gift; as a contribution to retirement owing to the different benefits it provides assisting in their daily livelihoods expenses. Mahagoni is used for fuel woods, construction material, making farm utilities (equipments), generating income, production of charcoal, also used as, shelter belt;

drainage and wind break for their fragmented land (Lemenih *et al.,* 2004). In Haiti, much of the branch wood and most of the crooked stems are converted to charcoal, particularly in regions isolated from urban markets by poor roads. *S. mahagoni* was the original Mahagoni in commercial trade and was exported from Hispaniola in the 16^{th} century. The heartwood is highly resistant to decay and insect attack, performing better than all other mahoganies on the world market. *S. mahagoni* is a medicinal plant throughout the Caribbean. The bark is considered an astringent and is taken orally as a decoction for diarrhoea, as a source of vitamins and iron, and as a medicine to induce haemorrhage. *S. mahagoni* has thrived as an ornamental tree in various parts of India. *Swietenia macrophylla* is suitable for large-scale timber production plantations because of its excellent timber quality. The wood can be used for construction materials, plywood (veneer), high-grade furniture and cabinet making. It is also suitable for panelling, framing, flooring, automobile bodies, interior trim of boats, radio and phonograph cabinets, bodiesof musical instruments, mouldings and other ornaments. *Swietenia mahagoni* also has great potential for reforestation and afforestation, particularly for improving soil. In the Philippines, the tree species is recommended for revegetation of scrubland and denuded areas (Soerianegara and Lemmens 1993). In Indonesia, it is also used in agroforestry systems, for example in Java with maize, upland rice and cassava, and in our study village in South Kalimantan with cassava, corn, peanuts and pumpkin.

The seeds and bark of this plant are used for the treatment of hypertension, diabetes, malaria, and epilepsy as a folk medicine (Pullaiah, 2006). The leaf decoction of *S. mahagoni* is used against nerve disorders, the seed infusion against chest pain, and a leaf or root poultice against bleeding. It has been reported to have medicinal uses, such as treatment for hypertension, cancer, amoebiasis, chest pains and intestinal parasitism (Al-Radahe *et al.,* 2012). The seed extracts of *S. mahagoni* had inhibitory effects on the shoot and root growth of both dicotyledonous and monocotyledonous plant species (Ma *et al*., 2011; Islam and Kato-Noguchi, 2016b). Fodder yield of guinea grass at 3 MAP was drastically reduced by leaf leachate of mahagoni. *S. mahagoni* could be a potential source for commercial production of bio-pesticides (John *et al.,* 2010).

Mukaromah *et al*. (2016) observed that increasing *S. macrophylla* leaf litter concentration was concomitant with inhibition of radicle lettuce seedling growth compared with the control.

2.5.9 Seed production

2.5.9.1 Seed collection

Swietenia mahagoni is propagated from seeds. The best outcomes can be achieved by using seeds from a mother tree in excellent form and health. Seed production fluctuates considerably from year to year. The fluctuation may reflect variation in flowering phenology, or failure of pollination or fertilisation (Mayhew and Newton, 1998). Flowering and fruiting regularly occur annually from 10 to 15 years of age. Flowering and fruiting seasons differ according to geographical location. For example, in the central and northern parts of South America, the tree blooms from April to June, and the fruits ripen from January to March of the following year (Schmidt and Joker, 2000). In Indonesia, the flowering months are usually between July and September and the fruiting season is between December and February. Flowering usually takes place when trees are leafless or just coming into new leaf shortly before the rainy season. The fruits ripen during the dry season, when the trees begin to lose part of their foliage and the warm air dries the fruits and promotes dehiscence (Mayhew and Newton, 1998). The fruits are preferably collected from the ground immediately after seed fall or from the trees just before they open by climbing the trees or using poles with metal hooks to cut down the seeds. Fruits should be harvested from the tree towards the middle or the end of the fruiting season. When the fruits are ripe, the pericarp changes to a light coffee colour just before the valves open and release the seeds.

2.5.9.2 Seed preparation

Mature dry fruits or dry seeds (capsules) collected from the forest floor can be stored for some days in sacks without significant deterioration. Unripe capsules may need to be dried out first to encourage them to open. The capsules can be dried in the sun. Alternatively, capsules can be placed on a rack over electric lamps at a temperature of 38°C for 36–48 hours to encourage them to open. The length of time required for drying depends on the ripeness of the capsule and ambient temperature and humidity. The fruits will split open when dried for 1–4 days, depending on maturity, after which the seeds are easily released by gentle shaking or raking of the fruits. Seed wings are removed by hand to facilitate handling and to reduce volume. The wing is broken 1 cm above its base, and the seeds without wings are placed in a container (Mayhew and Newton, 1998).

2.5.9.3 Seed storage and viability

The viability of fresh *S. macrophylla* seeds is around 80–90%, although that for stored seeds can vary (Mayhew and Newton, 1998). The seed viability also varies with size. For example, Chinte (1952) in Mayhew and Newton (1998) reported that large seeds have a 12% higher germination rate and produce healthier, faster-growing seedlings with better developed root systems than small seeds. Mayhew and Newton (1998) stated further that in general, *S.macrophylla* seed will not retain an acceptable level of viability if stored at room temperature and in humid conditions for more than about 3 months. Seeds of *Swietenia mahagoni* are susceptible to chilling damage below about 16 °C when they are moist. If they are to be refrigerated they have to be dried first. It has been reported that dried seeds refrigerated to 2–8 °C and maintained at constant humidity maintain viability for more than a year. If seeds are dried to a moisture content of 5% or less, deep freezing (at –20 °C) will maintain a high viability for at least 2 years and possibly many decades (Mayhew and Newton, 1998).

2.5.10 Propagation and planting

2.5.10.1 Sowing

The seeds are sown in a bed of light sand in furrows or holes 3–7 cm deep. Germinating seeds should be under shade and kept moist. The sowing density may vary depending on the desired size of the planting stock and whether or not transplanting is intended. As reported by Mayhew and Newton (1998), to obtain seedlings of 30–60 cm in height, a square spacing of 10–15 cm is commonly recommended, and to obtain seedlings of100 cm in height, a spacing of 20×30 cm is suggested. *Swietenia mahagoni* can also be sown in containers. Raising stock in containers may give a more fibrous root system and better results after planting out, but the cost may be high. Container planting stock may be more suitable for dry planting sites whereas bare rooted stock are suitable for wet sites or sites that are subject to very strong winds (Soerianegara and Lemmens, 1993).

2.5.10.2 Preparation for planting out

Good maintenance of *Swietenia mahagoni* seedlings is essential for the production of healthy and fast-growing plants. Weeding should be conducted in the nursery in every 2–4 weeks until the seedlings are ready to be planted out. Chemical weeding is not possible in *Swietenia mahagoni* as the seedlings are very sensitive to herbicide. Nurseries should also be thoroughly watered before seedlings are lifted to avoid straining or breaking the small fibrous roots (Busby 1967 *in* Mayhew and Newton, 1998). Lifting and subsequent preparation of bare-rooted stock must take place as close to the planting date as possible to minimise the risk of desiccation. Root pruning in the nursery helps to create a more fibrous root system. Root pruning should be carried out about 4 weeks before lifting, but should not be done whilst seedlings are flushing (Mayhew and Newton, 1998). The seedlings can be planted in the field when they are about 50–100 cm tall, when they are sufficiently strong and not tender and their fresh shoots have a chance to mature and harden. To increase the survival rate at the planting site, the seedlings should be handled carefully and roots kept moist. Some methods include wrapping the roots of the bundles in dry grass and soaking, putting bundles in wet sacks and putting individual plants in polythene bags, which are in turn placed in wet sacks to keep them cool (Lamb, 1966). Bundles, bags or sacks should then be kept in the shade until planting out.

2.5.10.3 Planting

All weeds should be cleared from the planting sites. The use of close spacing can shade the ground and thus reduce the growth of weeds. Close spacing will also serve to reduce the development of vigorous lateral branches (Soerianegara and Lemmens, 1993). Spacing for planting *Swietenia mahagoni* is usually 2–3 m. Planting *Swietenia mahagoni* amongst trees such as *Paraserianthes falcataria* and *Manglieta glauca* that are already a few years old can create mild shade for the *Swietenia mahagoni*, minimising lush growth of terminals and laterals (Soerianegara and Lemmens, 1993). Wider spacing of about 4–5×4–5 m^2 is also commonly applied by and Java in order to obtain multiple yields by intercropping the *S. macrophylla* trees with cassava, corn, peanut, pumpkin and other agricultural crops.

2.5.11 Plantation maintenance

2.5.11.1 Weeding

Weeding is required to ensure maximum growth and survival of seedlings. Some weeds commonly found in young *S. macrophylla* plantations are *Imperata cylindrica* Beauv., *Clibadium surinamense* L., *Melastoma malabathricum* L. and *Merremia umbellata* Hallier (Nazif and Pratiwi 1989). Weeds that are as tall as or taller than the seedlings should be removed. During the first 2 years after planting, weeding and hoeing should be done 4 times every 6 months (Directorate of Industrial Plantation Forests, 1990, Mindawati and Tata, 2001). Either line weeding (along the rows of main species) or ring weeding (in a 1-m diameter around the seedling) is recommended. To prevent the regrowth of weeds, cut grass is placed as mulch around the seedlings (Directorate of Industrial Plantation Forests, 1990).

2.5.11.2 Fertilising

Fertilising *S. macrophylla* seedlings may reduce susceptibility to shoot borer damage by altering the chemical composition of the apical shoots and/or enhancing tolerance by improving vigour (Mayhew and Newton, 1998). In Indonesia, fertilisers are usually applied after planting at a dose of 75–100 g NPK (chemical fertiliser) per plant in a ring around the seedlings (Directorate of Industrial Plantation Forests 1990, Mindawati and Tata 2001). In South Kalimantan, farmers often use organic fertiliser from animal waste.

2.5.11.3 Replanting

Replanting can be done twice during the rotation. The first replanting normally takes place in the rainy season at 1 month after planting to replace any dead seedlings and the second one is at the end of the second year. In large-scale plantations, further replanting may be necessary if the survival rate is less than 70% (Directorate of Industrial Plantation Forests, 1990).

2.5.11.4 Pruning

Pruning consists of removing dead or non-productive branches from the lower trunk to encourage the production of clear wood. It also reduces the risk of disease and pest infestations (e.g. shoot borer). Pruning is usually done for the first 3 years (Directorate of Industrial Plantation Forests 1990); this is expected sufficient to reduce the threat of shoot borer as the moth usually attacks young trees only. The best time for pruning is just before the rainy season. Sometimes *Swietenia mahagoni* trees have 2 or 3 stems during early growth at 6–9 months. In this case, pruning and singling should be done by removing the co-dominant stem. If the trees are not singled, the stem density might be too high. In addition, multiple stems usually become tall and slender, and thus can easily be broken by rain or wind (Soerianegara and Lemmens, 1993).

2.5.11.5 Thinning

The principal objective of thinning is to improve the growth of remaining trees with an acceptable form for the final crop. Trees selected for thinning should consist of diseased or pest-infested trees, deformed or poorly shaped trees and suppressed trees. Selective removal of damaged trees may help ensure that seeds produced by the final crop are genetically less susceptible or more tolerant to attack. Krisnawati *et al.* (2010) developed thinning scenarios for *S. mahagoni* plantations and suggested that the time of the first thinning should be around 5–10 years, depending on site quality and initial stand density. The number of thinning required in a rotation also varies depending on initial density and site quality. The interval period between thinning is 5–10 years. In the scenarios proposed by Krisnawati *et al.* (2010), multiple thinning are suitable only in stands planted at closer spacings (3 m × 3 m – 2 m × 3 m). For stands with high initial planting density (spaced at 2m × 3 m), four thinning in a rotation is recommended to obtain high timber volume at the end of the rotation. For intermediate initial density stands (spaced at 3 m × 3 m), two–three thinning appears to be essential for obtaining high timber volume, while in a wide spacing (4 m × 4 m) one thinning option is suitable. The intensity of thinning suggested by Krisnawati et al. (2010) should be heavier in the first thinning (45–55% of the standing trees removed) for high initial density in order to maintain high growth rates and shorten the rotation length. The intensity of subsequent thinning should then be reduced gradually to 25–30%. For stand of low initial density (spaced at 4 m × 4 m) the suitable thinning intensity is about 30–43%.

2.5.11.6 Control of pests and diseases

The most destructive pest in *S.mahagoni* plantations is the shoot-borer *Hypsipyla robusta*. Attacks are most often noticed on saplings and pole size trees when terminal shoots show symptoms of dieback, which ultimately result in malformed trees. The larvae bore into the growing shoots of saplings, destroying the terminal bud and causing growth retardation and stem forking. Often, multiple leaders are formed. According to Morgan and Suratmo (1976), in Java young trees 3–6 years old and 2–8 m tall were the most severely attacked by shoot borer. This finding is supported by Suratmo (1977), who observed that about 90% of 3-year-old trees (2.5 m tall) were affected compared with only 5% of trees 14 years old and 13 m tall. Older trees are not susceptible to attack. At present, there is no effective method to control this insect. Extensive pruning until 3 years after planting may reduce the threat of shoot borer. Planting of trees repellent to the moth along the plantation border or in a mixed stand has also been suggested to prevent the arrival of moths for egg laying. In preliminary trials, planting of *Acacia mangium* around a *S. mahagoni* plantation prevented *H. robusta* infestation (Matsumoto *et.al.* 1997). Interplanting neem (*Azadirachta indica*) with *S. mahagoni* also reduced shoot-borer attacks (Suharti *et al.* 1995). These preliminary results suggest the potential of this method, but more critical largescale trials are necessary to examine the effectiveness and feasibility of these methods. Minor pests observed in experimental plantings include the leaf-feeding caterpillar Attacus atlas (Lepidoptera, Saturnidae) and the leaf cutter bee *Megachile sp.* (Hymenoptera, Megachilidae) (Matsumoto 1994).

