# ALLELOPATHIC EFFECT OF *Eucalyptus camaldulensis* ON SEED GERMINATION, GROWTH AND YIELD CONTRIBUTING CHARACTERS OF RICE

**A THESIS**
**BY**

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**Student No. 1605106**

**Session: 2016**

**Thesis Semester: January-June, 2017**

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

**DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT**
**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200**

**JUNE, 2017**

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**JUNE, 2017**

DEDICATED

TO

MY BELOVED PARENTS

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***The Author***

# ALLELOPATHIC EFFECT OF *Eucalyptus camaldulensis* ON SEED GERMINATION, GROWTH AND YIELD CONTRIBUTING CHARACTERS OF RICE


## ABSTRACT

Two experiments were carried out at the Agroforestry and Environment laboratory of Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during 1st March 2016 to 31st July 2016 to find out the response of three rice varieties againist *Eucalyptus camaldulensis* allelopathic effect. For germination 1st, three rice varieties (Hybrid, BRRI Dhan 29 and BRRI Dhan 28) were sterilized in sodium hypochlorite solution for 5 minutes and finally rinsed with distilled water which were used as control at room temperature. Then seeds were placed in petridish which were tested in four allelopathic levels (0, 10, 15 and 20% concentration of eucalyptus leaf extract). The germination of all rice varieties were delayed and percentage of germination were reduced with increasing the level of eucalyptus leaf extract concentration compared to control. Shoot and root growth, and root number. Results on germination and seedling growth indicate that hybrid was more tolerant and BRRI Dhan 28 was more sensitive varieties to alletopathy effect of eucalyptus leaf. For determining yield contributing characters and yield of three rice varieties (Hybrid, BRRI Dhan 29, BRRI Dhan 28), another experiments were carried out at Agroforestry field of HSTU, Dinajpur during 1st March, 2016 to 31st July, 2016. Here 36 pots were used for planting seedling where the surface area of each pot was 0.14m$^2$. After 3 days of showing seedling in pots, seedlings overcome transplanting shock. Then the treatment were started after 7 days interval by using 0, 10, 15 and 20% concentration of eucalyptus leaf extract. Most of the growth and physiological characters viz, plant height, shoot length, root length, number of leaves, number of tiller, plant height at harvest time, number of tiller/ hill, number of effective tiller/ hill, number of sterile tiller/ hill, penicle length, weight of grain/panicle, number of spikelet/ panicle, number of unfilled grain/ panicle, number of filled grain/ panicle were performed better at control condition and showed the lowest performance in respect of all the treatments (10, 15 and 20% eucalyptus leaf extract) condition. More concentration of eucalyptus leaf extracts gave more inhabition on both yield contributing characters and yield of rice. The highest number of fill grain per panicle (139.6) was found in control whereas the lowest (111.8) was found at 20% leaf extract concentration. Again, among the three varieties of rice hybrid gave the highest fill grain per panicle (126.3) whereas BRRI Dhan 28 gave the lowest (120.7). Therefore, hybrid rice performed better in association with eucalyptus leaf extract than the other varieties (BRRI Dhan 29 and BRRI Dhan 28). So for eucalyptus plus rice based cropland agroforestry system, the amount of eucalyptus leaf present in the field and the variety of rice should be considered.

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# CHAPTER ONE

# INTRODUCTION

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# INTRODUCTION

Agroforestry is a collective name for land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components (ICRAF, 1993). Agroforestry is a modern tool to develop sustainable land use and to increase food production by growing woody species (trees, shrubs, palms; bamboos, etc.) with agricultural crops and/or animals in some form of spatial arrangement or temporal sequence (Rizvi *et al.,* 1999). Since two or more components co-exist in agroforestry systems, there must have either positive or negative interactions between or among the components. To optimize the gains of agroforestry, selection of suitable agroforestry species is very important. The inhibitory effect of one plant by another through releasing allelochemicals that is called "Allelopathy" has been well known (Djanaguiraman *et al.,* 2005). Allelopathy can simply be understood as the ability of plants to inhibit or stimulate growth of other plants in the environment by exuding chemicals. The concept of allelopathy was first introduced by Hans Molisch to describe both the beneficial and the detrimental chemical interactions of plants and microorganisms (Molisch, 1937). Since then, the term 'allelopathy' has undergone several changes and it has been defined as any direct or indirect harmful or beneficial effects of one plant on another through the production of chemical compounds that it releases into the environment (Rice, 1974). A large number of studies have been undertaken in recent years on such allelopathic interactions between the plants. Allelopathic properties have been reported for many species, especially trees. Although allelochemicals are present in practically all plant tissue, including leaves, flowers, fruits, stems, roots, rhizomes and seeds information on the of the active chemicals and their mode of action is lacking. In general, leaves are the most potent source of allelochemicals, however, the toxic metabolites are also distributed in all other plant parts in various concentrations. The presence of these allelochemicals often imparts plant resistance to pathogens, insects, nematodes, and reduces infestation of weeds (Copping 1996).

Rice is one of the most important crop in Bangladesh and Bangladesh has a long history of rice cultivation. Rice is grown throughout the country except in the southeastern hilly areas. The agroclimatic conditions of the country are suitable for growing rice year-round. However, the national average rice yield is much lower (2.94 t/ha) than that of other rice-growing countries (BBS, 2012). Rice is the staple food for about 156 million people of the country. The population growth rate is 2 million per year, and if the population increases at this rate, the total population will reach 238 million by 2050. An increase in total rice production is required to feed this ever-increasing population. At the same time, the total cultivable land is decreasing at a rate of more than 1% per year owing to the construction of industries, factories, houses, roads and highways. On the other hand, due to urbanization, food habits tend to change, demanding the cultivation of new crops that must share land used for rice cultivation.Therefore, attempts should be made to increase the yield per unit area of rice. Moreover, due to climate change, agriculture is facing different adverse conditions, such as drought, flood, salinity, extreme temperature stress, and low soil fertility. In these circumstances, policies should be implemented to increase rice production in a sustainable manner for the food and nutritional security of this highly populated country. Thus we may conclude that, we need to product more rice but land is limited. So complex Agroforestry is an alternative option.

*Eucalyptus camaldulensis* is one of the most important species which is widely found throughout Bngladesh growing in crop field, homestead, road site. *Eucalyptus* is a good agroforestry species, but we have no much idea about the effect of *Eucalyptus* on rice. In Bangladesh, about 2-3 species of *Eucalyptus* are widely planted for various uses. In the highlands of Bangladesh, Eucalyptus species (*Eucalyptus camaldulensis* is one of the most important plants used to prevent soil erosion and to recover the plant cover in studied area) are commonly integrated into the various farming systems and their planting has resulted in high economic profitability compared with use of high land for crop production. This plant also used in farmland as windbreak and medical plant. *Eucalyptus* belong to Myrtaceae family and are indigenous to Australia (May and Ash, 1990). They have been widely introduced into countries throughout the world (Turnbull, 1999). Large area of ground surface beneath of eucalyptus remains bare and is limited understory vegetation growth (El-Darier, 2002). Eucalypts have been reported to cause crop loss by outcompeting crops for water and soil nutrients (Tilashwork Chanie *et al.,* 2013), through shading (Tilashwork Chanie *et al.,* 2013) and producing allelochemicals (Ahmed *et al.,* 2008). It has been shown that where eucalyptus stand is replaced by the agricultural crop, that crop will not grow well, at least for a number of years (Fikreyesus *et al.,* 2011). Del Moral and Muller (1970) reported that annual vegetation adjacent to *Eucalyptus camaldulensisis* often severely inhibited by allelochemicals released by this species. The allelopathic effect of eucalyptus has been attributed to the production of several volatile terpenes and phenolic acids (Djanaguiraman *et al.,* 2005; Florentine and Fox, 2003; Sasikumar *et al.,* 2002). Phytotoxic phenolic substances in leaf extracts of *E. globulus* produce volatile terpenoids that have inhibitory effects on germination and seedling growth of various crops (Sasikumar *et al.,* 2002; Florentine and Fox, 2003). Phytotoxic substances are released into the soil ecosystem through volatilization, root exudation and leaching from the foliage (Djanaguiraman *et al.,* 2005). These chemicals exhibit a wide range of mode of action. They may influence cell division and elongation, growth substances, enzymatic activities, respiration, photosynthesis or chlorophyll content, stomata and membrane integrity, water relations and mineral uptake (El-khawas and Shehata, 2005; Mohamadi and Rajaie, 2009). 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; Djanaguiraman *et al.,* 2002). The allelopathic effect of leaf extract from *E. camaldulensis* was tested on tomato; the extract significantly inhibited germination and growth of this plant (Fikreyesus *et al.,* 2011). In studied area many plants (range species, cultivatable and medical plant) were cultivated based on different goals. Understanding allelopathic effect of plants on each other helps managers correctly to plan their vegetative projects for restoring and rehabilitating of destructive environments.

However, the allelopathic effect of *E. camaldulensis* should be tested before its commercial cultivation with other crop like rice. With this view in mind the present study was conducted to examine the effect of different concentrations of leaf extract of *E. camaldulensis* on germination, growth and yield of rice in pot condition. The objectives of the study were:

1. To evaluate the effect of different concentrations of *E. camaldulensis* leaf extracts on the rice seed germination.
2. To calculate the effect of different concentrations of *E. camaldulensis* leaf extracts on the seedling growth of rice.
3. To investigate the allelopathic effects of *Eucalyptus camaldulensis* on the yield contributing characters and yield of rice.
4. To screening that which rice variety is more tolerable against the allelopathic effect of *Eucalyptus camaldulensis.*

# CHAPTER TWO

# REVIEW OF LITERATURE

# CHAPTER TWO

# REVIEW OF LITERATURE

This research has been undertaken to observe the performance of rice grown in association with saplings of timber tree namely eucalyptus (*Eucalyptus camaldulensis*) in tree-crop agroforestry system. Literatures related to these aspects are very scanty in our country and also in abroad. Therefore, literatures related to the performance of crops in tree-crop agroforestry system, characteristics of tree species and importance of light in agroforestry system which was collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented and discussed in this chapter. According to the following sub-heading:

2.1 Concepts of Agroforestry

2.2 Characteristics of Tree Species in Agroforestry Systems

2.3 Importance of Eucalyptus (Eucalyptus camaldulensis) in Agroforestry Systems

2.4 Rice in Agroforestry

2.5 History of Allelopathy

2.6 Mechanisms of Allelopathy

2.7 Allelochemicals

2.8 Allelopathic effect of eucalyptus

## 2.1 Concepts of Agroforestry

Agroforestry is an old system or concept, but the term is definitely new. Agroforestry means practice of agriculture and forestry on the same piece of land. Bene *et al.* (1977) defined agroforestry as a sustainable management system for land that increases overall production, combines agricultural crops, tree crops and forest plants and animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of a local population. Agro forestry, the integration of tree and crop or vegetable on the same area of land is a promising production system for maximizing yield and maintaining friendly environment (Nair, 1990).

Recently ICRAF defined, “Agroforestry as a dynamic, ecologically based natural resources management systems that, through the integration of trees on farmland and in the agricultural landscape, diversifies and sustains production or increased social, economic and environmental benefits for land users at all levels.”

“Agroforestry is a collective name for all land use systems and technologies where woody perennials (trees, shrubs, palms, bamboo etc.) are deliberately grown on the same land management unit as agricultural crops and/or animals either in spatial mixture or in temporal sequence. There must be significant ecological non-woody components.” Vergara (1982) defined agroforestry as a ‘system of combining agricultural and tree crops of various longevity (ranging from annual through, biennial and perennial plants), arranged either temporally (crop rotation) or spatially (intercropping) to maximize and sustain agricultural production’. Agroforestry is an age-old and ancient practice. It is an integral part of the traditional farming system of Bangladesh. The concept of agroforestry probably originated from the realization that trees play range interests of agriculture and in making agriculture economically viable. The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the "marriage of forestry and agriculture" (PCARRD, 1983). Agriculture and forestry were considered before as two distinct areas but these practices are now considered as complementary. This was brought about by the increasing realization that agroforestry can become an important component of ecological, social and economic development efforts. From a bio-economic point of view, Harou (1983) stated that agroforestry is a combined agriculture-tree crop farming system which enables a farmer or land user to make more effective use of his land which may yield a higher net economic return on a sustainable basis.

Agroforestry is the idea of combining forestry and agriculture on the same piece of land. The basic concept of intercropping has been extended to agroforestry system. Many authors have defined agroforestry in different way. A widely used definition given by the International Council for Research in Agroforestry (Nair, 1980), is that agroforestry is a collective name for all land use systems and practices where Woody perennials are deliberately grown on the same land management unit as agricultural crop or animal is some form of spatial arrangement or temporal sequence.

Agroforestry systems improve and maintain soil fertility. It was hypothesized by Nair (1980) that an agroforestry system can play an important role in improving soil fertility by: (i) increasing organic matter content of soil through addition of leaf litter, pruning and other biomass, (ii) efficient nutrient recycling within the system, (iii) biological N2 fixation in case of leguminous shrubs and trees and (iv) possible complementary interactions among associated species due to differences in canopy structure, root system and active zone of water and nutrient absorption. Ong (1988) reported that by incorporating trees with arable crops, biomass production per unit area could be increased substantially when the roots of trees exploit water and nutrients below the shallow roots of crops and when a mixed Canopy intercepts more solar energy. Shankarnaryan (1984) claimed that tree in agroforestry systems conserve soil Moisture, increase atmospheric humidity and improve soil fertility. The process is enhanced by tree canopy cover which moderates the microclimate and enhances organic matter accumulation, microbial activity and mineralization (Verinumbe, 1987). Saxena (1984) pointed out that agroforestry utilize the inter space between tree rows for intercropping with agricultural crops and this does not impair the growth and development of the trees but enable farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

In traditional agroforestry systems of Bangladesh, farmers consider trees as saving and insurance against risk of crop failure or compensate low yields of crops (Akter *et al.,* 1989). Homestead gardens are common in Bangladesh where the farmers take up combination of 10-15 species of fruit, ornamental and multipurpose trees along with vegetables to meet their own or aesthetic value (Rang *et al.,* 1990). MacDicken and Vergara (1990) stated that agroforestry in a means of managing or using land (i.e., a land use system) that combines trees or shrubs with agricultural/horticultural crops and/or livestock. Bhatia and Singh (1994) observed that the agroforestry in India plays an important role in increasing biomass production, maintaining soil fertility, conserving and improving soil and averting risk. According to Solanki (1998), agroforestry can significantly contribute in increasing demand of fuel wood, fodder and lack of cash and infrastructure in many developing countries. He also stated that agroforestry has high potential to simultaneously satisfy 3 important objectives: (1) protecting and stabling the ecosystems, (ii) producing a high level of output of economics goods (fuel, fodder, small timber, organic fertilizer etc) and (iii) providing stable employment, improved income and basic material to rural populations. Agroforestry is a form of integrated land use systems, which consists of woody perennial favorably mixed with annual crops and other production enterprises like animals to derive various benefits and utilities from the same piece of land (Bhuiya *et al.,* 2001).

Agroforestry can contribute to household income/consumption directly through the production of goods (fruits, poles, fuel wood) and indirectly through goods and services such as fodder for livestock, reduction of land degradation, improved soil and water conservation. In addition, other benefits can be realized downstream through reduction of soil erosion and/or increased water flow control. These systems at a more aggregate level can also provide services for international consumers, through benefits for example of carbon sequestration and protection of international waters (FAO, 2001). Groot and Soumare (1995) observed that decomposition of tree roots and dice substances of the root exudes greatly enhance soil organic matter and thereby soil-fertility. Tree lateral roots may reduce loss of nutrients from the soil by recycling them that would have been otherwise leached from the system. Taproots may take up nutrients, which are released by weathering from deeper soil layers. A common hypothesis is strongly implied to the agroforestry system that integration of trees with annual crops improves the chemical properties of the soil.

## 2.2 Characteristics of Tree Species in Agroforestry Systems

Selection of suitable tree species is vital in an agroforestry system Nair (1980) considered the most choice of suitable plant species that can grow together as important factor in ensuring the sources of agroforestry. The most appropriate species for this system remains an open question for research. King (1979) listed the characteristics of tree species that should be grown with agricultural crops:

a) They should tolerate relatively high incidence of pruning;

b) They should have a low crown diameter to bole diameter ratio;

c) They should be light branching in their habit;

d) They should be tolerant of side shade;

e) Their phonology, particularly with reference to leaf flushing and leaf fall, should be advantageous to the growth of the annual crop in conjunction with which their being raised;

f) The rate of litter fall and litter decomposition should have positive effect on soil;

g) The above ground changes over time in structure and morphology should be such that they retain or improve those characteristics which reduce competition for scalars energy, nutrient and water.

h) Their phytotoxin should permit penetration of the light of the ground.

