PHYTOTOXIC EFFECTS OF *Eucalyptus camaldulensis* ON SOME SELECTED MONOCOT AND DICOT PLANT SPECIES

MD. UZZAL HOSSEN

DEPARTMENT OF AGRICULTURAL CHEMISTRY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA-1207

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BY

MD. UZZAL HOSSEN
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Approved by:

Supervisor	Co-Supervisor
Dr. Mohammed Ariful Islam	**Dr. Md. Sirajul Islam Khan**
Professor	**Associate Professor**
Department of Agricultural Chemistry	**Department of Agricultural Chemistry**

Dr. Md. Sirajul Islam Khan
Chairman
Department of Agricultural Chemistry
Examination Committee

DEPARTMENT OF AGRICULTURAL CHEMISTRY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No: SAU/AGCH

CERTIFICATE

*This is to certify that the thesis entitled, "**Phytotoxic effects of Eucalyptus camaldulensis on some selected monocot and dicot plant species**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL CHEMISTRY, embodies the result of a piece of bonafide research work carried out by **Md.Uzzal Hossen** , Registration No.:11-04641 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.

Dated: June, 2017
Place: Dhaka, Bangladesh

Supervisor
Dr. Mohammed Ariful Islam
Professor
Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University

Dedicated to
My Beloved Parents

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ABSTRACT

The present study was conducted to investigate the phytotoxic effects of aqueous methanol extract on leaf and bark of *Eucalyptus camaldulensis* on germination and seedling growth of some selected monocot (foxtail millet and barnyard grass) and dicot (cauliflower, broccoli and tomato) plant species from June 2016 to June 2017. The aqueous methanol extract obtained from leaf and bark of eucalyptus followed six different concentrations (T_0= 0 g mL^{-1}, T_1=0.001 g mL^{-1}, T_2=0.003 g mL^{-1}, T_3=0.01 g mL^{-1}, T_4=0.3 g mL^{-1}, T_5=0.1 g mL^{-1}) were tested on five test species under laboratory condition. The aqueous extract obtained from leaf of eucalyptus were tested on five test species under net house at six different concentrations (T_0= 0 ppm, T_1=1 ppm, T_2=2 ppm, T_3=3 ppm, T_4=4 ppm, T_5=5 ppm). Rsults revealed that a pronounced inhibitory effect of the aqueous and aqueous methanol leaf and bark extract of eucalyptus was observed on seed germination and seedling growth of five test plant species. The germination efficiency, plumule and radicle length and dry weight of plants were completely inhibited at the highest concentration of aqueous extracts (0.1g mL^{-1}) whereas least inhibition was observed at control at both laboratory and field condition. Maximum treatment effect was observed in germination and seedling growth of monocot plants (foxtail millet and barnyard grass) followed by three dicot plants (cauliflower, broccoli and tomato). Since foxtail millet and barnyard grass was mostly affected by different treatment effect, thus phytotoxic effect of eucalyptus may reduce weed competition with crops by affecting the germination and seedling growth of foxtail millet and barnyard grass. Therefore, it is possible to use these extracts as a component for production of bio-herbicides due to their phytotoxic effects on weeds and crops and considered as a natural way for sustainable weed management.

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CHAPTER I

INTRODUCTION

Phytotoxicity is defined as a delay of seed germination, inhibition of plant growth or any adverse effect on plants caused by specific substances (phytotoxins) or growing conditions (WRAP, 2002) . Phototoxicity in plants usually occurs in those that are overly sensitive to chemicals. It can also occur when tank mixed chemicals are applied in hot weather or when an adjuvant or solvent is added to the tank mixture. Stressed plants are also more prone to sensitivity than those that are well watered and healthy. Basically it is a toxic effect by a compound on plant growth. Such damage may be caused by a wide variety of compounds, including trace metals, salinity, pesticides, phytotoxins or allelochemicals. It is the degree of toxic effect of these chemical compounds on plant growth which creates a condition in a given substance in the environment is harmful to plants.

Eucalyptus camaldulensis is the most widespread member of its genus in Australia, where it is primarily a riparian species (Hillis, 1966). It thrives in plantations throughout much of the warm temperate world. It is concluded that eucalypt planting can be vastly expanded in Bangladesh without a serious impact on the environment and that environmental confusions of the use of eucalypts can be minimized in stand management with appropriate techniques. Eucalypts are favored due to their high productive potential and found superior to other species. Some 456,000 ha is assessed as suitable for eucalypt planting which on short rotations can produce 6-8 times more stem wood than present forest crops; highway and feeder road planting area are available, equivalent to 988,000 ha and could produce energy roughly 20 times more than present crude oil imports ($200 million/yr). No negative reaction to eucalyptus planting were noted by village people, a review showed 80% in favour of short rotation species with emphasis on cash crop objectives of fuel production. It is considered that further extension and explanation of land resource allocation and management inputs would increase choice of eucalypts because the crown structure is suitable for combination with agricultural crops. Problems of allelopathy, nutrient depletion and water use are considered together with appropriate management techniques. The lack of in country improved seed/plant sources is noted as is the need to develop markets and uses to increase the economic importance of eucalypt wood production. It is widely held in some countries, notably Indian region that eucalypts are strongly phytotoxic; that they produce foliar and root exudates directly toxic to other plants. This may not be true in all cases. It is more likely that the effect of eucalypt on understory plants or adjacent crops is the result of the very great capacity of eucalyptus to compete for short supply soil resources (nutrients and water). Where soil resources are not in short supply the understory vegetation may be maintained under a vigorous tree canopy.

Phytotoxicity is a biological phenomenon by which an organism produces one or more biochemicals that influence the germination, growth, survival, and reproduction of other organisms. These biochemicals are known as phytotoxins and can have beneficial or detrimental effects on the target organisms and the community. Phytotoxins are a subset of secondary metabolites, which are not required for metabolism (i.e. growth, development and reproduction) of the phytotoxic organism. Phytotoxins with negative allelopathic effects are an important part of plant defense against herbivore.

Allelopathy has been widely discussed and reviewed in recent years (eg., Barner, 1960; Evenari, 1961; Grodzinsky. 1965). Many plants have been shown to contain toxins and these have been specifically identified in numerous instances. Similarly, interference by one plant with the growth of another has in many cases been shown to be chemical in nature. Significant quantities of plant toxins in the environment have also been demonstrated. But in very few studies has a single instance of apparent allelopathy been successfully investigated from all these points of view.

Phytotoxicity must be considered as an ecological factor of wide significance, capable of influencing succession, dominance, vegetation dynamics, species diversity, community structure and productivity. Floyd and Rice (l967) and Wilson and Rice (1968) demonstrated the importance of phenolic compounds in altering the rate and nature of old field succession. Muller (1966) discussed the role of terpenes from *Saluia leucophylla* and other aromatic shrubs in the production of stands of single species dominance. Such stands alter immunity, productivity and diversity. The production and release of toxic chemicals by plants and their subsequent effective action in the environment constitute a process of obvious ecological significance.

The interaction of plants through chemical signals (allelopathy) has many possible agricultural applications. Decline in crop yields in cropping and agro-forestry system in recent years has been attributed to allelopathic effects. Allelopathy associated problems have been observed both in monocultures and multiples cropping system, continuous monoculture causes the accumulation of phytotoxins and harmful microbes in soil, which give rise to phytoxicity and soil thickness. Crop rotation is practiced to eliminate the effect of monoculture, but the succeeding crop may be influenced by the phytotoxins released by the preceding crop. A large number of weeds and trees possess allelopathic properties which have growth inhibiting effect on crops. Allelopathy also plays an important role in suppressing the growth of weed plants. Struggle for space and nutrients for propagation, continuity and university is the most powerful law of nature. In this trend, some plants have allelopathic potential by releasing allelochemicals to their surrounding that have either deleterious or beneficial effects on other plants. These compounds inhibited plant growth by affecting many physiological processes among them, the effect on ion uptake and hydraulic conductivity (i.e. water uptake) are particularly important since the root is the first organ to come into contact with the allelochemicals in the rhizosphere. The degree of inhibition depends on their concentration. Some plant genotypes are likely to escape the allelopathic chemical(s) by being "hypersensitive". In this regards the root tip may actually be strongly affected by allelochemical(s) and have its growth rate nearly stopped. Chemicals with allelopathic activity are present in many plants and in various organs, including leaves and fruitsm and have potential as either herbicides or templates for new herbicide classes. Many allelopathic compounds produced by plants are regulated by environmental factors, such as water potential of the environment, temperature, light intensity, soil moisture, nutrients, soil microorganisms and perhaps others. The compounds are released to the environment by means of volatilization, leaching, decomposition of residues and root exudation. They are; firstly, the terpenoids cineole, are released to the environment by volatilization, which is noticeable under drought conditions; secondly, the water born phenolic and alkaloids are washed out by rainfall through leaching; thirdly, phytotoxic aglycones, such sphenolics and others are produced during the decomposition of plant residues in soil; fourthly, many secondary metabolites such as scopoletin, may be released to the surrounding soil through root exudation. Several researches on phytotoxic effect of *Eucalyptus sp.* have emphasis on the effect of leaf and litter extract of the plant while other allelopathic sources of *Eucalyptus* were investigated, including root and litter leachates and affected soils, so as to detect the origine of any allelopathic effect and to analyse the effects of these sources on native species

Considering the above facts, the present study has been under taken to fulfill the following objectives:

1. To investigate the phytotoxic effects of *eucalyptus* leaf and bark.
2. To examine the inhibitionary effects of *Eucalyptus camaldulensis* of germination and growth of some monocot and dicot plant species.

CHAPTER II

REVIEW OF LITERATURE

Phytotoxicity is a process of producing one or more biochemical that influences the germination, growth, survival, and reproduction of plant species.

Alam and Islam (2002) reported that plants produce chemicals, which interfere with other plants and affect seed germination and seedling growth. These chemicals have harmful effects on crops in the eco-system resulting in the reduction and delayed germination, seedling mortality and reduction in growth and yield (McWhorter, 1984; Herro and Callaway, 2003).

Allolli and Narayanaredy (2000) reported that leaf extract of eucalyptus inhibited seed germination and reduced root and shoot lengths of cucumber and maximum inhibition was observed in higher concentrations of extract.