The only disease noted in S. *mahagoni* is bark rot, which occurs at the base of the trunk. A lesion appears in the middle of the rainy season, spreads rapidly from the bottom upwards and often kills the trees by the end of the season. The lesion always appears on the stem surface facing the water flow along the slope and it is assumed that the pathogen arrives through water and enters through wounds. The causative organism remains unidentified (Soerianegara and Lemmens, 1993).

2.5.12 Growth and yield

The ability to predict the growth and yield potential of *S. mahagoni* plantations is of considerable importance for plantation planning. However, relatively little reliable experimental data covering periodic stand measurement until the end of rotation are available. The information on growth and yield presented here is based on preliminary data of young *S. mahagoni* stands (up to 5 years old) collected from 76 temporary sample plots established in smallholder plantations in South Kalimantan and some data from 6 permanent plots (covering an age range of 5–10 years) collected by Susila and Njurumana (2005) in *S. mahagoni* plantations in Nusa Tenggara. For older stands, information was taken from 36 permanent sample plots spreading over several sites in Java, which were collected by Forest Research Institute and used by Wulfing (1949) and updated by Suharlan *et al.* (1975) to develop preliminary stand yield tables for mahogany (combining both *S. macrophylla* and *S. mahagoni* species).

2.5.12.1 Growth rates

Predictions of mean DBH and height for age have been reported for some young *S. macrophylla* plantations in Indonesia (e.g. Susila and Njurumana, 2005). Susila and

Njurumana (2005) reported that *S. mahagoni* trees in 5–9-year-old stands growing in the plantations of Sumbawa (West Nusa Tenggara) had a mean diameter of 16.6 cm and a mean height of 12 m. In a site in Kupang (East Nusa Tenggara), *S. mahagoni* trees in stands of 6–10 years old were reported to have a mean diameter of 13.2 cm and a mean height of 9.6 m. Our recent study in Tanah Laut (South Kalimantan) recorded that *S. mahagoni* trees growing in small farms have a mean diameter ranging from 2.8 to 13.2 cm with a maximum diameter of 21.0 cm for trees younger than 5 years old. The mean height of the corresponding stands ranges from 2.9 to 8.7 m with a maximum value of 11.8 m. The range of mean diameter from trees older than 10 years growing in several plantation sites in Java is 9.4–57.1 cm with a mean value of 29.3 cm. The oldest of these stands was 57.6 years. The wide variations in mean diameter and height as reported in these studies are due to the differences in site quality and management practices. The growing conditions in Nusa Tenggara are reported to be much drier than those in South Kalimantan. In addition, some *S. mahagoni* trees in South Kalimantan have been found to grow slowly, particularly in stands with dense ground vegetation and poor site quality. The relationships between mean diameter and age and between height and age of *S. mahagoni* taken from all available data are shown in. The diameter at breast height (DBH) generally increases up to 10–20 cm in trees younger than 10 years old. Growth rates slow noticeably after 10 years, and both diameter and total height begin to level off after 30 years. If the planting sites have a good condition of nutrient and water Mahagoni can starts to give output from third or fourth year depending on the intention of the farmers (Pohjonen and Pukkala, 1990).

2.5.12.2 Height–diameter relationship

Height and diameter are essential inventory measures for estimating tree volume. However, measurement of tree height is difficult and costly. Consequently, height is measured for only a subset of trees. Quantifying the relationship between tree height and diameter is therefore necessary to predict heights of the remaining trees. Despite the importance of height– diameter models in forest plantation management and planning, relatively little information is available on the height–diameter relationship for *S. mahagoni* plantations. Using measurement data collected from 721 *S. mahagoni* trees in smallholder plantations in Tanah Laut District, South Kalimantan, we investigated the relationship between total tree height (H) and diameter at breast height (D) of *S. macrophylla*. Six non-linear models were tested: Chapman–Richards, Curtis, exponential, Gompertz, Korf and Patterson. Of these, the Chapman–Richards model best fit the data. The functional form of the selected model was:

H = 1.3 + b0 (1 – exp (–b1 D) b2

The results of fitting the selected model, including non-linear least squares estimates of the parameters, the standard error (SE), t-statistic, p-value, the root mean squared error (RMSE) and the adjusted coefficient of determination. The model produced relatively low RMSE (about 0.8 m) and explained a relatively high proportion of the total variation in observed values of the tree height, accounting for 87.2%. However, care should be taken when using the model for older trees as the model was developed based on data from young trees only (mostly less than 5 years old with diameters less than 20 cm; only a few trees in the sample had larger diameter).

2.5.12.3 Stem volume estimation

The estimation of the volume of an individual tree is a necessary step in estimating the stand volume. Stem volume equations were produced for *S. macrophylla* in Indonesia by Wahjono and Sumarna (1987). They developed stem volume models to estimate stem volume up to the first branch (clear bole volume, Vc) and stem volume up to 7 cm in diameter (thick wood volume, V7) by relating stem volume to DBH and volume to DBH (D) and total height (H) together using log–log relationships:

log Vc = –0.5157 + 2.1623 logD

log Vc = –1.007 + 2.0086 logD + 0.6156 logH

logV7 = – 0.7618 + 2.3704 logD

logV7 = – 0.8956 + 2.3280 logD + 0.1699H

The models were developed based on data collected from 114 *S. macrophylla* sample trees grown in state owned plantations in Jember District, East Java. The range of the diameter used to develop the models was 25–59 cm and the height range was 9–22 m. The models have been used to produce single (DBH only) and double (both DBH and height) entry volume tables. The development of total wood volume of *S. macrophylla* trees growing in small farms in South Kalimantan and the thick wood and clear bole volume models of. As expected, the different top diameter specifications resulted in variation in the volume estimates. These higher estimates are not surprising as the data used to develop Wahjono and Sumarna's models came from sample trees in state owned plantations that have been well managed, whereas smallholder plantations typically are less well maintained.

2.5.12.4 Biomass estimation

The aboveground biomass estimation for *S. mahagoni* has been reported by Adinugroho and Sidiyasa (2006). They developed allometric equations to provide a method for estimating above ground biomass using a sample of 30 *S. mahagoni* trees grown in state-owned plantations in Cianjur, West Java. The range of the DBH of the sample trees was14.3–36.9 cm and the range of the total tree height was 8.5–25.8 m. The 30 trees were felled, and after felling, each tree was divided into 5 components: stem, branch, twig, stump and leaf. Total tree biomass was calculated as the sum of biomass of each tree component. Their study tested 9 different models, including both linear and non-linear models, for each tree component using DBH, height and a combination of both as independent variables; ultimately, only the DBH model was selected as the DBH is easy to measure accurately in the field. The best-fitting model in each case was selected based on R2, standard error and PRESS (predicted residual sum of squares). The largest amount of biomass was found in the stem (73%), followed by the branch (17%), stump (5%), leaf (3%) and twig (2%). The biomass expansion factor for *S. mahagoni* was 1.36 when calculated to the total tree height and 2.16 when calculated to the merchantable height (Adinugroho and Sidiyasa, 2006).

2.5.12.5 Productivity

Swietenia mahagoni plantations in Indonesia are predicted to reach a maximum volume mean annual increment (MAI) of 38.1 m^3/ha/year in 15 years in the best sites, producing up to 572 m3/ha over the rotation and in medium-quality sites, a volume MAI of 19.7 m^3/ha/year can be attained in 25 years, producing up to 493 m^3/ha (Wulfing, 1949). If the rotation is set to 30 years, stands growing in moderate sites can attain a mean height of 24.4 m and a mean diameter of 35.4 cm, producing a basal area of 30 m^2/ha and total volume including thinning is 583 m^3/ha. This value is much higher than that reported by Suharlan *et al.* (1975) who predicted the total volume of 439 m^3/ha for the same age (30 years) and site quality (moderate site). According to the scenarios proposed by Krisnawati *et al.* (2010) total timber volume (including thinning) yielded over the rotation of 15–30 years of age was between 200.5 and 501.6 m^3/ ha with a mean annual volume increment of 7.7–19.3 m^3/ha/year.

2.5.12.6 Rotation

Previously reported rotation lengths for *S. mahagoni* plantations were variable. Fattah (1992) reported that in the state-owned plantations in Java, the economic rotation for *S. macrophylla* plantations was defined to be around 30–50 years. In private farms of *S. macrophylla* plantations in the Philippines, Rodriguez (1996) suggested the harvesting time could be around 15–20 years of age. A longer rotation (up to 60 years) has also been reported in other country in Puerto Rico (Bauer and Francis 1998). The desired rotation length may be guided by the time taken for the stands to reach their maximum mean annual volume increment (MAI) in volume. Wulfing (1949) and Suharlan *et al.* (1975) constructed a preliminary stand yield table for a combined species of *S. macrophylla* and *S. mahagoni* for high initial stand density (spaced at 2 m × 3 m or closer) in Indonesia and predicted that these plantation will reach the maximum mean annual volume increment at sometime between 15 and 50 years, depending on site quality. Other report suggested that on average site, the maximum mean annual volume increment will be reached at around 35 years (Pandey 1983). This prediction is supported by Krisnawati *et al*. (2010) who estimated the feasible rotation length for *S. mahagoni* plantations in Indonesia is around 15–30 years of age, depending on site quality and initial stand density.

2.5.12.7 Management requirements

The seedlings of *S. mahagoni* require light; if they are deprived of overhead light they are damaged by insects. They do not develop if the overhead shade is too dense; best results are obtained by irregularly interrupted cover.

2.6 Allelopathy of *mahagoni* species

Das *et al*., (2019) suggest that the seed extracts of *'S. mahagoni'* may possess growth inhibitory substances and; therefore, might have possibility to be used in the biological weed management option. They found the suppression activity of 'S. mahagoni' seed extracts was concentration-dependent and species-specific. For 50% inhibition (I50) of shoot and root growth of monocotyledonous plants, the required concentrations ranged from 0.0433-0.1443 and 0.0007-0.0348 g DW equivalent extract/mL, respectively. In case of dicotyledonous plants, I50 values for the growth of shoot and root ranged from 0.0040-0.1077 and 0.0010-0.0248 g DW equivalent extract/mL, respectively.

S. mahagoni seeds have also been reported to have antimutagenecity, antitumour and anti-inflammatory activities (Guevara et al., 1996).

Das *et al*., (2019) reveal that significantly positive results for the presence of alkaloids, tannins, terpenoids, and glycosides for all the seed and bark extracts. From the result, it shows considerably high terpenoids content found in both the seed and bark extracts. The ethyl acetate, acetone, ethanol, methanol and aqueous extracts of the bark shows potentially +ve results for the presence of phytocompounds, among other extracts acetone bark extract, shows a high level of phyto-compounds for the majority of test methods. So it is concluded that, phytochemical screening *Swietenia mahagoni* (L.) Jacq seed and bark extract reveal the presence of maximum classes of phyto constituents in bark extract when compared to seed.

Soares *et al*., (2003) studied that Germacrene D and ãhimachalene of *S. macrophylla* leaves may play important role in attracting mahogany shoot borer (*Hypsipyla grandella*) to oviposit on mahogany leaves. Furthermore, ethanol extracts of *S. macrophylla* leaves reveal acaricidal activity to Varroa destructor mites inside colonies of honeybees (El Zalabani et al., 2012).

Mahogany leaf litter is one of the source of potent allelopathic substances which can inhibit sunflower(*Helianthus annuus* L.) seed germination and phenolic compound produced throughout decomposition of *S. mahagoni* leaf litter inhibit acacia (*Acacia mangium* Wild.) seedling growth (Muhartini, 1987; Tambaru, 1998).

Fathoni *et al*., (2013) showed that the use of extracts of Sour Sup leaf and Mahogani seed as insecticide either alone or in combination against pests *S. litura* causing stop eating, causing larval mortality, the ability of larvae to pupae, as well as the ability to imago. However, the most effective concentration is combination of pesticides obtained in MS 200 and SS 100 g/l with mortality as much as 53.33% at the 72nd hour after application.

Another research which was commenced on methanol extract of bark of *Swietenia mahagoni* (L.) admitted that while it was subjected to screening for cytotoxic, thrombolytic as well as membrane stabilizing activity it possesses moderate to good activity in all three experiments. It was concluded that different fractions of the plant could be a satisfactory candidate for further studies to segregate abuzz amalgam (Akter *et al*., 2014).

A study was done on *Swietenia mahagoni* leaves to identify phytochemical constituents along with acclimation of Mahogany tea ruffian. Rely upon the chemical components impending, verdant tea can be consumed for remedial or else for nourishing intents. Current practice has been complying for appraising phyto chemical assaying and evenness of Mahogany tea powder acquired from *Swietenia mahagoni* leaves. Orientations of the diverse meditative arbors used in trite physic are appearing higher imperative now-a-days with respect to the monetary of preparations rely upon these trees. The improvement system comprise organoleptic attributes, physicochemical criterions, sustentative wroth, poisonous bulky humor constituents, embodied viperous analysis, as well as microbiological impurities of *Swietenia mahagoni* leaves to get herbal tea. Phytochemical analysis consequents revealed existence of carbohydrates, saponins, terpenoids, glycosides, flavonoids, and tannins. The microbiological pollutants range of herbal tea from *Swietenia mahagoni* leaves prevailed within the brink declared in WHO (World Health Organization) protocol for substitute physic. It was halted that the emergence of flavonoids, glycoside, saponins, tannins, as well as triterpenes type phyto constituents in *S. mahagoni* leaves are accountable for antioxidant as well as hypoglycemic action. Furthermore, physicochemical guidelines of *S. mahagoni* leaves like the water-soluble, alcohol-soluble, and ether-soluble extractive values, moisture content, bulk density, pH, water soluble ash, acid-insoluble ash, organoleptic aspects, dietary values, toxic heavy metal contents, animal toxicity study, and microbiological pollutants range endure within WHO protocol's for surrogate cures. Thus, the S. mahagoni leaves (Mahogany tea powder) can be evenly used as modified herbal or substitute redress for anti-diabetic or antioxidant adjuncts independently even in a herbal preparation. The outcomes retrieved from the analysis could be exploited as a remark for assignation restraints for the advertence standards for the quality control along with quality assurance of Mahogany tea powder. Though, prevalent probes are mandatory to look for influential assumptions of S.*mahagoni* leaves with the assistance of chromatographic and spectroscopic method (*Matin et al*., 2013).