Rachie (1983) pointed out the following factors to be considered during the selection of woody legumes for intercropping with annuals in the low land tropics: i) case of establishment from seeds or seedlings. ii) rapid growth and high productivity of foliage and wood; iii) limited maximum size (may be optimum in small trees); iv) good coppicing ability (re growth following topping); v) effective nutrient recycling abilities especially di-nitrogen fixation; vi) multiple uses: food, feed, firewood, construction materials, and other products and services (shade, shelter etc.); vii) minimal competition with shallowly rooted annual crops; viii) small leaflets readily detached when dried and quickly decomposed when used as fertilizer; ix) good tolerance for drought, low fertility and others; x) freedom from pests and diseases and xi) case of control of eventual elimination.

Hegde and MacDicken (1990) pointed out some, criteria for planting trees under the agroforestry system: (a) non-interference with arable crops, (b) easy establishment, (c) fast growth and short gestation period, (d) non-allelopathic effects on arable crops, (e) ability to fix atmospheric nitrogen, (f) easy decomposition of litter, (g) ability to withstand frequent lopping multiple uses and high returns,, and (h) ability to generate employment. However, it is not possible to select having all the above mentioned criteria. Therefore, researchers should select which have most of the points and which are adapted to local soil and environmental condition. However, it is not possible to select having all the above mentioned criteria. Therefore, researchers should select which have most of the points and which are adapted to local soil and environmental conditions. Purohit (1984) suggested selecting those species which would (i) not compete for moisture, space and air; (ii) supply nitrogen in the soil; (Ai) provide food, fodder, fuel and timber, (iv) maintain proper ecosystems; (v) have no toxic effects to the crops and (vi) have thin and erect leaves. Singh *et al.* (1989) opined that suitable species should be multipurpose, well-adapted to different sites, easy to establish, have nitrogen-fixing ability, rapid growth and ability to coppice. However, it is not possible to select having all the above mentioned criteria. Therefore, researchers should select which have most of the points and which are adapted to local and environmental conditions.

### 2.3 Importance of Eucalyptus (*Eucalyptus camaldulensis*) in Agroforestry Systems

The Eucalyptus of Australia is the second dominant hardwood planted speciesafter Pines in an area of 10 to 15 million ha throughout the world (Neilson 2000). It isestimated that there will be more than 20 million ha of eucalypt plantations outside Australiaby the year 2010. Most of the myths associated with Eucalyptuslike depletion of underground water resources, deterioration of soils and allelopathic effectson agricultural crops are not based on scientific facts. On the contrary, soil and water resourcesare better conserved under any trees including Eucalyptus compared to keeping large tracts of land barren or even under grass cover. Eucalyptus is one of the trees can be grown with crops. Eucalyptus is the most popular choice to be planted along the edges, or bunds, of agricultural fields, and appears to be well incorporated and accepted in agro-forestry in India (Tejwani, 1994). The study showed that Eucalyptus consumed 0.48 liters of water to produce a gram of wood, compared to 0.55, 0.77, 0.50 and 0.88 liter per gram forSiris, Shisham, Jamun and Pongamia respectively (Prabhakar, 1998). Chaturvedi *et al.* (1988) reported that often species tested for water consumption, E. tereticornis was found to be themost efficient in biomass production per liter of water consumed. Demand for nutrients by Eucalyptus is less than others, principally because heartwood begins to form at approximately four years. After this point, a significant proportion of nutrients in wood are recycled to other parts of the tree or soil, and the quantities that are immobilized are kept to a minimum. Eucalyptus also contributes to the intense deposition of organic matter on the soil - through leaves, bark and roots - estimated at seven tonsper hectare per year (Carpanezzi, 1980; Poggiani, 1985; Lima, 1987), thus contributing to the soil fertility improvement.

Silviculturalproperties including straightness, narrow crown, self-pruning, high growth rates, adaptability to a wide range of soils and climates, coppicing ability, a tendency not to spread as a weed and wide utility of wood are some of the main features of Eucalyptus Clones making it popular among the farmers for raising as block plantations. Eucalyptus has more than 600 species, among which two species, Eucalyptus *camaldulensisDehnh* and *E. tereticornis* Smith are cultivated more among the farming community in Andhra Pradesh, as being sufficiently drought tolerant while also capable of withstanding, under irrigation and saturation, very hot summer temperatures and suitable for a wide range of sites. The species were, of course, also selected because they are suitable for the manufacturing of quality paper. Eucalyptus is the most famous, among various tree species, chosen for this because of its eminent specific characteristics: fast growth, high adaptability to any condition of soil and rain-fall, low maintenance, best for pulp, etc. The Government has decided to expand Eucalyptus throughout the country. There were different ways of adopting eucalypts depending on one's own background such as: large scale private plantation; small scale private plantation and/or mixed planting; and the Governmental plantations. Arriagada *et al.* (2007) stated the effects of saprobe and carbuncularmycorrhizal (AM) fungi on growth, chlorophyll and N, P and K content of Eucalyptus globules Labill. Growing in soil contaminated by heavy metals in the presence or absence of *Glycine max*was investigated. *Glomusmosseae* and *Glomusdeserticola* increased dry weight, shoot length, total N, P and K concentration and the quantity of chlorophyll in *E. globulus* shoots. The protection of Eucalyptus by AM fungi against the action of the heavy metals was more evident when this plant grew as an intercrop with soyabean than as a monoculture. The presence of the saprobe fungi *Fusariumconcolor* and *Trichodermakoningii* further enhanced shoot dry weight, N, P and K content of AM Eucalyptus. The co-inoculation of Eucalyptus with *Glomusdesert* cola and *T. koningii* was more effective for Cd uptake. In addition, *Glomusdesert cola* enhanced the amount of Pb absorbed by Eucalyptus plants. We showed that it is important to select the most efficient AM and saprobe fungi to stimulate plant growth in heavy-metal-contaminated soil and that the combination of both plays an important role in metal tolerance of Eucalyptus plants.

Seling *et al.* (2001) reported at different sites in the State of Rio Grande do Sul 420 Eucalyptus grandis trees of distinct stand phases were measured. A close relationship between crown width and diameter at breast height was found. For different variants of radial growth and distinct target diameters at the age of 20, respectively, the corresponding number of future crop trees in each specific stand phase was calculated (i. e. 74 future crop trees at the age of 20 in case of 15 mm radial growth per year). Using this thinning model and the yield table of Finger (1991), an economic comparison was made between a strategy aimed at producing sawn wood and at pulpwood. The internal rate of return and the soil expectation value of the sawn wood strategy were far more profitable. Market prospects and the conditions. Tripathi *et al.* (2002) stated a field experiment was conducted in Pantnagar, Uttar Pradesh, India, during the winter season of 1998-99 to evaluate the prospect of growing wheat (*T. aestivum*) cv. Raj 3077 under *E. tereticornis* planted in Nelder design for increased grain production and effective weed management. The average reduction of 5.6% in grain yield was recorded in sole crop without trees compared with the intercrop grown at a tree orientation of 168-192 degrees in which the maximum weed control efficiency and highest grain yield of intercrop wheat was observed under 10-year-old *E. tereticornis* trees. Palmaris minor dominated over the other weeds throughout the cropping season. Density and dry matter accumulation by weeds recorded at 60 and 90 days after sowing was significantly reduced in all the tree orientation treatments compared with that of sole crop. Broadleaved as well as grassy weeds can be effectively managed under the modified microclimate of 168-192 degrees - tree orientation. For higher production and optimum utilization of various resources, the intercrop wheat may be successfully grown under shallow water table conditions.

### 2.4 Rice in Agroforestry

Agroforestry is one of the most conspicuous land use systems across landscapes and agroecological zones of Bangladesh and tropical Asia, and also in African countries. Some forms of agroforestry require low external inputs (pro-poor), have a high recycling rate, and good integration of trees, crops and animals, making them good candidate for achieving both sustainable livelihood and climate changes objectives (Koohafkan *et al.*, 2012).

Rice is grown in the tropical and sub tropical regions of all continents. Because of its long history of cultivation and selection under diverse environments rice has acquired a broad range of adaptability and tolerance. Its cultivation extends over a wide range of climatic, soil and hydrological conditions. One of the main reasons for this wide range of climatic conditions is the genetic diversity of rice cultivars (Onwueme and Sinha, 1991). Rice is a unique food crop having several advantageous features: it grows under flooded and submerged conditions where other crops can not so, (2) because of its C4 nature it has high capacity of harvesting solar radiation, which is normally excess, and thereby it has high yield potential up to 50 quintals/ha under rain-fed and 100 quintals/ha under irrigation, (3) as contrast to many cereals rice is suitable for flood and furrow irrigation, (4) it is also one of the few crop plants that can grow on the same land year after year without serious soil problems, (5) it also grows under a wide range of altitude, temperature, soil acidity and alkalinity. Due to its comparative advantage of productivity from other food crops farmers producing rice mainly for consumption and for market. Its productivity is more attracting to allocate more land for rice production. In the Woreda now there are 14 PAs which are currently major rice producing area. Table 3 shows the number of PAs, participant farmers, production trend and productivity for the last 15 years.

Opportunities for intensifying rice-based systems in marginalized inland valleys are seen to have huge potential. At the national level, Philippines is insufficient in rice, a situation that has slowly improved since 1980's up to the present. This deficit is linked with increasing population, agricultural land areas decreased due to its conversion into industrial lands and putting too much stress on the fragile environment resulting to the slow increase in the rice yields. Furthermore, it was observed that in the national level, upland rice cultivation has an average yield of 1.5 metric ton per hectare (t/ha) during dry season and 2.5 mt/ha in wet season. The decrease in yields and the declining area for cultivation and expansion are due to the low and unstable productivity, degradation of the natural resource base, and high incidence of poverty in the upland areas. Improving the rice productivity in the inland valleys and upland can be an important point for addressing the problem of poverty (IRRI, 2001). And one important technological intervention with high potential for impact in the inland valleys is Agroforestry. Thus the adoption of this technology would result in substantial benefits to marginalized upland families and would eventually enable them to derive a higher income from their crops. More importantly, it will help restore and conserve soil fertility and stem the damage to the environment. Furthermore, it maximizes the use of the land and optimizes the benefits to farmers. Some of this scheme of integrating trees within the farm evolved without adversely affecting the growth and yield of rice can be done and studied.

The integration of trees, especially nitrogen fixing trees (NFT) into agroforestry systems can make contribution to low input sustainable agriculture by restoring and maintaining soil fertility, and by combating erosion besides providing multiple outputs. About 650 tree species have the ability to contribute to symbiotic nitrogen-fixation. Ladha *et al.*

(1989) have indicated that nitrogen fixed by Sesbania rostrata can significantly increase subsequent grain yield of lowland rice.

## 2.5 History of Allelopathy

Allelopathy is derived from the Greek words allelon "of each other" and pathos "to suffer" (Rizvi, *et al.,* 1992). Allelopathy occurs through the release by one plant species of chemicals which affect other species in its vicinity, usually to their detriment (An, *et al.,* 1998). The phenomenon of allelopathy has existed for thousands of years, for over 2000 years. Intensive scientific research into the recognition and understanding of allelopathy has only occurred over the past few decades (Weston, 2005). These include the symptoms and severity of adverse effects of living plants or their residues upon growth of higher plants and crop yields, interactions among organisms, ecological significance of allelopathy in plant communities, replanting problems, auto toxicity, problems with crop rotations, and the production, isolation and identification of allelochemicals in both natural and agro ecosystems (Rice, 1984).

In the past, a common problem in both Greek and Roman times was the so-called soil sickness, the declining yields of fields. They did not understood that the condition could be caused by various factors such as mineral deficiencies, toxin accumulation, pathogens and the imbalance of microrganisms (Bezuidenhout, 2005). The earliest recorded observations of weed and crop allelopathy were made by none other than Theophrastus, "the father of Botany", who in 300 B.C. wrote in his botanical works about how chickpea "exhausted" the soil and destroyed weeds (Khalid *et al.,* 2002). Willis (1985) pointed out that Theophrastus (300 B.C.) first noticed the deleterious effect of cabbage on vine and suggested that it is due to odors. Cato the Elder (234-140 B.C.), the famous Roman politician and writer, was a farmer in his youth. In his book, he wrote about how chick pea and barley "scorch up" corn land. He also mentioned that walnut trees were toxic to other plants (Inderjit *et al.,* 2008).

In China around the first century A.D, Yang and Tang described 267 plants that had pesticidal abilities, including those with allelopathic effects (An *et al.,* 1998). Pliny II (1 A.D) reported that chickpea (Cicer arietinum), barley (Hordeum vulgare), fenugreek (Trigonella foenum-graecum), and bitter vetch (Vicia ervilia) destroy or burn up farmland (Rice, 1984). He also described the shade of black walnut (Juglans spp.) as heavy and believed that walnut and its residues could cause potential injury to man and anything planted in the vicinity. Pliny was apparently aware that release of chemicals by plants contributed to this soil sickness; as evidenced by his statement "The nature of some plants though not actually deadly is injurious owing to its blend of scents or of juice." ( Inderjit and Weiner, 2001). Although allelopathy does not always cause negative effects to neighboring plants, throughout history it was probably easier to observe negative plant responses. In the seventeenth and eighteenth centuries, botanists relied strongly on a comparative approach. They compared both plant form and function, particularly in relation to nutrition (An *et al.,* 1998).

In the 1600's several naturalists noted in the English literature that certain plants do not grow well in the presence of each other (Macias, 2002).In the 1800's, agronomists started to note problems with repeated cropping of certain perennials. De Candolle in the 1800's was one of the first to actually perform experiments examining the toxicity associated with root exudates (Singh *et al.,* 2001). Interest in the concept of allelopathy was rekindled at the close of the nineteenth century, principally for two reasons: The first was that careful agricultural experiments yielded results that could not adequately be explained by the exhaustion of soil nutrients. Secondly, improved techniques in chemistry allowed organic toxins to be identified from unproductive soils. Interest in the field of allelopathy revived again in the 20$^{th}$ century, with the development of suitable techniques for extraction, bioassay, and chemical isolation and identification (Willis, 1997). Although this form of plant-plant interference had been known for quite some time, it was only (1937) that the Austrian plant physiologist, Hans Molisch, gave it a formal name, allelopathy, and as a consequence, he is currently recognized as the father of allelopathy (Thorpe *et al.,* 2009). Molisch in (1937) refers to allelopathy as chemical interactions among plants, including those mediated by microorganism. This definition, although broad, is reasonable as considerable research has recently indicated the involvement of microorganisms and lower plants in the production of phytochemically-active compounds (Willis, 2000). Mc Calla *et al.* published a series of papers from 1948 until 1965 that described allelochemicals produced from plant residues and the importance of the interaction of microbes upon the decomposition of these residues (Putnam and Weston, 1986). Willis (1997) reported that the adverse effect of a neighboring plant in association with others and defined it as interference. Putnam and Duke (1974) first explored the possibility of utilizing allelopathic crops to suppress weed growth in agricultural sites, including the development of weed-suppressive crops and later described rotational crops, intercrops or cover crops for effective weed suppression. According to Szczepancki (1977) the potential causes of interference include: Allelospoly (competition): the depletion of one or more resources required for growth; Allelopathy: the addition of chemical toxins by one or more species in association, and Allelomediation: selective harbouring of an herbivore that might selectively feed on one species, thus lending to the advantage of another.

Due to the limited analytical methods of the time, it was difficult to identify the allelochemicals. Not until the 1980's were various methods developed for the detection and quantification of phenolic compounds, which included such techniques as planar chromatography, column chromatography on silica, modified silica or dextran gels, ion exchange chromatography, capillary electrophoresis, and counter-current chromatography (Jensen *et al.,* 2001). Rice (1984) was found that chemicals inhibited the growth of a species at a certain concentration may stimulate the growth of the same species or another at a lower concentration. Aldrich (1984) describes two types of allelopathy: True type, the release into the environment of compounds that are toxic in the form in which they are produced, and Functional type, the release into the environment of a substance that is toxic as the result of transformation by microorganisms. Putnam (1985) reported that allelochemicals are present in virtually all plant tissue, i.e. leaves, fruit, stems, and roots. Putnam and Tang (1986) pointed out that the shortcomings of the discipline make it hard to differentiate between allelopathy and competition. These short comings include: a general lack of nomenclature to adequately describe the plant responses that occur in this manner; a dearth of techniques to separate allelopathic interactions from competition, and a failure to prove the existence of direct compared with indirect influences via other organisms/ micro-environmental modification.