Anjum and Bajwa (2008) while studying the allelopathy influence of the sunflower on some weeds indicated the strong suppressive potential of this plant on some growth and physiological parameters of the tested plants. Allelochemicals emancipated as residues, exudates and leaches by many plants from leaves, stem, roots, fruit and seeds reported to interfere with growth of other plants (Asgharipour and Armin, 2010). These chemicals products mainly affect plants at seed emergence and seedling levels (Alam and Islam, 2002; Hussain *et al*., 2007; Mohamadi and Rajaie, 2009; Naseem *et al*., 2009).

Arshad and Frankenberger (1998) found that allelochemicals have shown far-reaching effects on the growth and development of plants even at low concentration. A number of laboratory-based experiments have focused on the effects of leaf sap, volatile compounds, foliage decomposition and root exudation on seed germination and the early growth stages of various receptor species (Molina *et al*. 1991; Lisanework and Michelsen, 1993; Fang *et al*. 2009). This is in agreement with past studies which found that seedlings planted in Eucalyptus plantations were affected by allelopathic chemicals from volatilization, leaching, foliage litter decomposition and root exudation (May and Ash, 1990; Sasikumar *et al*. 2001).

Asgharipour and Armin (2010) observed that allelochemicals might affect both crop and weeds when found together. The crop was distress directly or indirectly by the allelochemicals and lead to either stimulation or inhibition of growth.

Asgharipour and Armin (2010) reported that the study the allelopathic of plant organs extract at seed germination and seedling growth stages was beneficial for it is difficult to separate the allelochemicals effects from that of competition among crop and allelopathic plants. The allelochemicals sometimes have positive effects on sorghum growth. For example, *Moringa oleifera* leaf extracts enhanced germination of sorghum by 29% (Phiri, 2010). The same kind of germination pomotary behaviour was also observed in extract of *Cassia angustifolia* (Hussain *et al*. 2007).

Azizi and Fujji (2006) found that *Eucalyptus* sp. essential oils had a strong inhibitory effect on the germination of *A. retroflexus*.

Batish *et al*. (2004) stated that the exact mechanism that germination and seedling growth are affected by eucalyptus leaf extracts is not known. However, studies show that besides phenolics, terpenoids, particularly monoterpenes are the main components of essential oils of Eucalyptus spp. that interfere in mitosis of growing cells and respiration and reduce photosynthesis. Inhibition of these vital processes can reduce or even inhibit seed germination and seedling growth.

Biodiversity reduction in fast-growing Eucalyptus plantations has been a crucial issue for the long-term sustainability of native ecosystems and allelopathy has been considered a factor for the loss of biodiversity in eucalyptus plantations (Sasikumar *et al*. 2001; Ahmed *et al.* 2008; Zhang and Fu, 2009).

Chapius-Lardy *et al*. (2002) observed that several phenolic compounds such as caffeic, coumaric, gallic, gentisic, hydroxybenzoic, syringic, ferulic and vanillic acids have been identified in the leaves and understorey soil of eucalyptus plantations and methanol and aqueous leaf extracts of three Eucalyptus hybrids that have allelopathic potential. These compounds have been reported to cause clogging of stomata, enhanced electrolyte leakage and impairment of photosynthetic and energy machinery. It has been reported that total phenolic content of methanolic leaf extracts of three eucalyptus hybrids was higher than aqueous leaf extracts. Therefore, the higher inhibitory effect of methanol extract can be due to higher amounts of phenolic compounds.

Chatiyanon *et al*. (2012) reported that the water and methanol extract of the leaves of *H. suaveolens* has allelopathic effects on the germination and seedling growth of *Pennisetum setosum* (Swartz.) L.C. Rich and *Mimosa invisa* Mart. Similar findings were also reported by Kapoor (2011) who worked with dry leaf residue of *H. suaveolens* and observed inhibitory activity on the growth and physiological parameters of *Parthenium hysterophorus* L.

Chung *et al*. (2001) assessed the allelopathic potential of 44 rice cultivars (*Oryza sativa* L.) on barnyard grass. All 44 cultivars exhibited marked differences in the inhibition of barnyard grass growth and development.

Colquhoun (2006) evaluated that allelopathic compounds, often considered plant-produced herbicides, can inhibit growth of nearby plants. These compounds could be an alternative weed management strategy for crop production and can offer environmental benefits.

Crawley (1997) reported that the allelopathic effects of eucalyptus are also due to inhibition of some physiological process such as nutrient uptake, cell division, synthesis of carbohydrates, proteins and nucleic acids and phosphorylation pathways. These inhibitory effects can mediate by phenolic compounds. Therefore, these phenolic compounds reduce seed germination and growth of seedlings.

Dawar *et al.* (2007) observed that aqueous eucalyptus extract was effective in general to cause growth inhibition. But all plants of same species were not equally susceptible to aqueous extracts of eucalyptus.

Dhima *et al*. (2009) indicated that green manure of aromatic plants, such as anise, dill, oregano or lacy phacelia could be used for the suppression of barnyard grass and some broadleaf weeds in maize which consequently minimize herbicide usage.

Djanaguiraman *et al*. (2005) observed that the leaf leachate of *E. globulus* inhibited germination and growth of rice, sorghum and blackgram. Moreover, the extract of *E. globulus* inhibited germination and seedling growth of greengram and cowpea.

Djanaguiraman et al. (2005) who found that seedling dry matter of rice, sorghum and blackgram significantly reduced by leaf leachate of *E. globulus* and highest inhibition was observed in highest concentration. Moreover, dry weights of broad bean and maize reduced by leaf-litter water extract of *E. rostrata*. Fresh and dry weights of three wheat cultivars decreased in response to aqueous eucalyptus extract. Many polyphenols have catechol groups and at higher concentrations can chelate divalent or trivalent metal ions. Therefore, they inhibit ion uptake and thus cause reduction in seedling dry matter.

Einhelling and Leather (1988) studied that there are about 400,000 secondary metabolites in plants with allelopathic activities (Swain, 1977), of which only a few have been examined. The rest of the compounds, might contain very promising growth inhibitors are still unknown. Since about 12.5% of the total plants species of the world are considered as medicinal plants (Wakdikar, 2004), therefore, they could be served as important candidates for allelopathic research. Isolation and characterization of that unknown allelochemicals from medicinal plants might provide the chemical basis for new natural herbicides developments.

El-khawas and Shehata (2005) found that leaf extract of *E. globulus* inhibited germination of maize and kidney-bean. The allelopathic effect of extract from *E. camaldulensis* was tested on tomato; the extract significantly inhibited germination and growth of this plant.

Fujii (2001) assessed 53 cover crop plant species (including 26 leguminous, 19 graminaceous, and 8 others) for their allelopathic activity. It was found that leguminous cover crops such as hairy vetch and velvetbean, and graminaceous cover crops, such as oat (*Avena sativa* L.) and rye (*Secale cereale* L.) as well as certain cultivars of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) showed high allelopathic potential. *Nerium oleander* extract was reported to have rutin, quercetin (flavonoids), oleandrin, neriine (cardiac glycosides), rosagenin, folinerin, neritaloside and other compounds (Rajyalakshmi *et al*. 2011).

Ghorbani *et al*. (2008) studied that aqueous extracts of sunflower reduced germination and mean daily germination.

Jeffersona and Pennacchio (2003) carried out an investigation and revealed that allelochemicals may reduce weed competition with crops by delaying weed germination. Aqueous extracts of leaves have notably inhibited seed germination of sorghum with application of *Parthenium hysterophorus* (Murthy *et al*. 1995), *Ipomoea cornea* (Jadhav *et al*. 1997) *Commelina bengahalensis* and *Cyperus rotundus* (Channappagoudar *et al*. 2003) and *Eucalyptus camaldulensis* (Mohamadi and Rajaie, 2009).

Kaur *et al.* (2011) showed that the leaf volatile oils of *E. tereticornis* caused a significant reduction in early seedling growth and vigor, respiration and photosynthetic pigments of *Amaranthus viridis*.

Kaur *et al.* (2012) revealed that the leaf extracts of *E. globulus* had varying degrees of phytotoxicity against *S. nigrum*. Methanolic and ethyl acetate extracts had maximum inhibitory effects while aqueous extract had least inhibition. Solubility of allelochemicals is one of the major factors determining their phytotoxicity.

Mohamadi and Rajaie (2009) showed that the effects of allelochemicals on seeds germination appear to be mediated through a disruption of normal cellular metabolism rather than through damage or organelles.The extract concentrations of allelochemcial will reduce sorghum seeds germination and ultimately results in reduction in yield. These results are in agreement with those of Singh *et al*. (1992), Nandal *et al*. (1999 a, b) and Patel *et al*. (2002) who all observed reduction in germination percentage with extract/ leachates application to wheat seed.

Mubarak *et al*. (2009) studied an agreement with other studies which showed that sorghum seeds germination was significantly reduced when treated with *Eucaliptus camaldulensis* (Mohamadi and Rajaie, 2009) and *Spina christi*, *Sesbania sesban* and *Tamarindus indica.*

Naseem *et al*. (2009) studied that today; allelopathy is recognized as appropriate potential technology to control weeds using chemicals released from decomposed plant parts of various species.

Niakan and Saberi (2009) found that aqueous extract of *E. camaldulensis* reduced fresh and dry weights of Phalaris seedlings. The results of present study are similar to above mentioned findings. A number of volatile and non-volatile allelochemicals have been reported to be released from eucalypt trees and involved in allelopathic effects of tree.

Patel *et al*. (2002) studied the allelopathic influence of aqueous extracts of *Eucalyptus camaldulensis L*. on the germination (%) and seedling growth of wheat. It was noted that aqueous extracts at a concentration of 10, 15 and 20% had inhibitory effect on wheat germination and effect was found significantly higher than the control. Fresh and dry weight of seedling was also reduced significantly over control. The inhibitory effects were increased as the extract concentration increased. They found that wheat sown in fields which had leaf litter of *E. camaldulensis L*. will be adversely affected the germination, growth and ultimately resulting in lower yields of wheat.