An analysis was outlined to appraise the antibacterial properties of *Swietenia mahagoni* crude methanolic seed extract. The antimicrobial enterprise of the oily extract against

Gram-positive, Gram-negative, yeast along with fungus strains was figured out depend on the resistant collar applying disc diffusion assay, minimal inhibition concentration as well as minimal bactericidal concentration grades. Various phytochemicals scrutiny was subjected to the plant crude extract. The manifested subjective phyto chemical attempts exhibited the existences of familiar phyto compounds along with alkaloids, antraquinones, cardiac glycosides, saponins, terpenoids and volatile oils as leading operating components. The *Swietenia mahagoni* crude methanolic seed extract had resistance influence on the production of Staphylococcus aureus, Candida albicans, *Streptococcus faecalis*, *Pseudomonas aeroginosa*, and *Proteus mirabillase* and adorned minimal inhibiton concentrations and minimal bactericidal concentrations grades starting from 25 mg/ml to 50 mg/ml. Though denial of momentous action demonstrated against *Saccharomyces cerevisiae* (yeast), *Rhizopus sp.*, *Penicillium sp.*, along with Aspergillus fumigatus. It was observed that methanolic extract was much abuzz in comparison to amoxicillin antibiotic which was acted as positive control, while assayed in opposition to *Bacillus thuringiensis* and *Pseudomonas aeroginosa* at a concentration of 1 mg/ml. The emergence of bioactive components along with phyto-chemical components in the extract has been linked to antibacterial characteristics, hence has remedial attributes contrary to micro-organisms. Distinct limonoids were antecedently deserted from *Swietenia mahagoni*. Separation of triterpenes was further proclaimed on *Swietenia mahagoni*. Consequently, *Swietenia mahagoni* crude mathanolic seed extract could provide just as a redress to similar defiance together with virulent microbial species. Plant-emerged antimicrobial contain enormous pharmaceutic anticipations as they can provide the intent with few aftereffects that are customarily related with spurious antibiotics. This consideration further implements a bit efficacy for the practice of the more advanced plant segments in classical medication and also as an ancestor of chemotherapeutic assistants. In concise, *Swietenia mahagoni* crude methanolic seed extracts shows a broad spectrum of action against a group of bacteria and fungus accordingly. These auspicious extracts expanded the feasibility of discovering advanced analytically impressive antibacterial components. Supplementary rectification of the abuzz components as well as in vivo amends of antimicrobial activity conjointly toxicity evaluations of the extracts of *Swietenia mahagoni* crude mathanolic seed extract are hence recommended for more effective outcome (Sahgal *et al.*, 2009).

Another similar study was done on *Swietenia mahagoni*. The seed ware preferred for antibacterial activity. The extracts with miscellaneous solvents like Petroleum Ether, Ethyl Acetate, Dichloromethane, and Methanol were analyzed in momentary trial. The antibacterial assay of these extracts was evaluated with respect to *Bacillus subtillis*, *Sarcina lutea*, *Xanthomonas campestris*, *Escherichia coli*, *Klebsiella pneumoniae* and anonymous kidney noxious bacteria depend on the area of reticence applying Agar disc diffusion technique. The antibacterial action of the extracts was generous in both gram positive and gram negative bacteria. Ethyl acetate and methanol extract shows major functioning compare to other solvents. The study revealed that *Swietenia mahagoni* (Seed) contains such phyto-chemicals which are operating in broad spectrum bacteria. Also, both ethyl acetate and methanol could be subjected for significant extraction to obtain compelling phyto-chemicals from seed of *Swietenia mahagoni* (Alam *et al.*, 2014).

Different fractions bark along with flower extracts of *Swietenia mahagoni* were subjected to assays for determination of antioxidant activities by evaluating free radical scavenging activity and absolute phenolic distribution and also antimicrobial action by using bacteria and fungi according to disc diffusion method. It was concluded that, in the exploratory studies, part of the test samples obtained from the flower and bark of *S. mahagoni* acknowledged momentous antioxidant activity and moderate antimicrobial activity (Rahman *et al.*, 2014).

Rahman *et al.*, (2010) reveals that seed extracts *Swietenia mahagoni* is rich in lipids, specifically neutral lipids, phospholipids and glycolipids, among which phosphatidylcholine is most generous. Fatty acid composition of *Swietenia mahagoni* seed oil consists of arachidic acid, myristic acid, stearic acid, palmitic acid, oleic acid, etc. Since the current data it is assumed that the plant may cherish numerous significant organic functions. The fundamental desideratum was to figure out the anti-nociceptive, also neuro pharmacological activities of the ethanol extract of seeds of *Swietenia mahagoni*. Outcome of various chemical experiments on the ethanol extract of seeds of *Swietenia mahagoni* (middle layer) revealed the existence of alkaloids, reducing sugars, glycosides, tannins, gums and saponins. Antinociceptive activity (reducing sensitivity to painful stimuli) of the extract was assayed by using acetic acid induced writhing model in experimental mice. Acetic acid that was incorporated to induce writhing, introduces analgesia by emancipation of internal connotations that further actuates the affliction nerve endings. The extract was compared with standard drug Diclofenac sodium. Rely on this, it was wrapped up that the extract of seed of *Swietenia mahagoni* probably show anti-nociceptive action. Experimental findings suggested that the extract potentiated sleeping time in mice from pentobarbital induced hypnosis test which further proposed its depressant activity towards CNS, thus suggesting the feasible tranquilizing action. Additionally, the experiment for empirical attitude in mice asserted that the extract concealed the broad area prediction, crater passing capacity and head immersion repercussion in mice, which also patronage the CNS demulcent properties of the quiddity. Shortly, a suggestion was drawn that the unrefined ethanol extract of *Swietenia mahagoni* seed might exert anti-nociceptive along with central nervous system depressant properties. Although, more trials that involves phyto-chemical probe of the plant are needed to ascertain the abuzz compounds, also appraisal for these performances by applying diverse paradigms are mandatory to certify its therapeutical characteristics significantly.

In order to determine recent bioactivities, the standardized screenings of diverse medicinal plants have become a constant effort in many phytochemical research laboratories. Therefore, the crude methanol extract of flowers of *Swietenia mahagoni* and its aqueous as well as organic soluble fractions were sought for cytotoxic, thrombolytic and membrane stabilizing activity assays. After assaying, the flower extract of *S. mahagoni* shows potential cytotoxic and membrane stabilizing activities with slight thrombolytic activity. From the investigation, it was implied that, the flower extractives should be further screened for bioactivities along with solitude, characterization and interpretation of the bioactive compounds. (Rahman *et al*., 2014).

Sahgal *et al*., (2009) studied that the antioxidant activities of the crude methanol extract in vitro of seeds of *Swietenia mahagoni* was done. The crude methanol extract was assayed for probable antioxidant properties by free radical scavenging action using xanthine oxidase inhibition, 2,2-Diphenyl-1-picrylhydrazyl, ferric-reducing antioxidant power assays and hydrogen peroxide scavenging activity. Entire flavonoid along with phenolic constituents was further resolved. *Swietenia mahagoni* crude methanolic seed extract exerting antioxidant ability is tantamount to that of diverse native herbs, fruits, nuts and edible seeds. Assorted trials were applied to assert the antioxidant characteristics of the methanol extract in the particular trial. It is imperious as few plant extracts with specious antioxidant property can deny satisfying antioxidant action within a specific probe. Therefore, various probes are required to decisively substantiate antioxidant action. The appearance of an antioxidant bioactive component (s) in the *Swietenia mahagoni* crude methanolic seed extract could certainly avail to the antioxidant action efficiently. Segregation of the bioactive antioxidant material from *Swietenia mahagoni* crude methanolic seed extract permits more trial.

Ethanol (90%) extractives of stem barks as well as leaves of *Swietenia macrophylla* as well as *Swietenia mahagoni* were fragmented and analogously investigated considering output, bioactivity and lipoidal composition. Ethanol extractives of barks were received in greater quantities compared to the leaves. Lipoids were recognized using chloroform-soluble fractions of ethanol extracts and petroleum ether. Fatty acid methyl esters of petroleum ether extracts and unsaponifiable lipoids were explored using gas chromatography. Resolution of the lipoids of the leaves and stems barks of *Swietenia mahogani* along with *Swietenia macrophylla King.*expressed a quantitative in place of qualitative variability in composition which could, however, be supportive for interspecies differentiation. Column chromatography of the non-polar and semi-polar fractions of *Swietenia macrophylla* stem bark ethanol extracts were allowed to seclusion of three known lipoids which are for the first time recorded from the plant. The ethanol extracts of the stem barks and leaves of the two species could be deliberated as secure based on their LD50s. Appraisement of the various pharmacological abilities of the extracts reflected their traditional medicinal management; thus encouraging the local flare of these species for both lucrative and pharmaceutical objectives. Though, further incorporation in herbal formulations will necessitate exact clinical trial. (Mousa *et al.*, 2014).

Majid *et al.*, (2004) reported that *Swietenia mahagoni* oil extract from the seed was assayed willfully to ascertain its appropriateness for medical purposes with exceptional focus on antimicrobial and toxic nature. A few of its tangible and viscose characteristics were tested and distinguished with those typical oils for example sunflower, olive, Linseed, cotton seed, coconut, soybean, castor and palm. The delicate oils was observed to exhibit optimal to average function against affliction creating bacteria *viz. Staphylococcus aureus, Salmonella typhi, Shigella dysenterial,* and fungal pathogen viz. *Alternaria alternata, Curvularia lunata Macrophomina phascolma*. Several seed extracts of *Swietenia mahagoni* exhibited subtle toxicity while employed on predatory fish's viz. *Anabas testudineus* and *Heteropneustes fossilis.*

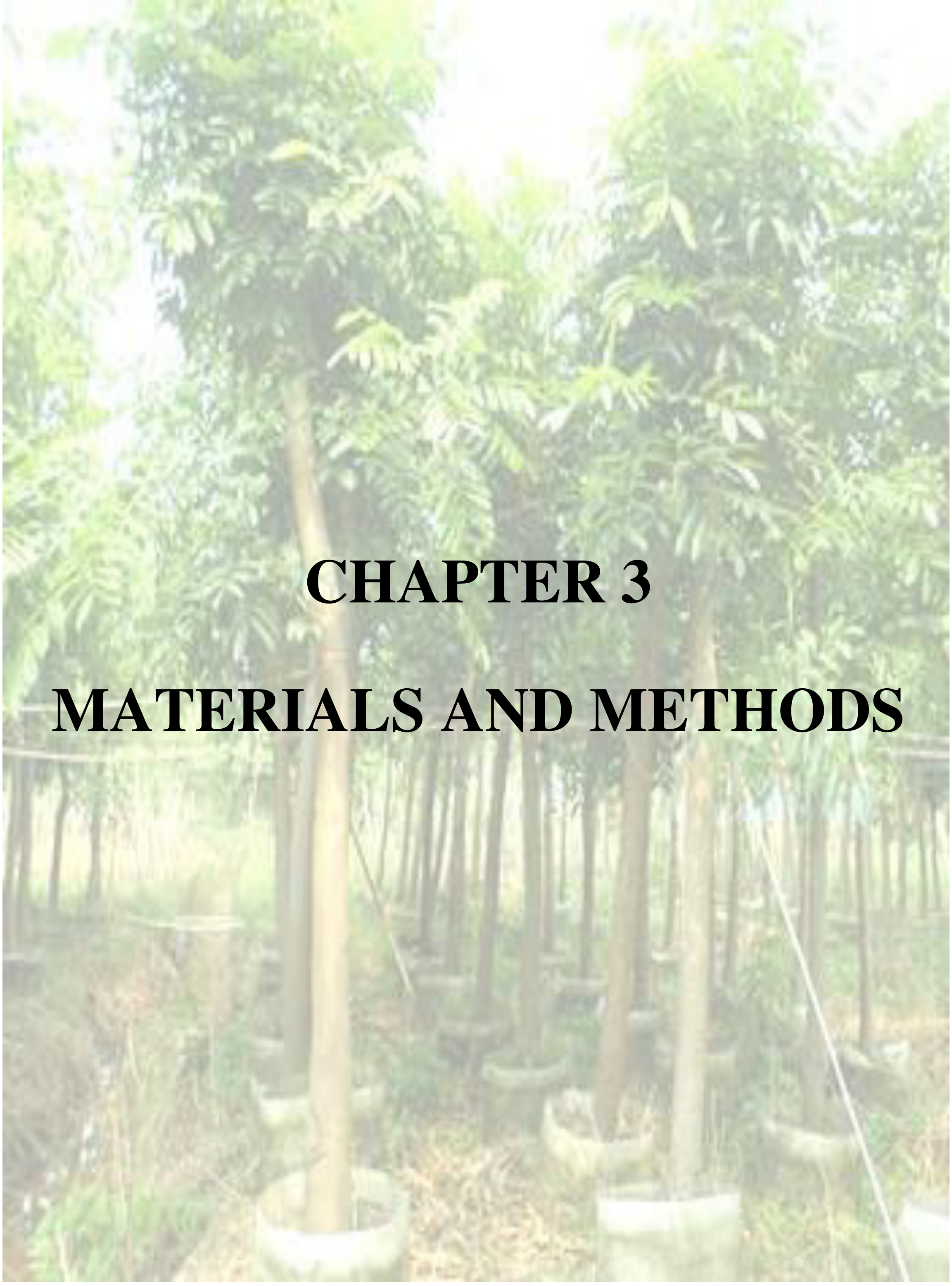
Eid *et al*., (2013) found that the genus *Swietenia* has wide range use for diverse objectives. *Swietenia mahagoni* is one of the prevailing plants in China, also several equatorial ambits in the universe. It had been recorded for its curative purposes, alike in the medication of inflammation, hypertension, diabetes, HIV, cancer, malaria, intestinal parasitism, chest pains, and amoebiasis. Anti- nociceptive activity, Anti-diarrheal, and anti-microbial action were also reported using this plant.