Over the next years, the term was used by other researchers to describe broader chemical interactions between organisms, and by the International Homeopathy Society defined allelopathy as "Any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influence the growth and development of agriculture and biological systems." (Anonymous, 1996). Bennett in 1994 indicates that "Many secondary metabolites found in plants have a role in defense against herbivores, pests and pathogens. The role of secondary metabolites in defense may involve deterrence/antifeedant activity, toxicity or acting as precursors to physical defenses (Abhilasha *et al.,* 2008). Cheng (1995) discussed the significance of retention, transformation and transport of allelochemicals in influencing the fate of phenolic allelochemicals. A considerable body of information has accumulated implicating allelopathy as an important form of plant interference. Contemporary researchers have tended to broaden the context of allelopathy to include interactions between plants and higher animals and have suggested that allelopathy may be part of a whole network of chemical communication between plants, and between plants and other organisms, and that such communication may contribute to plant defense (Wu *et al.,* 1998).

Recent research suggests that allelopathic properties can render one species more invasive to native species and thus potentially detrimental to both agricultural and naturalized settings (Bais *et al.,* 2003a; Bais *et al.,* 2003b). Blum in (2002) suggested that enhanced evapotranspiration and lower soil moisture will also result in decreased plant phytotoxicity of allelochemicals in the soil solution. Using tobacco, Inderjit *et al.* (2008) showed the first report demonstrating that the natural release of a volatile chemical inhibits the growth of neighboring siblings. Today, researchers are increasingly concerned with ecological and physiological relevance of these interactions and the mode of action of chemicals involved, despite their relative complexity (Bezuidenhout, 2005). With the rapid development of analytical techniques and biotechnology, research on allelopathy will be enhanced. Allelopathy will become an important component in the development of future integrated weed management strategies (Weston, 2005).

### 2.6 Mechanisms of Allelopathy

Allelopathy could be defined as" an important mechanism of plant interference mediated by the addition of plant-produced secondary products to the soil rhizosphere" (Weston, 2005). These plant produced secondary products are typically exuded into the soil profile and impact the growth of plants that are growing near the allelopathic species (Akemo *et al.,* 2000). Chemicals that impose allelopathic influences are called allelochemicals or allelochemics , which are generally considered to be those compounds such as alkaloids, phenolics, flavonoids, terpenoids, and glucosinolates (Singh and Ranjana, 2003). It has been well documented for many years (Rice, 1984) , but the mechanisms through which allelochemicals impact the development and growth of targeted plants remains obscure (Mohamadi and Rajaie, 2009). These compounds are biosynthetically produced but are not needed for the metabolism (i.e. growth, development and reproduction) of the allelopathic organism (Lau *et al.,* 2010). Although these compounds can affect plant growth indirectly by modifying the competition from other organisms including plants (Abhilasha *et al.,* 2008). In contrast to primary metabolism, which comprises several hundreds of low molecular weight compounds, tens of thousands of secondary substances are known today, but only a limited number has been implicated as allelochemicals(Rice, 1984). Allelochemics are present in virtually all plant tissues, including leaves, flowers, fruits, stems, roots, rhizomes, seeds and pollen (An *et al.,* 1998). Allelochemical concentrations in the producer plant may also vary over time and in the plant tissue produced. Foliar and leaf litter leachates of eucalyptus species, for example, are more toxic than bark leachates to some food crops (Singh *et al.,* 2009).

According to Rice (1984) and Putnam (1985), there are four ways in which the chemicals are released:

a. Volatilization, release into the atmosphere.
b. Leaching, rainfall, dew or irrigation may leach the chemicals from the aerial parts of plants
c. root exudation, from plant roots into the soil
d. Decomposition of plant residues

The mode of action of a chemical could broadly be divided into a direct and an indirect action (Blum, 2002). Effects through the alternation of soil properties, nutritional status and an altered population or activity of microorganisms and nematodes represent the indirect action. The direct action involves the biochemical/physiological effects of allelochemicals on various important processes of plant growth and metabolism.

**2.7 Allelochemicals**

Allelopathy is the direct influence of chemicals released from one plant on the development and growth of another plant (Olofsdotter, 1998). Allelopathic substance was first detected by Davis (1928) in black walnut tree (Juglans nigra).The term "allelochemicals" derives from "allelochemics," coined by Whittaker and Feeny (1971), and was first used by Chou and Waller in 1983. Since then, the term has been used in literature dealing with interspecific chemical interactions between organisms (Yang *et al.,* 2002). Different plant parts, including flowers, leaves, leaf litter and leaf mulch, stems, bark, roots, soil and soil leachates and their derived compounds, can have allelopathic activity that varies over a growing season (Uniyal and Chhetri, 2010).

Plants produce a large, diverse array of organic compounds that appear to have no direct function in growth and development. These substances are known as secondary metabolites, secondary products, or natural products. Secondary metabolites have no generally recognized, direct roles in the processes of photosynthesis, respiration, solute transport, translocation, protein synthesis, nutrient assimilation, differentiation, or the formation of carbohydrates, proteins, and lipids (Inderjit *et al.,* 2008). Secondary metabolites also differ from primary metabolites (amino acids, nucleotides, sugars, acyl lipids) in having a restricted distribution in the plant kingdom. That is, particular secondary metabolites are often found in only one plant species or related group of species, whereas primary metabolites are found throughout the plant kingdom. Plant secondary metabolites can be divided into three chemically distinct groups: terpenes; phenolics, and nitrogen-containing compounds (Gershenzon, 1998). Allelopathic secondary metabolites are typically released into the soil rhizosphere under appropriate conditions, although they can also be passed through the air as volatiles. Allelopathic compounds can be released into the soil by a variety of mechanisms that include decomposition of residues, root exudation, and volatilization (Weston, 2005). Traditionally, secondary metabolites in plants have been investigated by phytochemists. Originally classified as waste products, these compounds have recently been investigated extensively by ecologists and pharmacologists, and many complex biological functions have been discovered (Weston and Duke, 2003). Although most plant tissues contain potential allelochemicals, only those compounds released from the plant into the environment are available to exert an allelopathic effect on another organism (Batish *et al.,* 2008). For more than 100 years biologists and chemists have tried to answer the question as to why plants invest so much energy and care in the formation of these secondary products. For some time it was believed that these compounds are waste products or otherwise useless substances (Mothes, 1955). But for 3-4 decades it has generally been accepted that the secondary metabolites play an important role in the ecology of plants and are therefore crucial for their survival and fitness (Rizvi and Rizvi, 1992).

Plant cells produce a vast amount of secondary products. Many of these are highly toxic and are often stored in specific vesicles or in the vacuole. Although secondary plant products are very common, this does not mean that every plant can produce every product (Gniazowska and Bagatek , 2005). Some compounds are restricted to single species, others to related groups. But they are nearly always found only in certain specific plant organs, often in just one type of cell (and there again only in a certain compartment). Also, they are often generated only during a specific developmental period of the plant (Singh *et al.,* 2001). According to the different structures and properties of these compounds, allelochemicals can be classified into the following categories: a)water-soluble organic acids, straight-chain alcohols, aliphatic aldehydes, and ketones; b) simple unsaturated lactones; c) long-chain fatty acids and polyacetylenes; d) quinines (benzoquinone, anthraquinone and complex quinines); e) phenolics; f) cinnamic acid and its derivatives; g) coumarins; h) flavonoids; i) tannins; j) steroids and, k)terpenoids (sesquiterpene lactones, diterpenes, and triterpenoids) (Wang *et al.,* 2006) .

Allelopathic effects of these compounds are often observed to occur early in the life cycle, causing inhibition of seed germination and/or seedling growth. The compounds exhibit a wide range of mechanisms of action, affect on DNA (alkaloids), photosynthetic and mitochondrial function (quinones), phytohormone activity, ion uptake and water balance (phenolics). Interpretations of mechanisms of action are complicated by the fact that individual compounds can have multiple phytotoxic effects (Einhellig, 2002). Multiple physiological effects have commonly been observed from treatments with many allelochemical. These effects include decreases in plant growth, absorption of water and mineral nutrients, ion uptake, leaf water potential, shoot turgor pressure, and osmotic potential caused by ferulic acid (Yang *et al.,* 2002). Blair *et al.* (2009) reported that 10-30 mol/L caffeic acid, coumaric acid, ferulic acid, cinnamic acid, and vanillic acid could significantly inhibit the growth of soybean (Glycine max). Root length and fresh weight of maize (Zea mays L.) seedlings were significantly reduced after a 6-day treatment with ferulic acid. In addition, activities of hydrolase, maltase, phospholipase, and protease were also significantly reduced. In agro-ecosystems, allelochemicals have detrimental effects on the growth of associated and next season crops (Singh *et al.,* 2009). In addition, weeds can exhibit allelopathy against crop plants (Weston and Duke, 2003). In forest ecosystems, allelochemicals produced by invasive plants can inhibit the growth of competing vegetation through direct or indirect means, thereby providing the invader with a competitive advantage (Zeng *et al.,* 2008). In addition to effects on other plants, the allelochemicals produced by invasive plants can also contribute to pest and disease resistance, and subsequently confer a competitive advantage to the invader in the host range (Haribal and Enwick, 1998). Allelopathic effects are often observed to occur early in the life cycle, causing inhibition of seed germination and or seedling growth (Einhellig, 2002). Therefore, the activity of allelochemicals cannot be explained by just a single mode of action. The majority of effects such as reduction in seed germ inability and seedling growth, chlorosis, decreased ion uptake and other physiological, morphological and an atomically abnormalities are caused by a variety of more specific interactions between allelochemicals and cellular or molecular systems (Chon *et al.,* 2002).

Phenolic compounds are a class of the most important and common plant allelochemicals in the ecosystem. They are chemical compounds consisting of a hydroxyl group (-OH) bonded directly to an aromatic hydrocarbon group (Uniyal and Chhetri, 2010). These phenolics are released from the plant part through various mechanisms such as leachation from above ground parts, root exudation, volatilization or microbial degradation (Nardi *et al.,* 2000). They are universally distributed in plants and very common in plant decomposition products, and they are important precursors of humic substances in soils. In soil, phenolics can occur in the three following forms: free, reversibly bound, and bound forms. Ortho-substituted phenolics, such as salicylic and p-coumaric acids, and dihydro-substituted phenolics, such as protocatechuic and caffeic acids, are absorbed by clay minerals by forming chelate complexes with metals (Capasso, 1997). Free phenolic compounds may accumulate in rhizosphere soils, especially in soils flooded with vegetable waste waters, thereby influencing the accumulation and availability of soil nutrients and rates of nutrient cycling, which both ultimately affect plant growth (Tehmina and Bajwa, 2005). Artemisia herba alba fruit extract (mature and immature) may contain some phytotoxic substance(s) that inhibits germination and growth of Anabasis setifera. Aqueous extract of plants may contain phenolics such as ferulic acid, P-coumaric, vanillic, caffeic, chlorogenic and others (Hussain and Khan, 1988). These phenolics inhibit the germination process which was due to their interference with IAA metabolism, or synthesis of protein and ion uptake by the plants (Uniyal and Chhetri, 2010). Therefore, A. herba alba might release some soluble phenolic allochemicals to the environment (Xu *et al.,* 2003). Although phenolic extract concentration was higher in immature fruit aqueous extract and it showed higher inhibition in germination percentages and seedling growth compared to mature fruit aqueous extract. This may be due to differences in quality and quantity of phenolic compounds that were isolated from fruits (Chung *et al.,* 2007).

Eucalyptus belongs to the family Myraceae, mostly found in tropical region, and is a native to Australia. The tree is considered to have allelochemicals and volatile compounds in its all parts. These chemicals 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 (Mohamadi and Rajaie, 2009). Investigations done to identify the allelopathic compounds in the leachates of bark, fresh leaves and leaf litter of *Eucalyptus tereticornis*, *E. camaldulensis*, *E. polycarpa* and *E. microtheca* showed the presence of p-coumaric, gallic, gentisic, p-hydroxybenzoic, syringic and vanillic acids and catechol (Ghafar *et al.,* 2000). A large number of studies confirmed that Eucalyptus sp. leachates contained phenolic compounds such as coumaric, gallic, gentisic, catechol, hydroxybenzoic syringic and vanillic acid. Germination of cereals depends on ?-amylase activity that regulates starch break down, necessary for supplying substrates to respiratory metabolism. Eucalyptus (Eucaliptus globosus) leaf leachates decreased-amylase activity in seeds of finger milet (Eleusine coracanta), resulting in inhibition of germination (Padhy *et al.,* 2000). Phenolic compounds extracted from soils covered by beech (Fagus sylvatica) and pine markedly inhibited germination of pine seeds (Muscolo *et al.,* 2001). Further, the absorption of phenolics "the allelopathic compounds" by soil particles and their microbial breakdown and may account for the outcome of present observations which are further affected by various soil factors such as soil texture, organic carbon and organic matter etc. (Kobayashi, 2004). Chou and Lin (1976) found the aqueous extracts of decomposing rice residues in soil contained five phenolics and several unknown compounds and that extracts inhibited the radicle growth of lettuce and rice seeds and the growth of rice seedlings. Root residues of Ageratum conyzoides L. (billy goat weed; Asteraceae) released inhibitory substances (p-coumaric acid, gallic acid, ferulic acid, p-hydroxybenzoic acid, and anisic acid) in the rhizosphere soil and these phytotoxins negatively affected rice growth (Batish *et al.,* 2008). The quantitative analyses of putative phytotoxins in the rhizosphere soil showed it contained nearly six times more phenolics than the control soil. However, the amount of phenolics in the rhizosphere soils declined significantly when activated charcoal was added. Activated charcoal has a great affinity for phenolic metabolites and does not adsorb inorganic molecules (Olofsdotter *et al.,* 2001).

Allelochemicals besides imparting the plant allelopathic property also regulate the biotic communities of soil and alter the physical and chemical properties of soil (Nardi *et al.,* 2000). Variety of environmental conditions influence the quantity of chemicals produced include (Bezuidenhout, 2005; Kobayashi, 2004): a) Light: some allelochemicals are influenced by the amount, intensity and duration of light. The greatest quantities are produced during exposure to ultraviolet and long-day photoperiods. Thus under-storey plants will produce fewer allelochemicals because over-storey plants filter out the ultraviolet rays. At the peak plant growing period, it could be expected that more allelochemicals are produced than earlier or later in the growing season; b) Mineral deficiency : more allelochemicals are produced under conditions of mineral deficiency; c) Drought stress: under these conditions, more allelochemicals are produced; d) Temperature: in cooler temperatures, greater quantities are produce. The location within the plant and effects in specific allelochemicals seem to be variable; e) type and age of plant tissue during extraction is important since compounds are not uniformly distributed in plants. Production differs between species as well as within species; f) Shade; g) plant diseases and, h) herbicides can influence allelopathy.

## 2.8 Allelopathic effect of eucalyptus

This research was carried out to study allelopathic effect of aerial and underground part of *Eucalyptus camaldulens is* on germination and early growth seedling of *Vicia villosa*, *Onobrychis sativa*, *Festuca arundinacea* and *Trifolium rigidom*. The extraction was provided from aerial and underground part of *Eucalyptus camaldulensis*. Different concentrations of this species (0, 25, 50, 75 and 100 %) were provided by adding distilled water with four replications was used to analyze the data. Results indicated that there were significant differences among all traits (germination percentage, germination speed, root length, shoot length, plant length and seed vigor index) except for germination percentage in *Vicia villosa* ($P<0.01$). The highest germination percentage and speed, length of radical and plumule and seed vigority were belonged to control treatment and the lowest length belonged to 100 % extraction. Germination and early seedling growth of 4 species were reduced significantly by increase of extract concentration so that

*Onobrychis sativa* and *Trifolium rigidom* indicated more sensitive to allelopathic effect of *Eucalyptus camaldulensis* (Saberi *et al*., 2013).

Khybri *et al*. (1992) conducted various experiments on tree crop interaction under rainfed condition in Dehradun valley during 1977 to 1990. Grewia optiva (Bhimal), Morus alba (Mulbery) and Eucalyptus hybrid were planted along with rice and wheat rotation and the study showed that all tree species had deleterious effect on crop yields, whereas, wheat was highly affected by Grewia optiva. The effect on an average varied from 28 to 34 per cent depending upon the species. It was also observed that agricultural crop yield increased with the increase of crop distance from the tree (Sharma *et al*., 1996).