Patel *et al*. (2002) studied the allelopathic potential of leaf extracts (0, 150, 100 and 50 g L^{-1}) of *E. camaldulensis* on *T. aestivum*, *Avena fatua* and *Carthamus oxycantha*. They reported the germination percentage, seedling length (mm) and biomass (mg) per plant and found *C. oxycantha* was the most inhibited species while wheat was the most tolerant. Only 20% seed germination was obtained in *C. oxycantha* compared to the other germination trials when exposed to the *E.*

camaldulensis aqueous extract (150 g L^{-1}). Other concentrations of *E. camaldulensis* extracts severely inhibited the germination of *C. oxycantha*.

Patel *et al*. (2002) studied the effects of leaf extracts of Eucalyptus and other species on wheat and mungbean. He reported that the extract inhibited the rooting rate of wheat cuttings by 100%. Harmful effects of Eucalyptus did not degrade under field conditions. He observed reduction in germination percentage with Eucalyptus extract/leachates application to wheat seed.

Phiri, (2010) carried out an experiment on effect of *M. oleifera* leaf extracts on sorghum indicated 15.3% reduction in survival seedlings.

The leaches of *E. camaldulensis* (Mohamadi and Rajaie, 2009) and many plant extracts (Mubarak *et al*. 2009) were also reported to reduce seedlings growth of sorghum.

Rassaeifar *et al*. (2013) reported that the length of radicles and plumules of *Amaranthus blitoides* and *Cynodon dactylon* treated with essential oil extracted from leaves of *E. globulus* were shorter than control and higher concentration induced greater phytotoxicity.

Rice (1984) investigated the effects of aqueous extracts of Eucalyptus spp. stem and leaves on seed germination and seedling growth in *Pennisetum glaucum*, sorghum, sunflower and soyabeans. Leaf extracts were more effective than stem extracts in reducing germination and seedling growth. *P. glaucum* was most tolerant and sunflower was most susceptible to Eucalyptus extracts.

Rice (1984) found that allelochemicals cause germination and growth inhibition, and influence a wide variety of metabolic processes. These substances can be isolated from plant tissues. Allelochemicals can be found in numerous parts of a plant such as roots, rhizomes, leaves, stems, pollen, seed, and flowers, and are usually products of secondary plant metabolism. Weeds account for more than 1% of the total plant species on earth, but cause great damage by interfering with food production, health, economic stability and welfare (Qasem and Foy, 2001). They may be defined as plants with little economic value and possessing the potential to colonize disturbed habitats or those modified by human activities (Macias *et al*. 2004). Simply put, weeds are often plants that are uniquely adapted to a wide range of environmental conditions, and they did not acquire problem status until humans developed agriculture. Therefore, it is up to humans to find a solution to the problems weeds cause in agriculture.

Rice (1984) observed that a number of abnormalities have been found when the test species are subjected to allelochemicals, and is the plausible cause for their growth inhibition. For example, allelochemicals inhibit the process of cell division, elongation and expansion rate, (Ortega et al. 1988; Einhellig, 1996; Jacob and Sarada, 2012), respiration process (Inderjit and Keating, 1999), ion absorption process (Qasem and Hill, 1989).

Enzyme activity (Sato *et al*. 1982), plant endogenous hormones and protein synthesis (Jacob and Sarada, 2012), alteration of the phytochrome control of germination (Leather and Einhellig, 1988) and consequently, arrested the plant growth.

Rice (1984) reported that allelochemicals can stimulate the seedlings growth at very low concentrations but inhibit the seedlings growth at high concentrations. In devising laboratory and greenhouse studies, efforts have been made to assure that the biological activities obtained are indeed due to the extracellular toxins by the donor plants (Qasem and Foy, 2001). For example, Belz *et al*. (2009) conducted a study to investigate whether or not the plant metabolite parthenin is sufficiently persistent, phytotoxic, and bioavailable in soils to cause an allelopathic effect that makes it attributable to the invasive success of the weed *P. hysterophorus*. In this study, parthenin was found to be quickly degraded without any evident accumulation to toxic levels over time and therefore; the hypothesis that parthenin contributes to the invasiveness of *P. hysterophorus* was rejected.

Rice(2009) and Qasem (2002) stated that the aqueous extract of the donor plants showed a wide range of activities from partial and complete inhibition to stimulation which may indicate the presence of certain allelochemicals causing inhibition. Many researches around the world show their keen interest on medicinal plants for searching new novel compounds and reported that medicinal plants have growth inhibitory effects on different noxious weed species and have the potentiality to use them in the crop fields either directly or as a natural herbicides (Lin *et al*. 2003, 2004; Han *et al*. 2008; Sodaeizadeh *et al*. 2009; Li *et al*. 2009). Moreover, it was reported that screening of allelopathic plant from medicinal plants species is easier than other plants (Fujii *et al*. 2003) possibly due to their existed certain metabolic compounds which was used for curing many diseases of both animal and human being.

Saberi *et al.* (2013) showed that leaf extracts of *E. globulus* had phytotoxic effects on germination and seedling growth of *S. nigrum* seeds. The phytotoxicity of volatile oils and extracts of different Eucalyptus species has been reported against many weedy species.

Salam and Kato-Noguchi (2010) also reported that roots were more sensitive to the allelochemicals than hypocotyls/coleoptiles because the roots are the first organ to absorb allelochemicals from the environment. Whereas, Nishida *et al*. (2005) stated that the permeability of allelochemicals into root tissue is higher than the shoot tissue.

Sasikumar *et al*. (2001) studied the allelopathic effects of leachates of bark, fresh leaves and leaf litter of *Eucalyptus tereticornis*, *E. camaldulensis*, *E. polycarpa* and *E. microtheca* on the germination, seedling length, dry matter, vigour index and nitrogenase activity of red gram (*Cajanus cajan* [pigeon pea] cv. CO.5). Bioassay revealed that significant reduction in germination over control in all cases, 7 days after sowing. Dry matter production was affected by *E. camaldulensis* and *E. microtheca*. Meanwhile, vigour index was affected by *E. camaldulensis*, *E. polycarpa* and *E. microtheca*. Seedling length was affected in all cases except *E. camaldulensis*, 37 days after sowing. Simultaneously, reduction in vigour index and nitrogenase activity was also noted in all cases, compared to the control.

Singh *et al*. (1992) reported that aqueous extracts of air dried leaf litter of *E. citirodora* had inhibitory effect on the seed germination, in wheat, mustard and gram.

Turket *et al*. (1994) found that it is an established fact that one plant may influence the germination, growth and metabolism of another through the release of chemicals which may be beneficial or harmful for the germination or growth of the plants.

Verdeguer *et al*. (2009) found that the phytotoxic effects of eucalyptus species have been evaluated against a number of weed species. For example, essential oil of *Eucalyptus camaldulensis* suppressed germination and seedling growth of *Amaranthus* hybrid and *Portulaca oleracea*.

Xuan *et al*. (2004) reported that aqueous extract of neem (*Azadirachta indica* A. Juss.) had phytotoxic potential and inhibited growth of *E. crus-galli, Monochoria vaginalis* (Burm. f.), and *Aeschynomene indica* L.

Yang *et al.* (2002) observed that aqueous Eucalyptus extract of various concentrations inhibited the germination of twelve wheat varieties and also negatively affected their fresh weights. Similar results were obtained after treatment of rice plant with three allelopathic phenolics.

Zakaria and Razak (1990) revealed that the differences in the germination percentage between the cultivars could be attributed to differences in the selective permeability of the seeds coat of sorghum to inhibitory substances. *Moringa oleifera*, *Khaya senegalensis* and *Albizia lebek* leaf extracts found to have no significant effects on seed germination of sorghum (Mubarak *et al*., 2009; Phiri, 2010).

Zhang and Shenglei (2010) reported that the length of radicles and plumules of radish, cucumber and chinese cabbage treated with litter extracts of three eucalyptus species were shorter than control and higher concentration induced greater phytotoxicity. In addition, leaf extract of *E. camaldulensis* decreased root and shoot lengths of tomato.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from June 2016 to June 2017 to study the "Phytotoxic effect of *Eucalyptus camaldulensis* on some selected monocot and dicot plant species". The materials and methods describe a short description of the experimental site, experimental materials, treatments and design, data collection procedure and data analysis. The detailed materials and methods that were used to conduct the study are presented below under the following headings:

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted in the laboratory and net house of the Department of Agricultural Chemistry , Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207. It was located in $23^0$41' N latitude and $90^0$22' E longitude at a height of 8.6 m above the sea level.

3.1.2 Conditions of experimental field

The temperature and relative humidity of the net house were recorded during the study period in the SAU weather station. The average minimum and maximum temperature during the study periods of the field was 15.4^0C to 38.20^0C, respectively and average minimum and maximum relative humidity was 30.3% and 80.20%, respectively.

3.2 Test crops

Five test species i.e. cauliflower, broccoli, tomato, foxtail millet and barnyard grass were used for this experiment. These seeds were collected from Bangladesh Agricultural Research Institute (BARI). The collected seed species were free from any visible defects, disease symptoms and insect infestations and transported to the laboratory of the Department of Agricultural Chemistry, SAU, Dhaka with careful handling to avoid disease and injury.

3.3 Experimental materials

Petri dish, filter paper, forceps, rotary evaporator etc. were used for this study. Dicot- cauliflower, broccoli and tomato , monocot- foxtail millet and barnyard grass.

3.4 Solution preparation

Leaf and bark of *Eucalyptus camaldulensis* were collected from various places at SAU campus in Bangladesh. The samples were washed in tap water and air-dried. Then the samples were dried in an oven for few days at 60^0C until constant weight was gained. The samples were then grinded to make fine uniform texture and kept in air tight polybag until use.

A. Solution preparation

10 g of each samples were taken in a several conical flask and added 80 mL methanol 20 mL distilled water. Then stirred and was covered by aluminium foil for keeping it 24 hours. Finally extracted in aqueous solution for 48 hours. The extract was then filtered through one layer of filter paper. The residue was re-extracted with equal amount of water for 72 hours. filtering was done with filter paper whatman 1. Then, 50mL methanol was added to plant extract for further filteration to acquire maximum phytotoxicity while in the net house there was no methanol added to the solution.

50 mL sample extract was found separately and kept for few days. Evaporation was done by Rotary evaporator at 40^0C for 30 minutes to remain 30 mL of water and sample material. Again 20 mL methanol was added to each sample extract and shaken for sometimes.