Hasan *et al*., (2011) observed that the effect of *Swietenia mahagoni* seeds in case of lowering blood glucose level in experimentally induced diabetic rats. Diabetes was induced by alloxan. It was terminated by claiming that *Swietenia mahagoni* seeds have no response in non-diabetic rats considering reduction of glucose level in the blood stream.

Liman *et al.,* (2010) reported that the leaf extracts of the Mahagoni plant significantly (P_0.05) reduced the population of the nematodes compared to the untreated seedlings.

Gonçalves *et al*., (2005) studied that Mahagoni leaves showed differences in leaf area and dry mass in response to the two tested light environments ($P<0.01$). The area of mahogany leaves in plants grown under shade was 35% greater than those grown under full sunlight. For leaf dry mass, it was observed that shade leaves were 56% greater than those grown under full sunlight On the contrary; tonka bean did not change their leaf traits for both parameters leaf area and dry mass in contrasting light environments. However, the environmental influences tonka bean and mahogany leaves, for leaf area, were always larger in shade than in full sunlight.

Mahagoni seed only remain viable for a single rainy season and show a rapid drop in viability when stored in ambient conditions (Araujo, 1971; Mattobii and Komar, 1990; Gomez, 1996).



CHAPTER 3

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

In this chapter, the materials and methods have been presented which include brief description of location of the experimental site, climate, materials used and methodology followed in the experiment. Two experiments (Laboratory and Pot) were conducted to achieve the objectives of the research. The details of these sections are described in the following subheads-

3.1 Location

The experiments were conducted in the Agroforestry Laboratory and Agroforestry Research Field, Department of Agroforestry and Environment, HSTU Campus, Dinajpur. The geographical location of the site was between 25º 13' latitude and 88º 23' longitude, and about 37.5m above the sea level.

Figure 3.1: Map showing Dinajpur district

3.2 Soil characteristics

The pot experiment was conducted in Agroforestry field. The soil texture of pot was sandy loam in nature. The soil P^H was 5.1. The details soil properties are presented in Appendix-I.

3.3 Climate and Weather

The period of my research work was minimum rainfall during pot experiment (16 May to 19 September).

3.4 Duration

Duration of the experimental period was from May 2018 to September 2018.

3.5 Design

The experiments design were CRD (Complete Randomized Design) with 3 replications.

3.6 Seed collection

The seeds of test crops (chilli, brinjal and okra) were collected from Bangladesh Agriculture Development Corporation (BADC), Nashipur, Dinajpur.

3.7 The selected test crops

The selected crops were Chilli (*Capsicum annum*), Brinjal (*Solanum melangona)* and Okra (*Abelmoschus esculentas*). These crops were selected due to their common practice in the farmers' agroforestry fields with the *S. mahagoni* trees. Beside these, the species are locally available. Chilli is used as a spice for human consumption. Brinjal and Okra also used as a food for human consumption.

3.8 Laboratory experiment

3.8.1 Extracts preparation

The leaf was collected from *S. mahagoni* tree nearby area of HSTU. Leaf of *S. mahagoni* was chipped and air- dried at room temperature. The air-dried materials was soaked in distilled water for five days and then filtered through Whatman No. 3 filter papers. After preparing different concentrations of the extracts, they were kept into bottles. The bottles were then brought into laboratory for further use.

3.8.2 Treatment combination

For laboratory experiment, three different concentrations of leaf extracts (1%, 2% and 3%) were prepared. To prepare 1% concentration 1g air-dried material were soaked in 100ml water. Like 2% concentration, to prepare 2% concentration 2g air-dried material were soaked in 100ml water and 3g air-dried material were soaked in 100ml water to prepare 3 % concentration. Finally, treatments were replicated 3 times in completely randomized design in the laboratory experiment. Distilled water was used for control treatment. Therefore, the treatment combinations were as follows:

- T_1 = 1% concentration of leaf extracts
- T_2 = 2% concentration of leaf extracts
- T_3 = 3% concentration of leaf extracts
- T_4 = Control (Water)

3.8.3 Pre-sowing treatment

The seeds were surface-sterilized with 0.5% Mercuric Chloride solution and repeatedly rinsed in distilled water. 20 seeds were placed in each sterile Petridis (9 cm diameter) lined with two Whatman No.3 filter papers and 10 ml of test extracts will be added to each Petridish as per treatments. The germination experiments were conducted in laboratory with normal temperature.

3.8.4 Germination data

Seeds were considered as germinated seeds when root length were 1-2 mm and recorded every 8-hour and data were recorded until 15 days. Germination speeds were calculated as followed by (Zhang and Fu, 2010). The seedlings of chilli, brinjal and okra were removed from the Petridish after 6 days and the length of primary roots and shoots were measured. The effects of extracts on test crops were expressed in percentage (%) of control and were calculated according to T/C, where T is the "treatment" data and C is the "control" data. The effect is stimulatory when the result is greater than 100% and the effect is inhibitory when the result is less than 100%.

Germination data were collected on the germination percentage, germination speed and days of germination initiation etc. Germination speed was calculated as under (Chiapusio *et al*., 1997):

$$S= (N_1*1) + (N_2–N_1)*1/2 + (N_3- N_2)*1/3 + \ldots + (Nn- N_{n-1}) *1/n.$$

Where, N_1, N_2, N_3, …, N_{n-1}, Nn refers to the proportion of germinated seeds on the first, second , third days, …, n-1, n days.

3.9 Pot Experiment

The seeds of test crops were sown in the Research field of Agroforestry and Environment, HSTU to see their root-shoot growth parameters and fine root architecture (length and number) in pot condition.

3.9.1 Treatment combination

For field experiment, to prepare 1% concentration 1g air-dried materials were soaked in 100ml water. Finally, treatments were replicated 3 times in Completely Randomized Design. Distilled water was used for control treatment. For leaf exudates 36 pots each tested crops. Therefore, the treatment combinations are as follows:

- T_1 = 1% concentration of leaf extracts
- T_2 = 2% concentration of leaf extracts
- T_3 = 3% concentration of leaf extracts
- T_4 = Control (Water)

3.9.2 Germination data

Seeds were considered germinated when root length were 1-2 mm and recorded every 8-hour till 15 days. Germination data were collected on the germination percentage, germination speed and days of germination initiation etc. Germination speed was calculated as under (Chiapusio *et al*., 1997):

$$S= (N_1*1) + (N_2–N_1)*1/2 + (N_3- N_2)*1/3 + … + (Nn- N_{n-1}) *1/n.$$

Where, N_1, N_2, N_3, …, N_{n-1}, Nn refers to the proportion of germinated seeds on the first, second , third days, …, n-1, n days.

The effects of extracts on test crops were expressed in percentage (%) of control and were calculated according to T/C, where T is the “treatment” data and C is the “control” data. The effect is stimulatory when the result is greater than 100% and the effect is inhibitory when the result is less than 100%.

3.10 Data collection

Data were collected on the following parameter- shoot height.

3.11 Shoot height measurement

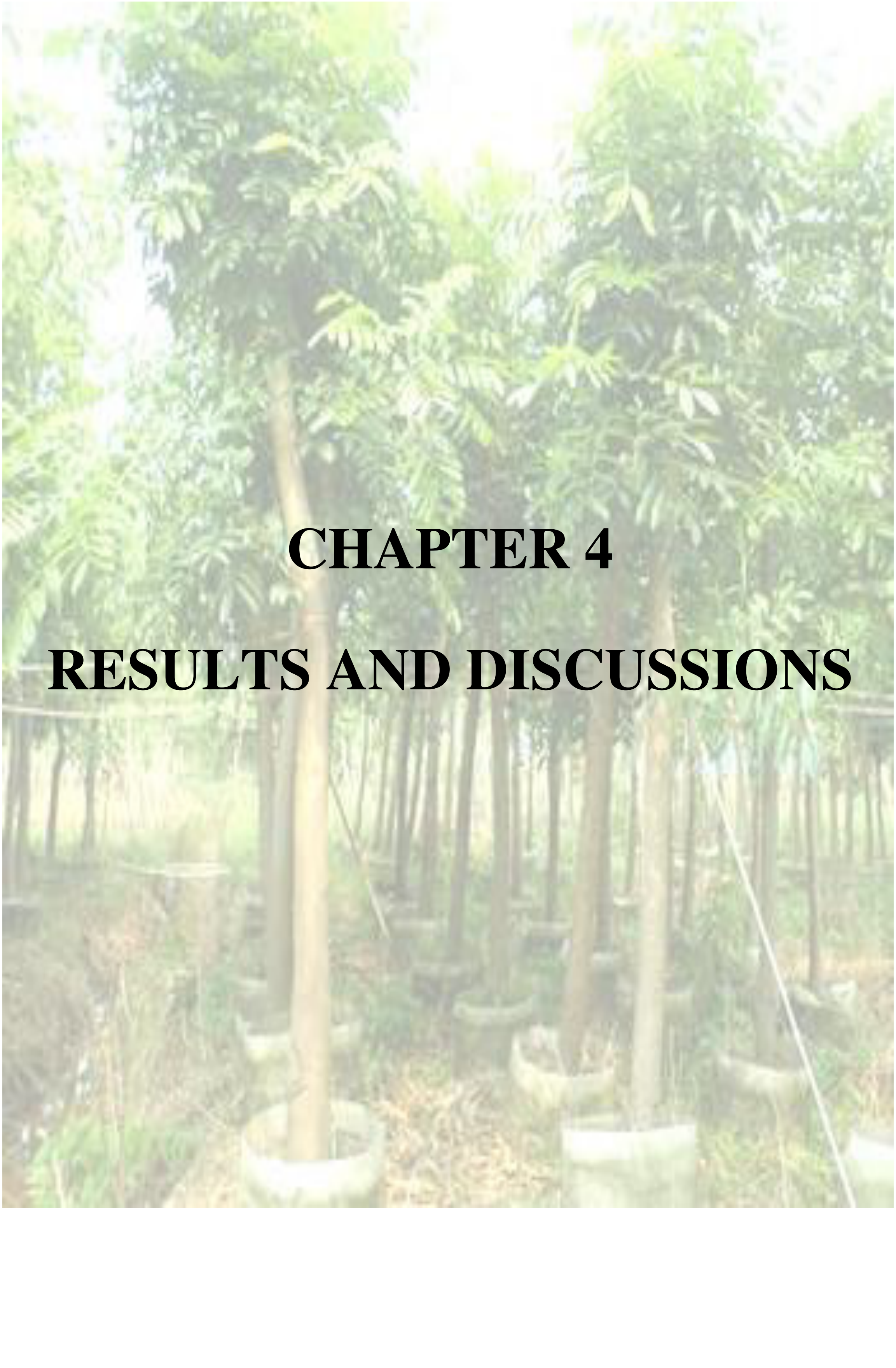
Shoot height is defined as the distance from the cotyledon scar to the base of the terminal bud on dormant seedlings or to the tip of the shoot on growing seedlings. In this experiment, shoot height was measured from the root collar to the base of terminal bud of the living shoot tip (Jacobs *et al*., 2005; Ritchie, 1984; Haase, 2007) by measuring tape and measuring pole.

3.12 Biomass measurement

For biomass measurement, the seedlings were oven-dried at 73°C (Royo *et al*., 2001; Tsakaldimi *et al.,* 2009) for 72 hours until they reached in a constant weight. They were weighed through an electric balance to get total dry weight (g). Then total oven dry weight (g) was calculated.

3.13 Statistical Analysis

All statistics were calculated with Statistics 10 software and Microsoft Excel 2013.



CHAPTER 4

RESULTS AND DISCUSSIONS

CHAPTER 4

RESULTS AND DISCUSSION

The results obtained from the present studies along with statistical analysis of data have been presented and discussed in this chapter. The present studies regarding effect of leaf extracts of *Swietenia mahagoni* on some selected agricultural crops were observed. The summaries of analysis of variance for germination and growth parameters studied have been presented under following sub headings.

4.1 Effect of leaf extracts of *Swietenia mahagoni* on agricultural crops under laboratory condition

The number of germinated seeds and germination percentage was found in different treatments. Germination traits were affected by different concentrations. Germination was found to start after 6 days of seed sowing.

4.1.1.1 Germination percentage of Chilli in laboratory

The germination percentage of Chilli was varied notably due to three treatments compared to control (Figure 4.1). In case of leaf extracts application the maximum inhibition (59.10%) over control was found in treatment T_3 (3% concentration) followed by 67.11% and 78.93% in treatment T_2 (2% conc.) and T_1 (1% conc.) respectively.