Narain *et al*. (1997) in a 10 years study (1983 to 1992) conducted on nine 15 × 90 m runoff plots at 4 per cent slope, compared the production efficiency of Leucaena leucocephala and Eucalyptus hybrid based agroforestry as well as monocropping land use systems in the warm, sub humid climate of the Western Himalaya. It was observed that integration of Leucaena leucocephala and Eucalyptus hybrid trees with crops caused severe reduction of crop yields. It was reported that Acacia nilotica in the upper surface layer of soil also caused higher reduction in wheat yield (Sharma, 1992). Lower yield of wheat was also recorded when associated with the Eucalyptus hybrid, Albizia procera, Morus Alba and Leucaena leucophloea (Akbar *et al*., 1990). Reduction of wheat under Ecalyptus hybrid was also reported by Malis and Sharma (1990).

Thakur and Bhardwaj (1992) studied the wheat and maize seeds exposed to leachates from leaf extracts of Eucalyptus globulus, Populus ciliata, Juglans regia and Robinia pseudoacacia. Wheat germination was not significantly affected by exposure to the leachates but maize germination rate was decreased to 89% when compared to control. Seedling vigour was decreased in both species by all the leachates; the greatest reduction was with J. regia leachate. Lisanework and Michelsen (1993) studied the allelopathic effect of Cupressus lusitanica, Eucalyptus globulus, E. camaldulensis and E. saligna on seed germination, radicle and seedling growth of four crops: Cicer arietinum, Zea mays, Pisum sativum and Eragrostis tef. Aqueous leaf extracts of all the tree species significantly reduced both germination and radicle growth of the majority of the crops, usually starting from concentrations of 1 or 2.5%. The shoot and root dry weight increase of the crops was significantly reduced after 10 weeks' treatment with leaf extracts. Among the four crops, chickpeas and teff were most susceptible with respect to germination, and tuff with respect to growth. From the overall data the leaf extracts of the four tree species can be arranged according to increasing allelopathic potential: C. lusitanica.

John and Nair (1999) conducted the experiments to assess the allelopathic effects of aqueous leaf extracts of 14 agroforestry tree species, using germination and seedling growth of rice cv. Jyothi and cowpea cv. Kanakamony as bioassays. Results indicated that all extracts inhibited the rice germination and plumule and radicle elongation, with Ailanthus triphysa, Tamarindus indica, Acacia auriculiformis and Thespesia populnea having most effect. Seven species inhibited cow pea germination, plumule and radicle growth with Eucalyptus tereticornis and T. indica producing the strongest effects.

# CHAPTER THREE

# MATERIALS AND METHODS

# CHAPTER THREE

# MATERIALS AND METHODS

The experiment was conducted to evaluate the performance of rice (*Oryza sativa*) in association with Eucalyptus (*Eucalyptus camaldulensis*) species. In this chapter the materials used, the methodologies followed and the related works done during the experimental period are presented. It includes short description of location of the experimental plot, characteristics of soil, climate, materials used for the experiment, experimental design and treatment combination, intercultural operation, harvest, data collection etc. The details of this experiment and its methods which are used described below:

## 3.1 Description of the Experimental Site

### 3.1.1 Location and Duration

The experiments were conducted at Agroforestry and Environment Laboratory, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during the period of March to July 2016. Experimental field is located at $25.56^{o}$ N latitude and $88.41^{o}$ E longitude at an altitude of 37.5 m above from the mean sea level. The land belongs to the Old Himalayan Piedmont Plain Agro Ecological Zone (AEZ-1) (Appendix-I) (UNDP and FAO, 1988).

### 3.1.2 Climate and Weather

The climatic condition of experimental area possesses sub-tropical climate. Usually the rainfall is heavy during Kharif season (Mid-March to Mid-October) and scantly in *Rabi* season (Mid-October to Mid-March). The weather condition such as monthly mean temperature (°C) (maximum and minimum), rainfall (mm) and relative humidity (%) are presented in Appendix-II (January to July, 2016), respectively. The mean minimum temperature value was recorded 10.5°C in the month of January and the mean maximum temperature was recorded 32.8°C in the month of July, 2016. The monthly total rainfall was the highest (331.5 mm) in the month of June and few rainfalls (24.00 mm) were recorded in the month of January, 2016. The mean humidity during the period of rice cultivation from January to June was recorded 78.71% (Appendix-III). The weather data were collected from the Wheat Research Centre (WRC), Nashipur, Dinajpur.

### 3.1.3 Soil Characteristics

The soil used in this experiment was collected from 0-15 cm depth from the HSTU farm. The collected soil samples were air dried, sterilized. The soil is sandy loam having pH 5.60 that belongs to Old Himalayan Piedmont Plain Agro-ecological zone (AEZ-1) (UNDP and FAO, 1988). The initial soil (0-15 cm depth) test revealed that the soil contained 0.10% total nitrogen, 1.06% organic matter, 24.00 µg/g available phosphorus, 0.26meq/100g available potassium, 3.2 µg/g available sulphur, available boron 0.27 µg/g, available iron 5.30 µg/g and available zinc 0.90 µg/g. The characteristics of the soil were previously tested in the Soil Resource Development Institute (SRDI), Dinajpur (Appendix-III).

### 3.1.4 Collection of seed

Three rice varieties were collected from Bangladesh Agricultural Research Institute (BARI) and used for the present study.

### 3.1.5 Extract preparation

#### 3.1.5.1 Plant Materials Collection

Mature leaves of *Eucalyptus camaldulensis* collected from agroforestry research field, HSTU, Dinajpur during March and July of 2016. The collected parts were air-dried for several days under sun light on a threshing floor. The dried plant parts were then ground to make fine powder using on eclectic grinder weighted using digital balance and then kept in plastic bags at room temperature.

#### 3.1.5.2 Preparation of Aqueous Extracts

Aqueous extracts were prepared mixing dried and ground plant parts (leaves) and distilled water. Glass beakers were sterilized and then 50, 75 and 100 g powder of respective plant parts were placed and then distilled water was added up to 500 ml mark to make 10, 15 and 20% extracts, respectively. To ensure good mixing, all mixtures (powder + water) were shaken for one hour by hand and then the mixtures were shaken over night by mechanical shaker. After shaking the aqueous extract was kept undisturbly for 48 hours at room temperature. Then filtration was done using Whatman filter paper 2. The extracts with different concentrations were poured in Conical Flasks and covered by Aluminum Foil. The prepared aqueous extracts were then stored under refrigeration at 4ºC until use.

## 3.2 Experiment-1: Allelopathic Effect of Eucalyptus Leaf Extract on Seed Germination and Seedling Growth of Rice

### 3.2.1 Experimental Design and Treatments

The experiment was carried out in two factors completely randomized design (CRD) with three replications.

The factors **A** and **B** were –

A. **Allelopathic treatments**

$C_0$= Control (distilled water)

$C_1$= 10.0% leaf extract

$C_2$= 15.0% leaf extract

$C_3$= 20.0% leaf extract

B. **Rice varieties**

$V_1$ = Hybrid Hira

$V_2$= BRRI Dhan 28

$V_3$= BRRI Dhan 29

### 3.2.2 Placement of Seed for Germination

Seeds of 3 rice varieties were surface sterilized by dipping the seeds in sodium hypochlorite solution for 5 minutes and rinsed thoroughly with sterilized water. Allelopathic concentration (0, 10, 15 and 20 % leaf extract) were prepared dissolving calculated amount of eucalyptus leaf powder in distilled water. Distilled water was used as control. Twenty five seeds of each genotype were placed in plastic glasses (7.5 cm diameter and 11.3 cm height) on sand bed irrigated with control and allelopathic concentration as per treatment and were kept at room temperature. To avoid coiling of root plastic glasses were used instead of petridishes. They were irrigated daily with required amount of concentration. For each allelochemical levels, three batches of plastic glasses were used.

### 3.2.3 Recording of Data

Germination was counted at 24-hour interval and continued upto $8^{th}$ day. A seed was considered germinated as plumule and radicle came out and were >2 mm long. Finally at 8 DAT for germination, total germinated seed were counting and ten seedlings from each plastic glass were sampled. Shoot and root length of individual seedling were recorded manually with scale and expressed in centimeter (cm). Fresh and dry weight of root, shoot were recorded with digital balance and expressed in gram (g). The following data were recorded:

**Germination Percentage (GP):**

Germination percentage at final count was calculated using the following formula.

$$\text{Germination percentage}(\%) = \frac{\text{Number of seeds germinated at final count}}{\text{Total number of seeds placed for germination}} \times 100$$

**Germination index (GI):**

It was calculated according to the following equation:

$$\text{Germination index}(\%) = \frac{\text{Germination percentage in each treatment}}{\text{Germination percentage in control condition}} \times 100$$

**Vigor index:** It was calculated according to the following equation No 3:

VI= {Average shoot length (cm) + Average root length (cm)} × Germination percentage

**Shoot length:** At 10 DAT for germination, seedlings from each plastic glass were collected as a sampling. The length of ten seedlings from the seed to the tip of the leaf blade was measured and then divided by ten.

**Root length:** At 10 DAT for germination, seedlings from each plastic glass were collected as a sampling. The root length of ten seedlings from the seed to the tip of the root was recorded.

**Shoot and root fresh weight:** The weight of ten seedling roots was recorded and expressed in gram (gm) in fresh condition and weight were recorded with an electrical balance (Model- AND EK- 300).

**Shoot and root dry weight:** The weight of ten seedling roots was recorded and expressed in gram (gm) after oven drying at 70ºC for 72 h in an electric oven (Model- E28# 03-54639, Binder, Germany) and weight were recorded with an electrical balance (Model-AND EK- 300).

### 3.3 Experiment-2: Allelopathic Effect of Eucalyptus leaf Extract Yield Contributing and Yield Characters of Rice

#### 3.3.1 Location and duration

The experiment was conducted at Agroforestry and Environment Laboratory, HSTU. The plants were grown in plastic pot (18 cm × 19 cm) under natural light during the month of March.

#### 3.3.2 Experimental Design and Treatments

The experiment was carried out in two factors completely randomized design (CRD) with three replications.

The factors **A** and **B** were –

**A. Allelopathic treatments**

$C_0$= Control (distilled water)
$C_1$= 10.0% leaf extract
$C_2$= 15.0% leaf extract
$C_3$= 20.0% leaf extract

**B. Three rice varieties**

$V_1$= Hybrid Hira
$V_2$= BRRI Dhan 28
$V_3$= BRRI Dhan 29

#### 3.3.3 Pot Preparation

Each plastic pot (18cm × 19cm) was filled-up with 10kg air-dried sandy loam soil and kept inside plastic house under natural light. The respective amount of nutrients was incorporated with the soil before seed sowing. A fertilizer dose of 1.6, 1.05,0.84, 0.84 and 0.14 g per pot of Urea, TSP, MoP, Gypsum and Zinc Sulphate was applied, respectively.

### 3.3.4 Sowing of Seeds

Twelve seeds were sown in each plastic pot during the month of March. After sowing, the pots were irrigated daily with required amount of concentration. For each allelopathic levels, five batches of plastic pots were used.

### 3.3.5 Intercultural Operations

**Thinning**

Seeds started germination from four days after sowing (DAS). Thinning was done in each pot at two times by keeping 10 and 5 healthy seedlings, respectively as to maintain optimum plant population in each pot.

**Irrigation and Weeding**

Irrigation was done as per requirements with eucalyptus leaf extract based on treatment. The hand weeding was done as necessary to keep the pots free from weeds.

**Protection against Insect and Pest**

At early stage of growth Stem-borer i.e majrapoka (*Scirpophaga incertulus)* infested the young plants. Cartap 4 G was sprayed @ 25 kg/ha to control the insects and at later stages of growth Ear-cutting caterpillar/ cutworm (*Mythimna separata*) attacked the plant. Quinalphos 25 EC was sprayed @ 1,600 ml/ha or Chlorpyriphos 20 EC @ 2,000 ml/ha to control the insects.

**Harvest and Post-Harvest Operations**

Harvesting was done when grain became golden in color. The matured grains were collected by hand picking from each pot.

### 3.3.6 Application of Treatments

Each pot was moistened with normal water up to the emergence of seedling. After seedling establishment normal water in control pots, 10.0% in $C_1$ pots, 15.0% in $C_2$ pots and 20.0% in $C_3$ pots. Plants in control groups were irrigated with distilled water. The allelopathic concentration and nutrient with concentration were applied till maturity.

### 3.3.7 Data Collection

Numbers of days from sowing to before flowering and physiological maturity of plants were determined visually. Final data was collected after 120 days during the month of July.

1. Plant height (cm)
2. Number of leaves per plant
3. Number of tiller/hill
4. Plant height at harvest time
5. Number of tiller/ hill at harvest time
6. Number of effective tiller/ hill
7. Number of sterile tiller/ hill
8. Penicle length
9. Weight of grain/panicle
10. Number of spikelet/ panicle
11. Number of filled grain/ panicle
12. Number of unfilled grain/ panicle

## 3.4 Statistical Analysis

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for factorial experiment in completely randomized design (CRD) as published by Gomez and Gomez (1984) with using means of "MSTAT-C" computer software package. Least Significant Difference (LSD) method was used to test the differences between treatment means at 5% level of probability as described by Snedecor and Cochran (1980).

# CHAPTER FOUR

# RESULTS AND DISCUSSION

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# RESULTS AND DISCUSSION

This chapter comprises the tabulation and discussion of the results from the experiment conducted to determine the allelopathy effect of eucalyptus (*Eucalyptus camaldulensis)* on morphological characters of different rice varieties. The data have been presented in tables and figures. Adequate discussion and possible interpretations whenever suitable have been provided in this chapter.

## 4.1 Experiment-1: Allelopathic Effect of Eucalyptus Leaf Extract on Seed Germination and Seedling Growth of Rice

### 4.1.1 Germination

The difference of germination (GP) due to the allelopathy effect was statistically significant (Table 1). At three days after placement (DAP) of rice seed, the highest germination (24.78%) was found at control condition whereas the lowest (12.78%) was recorded at 20% leaf aqueous extract. Similarly at the 4, 5 and 6 DAP of rice seed the highest germination was found at control condition whereas the lowest was recorded at 20% leaf aqueous extract. At 7 days after placement of rice seed, the highest germination (25.00%) was found at control condition whereas the lowest (22.67%) was recorded at 20% leaf aqueous extract. The result showed that germination decreased markedly with the increasing rate of leaf extract concentration.

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of germination, which was statistically significant (Table 2). At three days after placement of rice seed the highest germination (21.58%) was recorded in hybrid and the lowest germination (19.25%) was found in BRRI Dhan 28. At 7 days after placement of rice seed, the highest germination (24.00%) was recorded in hybrid and the lowest germination (23.75%) was found in BRRI Dhan 28. But incase of 4, 5 and 6 days after placement, the germination rate was statistically not significant. The result showed that different varieties had different degrees of concentration in relation to germination.

The interaction effect between eucalyptus leaf extract and the varieties on germination was statistically significant at different concentration of eucalyptus leaf extract (Table 3). The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At 7 days after placement, in control condition, the highest germination (25.00) was observed in hybrid which are statistically similar with BRRI Dhan 29 and BRRI Dhan 28. Again at 7 days after placement, in 20% condition the highest germination (23.00) was observed in hybrid and the lowest germination (22.33) was recorded from BRRI Dhan 28.

Germination reduction under allelopathic condition may be due to the hindrance of hilar opening in seeds treated with leaf extracts and these might have been adversely affected the normal opening of testa thereby reducing the uptake of water during germination which completely inhibition the germination of seeds. Plants having allelopathic potential can reduce seed germinability, speed of germination and TTC (2, 3, 5 - Triphenyl tetrazolium chloride) stainability along with deranging of seed membranes causing leaky membrane structure (Nayek, 2002; Maiti, 2008).

### 4.1.2 Normal Seedling

Normal seedling was affected significantly by eucalyptus leaf extract (Table 1). Without eucalyptus leaf extract (control), the highest normal seedling (27.67) was found whereas the lowest (15.22) was found at 20% concentration. The result showed that normal seedling decreased with increasing concentration.