3.5 Phytotoxic assessment

0.001, 0.003, 0.01, 0.03, 0.1 g mL^{-1} concentrated extract with few drops of Tween 20 , o.o5% was added with dissolved water to the Petridish. Placed all Petridish in growth chamber under 25^0C temperature with 2500 lux light intensity and added some water every alternative day.

3.6 Treatments

There were 6 levels of aqueous methanol solution of 5 test plants for laboratory condition. There are-

1. T_0= 0 g mL^{-1}
2. T_1= 0.001 g mL^{-1}
3. T_2= 0.003 g mL^{-1}
4. T_3= 0.01 g mL^{-1}
5. T_4= 0.03 g mL^{-1}
6. T_5= 0.1 g mL^{-1}

There were 6 levels of aqueous extract obtained from leaf against 5 selected plants for net house. There are-

1. T_0= 0 ppm
2. T_1= 1 ppm
3. T_2= 2 ppm
4. T_3= 3 ppm
5. T_4= 4 ppm
6. T_5= 5 ppm

3.7 Data collection heads

The following data was collected

1. Germination percentage
2. Plumule length
3. Radicle length
4. Dry weight

3.8 Data collection procedure

3.8.1 Total germination (TG %)

The standard germination test was performed by placing randomly selected 20 seeds in the earthen pots. Experimental units were arranged in a completely randomized design with three replications. Germination was considered to have occurred when radicles were 2 mm long (Akbari *et al*. 2007). Germination progress was inspected and data were collected at every 24 hr intervals and continued up to 8 days. The seedlings with short, thick and spiral formed hypocotyls and stunted primary root were considered as abnormally germinated seeds (ISTA, 2003). These types of abnormal or dead seedlings were excluded during counting. At the end of germination test (8 days), 6 seedlings from each of the treatment were selected randomly and roots and shoots were cut from the cotyledons and were transferred to brown paper. Then these seedlings were dried in an oven at 75°C for 48 hours.

Total germination (TG) was calculated as the number of seeds which was germinated within total days as a proportion of number of seeds shown in each treatment expressed as a percentage (Othman *et al*. 2006).

$$TG\ (\%) = \frac{\text{Number of germinated seed}}{\text{Total number of seed set for germination}a} \times 100$$

3.8.2 Shoot length and root length

Randomly selected seedlings from each treatment were collected and cotyledons were removed from them. Shoot and root length were measured with a ruler and accuracy of measurement was 1 mm.

3.9 Shoot dry weight and root dry weight

The dried radicles and shoots were weighted to the milligram (mg) and converted to gram. The mean radicle and shoot dry weight were determined with an electric balance. Then it was converted to total dry weight.

3.10 Statistical analysis

The data obtained different parameters were statistically analyzed to observe the significant difference among the treatments. The mean value of all the parameters was calculated and analysis of variance was performed. The significance of difference among the treatments means was estimated by the using Tukey's test at 5% level of significance. A computer software Statistic 10 was used to carry out the statistical analysis.

CHAPTER IV

RESULTS & DISCUSSION

4.1 Effects of *Eucalyptus camadulensis* (bark) aqueous methanol on germination percentage (GP)

Statistically significant variation was recorded for the effect of *Eucalyptus camaldulensis* (bark) aqueous methanol on germination percentage of cauliflower, broccoli, tomato, foxtail millet and barnyard grass (Figure 1). Highest germination of cauliflower was found at control conditions which was 90.25% decreased upon applying at 0.001, 0.003, 0.01 g mL^{-1} concentrations to 77.90, 76.00 and 61.75% respectively. However, the value of the germination percentages goes to a marked reduction at 0.03 and 0.1 g mL^{-1} concentrations (57.00 and 52.25% respectively). On the other hand the result indicates that different concentrations of *Eucalyptus camadulensis* (bark) extract apparently varied the germination percentage of broccoli seeds. The germination percentage values of broccoli at control conditions was 85.74%, this value was decreased to 74.01% at 0.001 g mL^{-1} concentrations on the other hand were also decreased upon applying 0.003. 0.01, 0.03 and 0.1 g mL^{-1} concentrations (72.20, 58.66, 54.15 and 49.64%). Similarly the germination percentage (GP) of tomato, foxtail millet and barnyard grass seeds were apparently varied with different concentrations of *Eucalyptus camaldulensis* (bark) aqueous extract. It was revealed from the table that the maximum value of germination percentage in all plants were found from the control treatment which were statistically superior to the rest of the treatments. As the treatment concentration value increased, the germination percentage value of the plants were decreased in consistent and the least value of germination percentage was found from 0.1 g mL^{-1} treatment while the other germination percentage took intermediate positions and they were statistically different among themselves.

The monocotyledonous plants eg. foxtail millet and barnyard grass showed great treatment effect among the different treatment effect of five selective plants and comparatively less effect was shown in dicot plants eg. cauliflower, broccoli and tomato. Whether, tomato plant showed much less effect followed by cauliflower and broccoli among the dicot plant. It's may be due to the size of the tomato seed as the size of the tomato seed is comparatively bigger than other four plants and we know that treatment concentration was negatively correlated with seed size. This study clearly supports Rice (1984) who investigated the effects of aqueous extracts of *Eucalyptus sp.* stem and leaves on seed germination and seedling growth in *Pennisetum glaucum*, sorghum, sunflower and soyabeans.

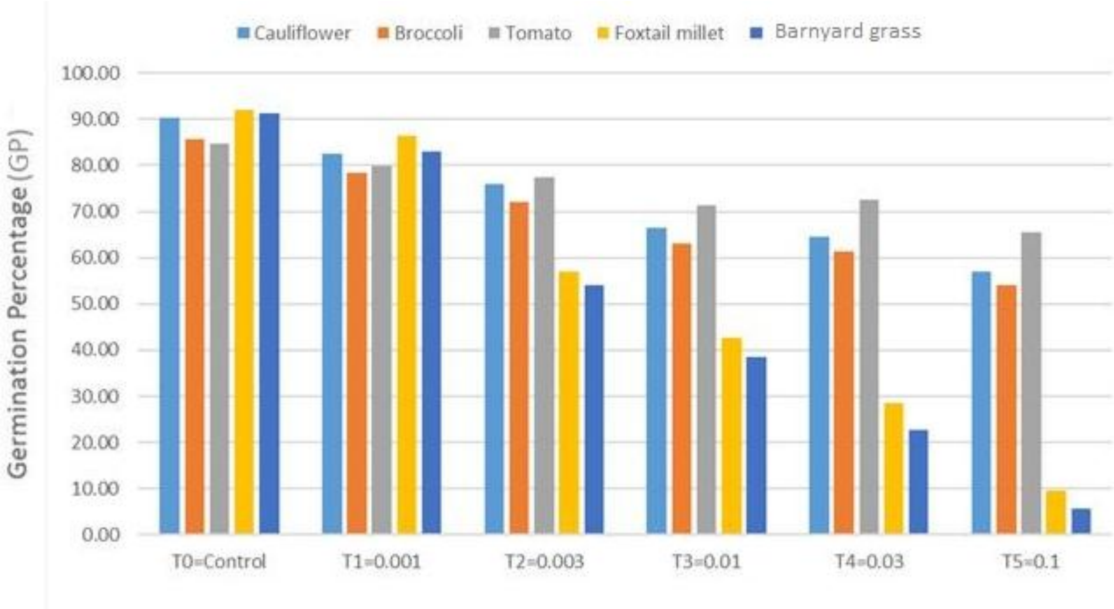

Figure 1: Variation in the germination percentage of cauliflower, broccoli, tomato, foxtail millet, barnyard grass as affected by different aqueous methanol of *Eucalyptus camaldulensis* (bark).

4.2 Effects of *Eucalyptus camaldulensis* (bark) aqueous methanol on plumule length (PL)

Cauliflower, broccoli, tomato, foxtail millet and barnyard grass under study showed variations in their plumule length (Table 1). Considerable significant differences of plumule length (PL) were indicating among the treatments studied. The data of the following showed that plumule length of cauliflower was significantly affected by each treatment. There was a noticed reduction on the values of plumule length, the control value was about 1.66 cm decreased at 1.62, 1.52, 1.14, 0.95 and 0.29 cm at 0.001, 0.003, 0.01, 0.03 and 0.1g mL^{-1} concentrations respectively. The plumule length data of other four plants eg. broccoli, tomato, foxtail millet and barnyard grass showed significantly affected in different concentration. There was a noticed reduction in values of plumule length with increasing treatment concentration. In broccoli, tomato, foxtail millet and barnyard grass the maximum plumule length was found in the control treatment and the value were about 1.58, 1.56, 1.49 and 1.43 cm respectively. Whether the shortest length of plumule was from 0.1 g mL^{-1} concentration and the value were about 0.29, 0.27, 0.43, 0.10, and 0.06 cm in cauliflower, broccoli, tomato, foxtail millet and barnyard grass respectively while the other treatment effect took intermediate positions though there were statistical differences among themselves.

Espinosa-Garcia and Francisco (1996) observed that eucalyptus is a prolific litter producer, prone to dropping leaves and bark. If phytotoxins are released from eucalyptus litter its accumulation in the soil could result in poor revegetation of native flora even after the tree's removal. Although the compounds isolated form eucalyptus are known to inhibit plant growth or germination it is not known to what extent water extract of the leaves of Eucalyptus affect germination and seedling development of california native plants.

4.3 Effects of *Eucalyptus camaldulensis* (bark) aqueous methanol on radicle length (RL)

The average marked difference on the length of radicle produced by cauliflower, broccoli, tomato, foxtail millet and barnyard grass were recorded and the effect of *Eucalyptus camaldulensis* (bark) aqueous methanol solution on radicle length of those five plants was presented in (Table 2). Evaluation of radicle length (RL) correlated with higher concentrations has demonstrated their depressing influence on cauliflower growth process. Furthermore, concentration was significantly affecting radicle length at the control the value was about 2.44 cm. At 0.001, 0.003, 0.01, 0.03 and 0.1 g mL^{-1} concentrations there have been a marked reduction in radicle length (2.28, 2.27, 1.79, 1.33 and 0.39 cm, respectively). Similarly the concentrations and interaction were significantly affecting the radicle length of broccoli, tomato and foxtail millet. The highest length of radicle (2.44, 2.32, 2.29, 2.18 and 2.10 cm) was attained from cauliflower, broccoli, tomato, foxtail millet and barnyard grass in control treatment whereas the lowest radicle length (0.39, 0.37, 0.37, 0.00 and 0.00 cm) was attained at higher concentration (0.1 g mL^{-1}). While the varieties in other treatments took intermediate positions and they were statistically different among themselves.