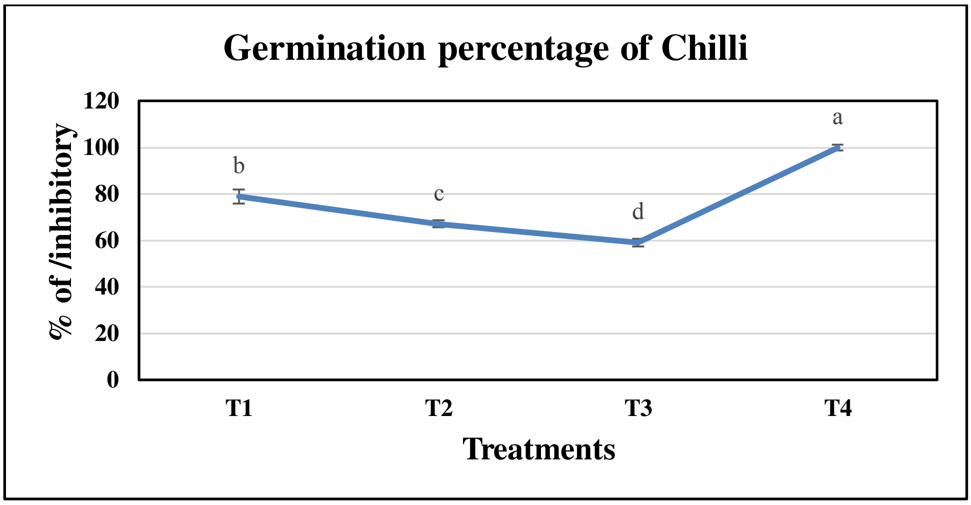


Figure 4.1: Effect of leaf extracts of *Swietenia mahagoni* on germination percentage of Chilli (*Capsicum anuum*). In a line diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.1.1.1Germination speed of Chilli in laboratory

Figure 4.2 shows the germination speed of Brinjal due to leaf extracts application. The highest germination speed was found in T_4 (Control), followed by T_1 (1%), T_2 (2%) and lowest in T_3 (3%) in leaf extracts. This result shows that higher concentration of *S. mahagoni* have inhibitory effect on the seed germination of Chilli than the control condition.

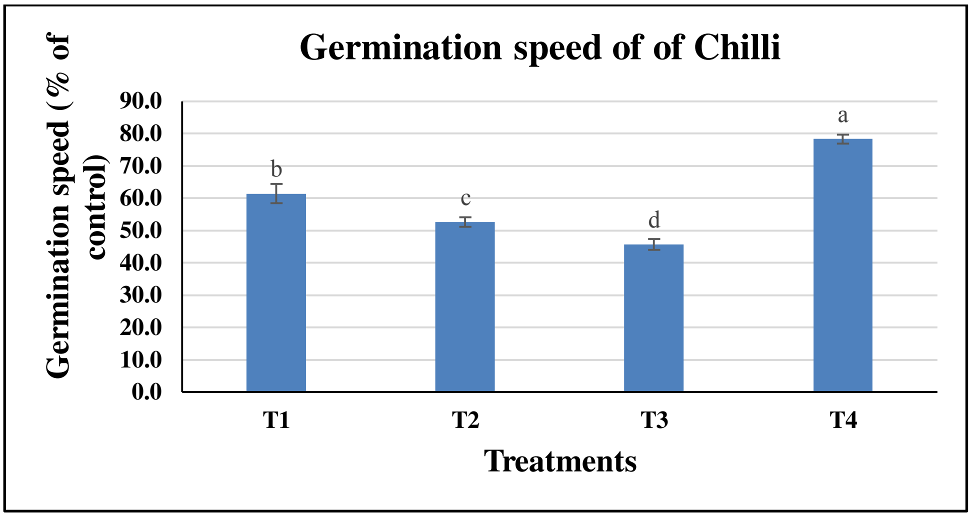


Figure 4.2: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Chilli (Capsicum anuum). In a bar diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

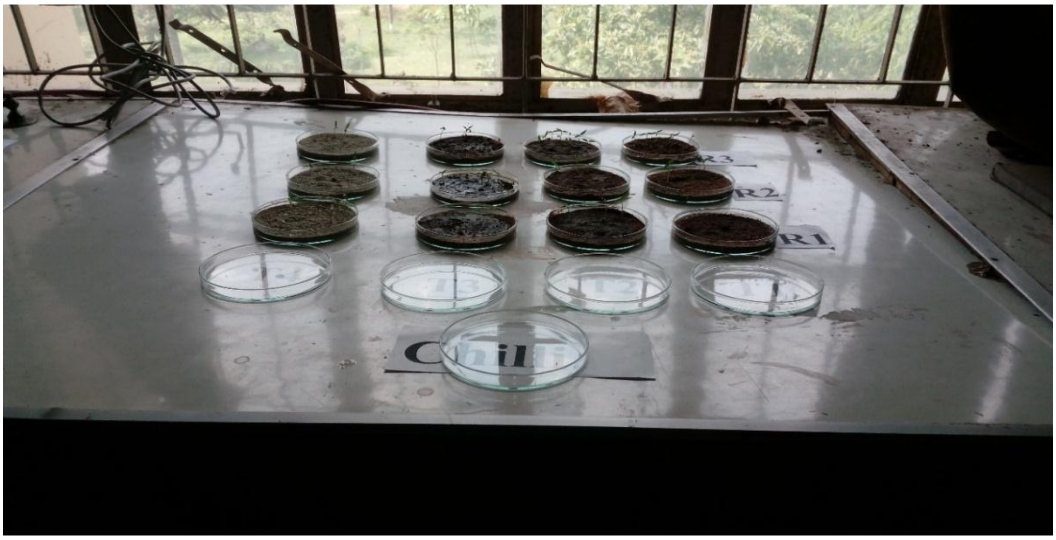


Plate 1: Germination of Chilli seeds with different treatments

4.1.1.2 Morphology of Chilli in laboratory

In case of leaf extracts application, plant height of Chilli (*Capsicum annum*) seedlings was statistically varied differently among the treatments. Tallest plant was recorded in T_4 (17.89cm) and lowest in T_3 (15.98cm). In case of leaf extracts, plant dry biomass of Chilli (*Capsicum annum*) varied among different treatment. The highest value of plant dry biomass was in treatment T_4 (0.0058g) and the lowest value was in treatment T_3 (0.0050g) (Table 4.1).

Table 4.1: Effect of different concentrations of leaf extracts of *S. mahogoni* on the plant morphological characteristics of *Capsicum annum* under lab condition

	Shoot height			Total height	
Treatments	**17days**	**23 days**	**27 days**	**27 days**	**Total dry weight (g)**
T_1	3.55±0.01b	5.27±.02 b	8.41±.02b	17.32±0.34 b	0.0056±0.0 b
T_2	3.36±0.02 c	5.13 ±0.02 c	7.97±.02 c	16.48 ±0.03 c	0.0053±0.0 c
T_3	3.29±0.01d	5±0.03 d	7.79±0.06 d	15.98±0.03 d	0.0050±0.0 d
T_4	3.62±0.18 a	5.41±0.01 a	8.66±0.06 a	17.89±0.83 a	0.0058±0.0 a
CV (%)	4.14	3.11	4.56	4.47	5.72

(T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water). In a column, different letter (s) show statistically significant at $P \leq 0.05$ by Duncan Multiple Range Test.

4.1.2 Effect of leaf extracts of *Swietenia mahagoni* on Brinjal

4.1.2.1 Germination speed of Brinjal in laboratory

The germination percentage of Brinjal was varied notably due to three treatments compared to control (Figure 4.3). In case of leaf extracts application, the maximum inhibition (56.28%) over control was found in treatment T_3 (3% concentration) followed by 65.29% and 78.10% in treatment T_2 (2% conc.) and T_1 (1% conc.) respectively.

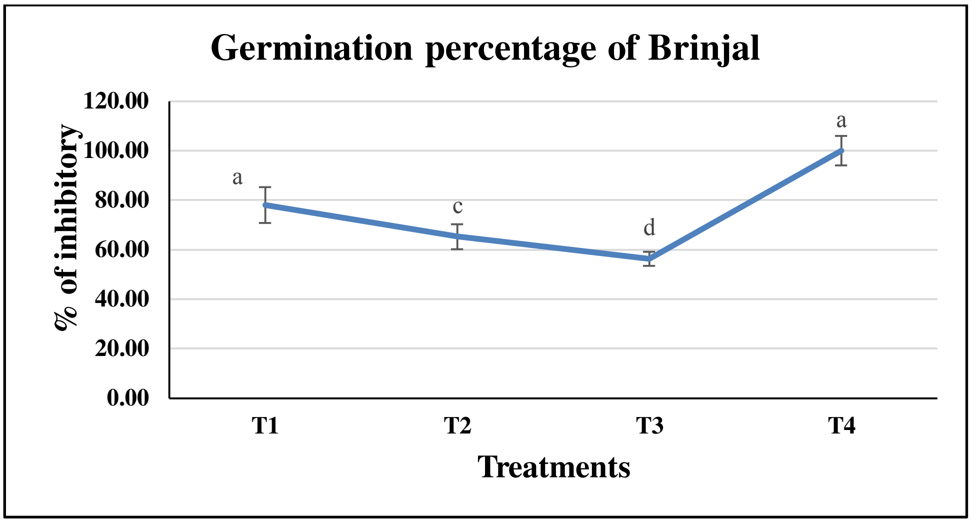


Figure 4.3: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Brinjal (*Solanum melongena*). In a line diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.1.2.1 Germination speed of Brinjal in laboratory

Figure 4.4 shows the germination speed of Brinjal due to leaf extracts application. Highest germination speed was found in T_4 (Control), followed by T_1 (1%), T_2 (2%) and lowest in T_3 (3%) in leaf extracts. This result shows that higher concentration of *S. mahagoni* have inhibitory effect on the seed germination of Brinjal than the control condition.

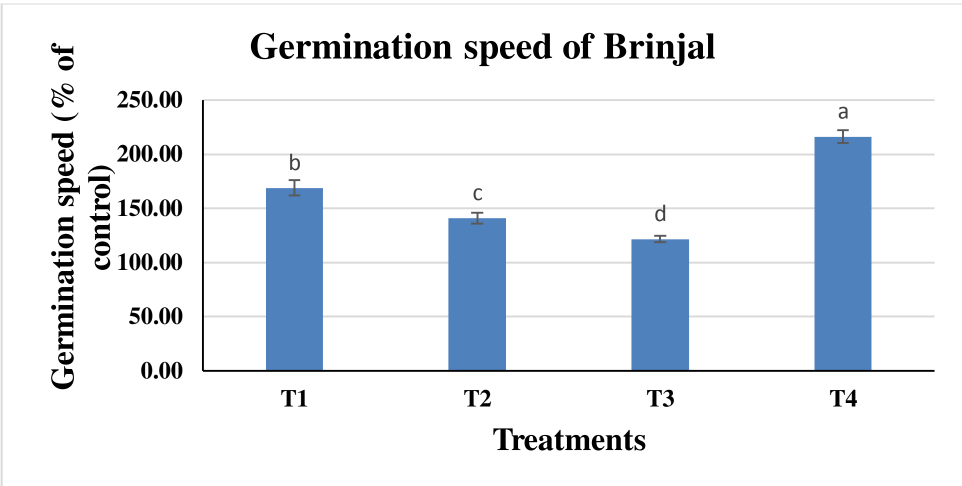


Figure 4.4: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Brinjal (*Solanum melangona*). In a bar diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

Plate 2: Germination of Brinjal seeds with different treatments

4.1.2.2 Morphology of Brinjal in laboratory

In case of leaf extracts application, plant height of Brinjal seedlings was statistically varied among the treatments. Plant height was highest in T_4 (14.53cm) and lowest in T_3 (12.47cm).In case of leaf extracts, plant dry biomass of Brinjal *(Solanum melangona)* varied among different treatment. The highest value of plant dry biomass was in treatment T_4 (0.0068g) and the lowest value was in treatment T_3 (0.0048g) (Table 4.2).

Table 4.2: Effect of different concentrations of leaf extracts of *S. mahogoni* on the plant morphological characteristics of *Solanum melongena* under lab condition

	Shoot height (cm)			**Total height (cm)**	
Treatments	**17days**	**23 days**	**27 days**	**27 days**	**Total dry weight (g)**
T_1	4.03±0.02 b	5.12± 0.03b	6.82±0.04 b	13.94±0.07b	0.0062±0.000082b
T_2	3.55±0.01c	4.72±0.04c	6.21 ±0.05c	13.08±0.07c	0.0053±0.000082c
T_3	3.38 ±0.03d	4.43 ±0.03d	5.77±0.06d	12.47 ±0.16d	0.0048±0.000082d
T_4	4.22 ±0.06 a	5.81± 0.05a	7.07 ±0.03a	14.53 ±0.09a	0.0068±0.00082 a
CV (%)	9.45	10.88	6.22	8.30	14.21

(T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water). In a column, different letter (s) show statistically significant at $P \leq 0.05$ by Duncan Multiple Range Test.

4.1.3 Effect of leaf extracts of *Swietenia mahagoni* on Okra

4.1.3.1 Germination percentage of Okra in laboratory

The germination percentage of Okra was varied notably due to three treatments compared to control (Figure 4.5). In case of leaf extracts application, the maximum inhibition (49.20%) over control was found in treatment T_3 (3% concentration) followed by 62.68% and 72.04 % in treatment T_2 (2% conc.) and T_1 (1% conc.) respectively.