Different varieties had different degrees of tolerance to eucalyptus leaf extract in relation to Normal seedling (Table 2). Hybrid recorded the highest values of normal seedling (22.75) whereas, BRRI Dhan 28 recorded the lowest values (21.50) of normal seedling.

The interaction effect between eucalyptus leaf extract and the varieties on normal seedling was significant (Table 3). The highest normal seedling (28.67) was observed in hybrid with control condition and the lowest normal seedling (26.67) was recorded from BRRI Dhan 29. On the other hand, at 20% treatment condition the highest normal seedling (17.00) was observed in Hybrid and the lowest normal seedling (14.00) was recorded from BRRI Dhan 29 which was statistically similar with BRRI Dhan 28.Similar type of result was observed by Sasikumar *et al.* (2006)

**Table 1: Effect of various concentration of eucalyptus leaf extracts on seed germination and seedling growth of rice**

| Treatments | Number of germinated seeds at 3rd day | Number of germinated seeds at 4th day | Number of germinated seeds at 5th day | Number of germinated seeds at 6th day | Number of germinated seeds at 7th day | Number of normal seedling | Number of abnormal seedling | Shoot length per seedling | Root length per seedling | Number of root per seedling |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_0$ | 24.78 a | 24.89 a | 24.11 a | 25.00 a | 25.00 a | 27.67 a | 8.444 a | 6.331 a | 6.478 a | 6.111 a |
| $C_1$ | 22.67 b | 23.67 b | 23.22 ab | 24.11 b | 24.22 b | 23.33 b | 5.000 b | 4.693 b | 2.667 b | 3.667 b |
| $C_2$ | 19.67 c | 22.56 c | 22.67 b | 23.67 c | 23.67 c | 19.67 c | 1.889 c | 3.836 c | 1.018 c | 2.000 c |
| $C_3$ | 12.78 d | 19.00 d | 21.22 c | 22.78 d | 22.67 d | 15.22 d | 0.2222 d | 2.429 d | 0.7444 d | 1.444 d |
| LSD (5%) | 1.775 | 0.4952 | 0.9385 | 0.2853 | 22.67 | 1.958 | 0.3020 | 0.2620 | 0.1534 | 0.3020 |
| CV% | 8.97% | 2.22% | 4.16% | 1.21% | 1.66% | 9.21% | 7.82% | 6.10% | 5.66% | 9.21% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$C_0$= Control (distilled water), $C_1$= 10.0% leaf extract, $C_2$= 15.0% leaf extract, $C_3$= 20.0% leaf extract

**Table 2: Effect of Eucalyptus leaf extracts on seed germination and seedling growth of different rice varieties**

| Varieties | Number of germinated seeds at 3rd day | Number of germinated seeds at 4th day | Number of germinated seeds at 5th day | Number of germinated seeds at 6th day | Number of germinated seeds at 7th day | Number of normal seedling | Number of abnormal seedling | Shoot length per seedling | Root length per seedling | Number of root per seedling |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_1$ | 21.58 a | 23.42 a | 23.083 | 24.000 | 24.000 | 22.750 | 4.833 a | 4.793 a | 3.260 a | 3.583 a |
| $V_2$ | 19.08 b | 21.50 c | 22.667 | 23.917 | 23.917 | 20 .167 | 2.917 c | 3.898 b | 2.190 c | 2.917 b |
| $V_3$ | 19.25 b | 22.67 b | 22.667 | 23.750 | 23.750 | 21.500 | 3.917 b | 4.275 b | 2.730 b | 3.417 a |
| LSD (5%) | 1.066 | 0.6863 | ns | ns | ns | ns | 0.4082 | 0.3817 | 0.2507 | 0.4082 |
| CV% | 8.97% | 2.22% | 4.16% | 1.21% | 1.66% | 9.21% | 7.82% | 6.10% | 5.66% | 9.21% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$V_1$= Hybrid Hira, $V_2$= BRRI Dhan 28, $V_3$= BRRI Dhan 29

**Table 3: Interaction effect of different rice varieties and various concentration of eucalyptus leaf extracts on seed germination and seedling growth of rice**

| Interaction | Number of germinated seeds at 3rd day | Number of germinated seeds at 4th day | Number of germinated seeds at 5th day | Number of germinated seeds at 6th day | Number of germinated seeds at 7th day | Number of normal seedling | Number of abnormal seedling | Shoot length per seedling | Root length per seedling | Number of root per seedling |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_1C_0$ | 25.00 a | 25.00 a | 24.33 a | 25.00 a | 25.00 a | 28.67 a | 9.667 a | 6.940 a | 7.633 a | 6.667 a |
| $V_1C_1$ | 23.33 b | 24.00 c | 23.67 bc | 24.67 b | 24.67 b | 24.67 d | 6.000 d | 5.413 d | 3.400 d | 4.000 d |
| $V_1C_2$ | 20.00 d | 23.67 d | 23.33 cd | 23.67 d | 23.67 d | 20.67 g | 3.000 g | 4.107 f | 1.147 g | 2.000 f |
| $V_1C_3$ | 18.00 f | 21.00 f | 21.00 f | 22.67 f | 22.67 f | 17.00 i | 0.6667 i | 2.713 i | 0.8600 i | 1.667 g |
| $V_2C_0$ | 24.33 a | 25.00 a | 24.00 ab | 25.00 a | 25.00 a | 26.67 c | 7.000 c | 5.820 c | 5.380 c | 5.667 c |
| $V_2C_1$ | 22.00 c | 23.00 e | 23.00 d | 24.00 c | 24.00 c | 21.67 f | 4.000 f | 4.200 f | 1.813 f | 3.000 e |
| $V_2C_2$ | 20.00 d | 21.00 f | 22.33 e | 23.67 d | 23.67 d | 18.33 h | 0.6667 i | 3.500 h | 0.9267 hi | 2.000 f |
| $V_2C_3$ | 10.00 g | 17.00 h | 21.33 f | 23.00 e | 23.00 e | 14.00 j | 0.0000 j | 2.073 k | 0.6400 k | 1.000 h |
| $V_3C_0$ | 25.00 a | 24.67 b | 24.00 ab | 25.00 a | 25.00 a | 27.67 b | 8.667 b | 6.233 b | 6.420 b | 6.000 b |
| $V_3C_1$ | 22.67 bc | 24.00 c | 23.00 d | 23.67 d | 24.00 c | 23.67 e | 5.000 e | 4.467 e | 6.420 b | 4.000 d |
| $V_3T_2$ | 19.00 e | 23.00 e | 22.33 e | 23.67 d | 23.67 d | 20.00 g | 2.000 h | 3.900 g | 0.9800 h | 2.000 f |
| $V_3C_3$ | 10.33 g | 19.00 g | 21.33 f | 22.67 f | 22.33 g | 14.67 j | 0.0000 j | 2.500 j | 0.7333 j | 1.667 g |
| LSD (5%) | 0.8876 | 19.00 | 0.4693 | 0.1427 | 0.1962 | 0.9788 | 0.1510 | 0.1310 | 0.07671 | 0.1510 |
| CV% | 8.97% | 2.22% | 4.16% | 1.21% | 1.66% | 9.21% | 7.82% | 6.10% | 5.66% | 9.21% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$V_1C_0$ = Hybrid Hira × Control (distilled water), $V_1C_1$ = Hybrid Hira × 10.0% leaf extract, $V_1C_2$ = Hybrid Hira × 15.0% leaf extract, $V_1C_3$ = Hybrid Hira × 20.0% leaf extract; $V_2C_0$ = BRRI Dhan 28 × Control (distilled water), $V_2C_1$ = BRRI Dhan 28 × 10.0% leaf extract, $V_2C_2$ = BRRI Dhan 28 × 15.0% leaf extract, $V_2C_3$ = BRRI Dhan 28 × 20.0% leaf extract; $V_3C_0$ = BRRI Dhan 29 × Control (distilled water), $V_3C_1$ = BRRI Dhan 29 × 10.0% leaf extract, $V_3C_2$ = BRRI Dhan 29 × 15.0% leaf extract, $V_3C_3$ = BRRI Dhan 29 × 20.0% leaf extract.

### 4.1.3 Abnormal Seedling

Increasing eucalyptus leaf extract concentration causes a significant decrease of abnormal seedling (Table 1). The highest abnormal seedling (8.444) was found with control condition whereas the lowest (0.2222) was found at 20% concentration.

Effect of eucalyptus leaf extract on different varieties was statistically significant (Table 2).The degree of reduction of abnormal seedling was not similar for all varieties from control to highest level of concentration. The abnormal seedling have been shown to reduce drastically with rising concentration and the magnitude of reduction was more in BRRI Dhan 28 (3.917) whereas the highest abnormal seedling (4.833) was recorded in Hybrid. The result showed that different varieties had different degrees of eucalyptus leaf extract tolerance in relation to abnormal seedling.

The interaction effect between eucalyptus leaf extract and the varieties on abnormal seedling was significant at different concentration (Table 3). Hybrid was the least affected than the other varieties. The highest abnormal seedling (9.667) was observed in Hybrid at control and besides this the lowest abnormal seedling (7.0) was recorded from BRRI Dhan 29. At 20% concentration the highest abnormal seedling (0.6667) was observed in Hybrid and the lowest abnormal seedling (0.00) was recorded from BRRI Dhan 28 which was statistically significant with BRRI Dhan 29.

### 4.1.4 Shoot Length per Seedling

The effect of eucalyptus leaf extract on the shoot length was statistically significant (Table 1). The tallest shoot length (6.331cm) was found at control condition whereas the shortest (2.429 cm) was found at 20% concentration.

The shoot length was significantly different in rice varieties under different concentration (Table 2). Hybrid showed the tallest shoot length (4.793cm) while the shortest shoot length (4.275cm) was recorded in BRRI Dhan 29.

The interaction effect between eucalyptus leaf extract and the varieties on shoot length was significant at different concentration (Table 3). The shoot length at control was significantly greater than the subsequent higher concentration (20%) for all the varieties. The tallest shoot length (6.94cm) was observed in Hybrid at control condition and the shortest shoot length (5.820cm) was recorded from BRRI Dhan 28. At 20%, the tallest shoot length (2.713 cm) was observed in Hybrid and the shortest shoot length (2.073cm) was recorded from BRRI Dhan 28.

Length of shoot grown in control $T_0$ was better than any other treatments due to subdued levels of protein, insoluble carbohydrate, nucleic acids (DNA and RNA), chlorophyll as well as activity of catalase enzyme and other growth resources. Similar type of result was observed by Saberi *et al.* (2013).

### 4.1.5 Root Length per Seedling

There were significant differences on root length at various level of eucalyptus leaf extract (Table 1). The tallest root length (6.478cm) was found under control condition than that of growing fewer than 20% concentration (0.744cm).

The performance of different rice varieties was significant in respect of root growth under allelopathic condition (Table 2). Hybrid showed the highest root length (3.260cm) while the lowest root length (2.190cm) was recorded in BRRI Dhan 28.

The interaction effect between eucalyptus leaf extract and the varieties on root length was significant at different concentration (Table 3). The largest root length (7.633cm and 0.860cm) was observed in Hybrid both at control and 20% concentration, respectively. The shortest root length (5.380cm and 0.640cm) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively.

Reduction of root length under allelopathic condition may be due to the significant decline in the mitotic index of the treated root tip cells of *Oryza sativa* undoubtedly pinpointed that the inhibitory effect of leaf extracts of *Eucalyptus* on cell division of root tips. The inhibitory effects on mitotic cell division behaviour indicate the action of leaf extracts on possible alteration of the metabolism of interphase nucleus. Decrease in the mitotic index of this study clearly indicates the cytotoxic effect and such reports are available in the literature (Ukaebu and Odeigah, 2009). Similar type of result was observed by Saberi *et al.* (2013).

### 4.1.6 Number of Root per Seedling

Eucalyptus leaf extract interacted significantly and influenced the number of root in plants (Table1). The highest number of root (6.111) was found at control condition whereas the lowest (1.444) was found at 20% concentration which was statistically similar to that of 15% concentration.

The number of root decreased with increasing the level of allelopathy and the magnitude of reduction was more in BRRI Dhan 28. Hybrid showed maximum number of root (3.583) while the lowest number of root (2.917) was recorded in BRRI Dhan 28 (Table 2).

The interaction effect between eucalyptus leaf extract and the varieties on root number was significant at different concentration (Table 3). The highest root number (6.667and 1.667) was observed in Hybrid both at control and 20% concentration, respectively. The shortest root length (5.667 and 1.00) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively.

### 4.2 Experiment-2: Allelopathic Effect of *Eucalyptus camuldulensis*on on Yield Contributing and Yield Chatracters of Rice.

#### 4.2.1 Plant Height (cm)

The difference of plant height (GP) due to the allelopathy effect was statistically significant (Table 4). At 30 days after transplanting (DAT) of rice seed, the highest plant height (57.59cm) was found at control condition whereas the lowest (40.02cm) was recorded at 20% leaf aqueous extract. Similarly at 40 and 60 DAT of rice seed the highest plant height was found at control condition whereas the lowest was recorded at 20% leaf aqueous extract. The result showed that plant height decreased markedly with the increasing the concentration.

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of plant height which was statistically significant (Table 6). At 30 DAT of rice seed the highest plant height (51.42) was recorded in hybrid and the lowest plant height (45.92) was found in BRRI Dhan 28. Similarly at 40 and 60 DAT of rice seed the highest plant height was found in hybrid whereas the lowest was recorded in BRRI Dhan 28.The result showed that different varieties had different degrees of concentration in relation to plant height.

The interaction effect between eucalyptus leaf extract and the varieties on plant height was statistically significant at different concentration of eucalyptus leaf extract (Table 8).

The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At 30 DAT in control condition the highest plant height (62.17) was observed in hybrid and lowest plant height (53.53) was found in BRRI Dhan 28. Similarly at 40 and 60 DAT of rice seed the highest plant height was found in hybrid whereas the lowest was recorded in BRRI Dhan 28.

### 4.2.2 Number of Leaves per Plant

The difference of number of leaves (GP) due to the allelopathy effect was statistically significant (Table 4). At 30 DAT of rice seed the highest number of leaves (78.22) was found at control condition whereas the lowest (39.22) was recorded at 20% leaf aqueous extract. Similarly at 45 and 60 DAT of rice seed the highest number of leaves was found at control condition whereas the lowest was recorded at 20% leaf aqueous extract.

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of number of leaves which was statistically significant (Table 6). At 30 DAT of rice seed the highest number of leaves (65.83) was recorded in hybrid and the lowest number of leaves (53.25) was found in BRRI Dhan 28. Similarly at 40 and 60 DAT of rice seed the highest plant height was found in hybrid whereas the lowest was recorded in BRRI Dhan 28. The result showed that different varieties had different degrees of concentration in relation to number of leaves.

The interaction effect between eucalyptus leaf extract and the varieties on number of leaves was statistically significant at different concentration of eucalyptus leaf extract (Table 8). The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At 30 DAT in control condition the highest number of leaves (85.67) was observed in hybrid and the lowest number of leaves (69.67) was found in BRRI Dhan 28. Similarly at 40 and 60 DAT of rice seed the highest plant height was found in hybrid whereas the lowest was recorded in BRRI Dhan 28.