Table 1: Effects of *Eucalyptus camaldulensis* (bark) aqueous methanol on plumule length (cm) of cauliflower, broccoli, tomato, foxtail millet and barnyard grass

Treatmens	Cauliflower	Broccoli	Tomato	Foxtail millet	Barnyard grass
T_0=Control	1.69	1.62	1.58	1.55	1.39
T_1=0.001	1.62	1.54	1.51	0.57	0.55
T_2=0.003	1.52	1.44	1.42	0.40	0.39
T_3=0.01	1.14	1.08	1.16	0.15	0.15
T_4=0.03	0.95	0.90	0.97	0.02	0.02
T_5=0.1	0.29	0.27	0.43	0.10	0.06

Table 2: Effects of *Eucalyptus camaldulensis* (bark) aqueous methanol on radicle length (cm) of cauliflower, broccoli, tomato, foxtail millet and barnyard grass

Treatmens	Cauliflower	Broccoli	Tomato	Foxtail millet	Barnyard grass
T_0=Control	2.44	2.32	2.29	2.18	2.10
T_1=0.001	2.28	2.17	2.12	0.84	0.80
T_2=0.003	2.27	2.16	2.11	0.59	0.57
T_3=0.01	1.79	1.70	1.66	0.23	0.22
T_4=0.03	1.33	1.26	1.24	0.05	0.05
T_5=0.1	0.39	0.37	0.37	0.00	0.00

4.4 Interaction effects of increasing concentration of *Eucalyptus camaldulensis* (bark) on aqueous methanol with tested plants

Table 3 shows the data on interaction effect of *Eucalyptus camaldulensis* (bark) aqueous methanol on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass indicated considerable differences due to different treatment concentrations. The maximum length of both plumule (1.67cm) and radicle (2.44cm) were recorded in cauliflower and broccoli from control treatment, whereas the no plumule length (0.00cm) was found in both in barnyard grass and foxtail millet and minimum radicle length (0.0001) in both foxtail millet and tomato were attained from 0.1gmL^{-1} aqueous *Eucalyptus camaldulensis* (bark) extracts which was the highest concentration among all the treatments. The increasing treatment concentration has vast negative impact on plumule length and radicle length performance and this was clearly showed in the data found in the(Table 3).

Table 3: Interaction effects of *Eucalyptus camaldulensis* (bark) aqueous methanol on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass with treatments

Combined interaction	Plumule	Radicle
T_0=Control Broccoli	1.5800 abc	2.4400 a
T_0=Control Barnyard grass	1.4250 ef	2.3200 ab
T_0=Control Cauliflower	1.6650 a	2.2900 bc
T_0=Control Foxtail millet	1.4900 cdef	2.2800 bcd
T_0=Control Tomato	1.5600 bc	2.2700 bcd
T_1=0.001 Broccoli	1.5400 bc	2.1850 cde
T_1=0.001 Barnyard grass	0.5450 i	2.1650 cde
T_1=0.001 Cauliflower	1.6250 ab	2.1550 de
T_1=0.001 Foxtail millet	0.5700 i	2.1200 e
T_1=0.001 Tomato	1.5100 cde	2.1150 e
T_2=0.003 Broccoli	1.4450 def	2.1000 e
T_2=0.003 Barnyard grass	0.3900 j	1.7850 f
T_2=0.003 Cauliflower	1.5200 cd	1.7000 f
T_2=0.003 Foxtail millet	0.4050 j	1.6650 f
T_2=0.003 Tomato	1.4150 f	1.3300 g
T_3=0.01 Broccoli	1.0850 g	1.2650 g
T_3=0.01 Barnyard grass	0.1450 l	1.2350 g
T_3=0.01 Cauliflower	1.1400 g	0.8350 h
T_3=0.01 Foxtail millet	0.1550 l	0.8000 h
T_3=0.01 Tomato	1.1600 g	0.5950 i
T_4=0.03 Broccoli	0.9050 h	0.5700 i
T_4=0.03 Barnyard grass	0.0200 m	0.3900 j
T_4=0.03 Cauliflower	0.9500 h	0.3700 j
T_4=0.03 Foxtail millet	0.0200 m	0.3700 j
T_4=0.03 Tomato	0.9700 h	0.2250 k
T_5=0.1 Broccoli	0.2750 k	0.2150 k
T_5=0.1 Barnyard grass	0.0000 m	0.0500 l
T_5=0.1 Cauliflower	0.2850 k	0.0450 l
T_5=0.1 Foxtail millet	0.0000 m	0.0000 l
T_5=0.1 Tomato	0.4250 j	0.0000 l
CV%	7.2	6.5
LSD	0.0915	0.134

4.5 Effect of *Eucalyptus camaldulensis* (bark) on aqueous methanol on dry weight (DW)

Five different selective plants showed statistically significant variation in terms of the effect of *Eucalyptus camaldulensis* (bark) aqueous methanol on dry weight (Figure 2). Inhibition of dry weight was increased when the extract concentration was increased. The control showed 0.048, 0.046, 0.042, 0.036, 0.037 and 0.019g for cauliflower, broccoli, tomato, foxtail millet and barnyard grass dry weight which was the highest value among all. On a dry weight basis, the most reduction was recorded when selected plants were treated with an extract of *Eucalyptus camaldulensis* (bark) at 0.1 g mL^{-1} concentration. From the table it was observed that, the higher concentration of *Eucalyptus camaldulensis* (bark) aqueous methanol solution reveal negative effects on dry weight but with variation among the five plants. The dry weight of all but tomato were significantly inhibited by the extracts at any concentrations of *Eucalyptus camaldulensis* (bark). Significant impact on the dry weight of monocot than dicot was observed with the effect of *Eucalyptus camaldulensis* (bark) aqueous extract as the maximum value was found in foxtail millet and barnyard grass followed by cauliflower and broccoli. This result partially follows Sasikumar et al., (2001) who studied the allelopathic effects of leachates of bark, fresh leaves and leaf litter of *Eucalyptus tereticornis*, *E. camaldulensis*, *E. polycarpa* and *E. microtheca* on the germination, seedling length, dry matter, vigour index and nitrogenase activity of red gram (*Cajanus cajan* [pigeon pea] cv. CO.5).

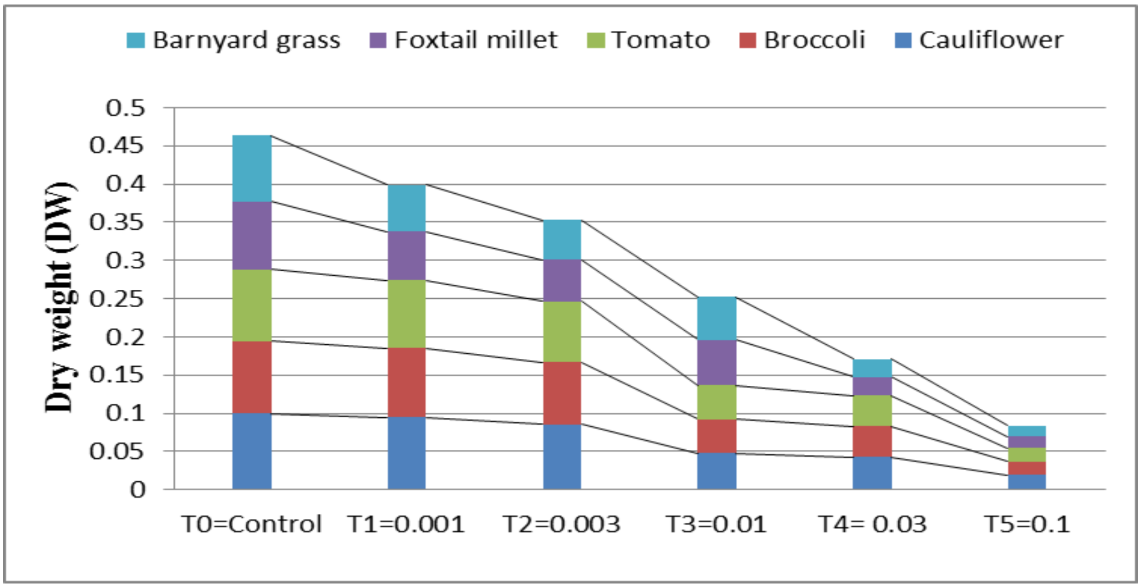

Figure 2: Variation in the dry weight (g) of cauliflower, broccoli, tomato, foxtail millet barnyard grass as affected by different aqueous methanol of *Eucalyptus camaldulensis* (bark)

4.6 Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on germination percentage (GP)

Statistically significant variation was recorded for the effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol on germination percentage of cauliflower, broccoli, tomato, foxtail millet and barnyard grass (Figure 3). 90.25% germination of cauliflower was found at control conditions which was decreased upon applying at 0.001, 0.003, 0.01 g mL^{-1} concentrations to 82.65, 76.00, 66.50% respectively. However, the value of the germination percentages goes to a marked reduction at 0.03 and 0. g mL^{-1} concentrations (64.60 and 57.00% respectively). On the other hand the data of the table indicate that different concentrations of *Eucalyptus camaldulensis* (leaf) extract apparently varied the germination percentage of broccoli seeds. The germination percentage values of broccoli at control conditions was 85.74%, this value was decreased to 78.52% at 0.001 g mL^{-1} concentrations on the other hand were also decreased upon applying 0.003. 0.01, 0.03 and 0.1 g mL^{-1} concentrations (72.20, 63.18, 61.37 and 54.15%). Similarly the germination percentage (GP) of tomato, foxtail millet and barnyard grass seeds were apparently varied with different concentrations of *Eucalyptus camaldulensis* (leaf) aqueous extract which is supported statistically. It was revealed from the figure that the maximum value of germination percentage in all plants were found from the control treatment which were statistically superior to the rest of the treatments. As the treatment concentration value increased, the germination percentage value of the plants were decreased in consistent and the least value of germination percentage was found from 0.1 g/mg treatment while the other germination percentage took intermediate positions and they were statistically different among themselves.