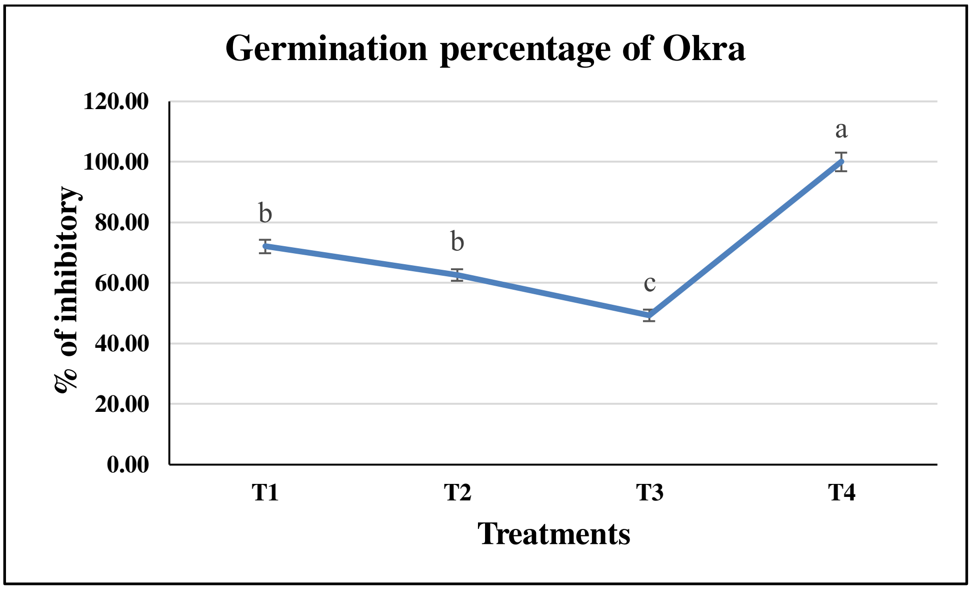


Figure 4.5: Effect of leaf extracts of *Swietenia mahagoni*on germination percentage of Okra (*Abelomoschus esculentas*). In a line diagram, different letter (s) show statistically significant at $P \leq 0.05$ Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.1.3.2 Germination speed of Okra in laboratory

Figure 4.6 shows the germination speed of okra due to leaf extracts application. The highest germination speed was found in T_4 (Control), followed by T_1 (1%), T_2 (2%) and lowest in T_3 (3%) This result shows that higher concentration of *S. mahagoni* have inhibitory effect on the seed germination of Okra than the control condition.

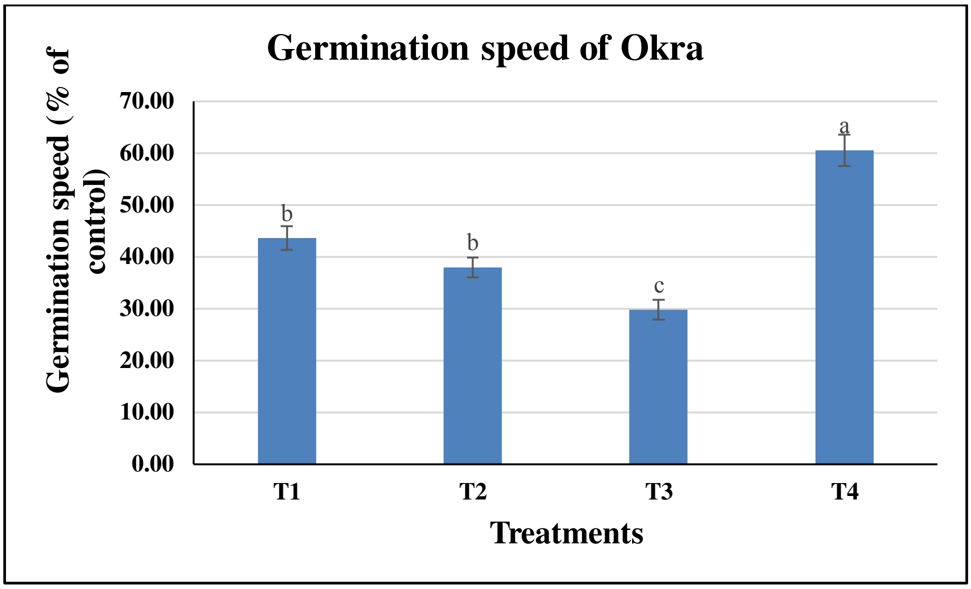


Figure 4.6: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Okra (*Abelomoschus esculentas*). In a bar diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

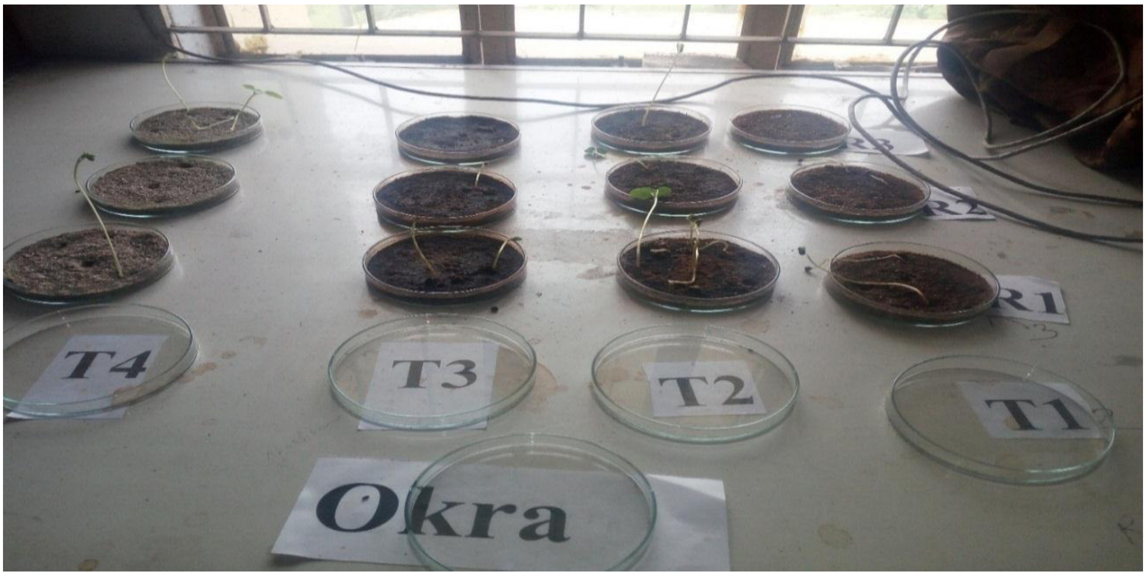


Plate 3: Germination of Okra seeds in different treatments

4.1.3.3 Morphology of Okra in laboratory

In case of leaf extracts application, plant height of Okra seedlings was statistically varied differently among the treatments. Tallest plant was recorded in T_4 (22.81cm) and shortest in T_3 (18.82 cm). In case of leaf extracts, plant dry biomass of Okra (*Abelomoschus esculentus)* varied among different treatment. The highest value of plant dry biomass was in treatment T_4 (0. 008g) and the lowest value was in treatment T_3 (0. 0067 g) (Table 4.3).

Table 4.3: Effect of different concentrations of leaf extracts of *S. mahogoni* on the plant morphological characteristics of *Abelomoschus esculentus* under lab condition

	Shoot height (cm)			Total height (cm)	
Treatments	**17days**	**23 days**	**27 days**	**27 days**	**Total dry weight (g)**
T_1	7.36± 0.005b	9.84±0.055b	12.88±0.049b	21.58±0.112b	0.0075±.0.0029 b
T_2	6.57±0.046c	9.29 ±0.038 c	12.21±0.044c	20.3±0.159 c	0.0076±.0.0018b
T_3	6.28±0.426d	8.94±0.027d	11.59±0.049 d	18.82±0.136d	0.0067±.0.0001c
T_4	7.78±0.095a	10.43±0.069a	13.41±0.040ab	22.81±0.155a	0.008± 0.00014 a
CV (%)	9.07	6.18	5.74	7.47	9.02

(T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water). In a column, different letter (s) show statistically significant at $P \leq 0.05$ by Duncan Multiple Range Test.

4.2 Effect of leaf extracts of *S. mahagoni* on agricultural crops under pot condition

The number of germinated seeds, germination percentage and shoot percentage was calculated in different treatments. Germination traits were affected by different treatments. Germination was found to start after 8 days of seed sowing.

4.2.1 Effect leaf extracts of *S. mahagoni* on Chilli

4.2.1.1 Germination percentage of Chilli in pot

The germination percentage of Chilli was varied notably due to three treatments compared to control (Figure 4.7). In case of leaf extracts application, the maximum inhibition (55.69%) over control was found in treatment T_3 (3% concentration) followed by 64.49% and 77.54 % in treatment T_2 (2% conc.) and T_1 (1% conc.), respectively.

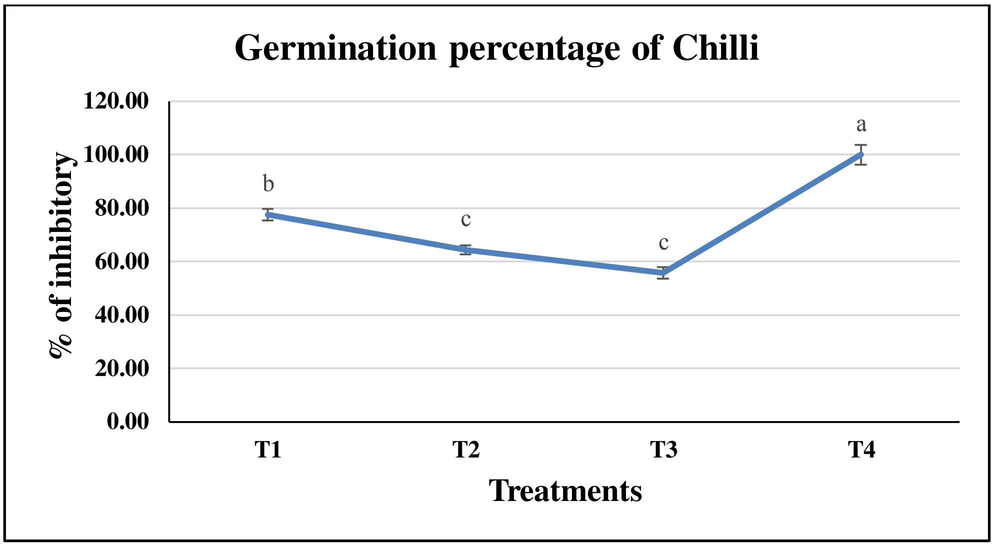


Figure 4.7: Effect of leaf extracts of *Swietenia mahagoni* on germination percentage of Chilli (*Capsicum annum*). In a bar diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.2.1.2 Germination speed of Chilli in pot

Figure 4.8 shows the germination speed of Chilli due to leaf extracts application. The highest germination speed was found in T_4 (Control), followed by T_1 (1%), T_2 (2%) and lowest in T_3 (3%) This result shows that higher concentration of *S. mahagoni* have inhibitory effect on the seed germination of Chilli than the control condition.

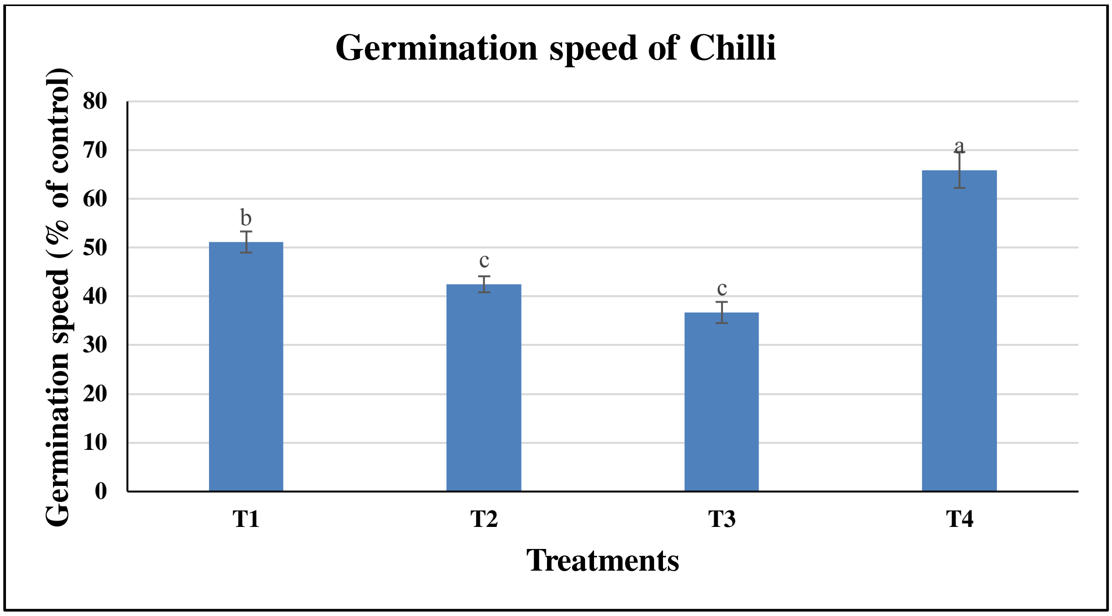


Figure 4.8: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Chilli (*Capsicum annum*). In a bar diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.2.1.3 Morphology of Chilli in pot

In case of leaf extracts application, plant height of Chilli (*Capsicum annuum)* seedlings was statistically varied differently among the treatments. Plant height was the highest in T_4 (51.78cm) and lowest in T_3 (45.96cm) (Table 4.4).

Table 4.4: Effect of different concentrations of leaf extracts of *S. mahogoni* on the plant morphological characteristics of *Capsicum annuum* under pot condition

	Shoot height (cm)		
Treatments	**16 days**	**52 days**	**126 days**
T_1	5.29 ±.0.03b	30.33 ±0.88b	50.25 ±0.47a
T_2	5.05±0.0.04c	28.98 ±2.90b	46.52 ±0.34b
T_3	4.94 ±0.09c	30.33 ±0.34b	45.96 ±0.23b
T_4	5.54 ±0.03a	32.67 ±0.33a	51.78 ±0.95a
CV (%)	4.88	6.53	5.54

(T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water). In a column, different letter (s) show statistically significant at $P \leq 0.05$ by Duncan Multiple Range Test.

4.2.2 Effect leaf extracts of *S. mahagoni* on Brinjal

4.2.2.1 Germination percentage of Brinjal in pot

The germination percentage of Brinjal was varied notably due to three treatments compared to control (Figure 4.9). In case of leaf extracts application, the maximum inhibition (48.26%) over control was found in treatment T_3 (3% concentration) followed by 57.38% and 72.42 % in treatment T_2 (2% conc.) and T_1 (1% conc.) respectively.