**Table 4: Effect of various concentration of eucalyptus leaf extracts on yield contributing characters and yield of rice**

| Treatment | Plant height (cm) | | | | Number of leaves/plant | | | Number of tiller/hill | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAP | 45 DAP | 60 DAP | At Harvest Time | 30 DAP | 45 DAP | 60 DAP | 30 DAP | 45 DAP | 60 DAP |
| $C_0$ | 57.59 a | 77.87 a | 96.01 a | 103.3 a | 78.22 a | 122.1 a | 40.33 a | 23.78 a | 31.67 a | 40.33 a |
| $C_1$ | 50.62 b | 72.00 b | 90.92 b | 99.13 b | 67.22 b | 111.1 b | 36.33 b | 19.78 b | 27.56 b | 36.33 b |
| $C_2$ | 45.91 c | 67.03 c | 86.52 c | 94.83 c | 54.78 c | 99.67 c | 32.78 c | 16.33 c | 23.89 c | 32.78 c |
| $C_3$ | 40.02 d | 61.56 d | 80.39 d | 89.37 d | 39.22 d | 79.22 d | 27.56 d | 12.44 d | 19.22 d | 27.56 d |
| LSD (5%) | 1.825 | 1.623 | 2.149 | 1.930 | 6.933 | 10.30 | 1.271 | 1.381 | 1.371 | 1.271 |
| CV% | 3.80% | 2.35% | 2.45% | 2.02% | 11.69% | 10.10% | 5.71% | 7.71% | 5.41% | 3.75% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$C_0$= Control (distilled water), $C_1$= 10.0% leaf extract, $C_2$= 15.0% leaf extract, $C_3$= 20.0% leaf extract

**Table 5: Effect of various concentration of eucalyptus leaf extracts on yield contributing characters and yield of rice**

| Treatment | Number of tiller/ hill at harvest time | Number of effective tiller/ hill | Number of sterile tiller/ hill | Penicle length | Weight of grain/panicle | Number of spikelet/ panicle | Number of filled grain/ panicle | Number of unfilled grain/ panicle |
|---|---|---|---|---|---|---|---|---|
| $C_0$ | 40.00 a | 36.56 a | 6.667 a | 23.49 a | 2.368 a | 156.2 a | 139.6 a | 18.00 a |
| $C_1$ | 36.00 b | 32.00 b | 5.222 b | 22.01 b | 2.069 b | 142.4 b | 124.6 b | 14.00 b |
| $C_2$ | 32.67 c | 28.22 c | 3.444 c | 22.01 b | 1.839 c | 136.1 c | 118.2 c | 11.00 c |
| $C_3$ | 28.00 d | 24.89 d | 2.222 d | 18.70 d | 1.676 d | 130.0 d | 111.8 d | 8.000 d |
| LSD (5%) | 1.155 | 1.202 | 0.2525 | 0.1853 | 0.03132 | 130.0 | 4.151 | 0.4666 |
| CV% | 2.61% | 3.99% | 5.80% | 0.88% | 1.71% | 1.68% | 3.39% | 3.70% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$C_0$= Control (distilled water), $C_1$= 10.0% leaf extract, $C_2$= 15.0% leaf extract, $C_3$= 20.0% leaf extract

**Table 6: Effect of eucalyptus leaf extracts on yield contributing characters and yield of rice varieties**

| Varietes | Plant height (cm) | | | | Number of leaves/plant | | | Number of tiller/hill | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAP | 45 DAP | 60 DAP | At Harvest Time | 30 DAP | 45 DAP | 60 DAP | 30 DAP | 45 DAP | 60 DAP |
| $V_1$ | 51.42 a | 72.29 a | 90.675 | 98.32 a | 65.83 a | 109.9 a | 36.00 a | 20.42 a | 28.17 a | 36.00 a |
| $V_2$ | 45.92 b | 67.03 b | 86.208 | 94.78 b | 53.25 b | 95.42 a | 32.67 b | 15.92 b | 22.92 b | 32.67 b |
| $V_3$ | 48.27 ab | 69.52 ab | 88.500 | 96.89 ab | 60.50 ab | 103.8 | 34.08 ab | 17.92 ab | 25.67 ab | 34.08 ab |
| LSD (5%) | 3.368 | 4.455 | ns | 2.290 | 9.293 | 17.07 | 3.153 | 2.773 | 3.575 | 3.153 |
| CV% | 3.80% | 2.35% | 2.45% | 2.02% | 11.69% | 10.10% | 5.71% | 7.71% | 5.41% | 3.75% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$V_1$= Hybrid Hira, $V_2$= BRRI Dhan 28, $V_3$= BRRI Dhan 29

**Table 7: Effect of eucalyptus leaf extracts on yield contributing characters and yield of rice varieties**

| Varieties | Number of tiller/ hill at harvest time | Number of effective tiller/ hill | Number of sterile tiller/ hill | Penicle length | Weight of grain/panicle | Number of spikelet/ panicle | Number of filled grain/ panicle | Number of unfilled grain/ panicle |
|---|---|---|---|---|---|---|---|---|
| $V_1$ | 35.67 a | 32.167 | 5.000 a | 21.883 | 2.065 a | 144.500 | 126.3 a | 14.33 a |
| $V_2$ | 32.58 b | 28.917 | 3.667 b | 20.568 | 1.899 b | 137.583 | 120.7 b | 11.25 c |
| $V_3$ | 34.25 ab | 30.167 | 4.500 a | 21.326 | 2.000 ab | 141.500 | 123.6 ab | 12.67 b |
| LSD (5%) | 3.002 | ns | 0.6002 | ns | 0.1048 | ns | 5.069 | 0.4707 |
| CV% | 2.61% | 3.99% | 5.80% | 0.88% | 1.71% | 1.68% | 3.39% | 3.70% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$V_1$= Hybrid Hira, $V_2$= BRRI Dhan 28, $V_3$= BRRI Dhan 29

**Table 8: Interaction effect of different varieties and various concentration of eucalyptus leaf extracts on yield contributing characters and yield of rice**

| Interaction | Plant height (cm) | | | | Number of leaves/plant | | | Number of tiller/hill | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAP | 45 DAP | 60 DAP | At Harvest Time | 30 DAP | 45 DAP | 60 DAP | 30 DAP | 45 DAP | 60 DAP |
| $V_1C_0$ | 62.17a | 83.27 a | 98.83 a | 105.7 a | 85.67 a | 133.0 a | 146.7 a | 28.33 a | 36.67 a | 42.00 a |
| $V_1C_1$ | 52.87 c | 73.90 c | 92.70 d | 100.2 d | 71.67 c | 113.3 c | 126.7 cd | 21.33 c | 29.67 c | 38.00 d |
| $V_1C_2$ | 48.07 e | 68.67 f | 88.50 f | 96.00 f | 60.00 d | 107.0 d | 118.7 f | 17.33 e | 25.67 f | 34.00 g |
| $V_1C_3$ | 42.60 h | 63.33 i | 82.67 i | 91.37 h | 46.00 g | 86.33 fg | 111.3 h | 14.67 g | 20.67 i | 30.00 j |
| $V_2C_0$ | 53.53 c | 72.67 d | 93.90 c | 101.3 c | 69.67 c | 113.7 c | 129.7 c | 19.67 d | 27.00 e | 39.00 c |
| $V_2C_1$ | 48.67 e | 70.03 e | 89.37 f | 97.77 e | 61.67 d | 108.7 cd | 122.7 e | 18.00 e | 25.00 f | 34.67 f |
| $V_2C_2$ | 43.67 g | 65.41 h | 84.40 h | 93.17 g | 50.00 f | 91.33 f | 114.7 gh | 15.67 f | 22.33 h | 31.67 i |
| $V_2C_3$ | 37.80 j | 60.00 k | 77.17 k | 86.83 j | 31.67 i | 68.00 h | 98.00 j | 10.33 i | 17.33 k | 25.33 l |
| $V_3C_0$ | 57.07 b | 77.67 b | 95.30 b | 102.9 b | 79.33 b | 119.7 b | 133.3 b | 23.33 b | 31.33 b | 40.00 b |
| $V_3C_1$ | 50.33 d | 72.08 d | 90.70 e | 99.40 d | 68.33 c | 111.3 cd | 124.7 de | 20.00 d | 28.00 d | 36.33 e |
| $V_3T_2$ | 46.00 f | 67.00 g | 86.67 g | 95.33 f | 54.33 e | 100.7 e | 115.3 fg | 16.00 f | 23.67 g | 32.67 h |
| $V_3C_3$ | 39.67 i | 61.33 j | 81.33 j | 89.90 i | 40.00 h | 83.33 g | 102.0 i | 12.33 h | 19.67 j | 27.33 k |
| LSD (5%) | 0.9124 | 0.8114 | 1.074 | 0.9649 | 3.467 | 5.150 | 3.403 | 0.6904 | 0.6856 | 0.6357 |
| CV% | 3.80% | 2.35% | 2.45% | 2.02% | 11.69% | 10.10% | 5.71% | 7.71% | 5.41% | 3.75% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$V_1C_0$ = Hybrid Hira × Control (distilled water), $V_1C_1$ = Hybrid Hira × 10.0% leaf extract, $V_1C_2$ = Hybrid Hira × 15.0% leaf extract, $V_1C_3$ = Hybrid Hira × 20.0% leaf extract; $V_2C_0$ = BRRI Dhan 28 × Control (distilled water), $V_2C_1$ = BRRI Dhan 28 × 10.0% leaf extract, $V_2C_2$ = BRRI Dhan 28 × 15.0% leaf extract, $V_2C_3$ = BRRI Dhan 28 × 20.0% leaf extract; $V_3C_0$ = BRRI Dhan 29 × Control (distilled water), $V_3C_1$ = BRRI Dhan 29 × 10.0% leaf extract, $V_3C_2$ = BRRI Dhan 29 × 15.0% leaf extract, $V_3C_3$ = BRRI Dhan 29 × 20.0% leaf extract.

**Table 9: Interaction effect of different varieties and various concentration of eucalyptus leaf extracts on yield contributing characters and yield of rice**

| Interaction | Number of tiller/ hill at harvest time | Number of effective tiller/ hill | Number of sterile tiller/ hill | Penicle length | Weight of grain/panicle | Number of spikelet/ panicle | Number of filled grain/ panicle | Number of unfilled grain/ panicle |
|---|---|---|---|---|---|---|---|---|
| $V_1C_0$ | 41.33 a | 39.00 a | 7.000 a | 24.17 a | 2.460a | 161.3 a | 142.7 a | 21.33 a |
| $V_1C_1$ | 37.00 d | 33.67 d | 6.000 b | 22.57 d | 2.131d | 145.3 d | 128.0 c | 15.00 c |
| $V_1C_2$ | 34.00 g | 29.33 g | 4.000 e | 22.57 d | 1.920g | 138.7 g | 119.7 ef | 12.00 f |
| $V_1C_3$ | 30.33 j | 26.67 i | 3.000 g | 19.67 j | 1.750i | 132.7 i | 115.0 h | 9.000 i |
| $V_2C_0$ | 38.67 c | 34.67 c | 6.000 b | 22.73 c | 2.240c | 150.0 c | 135.3 b | 15.00 c |
| $V_2C_1$ | 35.00 f | 30.67 f | 4.333 d | 21.50 f | 2.010f | 140.0 f | 121.3 e | 13.00 e |
| $V_2C_2$ | 31.33 i | 27.00 i | 3.000 g | 20.51 i | 1.760i | 133.7 i | 117.3 g | 10.00 h |
| $V_2C_3$ | 25.33 l | 23.33 k | 1.333 i | 17.53 l | 1.585k | 126.7 k | 108.7 j | 7.000 k |
| $V_3C_0$ | 40.00 b | 36.00 b | 7.000 a | 23.57 b | 2.403b | 157.3 b | 140.7 a | 17.67 b |
| $V_3C_1$ | 36.00 e | 31.67 e | 5.333 c | 21.97 e | 2.067 e | 142.0 e | 124.3 d | 14.00 d |
| $V_3T_2$ | 32.67 h | 28.33 h | 3.333 f | 20.87 h | 1.837 h | 136.0 h | 117.7 fg | 11.00 g |
| $V_3C_3$ | 28.33 k | 24.67 j | 2.333 h | 18.90 k | 1.693j | 136.0 h | 111.7 i | 8.000 j |
| LSD (5%) | 0.4418 | 0.6008 | 0.1262 | 0.09264 | 0.050 | 1.174 | 2.075 | 0.2333 |
| CV% | 2.61% | 3.99% | 5.80% | 0.88% | 1.71% | 1.68% | 3.39% | 3.70% |

The figures in a column having common letter(s) do not differ significantly at 5% level of significance as per DMRT.

$V_1C_0$ = Hybrid Hira × Control (distilled water), $V_1C_1$ = Hybrid Hira × 10.0% leaf extract, $V_1C_2$ = Hybrid Hira × 15.0% leaf extract, $V_1C_3$ = Hybrid Hira × 20.0% leaf extract; $V_2C_0$ = BRRI Dhan 28 × Control (distilled water), $V_2C_1$ = BRRI Dhan 28 × 10.0% leaf extract, $V_2C_2$ = BRRI Dhan 28 × 15.0% leaf extract, $V_2C_3$ = BRRI Dhan 28 × 20.0% leaf extract; $V_3C_0$ = BRRI Dhan 29 × Control (distilled water), $V_3C_1$ = BRRI Dhan 29 × 10.0% leaf extract, $V_3C_2$ = BRRI Dhan 29 × 15.0% leaf extract, $V_3C_3$ = BRRI Dhan 29 × 20.0% leaf extract.

### 4.2.3 Number of Tiller per Hill

The difference of number of tiller (GP) due to the allelopathy effect was statistically significant (Table 4). At 30 DAT of rice seed the highest number of tiller (23.78) was found at control condition whereas the lowest (12.44) was recorded at 20% leaf aqueous extract. Similarly at 30 and 60 DAT of rice seed the highest number of tiller was found at control condition whereas the lowest was recorded at 20% leaf aqueous extract. The result showed that number of tiller decreased markedly with the increasing the concentration.

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of number of tiller which was statistically significant (Table 6). At 30 DAT of rice seed the highest number of tiller (20.42) was recorded in hybrid and the lowest number of tiller (15.92) was found in BRRI Dhan 28. At 60 DAT of rice seed the highest number of tiller (36.00) was recorded in hybrid and the lowest number of tiller (32.67) was found in BRRI Dhan 28. The result showed that different varieties had different degrees of concentration in relation to number of tiller.

The interaction effect between eucalyptus leaf extract and the varieties on number of tiller was statistically significant at different concentration of eucalyptus leaf extract (Table 8). The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At 30 DAT in control condition the highest number of tiller (28.33) was observed in hybrid and the lowest number of tiller (19.67) was recorded from BRRI Dhan 28. At 30 DAT in 20% condition the highest number of tiller (14.67) was observed in hybrid and the lowest number of tiller (10.33) was recorded from BRRI Dhan 28.

### 4.2.4 Plant Height at Harvest Time

Plant height at harvest time (PHHT) affected significantly by eucalyptus leaf extract (Table 4). Without eucalyptus leaf extract, the highest Phh (103.3 ) was found whereas the lowest (89.37) was found at 20% concentration. The result showed that Phh decreased with increasing concentration.

Different varieties had different degrees of tolerance to eucalyptus leaf extract in relation to PHHT (Table 6). Hybrid recorded the highest values of Phh (98.32) whereas, BRRI Dhan 28 recorded the lowest values (94.78) of PHHT.

The interaction effect between eucalyptus leaf extract and the varieties on Phh was significant (Table 8). The highest Plant height at harvest time (105.7) was observed in Hybrid with control treatment condition and the lowest Plant height at harvest time (101.3) was recorded from BRRI Dhan 29. On the other hand, at 20% treatment condition the highest Plant height at harvest time (91.37) was observed in Hybrid and the lowest Plant height at harvest time (86.83) was recorded from BRRI Dhan 28 which was statistically similar with BRRI Dhan 28.

### 4.2.5 Number of Tiller/ hill at Harvest Time

Increasing eucalyptus leaf extract concentration causes a significant decrease of number of tiller/ hill (Table 4). The highest number of tiller/ hill (40.00) was found with control condition whereas the lowest (28.00) was found at 20% concentration.

Effect of eucalyptus leaf extract on different varieties was statistically significant (Table 6).The degree of reduction of number of tiller/ hill was not similar for all varieties from control to highest level of concentration. The number of tiller/ hill have been shown to reduce drastically with rising concentration and the magnitude of reduction was more in BRRI Dhan 28 (32.58) whereas the highest number of tiller/ hill (35.67) was recorded in Hybrid. The result showed that different varieties had different degrees of eucalyptus leaf extract tolerance in relation to number of tiller/ hill.

The interaction effect between eucalyptus leaf extract and the varieties on number of tiller/ hill was significant at different concentration (Table 8). Hybrid was the least affected than the other varieties. The highest number of tiller/ hill (41.33) was observed in Hybrid at control and besides this the lowest number of tiller/ hill (38.67) was recorded from BRRI Dhan 28. At 20% concentration the highest number of tiller/ hill (30.33) was observed in Hybrid and the lowest number of tiller/ hill (25.33) was recorded from BRRI Dhan 28.

### 4.2.6 Number of Effective Tiller/ hill

There were significant differences on number of effective tiller/ hill at various level of eucalyptus leaf extract (Table 5). The tallest number of effective tiller/ hill (36.56) was found under control condition than that of growing fewer than 20% concentration (24.89).

The performance of different rice varieties was significant in respect of number of effective tiller/ hill under allelopathic condition (Table 7). Hybrid showed the highest number of effective tiller/ hill (32.167) while the lowest number of effective tiller/ hill (28.917) was recorded in BRRI Dhan 28.