The monocotyledonous plant eg. foxtail millet and barnyard grass showed great treatment effect among the different treatment effect of five selective plants and comparatively less effect was shown in dicot plants eg. cauliflower, broccoli and tomato. Whether, tomato plant showed much less effect followed by cauliflower and broccoli among the dicot plant. It's may be due to the size of the tomato seed as the size of the tomato seed is comparatively bigger than other four plants and we know that treatment concentration was negatively correlated with seed size. Patel et al., (2002) shows the same result on the allelopathic potential of leaf extracts (0, 150, 100 and 50 g L^{-1}) of *E. camaldulensis* on *T. aestivum*, *Avena fatua* and *Carthamus oxycantha*.

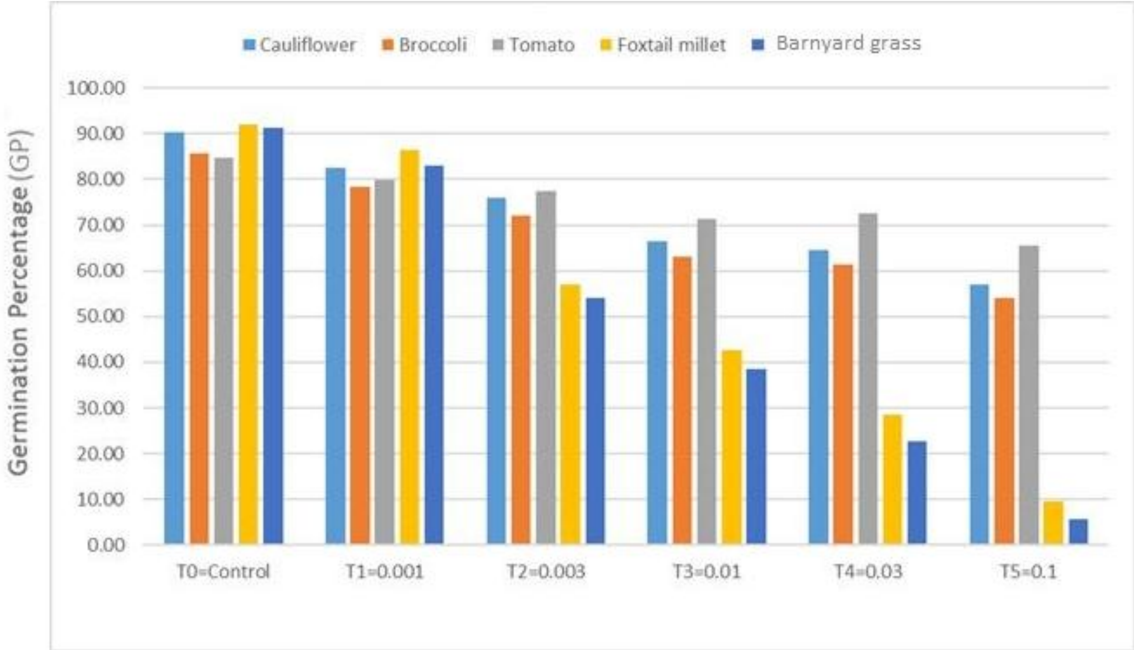

Figure 3: Variation in the germination percentage of cauliflower, broccoli, tomato, foxtail millet, barnyard grass as affected by different aqueous methanol of *Eucalyptus camaldulensis* (leaf)

4.7 Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on plumule length (PL)

Cauliflower, broccoli, tomato, foxtail millet and barnyard grass under study showed variations in their plumule length (Table 4). Considerable significant differences of plumule length (PL) was indicating among the treatments studied. The data of the following showed that plumule length of cauliflower was significantly affected by each treatment. There was a noticed reduction on the values of plumule length, the control value was about 1.66 cm decreased to 1.62, 1.60, 1.14, 1.05 and 0.38 cm at 0.001, 0.003, 0.01, 0.03 and 0.1 g mL^{-1} concentrations respectively. The plumule length data of other four plants eg.broccoli, tomato, foxtail millet and Barnyard grass showed significantly affected in different concentration. There was a noticed reduction in values of plumule length with increasing treatment concentration. In broccoli, tomato, foxtail millet and barnyard grass the maximum plumule length was found in the control treatment and the value were about 1.58, 1.56, 1.49 and 1.43 cm respectively. Whether the shortest length of plumule was from 0.1 g mL^{-1}

concentration and the value were about 0.38, 0.36, 0.52, 0.00 and 0.00 cm in cauliflower, broccoli, tomato, foxtail millet and barnyard grass respectively while the other treatment effect took intermediate positions though there were statistical differences among themselves.

4.8 Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on radicle length (RL)

The average marked difference on the length of radicle produced by cauliflower, broccoli, tomato, foxtail millet and barnyard grass were recorded and the effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol on radicle length of those five plants was presented in (Table 5). Evaluation of radicle length (RL) correlated with higher concentrations has demonstrated their depressing influence on cauliflower growth process. Furthermore, concentration was significantly affecting radicle length at the control the value was about 2.44 cm. At 0.001, 0.003, 0.01, 0.03 and 0.1 g mL^{-1} concentrations there have been a marked reduction in radicle length (2.38, 2.33, 1.90, 1.43 and 0.48 cm, respectively).

Similarly the concentrations and interaction were significantly affecting the radicle length of broccoli, tomato and foxtail millet. The highest length of radicle (2.44, 2.32, 2.29, 2.18 and 2.10 cm) was attained from cauliflower, broccoli, tomato, foxtail millet and Barnyard grass in control treatment whereas the lowest radicle length (0.48, 0.45, 0.45, 0.02 and 0.02 cm) was attained at higher concentration (0.1 g mL^{-1}). While the varieties in other treatments took intermediate positions and they were statistically different among themselves.

Table 4: Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on plumule length (cm) of cauliflower, broccoli, tomato, foxtail millet and barnyard grass

Treatments	Cauliflower	Broccoli	Tomato	Foxtail millet	Barnyard grass
T_0=Control	1.66	1.58	1.56	1.49	1.43
T_1=0.001	1.62	1.54	1.51	0.57	0.55
T_2=0.003	1.60	1.52	1.49	0.40	0.39
T_3=0.01	1.14	1.08	1.16	0.15	0.15
T_4=0.03	1.05	0.99	1.06	0.02	0.02
T_5=0.1	0.38	0.36	0.52	0.00	0.00

Table 5: Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on radicle length (cm) of cauliflower, broccoli, tomato, foxtail millet and barnyard grass

Treatmens	Cauliflower	Broccoli	Tomato	Foxtail millet	Barnyard grass
T_0=Control	2.44	2.32	2.29	2.18	2.10
T_1=0.001	2.38	2.26	2.21	0.84	0.80
T_2=0.003	2.33	2.21	2.17	0.59	0.57
T_3=0.01	1.90	1.81	1.77	0.23	0.22
T_4=0.03	1.43	1.35	1.33	0.12	0.12
T_5=0.1	0.48	0.45	0.45	0.02	0.02

4.9 Interaction effects of increasing concentration of *Eucalyptus camaldulensis* (leaf) aqueous methanol with test plants

Table 6 shows the data on interaction effect of *Eucalyptus camidulensis* (leaf) aqueous methanol solution on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass indicated considerable differences due to different treatment concentrations. The maximum length of both plumule (1.67 cm) and radicle (2.44 cm) were recorded in cauliflower from control treatment, whereas the no plumule length (0.00cm) and minimum radicle length (0.02 cm) was found in barnyard from 0.1 g mL^{-1} aqueous *Eucalyptus camaldulensis* (leaf) extracts which was the highest concentration among all the treatments. The increasing treatment concentration has vast negative impact on plumule length and radicle length performance and this was clearly showed in the data found in the(Table 8).

Table 6: Interaction effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass with treatments

Combined interaction	Plumule	Radicle
T_0=Control × Broccoli	1.5800 abcd	2.3200 abcd
T_0=Control × Barnyard grass	1.4250 f	2.1000 f
T_0=Control × Cauliflower	1.6650 a	2.4400 a
T_0=Control × Foxtail millet	1.4900 def	2.1850 def
T_0=Control × Tomato	1.5600 bcde	2.2900 bcde
T_1=0.001 × Broccoli	1.5400 bcde	2.2600 bcde
T_1=0.001 × Barnyard grass	0.5450 j	0.8000 i
T_1=0.001 × Cauliflower	1.6250 ab	2.3750 ab
T_1=0.001 × Foxtail millet	0.5700 j	0.8350 i
T_1=0.001 × Tomato	1.5100 cdef	2.2100 cdef
T_2=0.003 × Broccoli	1.5200 cde	2.2100 cdef
T_2=0.003 × Barnyard grass	0.3900 k	0.5700 jk

T_2=0.003 × Cauliflower	1.5950 abc	2.3300 abc
T_2=0.003 × Foxtail millet	0.4050k	0.5950 j
T_2=0.003 × Tomato	1.4850 ef	2.1650 ef
T_3=0.01 × Broccoli	1.0850 ghi	1.8050 g
T_3=0.01 × Barnyard grass	0.1450 l	0.2150 l
T_3=0.01 × Cauliflower	1.1400 gh	1.9000 g
T_3=0.01 × Foxtail millet	0.1550 l	0.2250 l
T_3=0.01 × Tomato	1.1600 g	1.7700 g
T_4=0.03 × Broccoli	0.9950 i	1.3550 h
T_4=0.03 × Barnyard grass	0.0200 m	0.1150 lm
T_4=0.03 × Cauliflower	1.0450 i	1.4250 h
T_4=0.03 × Foxtail millet	0.0200 m	0.1250 lm
T_4=0.03 × Tomato	1.0550 hi	1.3300 h
T_5=0.1 × Broccoli	0.3600 k	0.4550 k
T_5=0.1 × Barnyard grass	0.0000 m	0.0200 m
T_5=0.1 × Cauliflower	0.3800 k	0.4750 jk
T_5=0.1 × Foxtail millet	0.0000 m	0.0250 m
T_5=0.1 × Tomato	0.5150 j	0.4450 k
CV%	7.2	6.5
LSD	0.034	0.0551

4.10 Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on dry weight (DW)

Five different selective plants showed statistically significant variation in terms of the effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol on dry weight (Figure 4). Inhibition of dry weight was increased when the extract concentration was increased. The control showed 0.048, 0.046, 0.042, 0.036, 0.037 and 0.019 g for cauliflower, broccoli, tomato, foxtail millet and barnyard grass dry weight which was the highest value among all. On dry weight basis, the most reduction was recorded when selected plants were treated with an extract of *Eucalyptus camaldulensis* (leaf) at 0.1 g mL^{-1} concentration. From the table it was observed that, the higher concentration of *Eucalyptus camaldulensis* (leaf) aqueous methanol solution reveal negative effects on dry weight but with variation among the five plants. The dry weight of all but tomato was significantly inhibited by the extracts at any concentrations of *Eucalyptus camaldulensis* (leaf). Significant impact on the dry weight of monocot than dicot was observed with the effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol solution as the maximum value was found in foxtail millet and barnyard grass followed by cauliflower and broccoli. Patel *et al.* (2002) also studied the phytotoxic influence of aqueous methanol solution of *Eucalyptus camaldulensis L*. on wheat and found almost the same result.