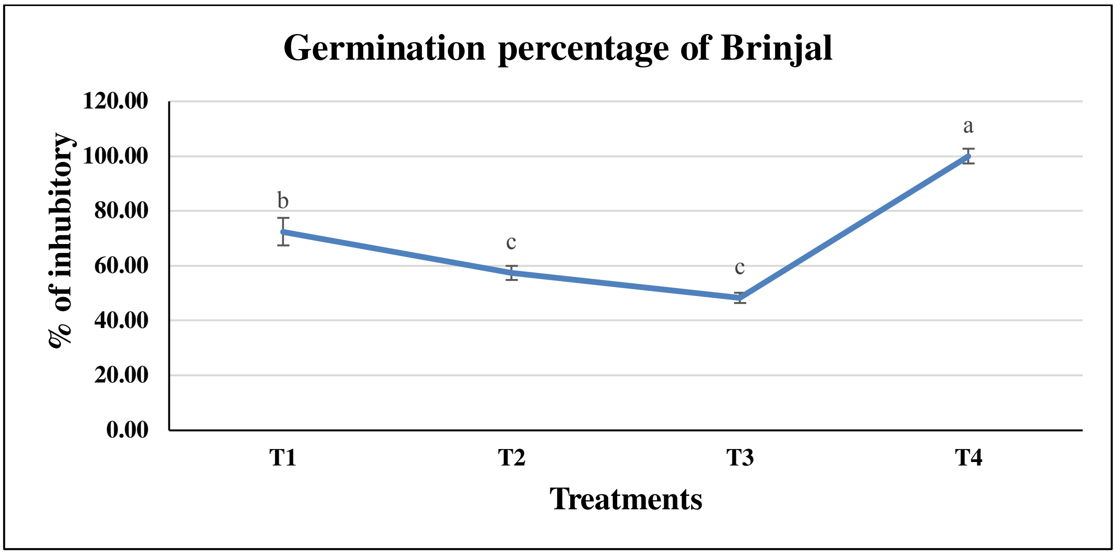


Figure 4.9: Effect of leaf extracts of *Swietenia mahagoni* on germination percentage of Brinjal (*Solanum melongena*). In a line diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.2.2.2 Germination speed of Brinjal in pot

Figure 4.10 shows the germination speed of Brinjal due to leaf extracts application. Highest germination speed was found in T_4 (Control), followed by T_1 (1%), T_2 (2%) and lowest in T_3 (3%) This result shows that higher concentration of *S. mahagoni* have inhibitory effect on the seed germination of Brinjal than control condition.

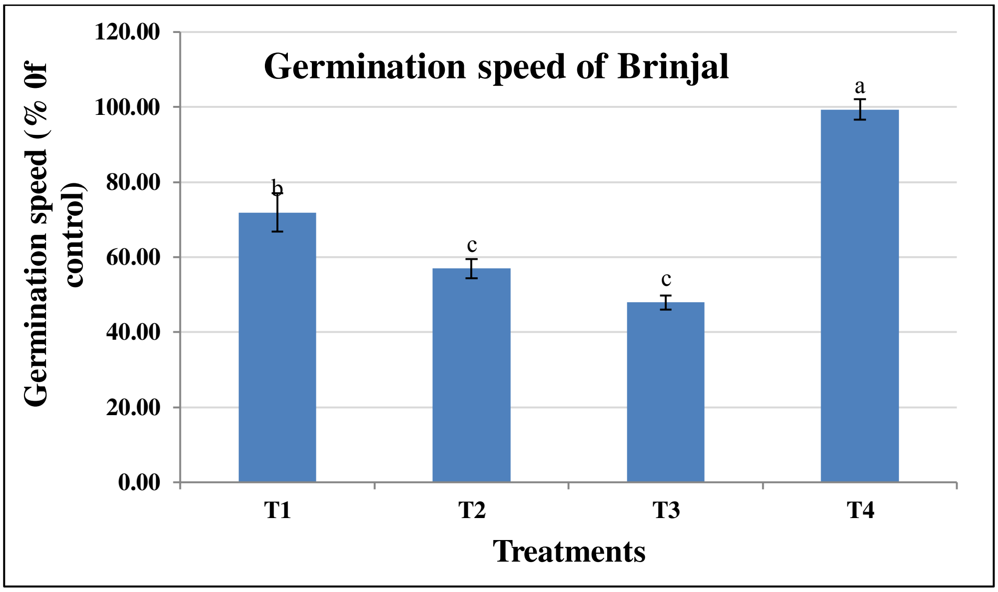


Figure 4.10: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Brinjal (*Solanum melongena*). In a bar diagram, different letter (s) show statistically significant at P≤0. Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.2.2.3 Morphology of Brinjal in pot

Plant height of Brinjal seedlings was statistically varied among the different treatments. Plant height was highest in T_4 (44.43cm) and lowest in T_3 (39.92cm) (Table 4.5).

Table 4.5: Effect of different concentrations of leaf extracts of *S. mahogoni* on the plant morphological characteristics of *Solanum melongena* under pot condition

	Shoot height (cm)		
Treatments	**16 days**	**52 days**	**126 days**
T_1	5.39±.52b	31.13 ±0.59a	42.31 ±0.50b
T_2	5.28±.0.04bc	28.52 ±0.29b	41.19 ±0.63bc
T_3	5.16 ±0.03c	24.59±0.30c	39.92±0.25c
T_4	5.64± 0.04a	32.52 ±0.48a	44.43±0.296a
CV (%)	3.62	11.02	4.42

(T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water). In a column, different letter (s) show statistically significant at $P \leq 0.05$ by Duncan Multiple Range Test.

4.2.3 Effect of leaf extracts of *S .mahagoni* on Okra

4.2.3.1 Germination percentage of Okra in pot

The germination percentage of Okra was varied notably due to three treatments compared to control (Figure 4.11). . The germination percentage of Okra was varied notably due to three treatments compared to control (Figure 4.5). In case of leaf extracts application, the maximum inhibition (50.23%) over control was found in treatment T_3 (3% concentration) followed by 63.06% and 77.95% in treatment T_2 (2% conc.) and T_1 (1% conc.) respectively.

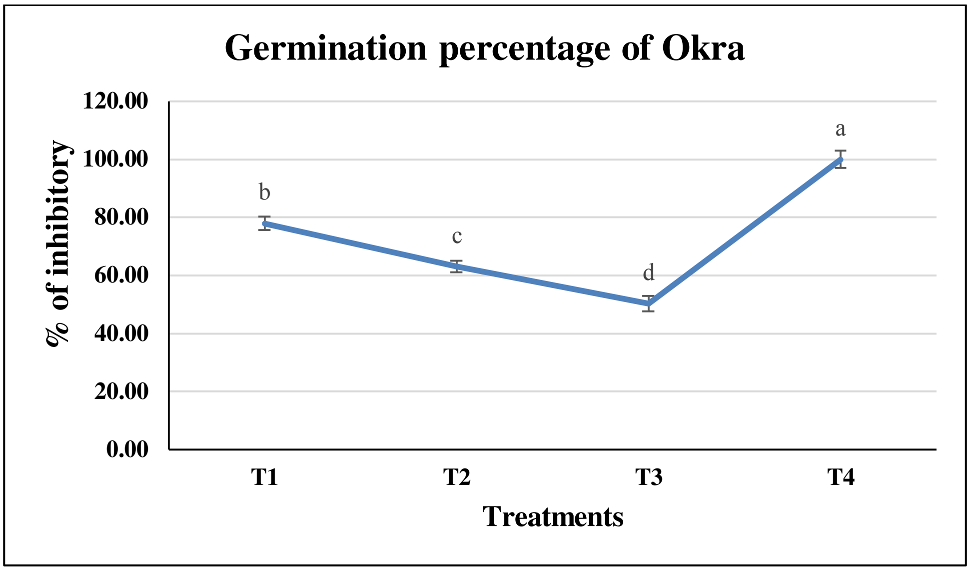


Figure 4.11: Effect of leaf extracts of *Swietenia mahagoni* on germination percentage of Okra (*Abelomoschus esculentas*). In a line diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.2.3.2 Germination speed of Okra in pot

Figure 4.12 shows the germination speed of Okra due to leaf extracts application. Highest germination speed was found in T_4 (Control), followed by T_1 (1%), T_2 (2%) and lowest in T_3 (3%) This result shows that higher concentration of *S. mahagoni* have inhibitory effect on the seed germination of Okra than the control condition.

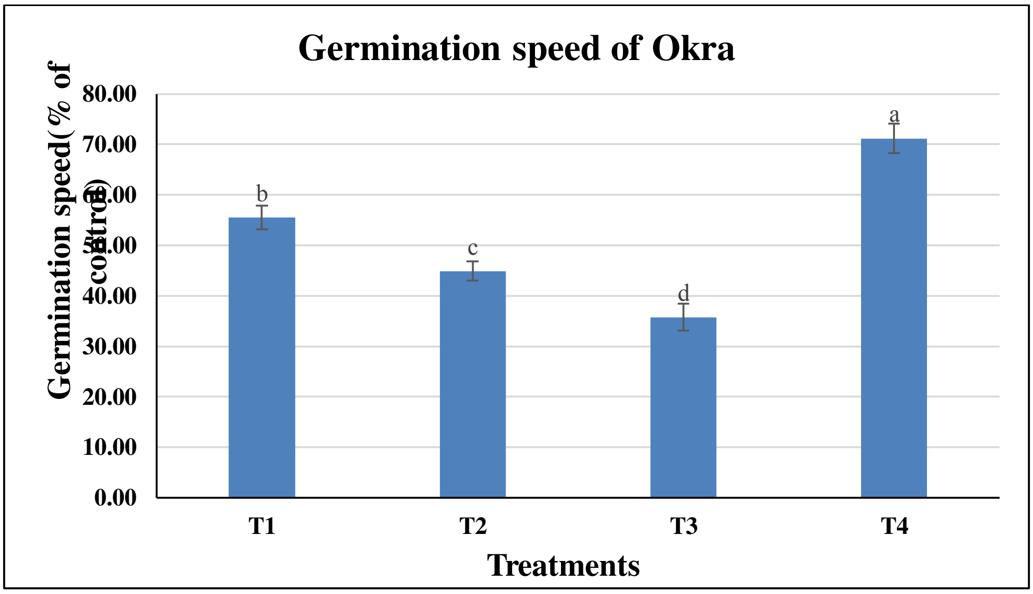


Figure 4.12: Effect of leaf extracts of *Swietenia mahagoni* on germination speed of Okra (*Abelomoschus esculentus*). In a bar diagram, different letter (s) show statistically significant at P≤0.05 Duncan Multiple Range Test. (T_1 = 1% concentration, T_2 = 2% concentration, T_3 = 3% concentration, T_4 = only water).

4.2.3.3 Morphology of Okra in pot

Plant height of Okra (*Abelomoschus esculentas*) seedlings was statistically varied among the different treatments. Plant height was the highest in T_4 (109.56) cm and the lowest in T_3 (96.19cm) (Table 4.6).

Table 4.6: Effect of different concentrations of leaf extracts of *S. mahagoni* on the plant morphological characteristics of *Abelomoschus esculentas* under pot condition

	Shoot height (cm)		
Treatments	**16 days**	**52 days**	**126 days**
T_1	11.496 ±0.16 b	43.40 ±0.31b	103.98 ±0.76b
T_2	10.21 ± 0.05 c	41.91 ±0.14c	98.55±0.56c
T_3	9.28 ±0.23 d	41.57±0.25c	96.19 ±0.43d
T_4	12.31 ±0.30 a	47.67 ±0.67	109.56 ±0.73 a
CV (%)	11.58	5.96	5.36

(T_1=1% concentration, T_2= 2% concentration, T_3=3% concentration, T_4= only water). In a column, different letter (s) show statistically significant at $P \leq 0.05$ by Duncan Multiple Range Test.

4.3 Discussion

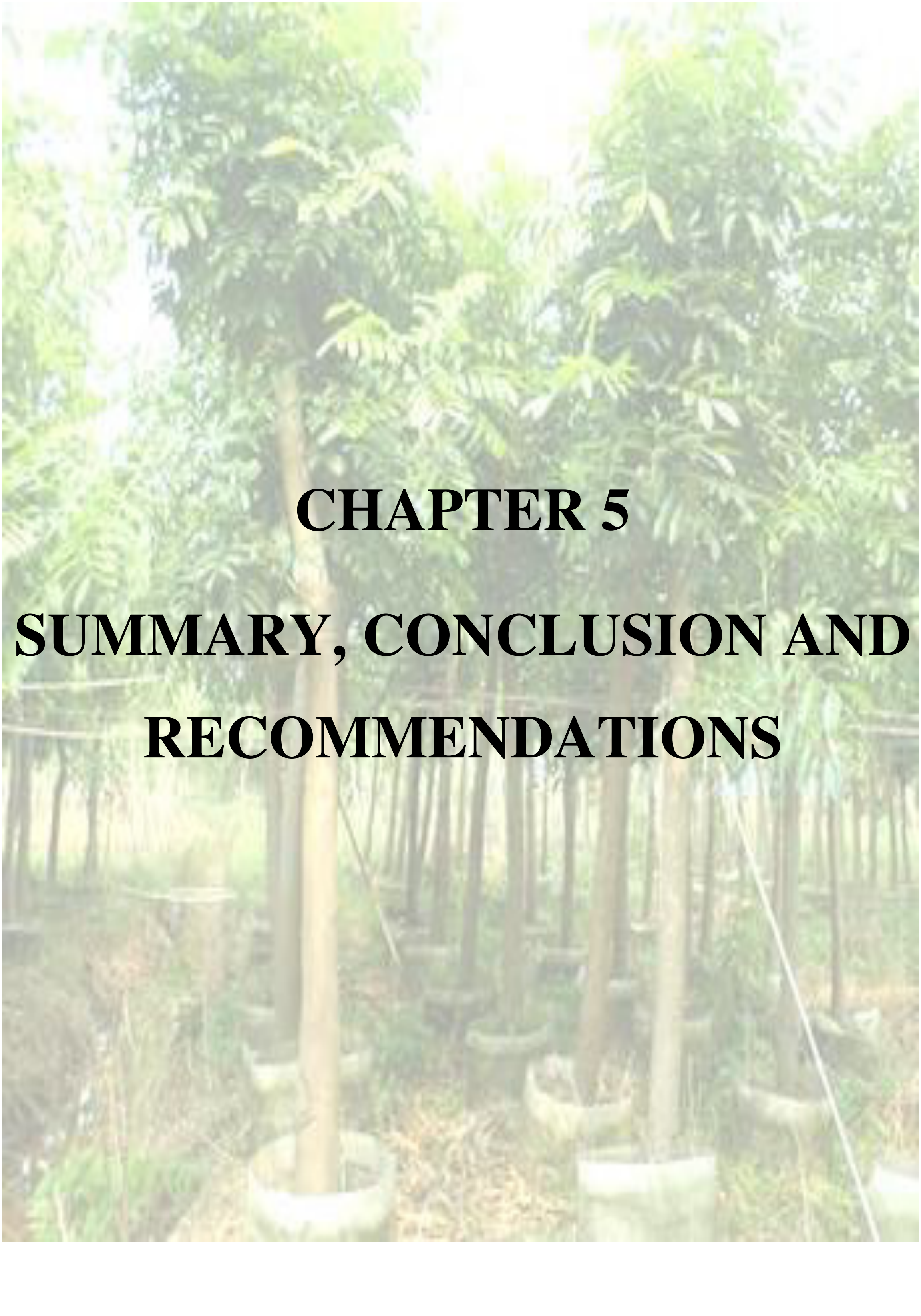
The results showed that the leaf extracts of *Swietenia mahagoni* inhibited the seed germination and seedling growth of all the three tested crops i.e. chilli, brinjal and okra. Therefore, leaf extracts of *S. mahagoni* exerted allelopathic effects on those crop species. However, the allelopathic effects of *S. mahagoni* were not same and it was depending on test species. The results are consistent with the reports on allelopathic effects in literatures (Zhang and Fu, 2010).