The interaction effect between eucalyptus leaf extract and the varieties on number of effective tiller/ hill was significant at different concentration (Table 9). The largest number of effective tiller/ hill (39.00 and 26.67) was observed in Hybrid both at control and 20% concentration, respectively. The shortest number of effective tiller/ hill (34.67and 23.33) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively.

### 4.2.7 Number of Sterile Tiller/ hill

The difference of number of sterile tiller/ hill (GP) due to the allelopathy effect was statistically significant (Table 5). At 30 DAT of rice seed the highest number of sterile tiller/ hill (6.667) was found at control condition whereas the lowest (2.222) was recorded at 20% leaf aqueous extract. The result showed that number of sterile tiller/ hill decreased markedly with the increasing the concentration.

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of number of sterile tiller/ hill which was statistically significant (Table 7). At 30 DAT of rice seed the highest number of sterile tiller/ hill (5.000) was recorded in hybrid and the lowest number of sterile tiller/ hill (3.667) was found in BRRI Dhan 28.The result showed that different varieties had different degrees of concentration in relation to number of sterile tiller/ hill.

The interaction effect between eucalyptus leaf extract and the varieties on number of sterile tiller/ hill was statistically significant at different concentration of eucalyptus leaf extract (Table 9). The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At control condition the highest number of sterile tiller/ hill (7.000) was observed in hybrid and lowest number of sterile tiller/ hill (6.000) was found in BRRI Dhan 28.

### 4.2.8 Penicle Length

The difference of Penicle length (GP) due to the allelopathy effect was statistically significant (Table 5). At 30 DAT of rice seed the highest Penicle length (23.49) was found at control condition whereas the lowest (18.70) was recorded at 20% leaf aqueous extract.

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of Penicle length which was statistically significant (Table 7). The highest Penicle length (21.883) was recorded in hybrid and the lowest Penicle length(20.568) was found in BRRI Dhan 28. The result showed that different varieties had different degrees of concentration in relation to number of leaves.

The interaction effect between eucalyptus leaf extract and the varieties on Penicle length was statistically significant at different concentration of eucalyptus leaf extract (Table 9). The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. In control condition the highest Penicle length (24.17) was observed in hybrid.

### 4.2.9 Weight of Grain/panicle

The difference of number of tiller (GP) due to the allelopathy effect was statistically significant (Table 5). the highest weight of grain/panicle (2.368) was found at control condition whereas the lowest (1.676) was recorded at 20% leaf aqueous extract..

Different rice varieties showed different degrees of response to eucalyptus leaf extract in respect of number of tiller which was statistically significant (Table 7). The highest weight of grain/panicle (2.065) was recorded in hybrid and the lowest weight of grain/panicle (1.899) was found in BRRI Dhan 28. The result showed that different varieties had different degrees of concentration in relation to number of tiller.

The interaction effect between eucalyptus leaf extract and the varieties on weight of grain/panicle was statistically significant at different concentration of eucalyptus leaf extract (Table 9). The tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. In control condition the highest weight of grain/panicle (2.460) was observed in hybrid and the lowest number of tiller (2.240) was recorded from BRRI Dhan 28. In 20% condition the highest weight of grain/panicle (1.750) was observed in hybrid and the lowest number of tiller (1.585) was recorded from BRRI Dhan 28.

### 4.2.10 Number of Spikelet/ panicle

Number of spikelet/ panicleaffected significantly by eucalyptus leaf extract (Table 5). Without eucalyptus leaf extract, the highest number of spikelet/ panicle (156.2) was found whereas the lowest (130.0) was found at 20% concentration. The result showed that number of spikelet/ panicle decreased with increasing concentration.

Different varieties had different degrees of tolerance to eucalyptus leaf extract in relation to number of spikelet/ panicle (Table 7). Hybrid recorded the highest values of number of spikelet/ panicle (144.5) whereas, BRRI Dhan 28 recorded the lowest values (137.5) of Phh.

The interaction effect between eucalyptus leaf extract and the varieties on number of spikelet/ paniclewas significant (Table 9). The highest number of spikelet/ panicle (161.3) was observed in Hybrid with 5% treatment condition and the lowest number of spikelet/ panicle (150.0) was recorded from BRRI Dhan 29. On the other hand, at 20% treatment condition the highest number of spikelet/ panicle (132.7) was observed in Hybrid and the lowest number of spikelet/ panicle (126.7) was recorded from BRRI Dhan 29 which was statistically similar with BRRI Dhan 28.Similar type of result was observed by Sasikumar *et al.* (2006).

### 4.2.11 Number of Filled Grain/ panicle

Increasing eucalyptus leaf extract concentration causes a significant decrease of number of filled grain/ panicle (Table 5). The highest number of filled grain/ panicle (139.6) was found with control condition whereas the lowest (111.8 ) was found at 20% concentration.

Effect of eucalyptus leaf extract on different varieties was statistically significant (Table 7). The degree of reduction of number of filled grain/ panicle was not similar for all varieties from control to highest level of concentration. The number of filled grain/ panicle have been shown to reduce drastically with rising concentration and the magnitude of reduction was more in BRRI Dhan 28 (120.7) whereas the highest number of filled grain/ panicle (126.3) was recorded in Hybrid. The result showed that different varieties had different degrees of eucalyptus leaf extract tolerance in relation to number of filled grain/ panicle.

The interaction effect between eucalyptus leaf extract and the varieties on number of filled grain/ panicle was significant at different concentration (Table 9). Hybrid was the least affected than the other varieties. The highest number of filled grain/ panicle (142.7) was observed in Hybrid at control and besides this the lowest number of filled grain/ panicle (135.3) was recorded from BRRI Dhan 29. At 20% concentration the highest number of filled grain/ panicle (115.0) was observed in Hybrid and the lowest number of filled grain/ panicle (108.7) was recorded from BRRI Dhan 28 which was statistically significant with BRRI Dhan 29.

### 4.2.12 Number of Unfilled Grain/ panicle

There were significant differences on number of unfilled grain/ panicleat various level of eucalyptus leaf extract (Table 5). The tallest number of unfilled grain/ panicle (18.00) was found under control condition than that of growing fewer than 20% concentration (8.000).

- The performance of different rice varieties was significant in respect of root growth under allelopathic condition (Table 7). Hybrid showed the highest number of unfilled grain/ panicle (14.33) while the lowest number of unfilled grain/ panicle (11.25) was recorded in BRRI Dhan 28.

The interaction effect between eucalyptus leaf extract and the varieties on number of unfilled grain/ paniclewas significant at different concentration (Table 9). The largest number of unfilled grain/ panicle(21.33and 9.000) was observed in Hybrid both at control and 20% concentration, respectively. The shortest number of unfilled grain/ panicle (15.00 and 7.00) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively.

# CHAPTER FIVE

# SUMMARY, CONCLUSION AND RECOMMENDATIONS

# CHAPTER FIVE

# SUMMARY, CONCLUSION AND RECOMMENDATIONS

## 5.1 Summary

Selection of allelopathic tolerant rice varieties may be a feasible and economical approach for utilizing tree species with cereals crops in the Bangladesh. To evaluate germination characters and seedling growth of rice as screening criteria against eucalyptus leaf extract, three rice genotypes were tested at Agroforestry Laboratory, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur. The seeds of three rice varieties were placed in plastic pots (7.5 cm diameter and 11.3 cm height) on sand area irrigated with tap water (control) and eucalyptus leaf extract (10, 15 and 20% concentration) solution. Again the seeds of same rice genotypes were placed in plastic pots (14 cm diameter and 13 cm height) irrigated with distilled water (control) and eucalyptus leaf extract (10, 15 and 20% concentration) solution in a net house.

Incase of Germination the highest germination (25.00) was observed in hybrid which are statistically similar with BRRI Dhan 29 and BRRI Dhan 28. Again at 7 days after placement (DAP) in 20% condition the highest germination (23.00) was observed in hybrid and the lowest germination (22.33) was recorded from BRRI Dhan 28. For normal seedling the highest normal seedling (28.67) was observed in hybrid with control condition and the lowest normal seedling (26.67) was recorded from BRRI Dhan 29. On the other hand, at 20% treatment condition the highest normal seedling (17.00) was observed in Hybrid and the lowest normal seedling (14.00) was recorded from BRRI Dhan 29. Incase of abnormal seedling, the highest abnormal seedling (9.667) was observed in Hybrid at control and besides this the lowest abnormal seedling (7.0) was recorded from BRRI Dhan 29. At 20% concentration the highest abnormal seedling (0.6667) was observed in Hybrid and the lowest abnormal seedling (0.00) was recorded from BRRI Dhan 28 which was statistically significant with BRRI Dhan 29. For shoot, the shoot length at control was significantly greater than the subsequent higher concentration (20%) for all the varieties. The tallest shoot length (6.94cm) was observed in Hybrid at control condition and the shortest shoot length (5.820cm) was recorded from BRRI Dhan 28. At 20%, the tallest shoot length (2.713 cm) was observed in Hybrid and the shortest shoot length (2.073cm) was recorded from BRRI Dhan 28. The largest root length (7.633cm and 0.860cm) was observed in Hybrid both at control and 20% concentration, respectively. The shortest root length (5.380cm and 0.640cm) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively. For root, the highest root number (6.667and 1.667) was observed in Hybrid both at control and 20% concentration, respectively. The shortest root length (5.667 and 1.00) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively.

Incase of plant height the highest plant height (62.17) was observed in hybrid and lowest plant height (53.53) was found in BRRI Dhan 28. Similarly at 40 and 60 days after transplanting (DAT) of rice seed the highest plant height was found in hybrid whereas the lowest was recorded in BRRI Dhan 28. For number of leaves, the tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At 30 DAT in control condition the highest number of leaves (85.67) was observed in hybrid and the lowest number of leaves (69.67) was found in BRRI Dhan 28. Similarly at 40 and 60 DAT of rice seed the highest plant height was found in hybrid whereas the lowest was recorded in BRRI Dhan 28. Incase of number of tiller, the highest number of tiller (28.33) was observed in hybrid and the lowest number of tiller (19.67) was recorded from BRRI Dhan 28. At 30 DAT in 20% condition the highest number of tiller (14.67) was observed in hybrid and the lowest number of tiller (10.33) was recorded from BRRI Dhan 28. For plant height, the highest Plant height at harvest time (105.7) was observed in Hybrid with control treatment condition and the lowest Plant height at harvest time (101.3) was recorded from BRRI Dhan 29. On the other hand, at 20% treatment condition the highest Plant height at harvest time (91.37) was observed in Hybrid and the lowest Plant height at harvest time (86.83) was recorded from BRRI Dhan 28 which was statistically similar with BRRI Dhan 28. For effective tiller, the highest number of tiller/ hill (41.33) was observed in Hybrid at control and besides this the lowest number of tiller/ hill (38.67) was recorded from BRRI Dhan 28. At 20% concentration the highest number of tiller/ hill (30.33) was observed in Hybrid and the lowest number of tiller/ hill (25.33) was recorded from BRRI Dhan 28. Incase of sterile tiller, the largest number of effective tiller/ hill (39.00 and 26.67) was observed in Hybrid both at control and 20% concentration, respectively. The shortest number of effective tiller/ hill (34.67and 23.33) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively. For grain weight, the tendency of inhibition at 5, 10, 15 and 20% treatments was not similar for all the varieties. At control condition the highest number of sterile tiller/ hill (7.000) was observed in hybrid and lowest number of sterile tiller/ hill (6.000) was found in BRRI Dhan 28. For spikelet, the highest number of spikelet/ panicle (161.3) was observed in Hybrid with 5% treatment condition and the lowest number of spikelet/ panicle (150.0) was recorded from BRRI Dhan 29. On the other hand, at 20% treatment condition the highest number of spikelet/ panicle (132.7) was observed in Hybrid and the lowest number of spikelet/ panicle (126.7) was recorded from BRRI Dhan 29 which was statistically similar with BRRI Dhan 28.Similar type of result was observed by Sasikumar *et al.* (2006). Incase of filled grain, the highest number of filled grain/ panicle (142.7) was observed in Hybrid at control and besides this the lowest number of filled grain/ panicle (135.3) was recorded from BRRI Dhan 29. At 20% concentration the highest number of filled grain/ panicle (115.0) was observed in Hybrid and the lowest number of filled grain/ panicle (108.7) was recorded from BRRI Dhan 28 which was statistically significant with BRRI Dhan 29. For unfilled grain, the largest number of unfilled grain/ panicle (21.33and 9.000) was observed in Hybrid both at control and 20% concentration, respectively. The shortest number of unfilled grain/ panicle (15.00 and 7.00) was recorded from BRRI Dhan 28 at control and 20% concentration, respectively.

### 5.2 Conclusion

The result of the experiment revealed that the morphological and physiological parameters of rice plant affected considerably due to allelopathic effect of eucalyptus leaves. The longest shoot length, root length , plant height, number of leaves, number of tiller, plant height at harvest time, number of tiller/hill, number of effective tiller/hill, number of sterile tiller/ hill, penicle length, weight of grain/panicle, number of spikelet/ panicle, number of unfilled grain/ panicle, number of filled grain/ panicle, were obtained from the control condition. On the other hand the shortest shoot length, root length, Plant height, number of leaves, number of tiller, plant height at harvest time, number of tiller/ hill, number of effective tiller/ hill, number of sterile tiller/ hill, Penicle length, weight of grain/panicle, number of spikelet/ panicle, number of unfilled grain/ panicle, number of filled grain/ panicle, and minimum yield contributing characters were obtained with 20% solution treated plants. Among the three rice varieties hybrid showed the highest number of filled grain/ panicle, while the BRRI Dhan 28 provided lower number of filled grain/ panicle at all the concentration of eucalyptus leaf extracts.Finally It can be concluded that hybrid was the best varieties in allelopathic condition of eucalyptus as compared to other variesties (i.e. BRRI Dhan 28 and BRRI Dhan 29). Moreover, if the leaf concentration was increased then the inhabition of rice was occurred.

**5.3 Recommendations**

- Different remedial practices (like removal of excess leaf litters, planting after the rains) should be done before planting rice, in land previously planted with *Eucalyptus* in order to reduce the potential risks.
- It should carry out long-term field based studies to investigate the significance of these results.
- Further studies are needed in different agro-ecological zones of the country in order to develop a general guideline for minimize the allelopathic effect under eucalyptus tree for optimizing yield of rice.