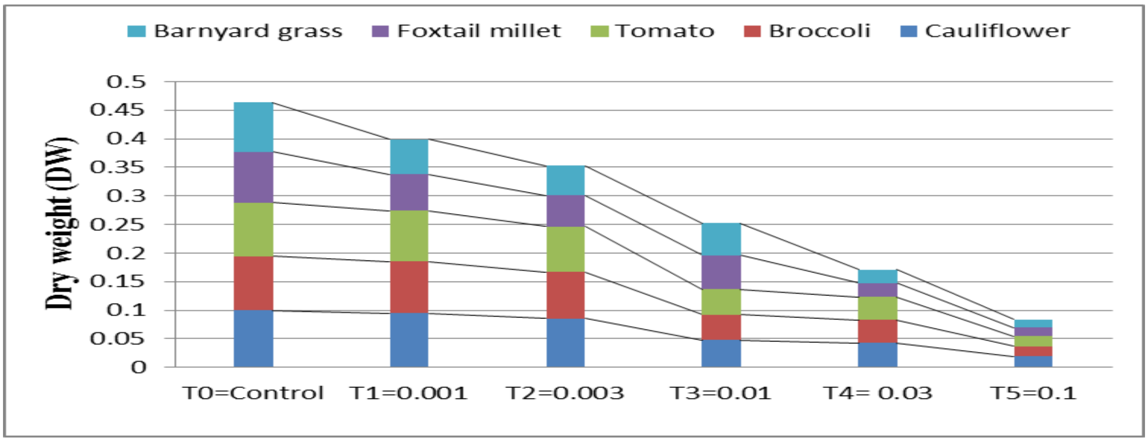

Figure 4: Variation in the dry weight (g) of cauliflower, broccoli, tomato, foxtail millet barnyard grass as affected by different aqueous methanol of *Eucalyptus camaldulensis* (leaf)

4.11 Effects of *Eucalyptus camaldulensis* (leaf) aqueous extract on germination percentage (GP) in net house

Wide range of variability was observed in respect of the effect of *Eucalyptus camaldulensis* (leaf) aqueous extract on germination percentage of cauliflower, broccoli, tomato, foxtail millet and barnyard grass (Figure 5). The attained germination percentage of cauliflower values at control conditions (76.95%) was decreased upon applying at 1.0, 2.0, 3.0 ppm concentrations to 76.00, 72.20 and

63.65% respectively. However, this current motivation goes to a marked reduction at 4.0 and 5.0 ppm concentrations (55.1 and 38.0 % respectively). The germination percentage values of broccoli at control conditions was 73.10 %, this value was decreased to 36.10% at 5.0 ppm concentrations. Similarly the germination percentage of tomato, foxtail millet and barnyard grass seeds were apparently varied with different concentrations of *Eucalyptus camaldulensis* (leaf) aqueous extract which is supported statistically. From the table it was revealed that in all plants the maximum value of germination percentage were found from the control treatment which were statistically superior to the rest of the treatments. As the treatment concentration value increased, the germination percentage value of the plants were decreased in consistent and the least value of germination percentage was found from 5.0 ppm treatment while the other germination percentage took intermediate positions and they were statistically different among themselves.

Based on different treatment effect of five selective plants in field condition, vast treatment effect was observed in the monocot plant eg. foxtail millet and barnyard grass and comparatively less effect was shown in dicot plants eg. cauliflower, broccoli and tomato as like as laboratory condition. On the other hand, among the dicot plant tomato plant showed much less effect followed by cauliflower and broccoli. It's may be due to the size of the tomato seed as the size of the tomato seed is comparatively bigger than other four plants and we know that treatment concentration was negatively correlated with seed size.

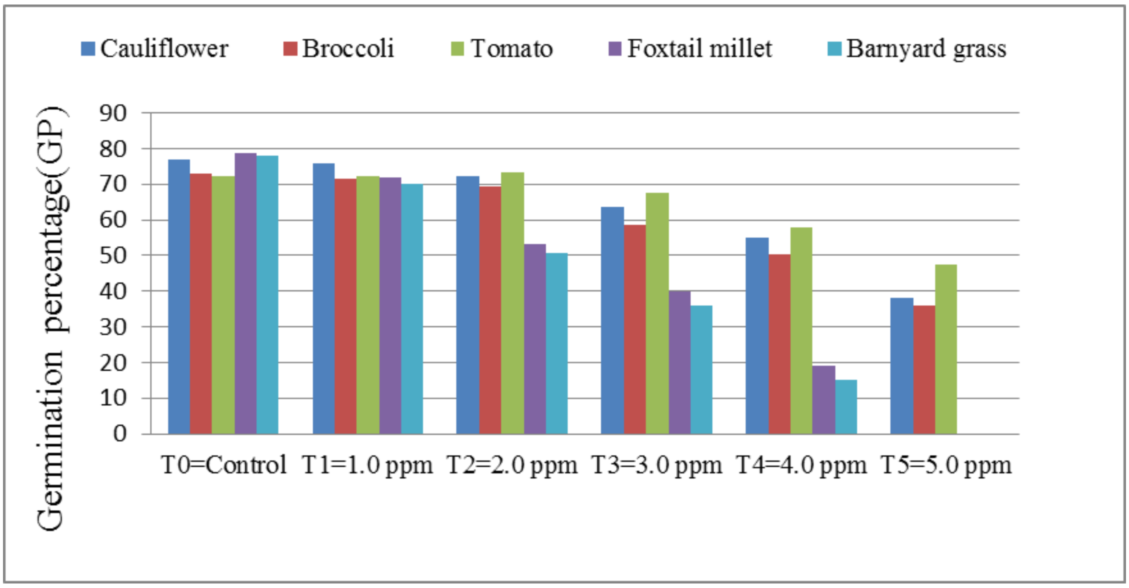

Figure 5: Variation in the germination percentage of cauliflower, broccoli, tomato, foxtail millet barnyard grass as affected by different aqueous extract in net house of *Eucalyptus camaldulensis* (leaf)

4.12 Effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol on plumule length (PL) in net house

Plumule length (PL) was significant indicating considerable differences among the treatments studied. The demonstrated data pointed up that plumule length of plants was significantly affected by each treatment especially to the monocot plants than the dicot. There was a reduction on the values of plumule length in five plants eg. cauliflower, broccoli, tomato, foxtail millet and barnyard grass showed significantly affected in different concentration. There was a noticed reduction in values of plumule length with increasing treatment concentration. Among all the treatments in all the plants maximum plumule length was found in the control treatment and the value were about 3.23, 3.07, 3.03, 2.89 & 2.77 cm in cauliflower, broccoli, tomato, foxtail millet and barnyard grass respectively. Whether the shortest length of plumule was from 5.0 ppm concentration and the value were about 0.33, 0.32, 0.47 cm in cauliflower, broccoli, tomato respectively and plumule length reduced to zero in foxtail millet and Barnyard grass. The remaining treatments were intermediate in this regard (Table 7). Statistically tomato produced minimum plumule length than rest of the line.

4.13 Effects of *Eucalyptus camaldulensis* (leaf) aqueous extract on radicle length (RL) in net house

The length of radicle produced by five selective plants were recorded the effect of *Eucalyptus camaldulensis* (leaf) aqueous extract on radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass presented in (Table 8). The highest length of radicle (6.29, 5.97, 5.90, 5.63, 5.40 cm) was attained from cauliflower, broccoli, tomato, foxtail millet and barnyard grass in control treatment whereas the lowest radicle length (RL) (2.85, 2.71, 2.68, 0.06, 0.06 cm) was attained at higher concentration (5.0 ppm). While the varieties in other treatments took intermediate positions and they were statistically different among themselves. Here among the five plants, tomato gives least value than all other.

Table 7: Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on plumule length (cm) of cauliflower, broccoli, tomato, foxtail millet and barnyard grass

Treatments	Cauliflower	Broccoli	Tomato	Foxtail millet	Barnyard grass
T_0=Control	1.80	1.71	1.69	1.61	1.55
T_1=1.0 ppm	1.75	1.66	1.63	1.16	1.11
T_2=2.0 ppm	1.65	1.57	1.53	0.98	0.94
T_3=3.0 ppm	1.40	1.33	1.41	1.07	1.02
T_4=4.0 ppm	1.34	1.27	1.34	0.44	0.43
T_5=5.0 ppm	1.15	1.10	1.25	0.27	0.26

Table 8: Effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on radicle length (cm) of cauliflower, broccoli, tomato, foxtail millet and barnyard grass

Treatments	Cauliflower	Broccoli	Tomato	Foxtail millet	Barnyard grass
T_0=Control	2.65	2.51	2.48	2.37	2.27
T_1=1.0 ppm	2.58	2.45	2.40	1.70	1.63
T_2=2.0 ppm	2.26	2.14	2.10	1.44	1.38
T_3=3.0 ppm	2.24	2.12	2.08	1.57	1.50
T_4=4.0 ppm	2.04	1.94	1.90	0.65	0.62
T_5=5.0 ppm	1.75	1.66	1.65	0.40	0.38

4.14 Interaction effects of increasing concentration of *Eucalyptus camaldulensis* (leaf) aqueous methanol with test plants

The data on interaction effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol solution on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass indicated considerable differences due to different treatment concentrations (Table 9). The maximum length of both plumule (3.23 cm) and radicle (6.29 cm) were recorded in cauliflower from control treatment, whereas the minimum plumule length (0.00 cm) and radicle length (0.06) were attained in barnyard grass as well as in foxtail millet from 5.0 ppm *Eucalyptus camaldulensis* (leaf) aqueous extracts which was the highest concentration among all the treatments. Thus the data found in this table indicated that the increasing treatment concentration has vast negative impact on plumule length and radicle length performance.