Results of laboratory experiment showed that 3% concentration of leaf extracts of *S. mahagoni* inhibited more in germination of the three tested crops compared to other concentrations. Leaf extracts of *S. mahagoni* showed germination percentage were inhibited 59.10% in Chilli, 56.28% in Brinjal and 49.20% in Okra over control. So, Chilli was more affected compare to other two crops.

In case of pot experiments, leaf extracts of *S. mahagoni* also inhibited the germination of the three tested crop. Results of field experiment showed that 3% concentration of leaf extracts of *S. mahagoni* inhibited more in germination of three tested crops compared to other concentrations. Leaf extracts of *S. mahagoni* showed the germination percentage were inhibited 55.69% in Chilli, 48.26% in Brinjal and 50.23% in Okra over control. The leaves powder of Mahagoni induced significant inhibitory effect on germination and seedling growth of each crops compared to the control treatments. In pot condition Okra was more affected compare to other two crops.

Morphological parameters like plant height (cm) showed significantly higher growth in control over leaf in all the tested crops at both the laboratory and pot experiments. Similar results were recorded for biomass allocation like dry weight (gm).The results showed that the inhibitory effect increased with increasing concentrations level of leaf extracts. This result was in agreement with many researchers (Fikreyesus *et al*., 2011; Saberi *et al.,* 2013; Djanaguiraman *et al*., 2002). Greater concentration of allelochemicals might inhibit the seed germination by suppressing the synthesis of gibberellins and indole acetic acid (Moradshahi, 2003). The inhibitory effect was proportional to the concentrations of the extracts and the higher concentration had the strongest inhibitory effect (Fikreyesus *et al.,* 2011).

From the overall result it can be concluded that in addition to the allelopathic effect of leaf and root of *S. mahagoni* have also allelopathic effect on the agricultural crops which inhibited more in laboratory compared to pot condition. Alrababah (2009) found that the yields of agriculture crops were reduced in field, perhaps due to allelopathic effects of trees on the crop through the release of phytotoxic phenolics from leaf litter and the accumulation of these phytotoxins in the soil.



CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

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5.1 Summary

A study was conducted at the laboratory and departmental research field of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Bangladesh during May 2018 to September 2018 to find out the leaf extracts of *Swietenia mahagoni* on the germination, root architecture and shoot growth of three agricultural crops like Chilli, Brinjal and Okra.

There were two experiments. Experiment 1 was laboratory experiment and experiment 2 was pot experiment. The experiments were laid out in complete randomized design. Experiment 1was conducted in petridish and experiment 2 was conducted in pot. There were four treatments including control viz. T_1 (1% concentration), T_2 (2% concentration), T_3 (3% concentration) and T_4 (only water; Control).All statistics were calculated with Statistics 10 software and MS Excel 2013.

Results of laboratory experiment showed that 3% concentration of leaf extracts of *Swietenia mahagoni* inhibited more in germination of three tested crops compared to other concentrations. Leaf extracts of *Swietenia mahagoni* showed germination percentage were inhibited 59.10% in Chilli, 56.28% in Brinjal and 49.20% in Okra over control.

Results of pot experiments showed that the germination of the three tested crops is also inhibited by leaf extracts of *S. mahagoni*. Application of *S. mahagoni* leaf extracts 55.69% in Chilli, 48.26% in Brinjal and 50.23% in Okra over control.

Due to the effect of leaf of *S. mahagoni* plant height (cm), of three tested crops showed significantly lower compared to control at both the laboratory and pot experiments. Similar results were recorded for biomass allocation like total dry weight (g).The results showed that the inhibitory effect increased with increasing concentrations.

5.2 Conclusion

From the present study it should be concluded that germination of Chilli, Brinjal and Okra seeds were affected by different concentrations of leaf extracts of *S. mahagoni*.

Higher concentrations of extracts had strongest inhibitory effect on the tested crops. Among the three tested crops, Okra was more affected by leaf extracts compare to other two crops.

Therefore, if Mahagoni is incorporated with a wider spacing for agroforestry practice, inhibitory effect might be reduced by reducing the concentration of its litter fall. Overall, findings of this study will help farmers and decision makers to choose this tree in the field of agroforestry for higher yield from a piece of land.

5.3 Recommendations

The recommendations that can be put forward from the present study are as follows:

- In the experiment water was used as the solvent. Therefore, other solvent like alchol or acetone should be used further.
- The experiment was conducted in laboratory and pot, but further it should be done in farmers' field to validate the result.
- The allelopathic effect of leaf fallen from the *Swietenia mahagoni* tree may be minimized by regular collection for household purposes.
- The allelopathic effect can be minimized by planting low- density of *Swietenia mahagoni* tree.
- Crops like Chilli, Brinjal and Okra should not be planted very close to *Mahagoni* trees to get the maximum germination of the associated crops.

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APPENDICES

APPENDICES

Appendix-I: The physical and chemical properties of soil in Agroforestry and Environment farm HSTU, Dinajpur

Soil characters	Physical and chemical properties
Texture	
Sand (%)	65
Silt (%)	30
Clay (%)	5
Textural class	Sandy loam
CEC (meq/ 100g)	8.07
pH	5.35
Organic matter (%)	1.06
Total nitrogen (%)	0.10
Sodium (meq/ 100g)	0.06
Calcium (meq/ 100g)	1.30
Magnesium (meq/ 100g)	0.40
Potassium (meq/ 100g)	0.26
Phosphorus (μg/g)	24.0
Sulphur (μg/g)	3.2
Boron (μg/g)	0.27
Iron (μg/g)	5.30
Zinc (μg/g)	0.90

Source: Soil Resources Development Institute, Dinajpur (2018)

Appendix-II: Descriptive Statistics of Germination speed of Chilli influenced by *Swietenia mahagoni* leaf (in Laboratory)

Treatment	N	Mean	SD	SE Mean	Minimum	Maximum
T_1	3	0.6143	0..05064	0.02924	0.57	0..67
T_2	3	0.5263	0.02616	0.01510	0.50	0.55
T_3	3	0.4570	0.03027	0.01747	0.42	0.48
T_4	3	0.7833	0.02363	0.01364	0.77	0.81

Appendix-III: Descriptive Statistics of germination speed of Brinjal influenced by *Swietenia mahagoni* leaf (in Laboratory)

Treatment	N	Mean	SD	SE Mean	Minimum	Maximum
T_1	3	1.6887	0.12561	0.07252	1.54	1.77
T_2	3	1.4117	0.05071	0.05002	1.32	1.49
T_3	3	1.2170	0.05071	0.02928	1.16	1.25
T_4	3	2.1623	0.10286	0.05939	2.07	2.27

Appendix-IV: Descriptive Statistics of germination speed of Okra influenced by *Swietenia mahagoni* leaf (in Laboratory)

Treatment	N	Mean	SD	SE Mean	Minimum	Maximum
T_1	3	0.44	0.04	0.023	0.39	0.47
T_2	3	0.38	0.03	0.019	0.35	0.42
T_3	3	0.30	0.03	0.019	0.28	0.34
T_4	3	0.05	0.09	0.03005	0.57	0.66

Appendix-V: Descriptive Statistics of germination speed of Chilli influenced by *Swietenia mahagoni* leaf (in Pot)

Treatment	N	Mean	SD	SE Mean	Minimum	Maximum
T_1	3	0..51	0.04	0.022	0..47	0.55
T_2	3	0.43	0.03	0.017	0.39	0.45
T_3	3	0.37	0.04	0.022	0.33	0.40
T_4	3	0.66	0.06	0.037	0.61	0.73

Appendix-VI: Descriptive Statistics of germination speed of Brinjal influenced by *Swietenia mahagoni* leaf (in Pot)

Treatment	N	Mean	SD	SE Mean	Minimum	Maximum
T_1	3	0.72	0.09	0.05	0..65	0.82
T_2	3	0.57	0.04	0.03	0.52	0.60
T_3	3	0.48	0.03	0.02	0.44	0.50
T_4	3	0.99	0.05	0.03	0.95	1.04

Appendix-VII: Descriptive Statistics of germination speed of Okra influenced by *Swietenia mahagoni* leaf (in Pot)

Treatment	N	Mean	SD	SE Mean	Minimum	Maximum
T_1	3	0..56	0..04	0.024	0..52	0.60
T_2	3	0.45	0. 03	0.019	0.42	0.49
T_3	3	0.36	0.05	0.027	0.31	0.41
T_4	3	0.71	0.05	0.030	0.67	0.77

Appendix-VIII: Some plates on my research experiment

Plate 4: Seeds were sown in petridishes in agroforestry laboratory

Plate 5: Different concentrations were used in petridish

Plate 6: Germination of seeds were counted

Plate 7: Germination of tested species in different treatments

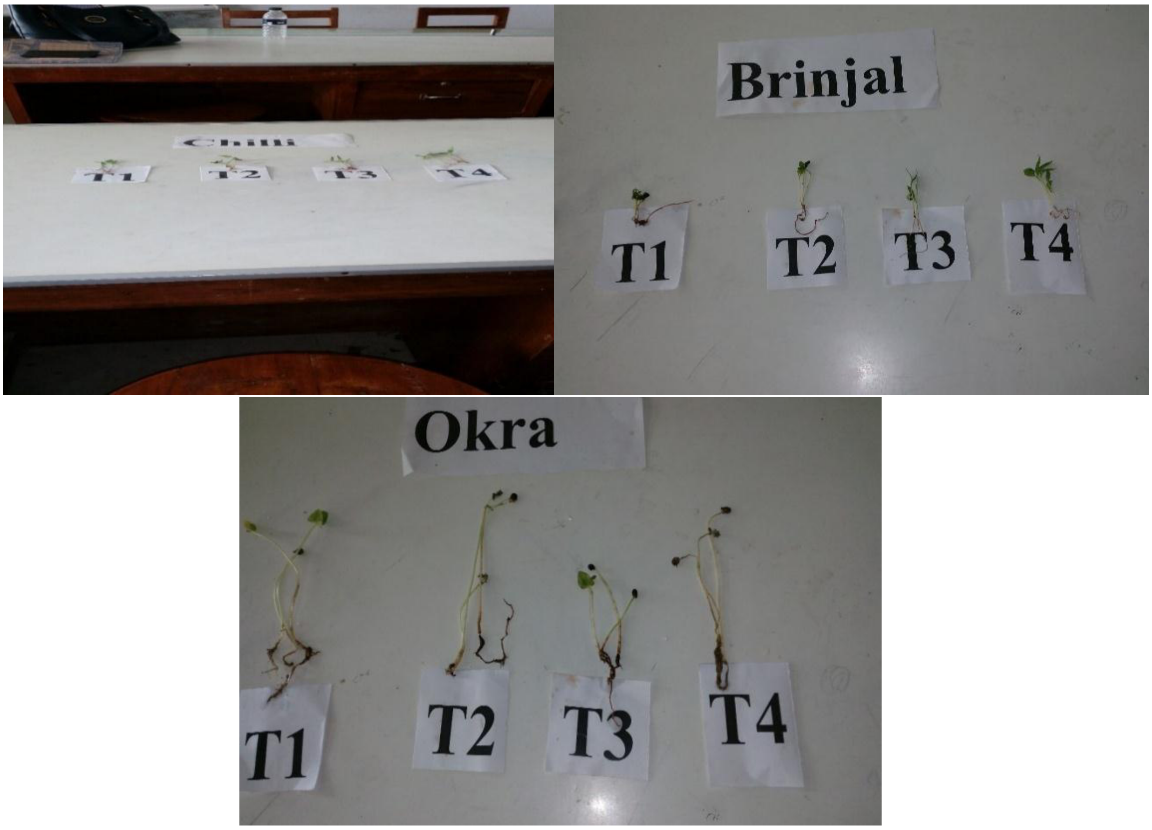

Plate 8: Morphological measurement of Chilli, Brinjal and Okra

Plate 9: Seeds were sown in pot

Plate 10: Germination tested in different treatments

Plate 11: Seedlings of the different crops

Plate 12: Different heights of plants were shown in the pot