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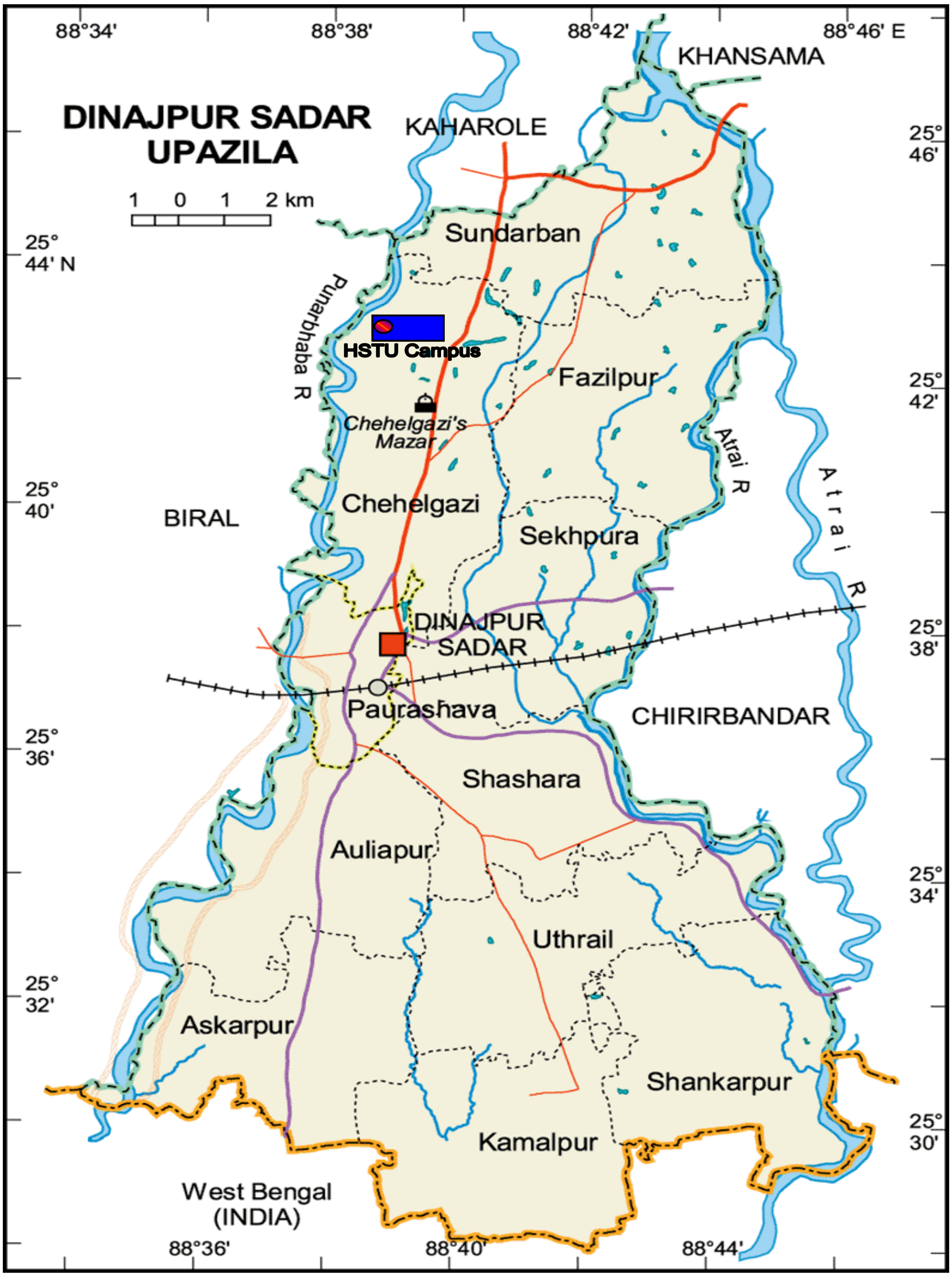
# APPENDICES

# APPENDICES

**Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research area).**



**Appendix II.Weather data of the experimental site during the period from January to July, 2016.**

| Month | Air Temperature (°C) | | | *Rainfall (mm) | Relative Humidity (%) |
|---|---|---|---|---|---|
| | Minimum | Maximum | Average | | |
| January | 10.5 | 22.0 | 16.25 | 24.0 | 86.0 |
| February | 13.4 | 26.9 | 20.15 | 0.0 | 80.0 |
| March | 16.9 | 30.7 | 23.80 | 25.5 | 74.0 |
| April | 20.1 | 31.0 | 25.55 | 66.0 | 70.0 |
| May | 22.6 | 32.7 | 27.65 | 331.5 | 76.0 |
| June | 24.7 | 32.1 | 28.40 | 282.0 | 85.0 |
| July | 25.0 | 32.8 | 28.90 | 255.0 | 80.0 |

**Appendix III. The physical and chemical properties of soil used in the experiment.**

| 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 (SRDI), Dinajpur-5200

**Appendix-IV: Some plates on my research experiment**

Plate 1: Drying (Air drying and Oven drying 40°C) of Leaves and Making Dust of Eucalyptus leaves

Plate 2: Different concentrations preparation from eucalyptus leaves


Plate 3: Seeds were sown in petridishes in agroforestry laboratory

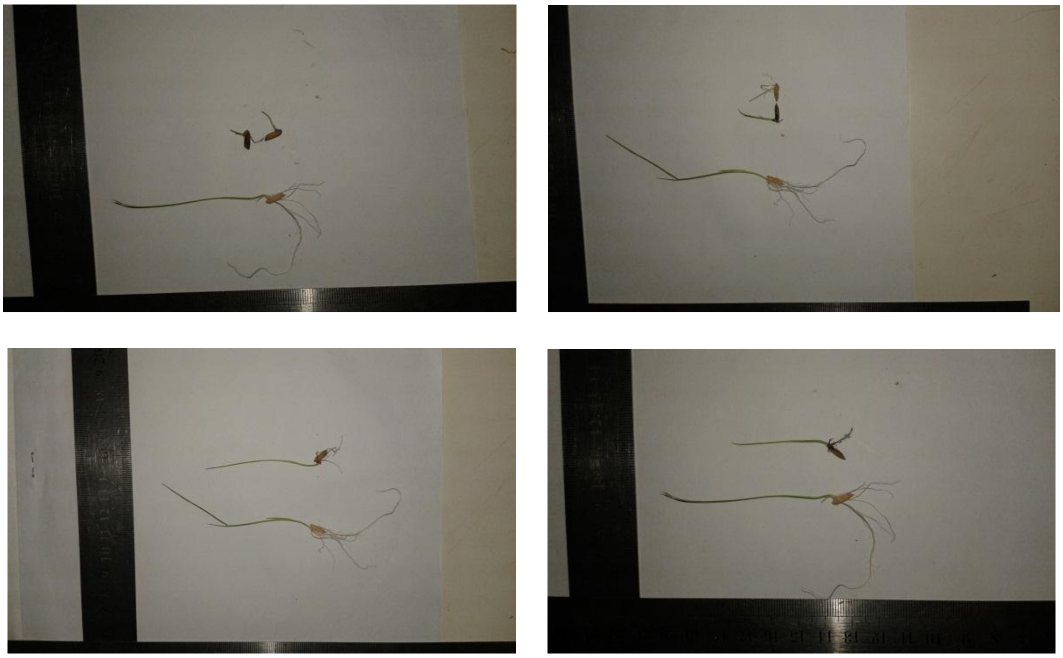


Plate 4: Morphological measurements of rice seedlings (Normal and Abnormal)

Plate 5: Seedling planting in pot (0.14 $m^2$)

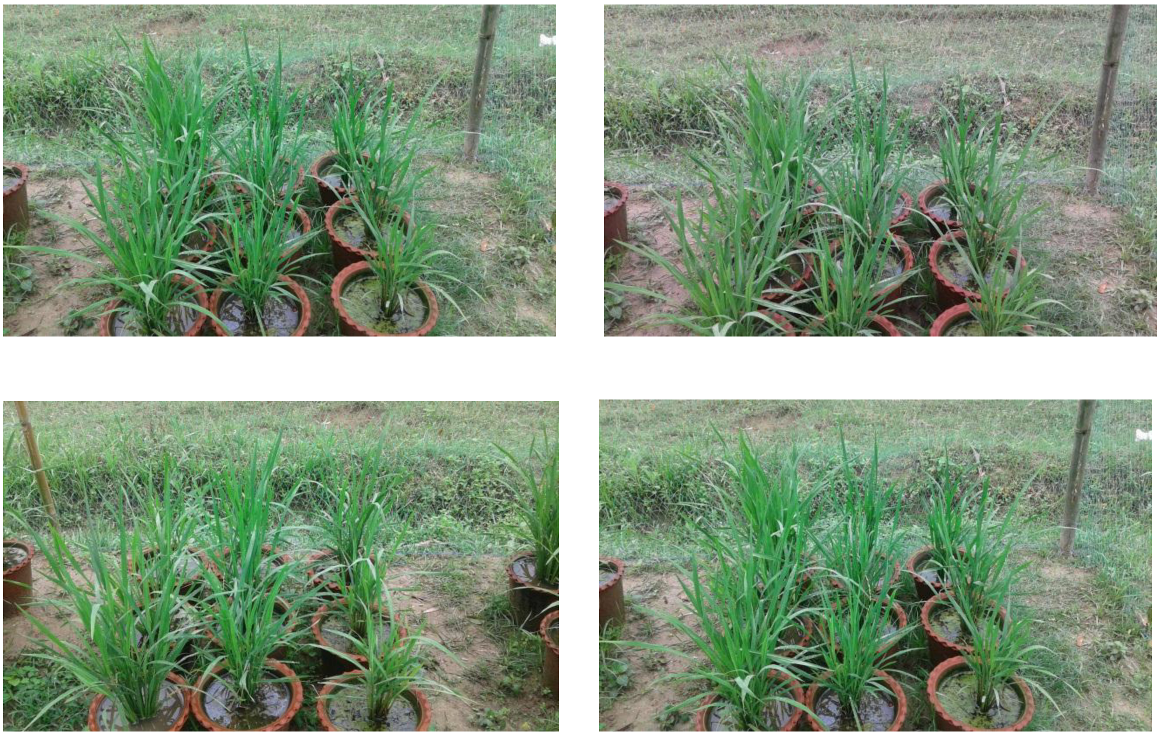


Plate 6: Pot of 30 DAP in research field

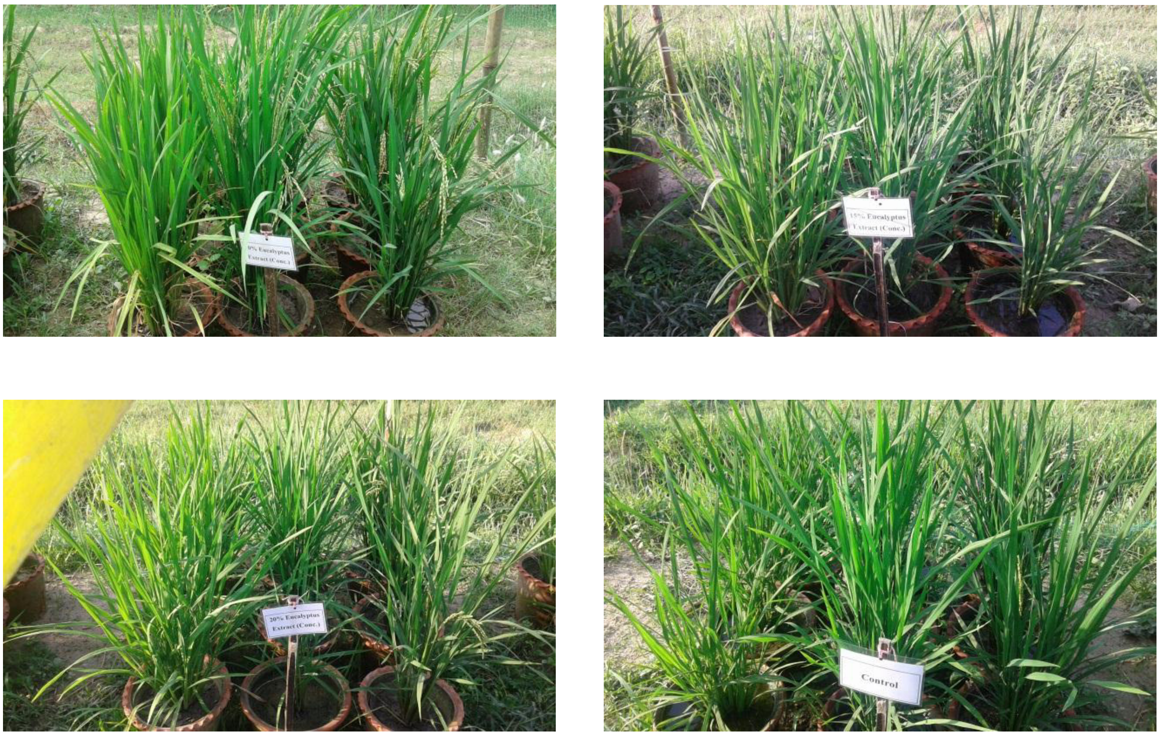



Plate 7: Pot of 45 DAP in research field

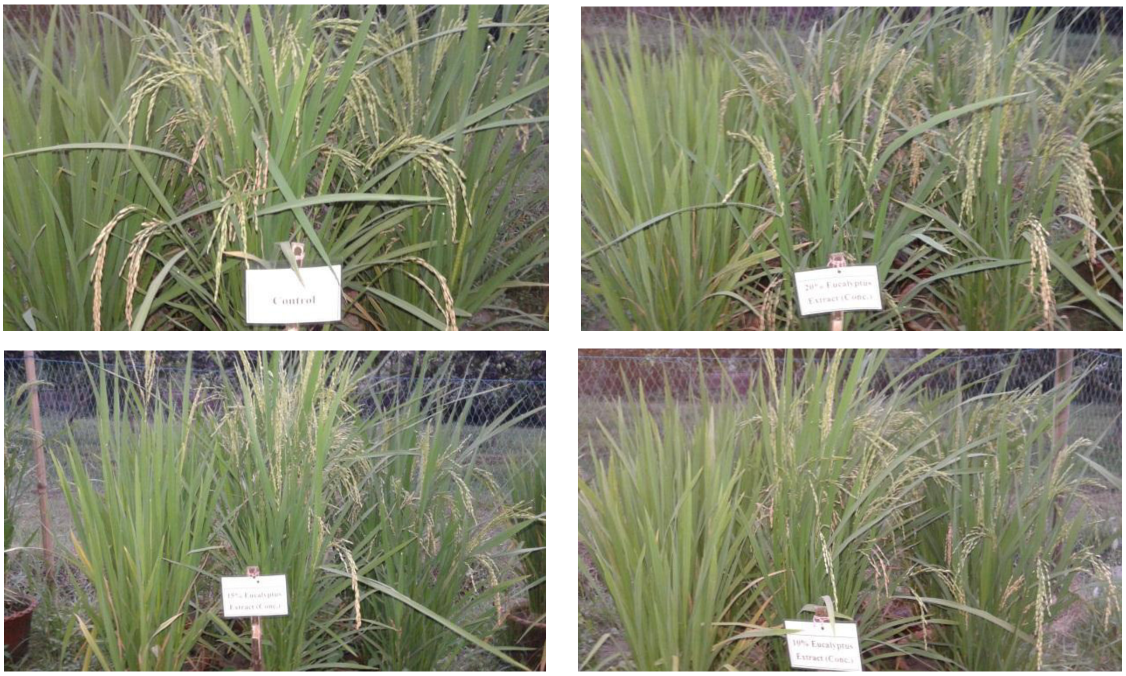



Plate 8: Pot of 60 DAP in research field

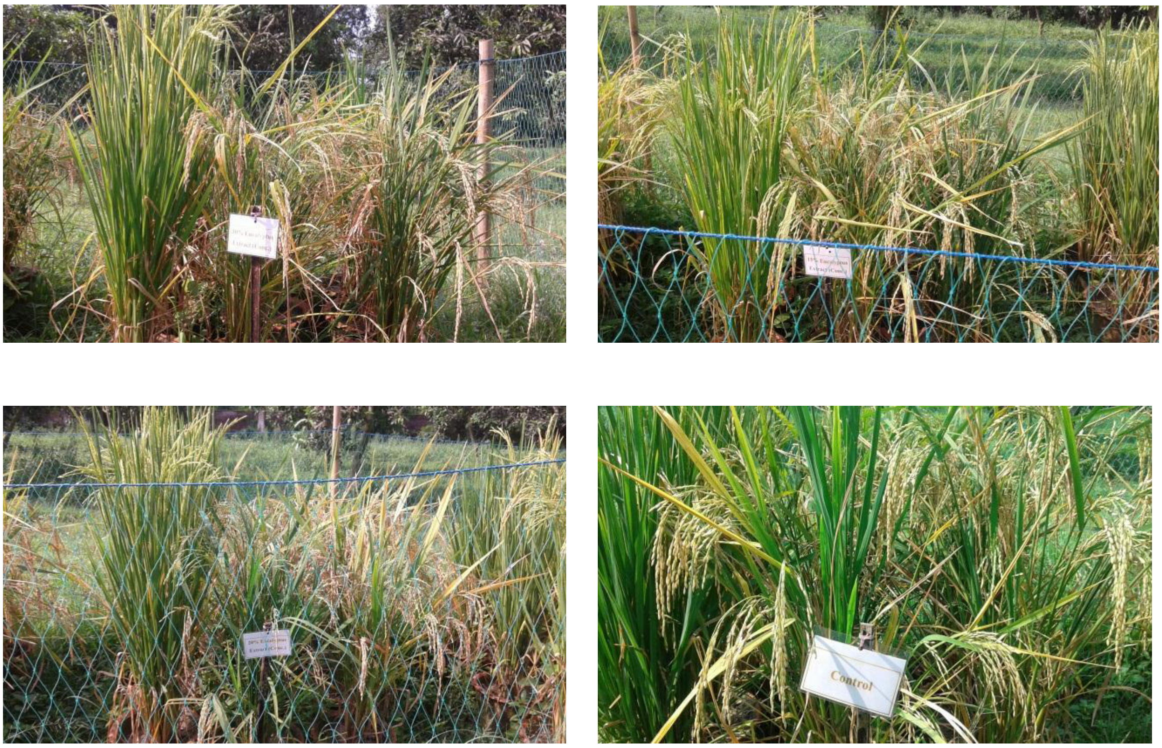



Plate 9: At the harvesting time


Plate 10: After harvesting before identification of filled grain and unfilled grain