Table 9: Interaction effects of *Eucalyptus camaldulensis* (leaf) aqueous methanol on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass with treatments

Combined interaction	Plumule	Mean
T_0=Control × Broccoli	3.0700 ab	5.9750 abc
T_0=Control × Barnyard grass	2.7750 def	5.4050 ef
T_0=Control × Cauliflower	3.2300 a	6.2900 a
T_0=Control × Foxtail millet	2.8900 cd	5.6250 de
T_0=Control × Tomato	3.0300 bc	5.9000 bcd
T_1=1.0 ppm × Tomato	2.6250 fg	5.7750 bcd
T_1=1.0 ppm × Broccoli	2.6800 ef	2.0650 n
T_1=1.0 ppm × Barnyard grass	1.0600 jk	6.0800 ab
T_1=1.0 ppm × Cauliflower	2.8500 de	2.1500 n
T_1=1.0 ppm × Foxtail millet	1.1050 j	5.6600 cde
T_2=2.0 ppm × Broccoli	2.3750 h	4.8750 gh
T_2=2.0 ppm × Barnyard grass	0.7500 m	1.4700 o
T_2=2.0 ppm × Cauliflower	2.4700 gh	5.1300 fg
T_2=2.0 ppm × Foxtail millet	0.7850 lm	1.5300 o
T_2=2.0 ppm × Tomato	2.3450 h	4.7750 h
T_3=3.0 ppm × Broccoli	1.7500 i	3.6100 ij
T_3=3.0 ppm × Cauliflower	1.9000 i	0.5600 p
T_3=3.0 ppm × Tomato	1.7400 i	3.8000 i
T_3=3.0 ppm × Barnyard grass	0.2850 o	0.5800 p
T_3=3.0 ppm × Foxtail millet	0.2950 no	3.5350 ij
T_4=4.0 ppm × Broccoli	0.8650 lm	3.1600 kl
T_4=4.0 ppm × Cauliflower	0.9500 jkl	0.3050 pq
T_4=4.0 ppm × Tomato	0.9150 klm	3.3250 jk
T_4=4.0 ppm × Barnyard grass	0.0300 p	0.3150 pq
T_4=4.0 ppm × Foxtail millet	0.0300 p	3.0950 kl
T_5=5.0 ppm × Tomato	0.4650 n	2.7100 m
T_5=5.0 ppm × Broccoli	0.3150 no	2.8500 lm
T_5=5.0 ppm × Barnyard grass	0.0000 p	0.0600 q
T_5=5.0 ppm × Cauliflower	0.3350 no	2.6800 m
T_5=5.0 ppm × Foxtail millet	0.0000 p	0.0650 q

4.15 Effects of *Eucalyptus camaldulensis* (leaf) aqueous extract on dry weight (DW) in net house

The effect of *Eucalyptus camaldulensis* (leaf) aqueous extract on dry weight of five selective plants exhibited wide variation. Dry weight inhibition was increased when the extract concentration was increased (Figure 6). The control showed 0.100, 0.095, 0.094, 0.089 and 0.086g for cauliflower, broccoli, tomato, foxtail millet and barnyard grass dry weight which was the highest value among all. On a dry weight basis, the most reduction was recorded when selected plants were treated with an extract of *Eucalyptus camaldulensis* at 5.0 ppm concentration. From the figure it was observed that, the higher concentration of *Eucalyptus camaldulensis* (leaf) aqueous extract reveal negative effects on dry weight but with variation among the five plants. The dry weight of all but tomato was significantly inhibited by the extracts at any concentrations of *Eucalyptus camaldulensis*. Maximum value was observed in foxtail millet and barnyard grass followed by cauliflower and broccoli with the effect of *Eucalyptus camaldulensis* (leaf) aqueous methanol solution that indicates significant impact on monocot than dicot.

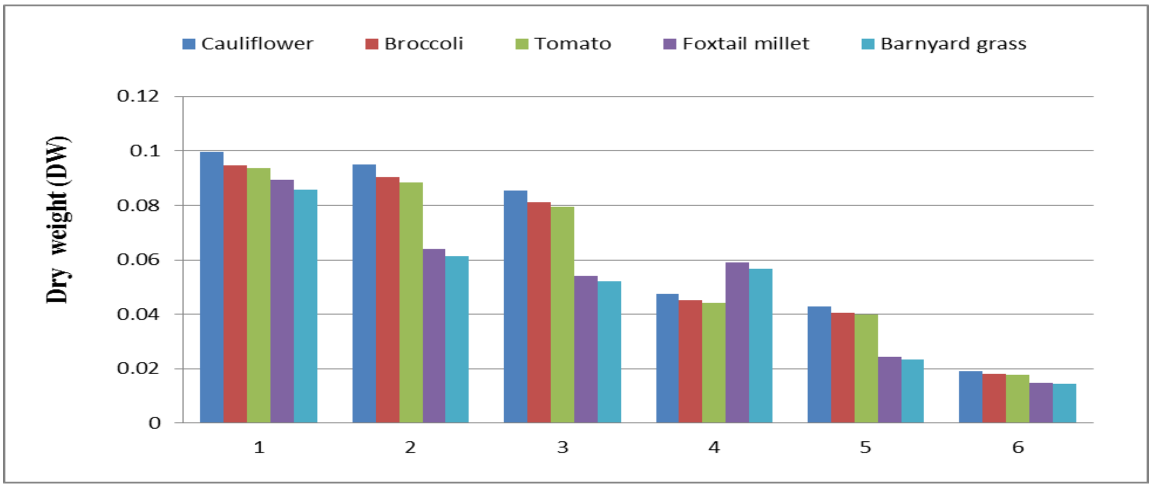

Figure 6: Variation in the dry weight (g) of cauliflower, broccoli, tomato, foxtail millet, barnyard grass as affected by different concentrations of *Eucalyptus camaldulensis* (leaf) aqueous extract in net house

CHAPTER IV

SUMMARY AND CONCLUSION

The various leaf and bark extracts of *Eucalyptus camaldulensis* had different degrees of inhibition on germination percentage of monocot and dicot seeds. The phytotoxic effects of *Eucalyptus camaldulensis* extracts (leaf and bark) on seed germination depended on their concentrations, the inhibition was stronger at the higher concentrations. The germination percentage values of five plants was recorded maximum at control conditions and was decreased upon applying at 0.001, 0.003, 0.01, 0.03 and 0.1 g mL^{-1} concentrations respectively. The minimum inhibitory activity was observed with control treatment. As the treatment concentration value increased, the germination percentage value of the plants were decreased in consistent and the least value of germination percentage was found from 0.1 g mL^{-1} treatment while the other germination percentage took intermediate positions and they were statistically different among themselves. The aqueous extract (leaf and bark) of eucalyptus showed high phytotoxicity against monocot plant eg. foxtail millet and barnyard grass and comparatively less effect was shown in dicot plants eg. cauliflower, broccoli and tomato. On the other hand among the three dicotyledonous plants, minimum treatment effect was observed in tomato plant followed by cauliflower and broccoli as because the size of the tomato seed was much bigger than other four plants.

The difference in phytotoxic effect of *Eucalyptus camaldulensis* extracts (leaf and bark) on plumule and radicle length, and seedling biomass was showed considerable differences among monocot and dicot plant species due to different treatment concentrations. For initial seedling growth, all various concentrated leaf and bark aqueous extracts had different effects on plumule length and radicle length of cauliflower, broccoli, tomato, foxtail millet and barnyard grass. The stronger inhibitory effect on plumule and radicle lengths were found in 0.1g mL^{-1} aqueous eucalyptus plant extracts (leaf and bark) which was the highest concentration among all the treatments, whereas the maximum length of both plumule and radicle were recorded in five plants was from control treatment.

Moreover in all eucalyptus plant extracts (leaf and bark) higher concentrations caused greater reduction of plumule and radicle growth. So, seedling growth ceased completely at higher (0.1g mL^{-1}) concentration.

For dry weights, higher concentrated aqueous eucalyptus leaf and bark extracts caused greater phytotoxicity in comparison with other treatments. In all extracts, decrease in dry weights of seedlings became greater with increase in concentration, so that the minimum dry weights of cauliflower, broccoli, tomato, foxtail millet and barnyard grass seedlings were observed at 0.1 g mL^{-1} concentration where control gives the highest value.

For field attributes, results showed similarities as in the laboratory experiment. Maximum treatment effect was observed on germination and seedling growth of monocot plants (foxtail millet and barnyard grass) followed by three dicot plants (cauliflower, broccoli and tomato).

The present study reveals that the leaf and bark aqueous extracts of eucalyptus significantly reduced the germination and also suppress the plumule and radicle growth and more inhibition was seen with higher concentrations. These inhibitory effects may be attributed to the allelochemicals such as phenolic acids, tannins and flavonides present in Eucalyptus leaves and bark. The treatment concentration which caused the least inhibition of plants germination and seedling growth were at control. Findings of the present investigation indicated greatest variation of treatment effect between the monocot and dicot plants where monocot plants (foxtail millet and barnyard grass) showed great treatment effects than dicot plants (Cauliflower, broccoli and tomato) and out of three dicot plants, the least variation of treatment effect was found in tomato because of its larger seed size. The treatment effect of *Eucalyptus camaldulensis* extracts (leaf and bark) caused the greatest variation in the germination percentages, plumule length, radicle length and dry weight of five selective plants but mostly in foxtail millet and barnyard grass. Thus, phototoxic effect of eucalyptus may reduce weed competition with crops by affecting the germination and seedling growth of foxtail millet and barnyard grass. Therefore, it is possible to use these extracts as a component for production of bio-herbicides. However further works are needed for greenhouse and field test and chemical characterization of these extracts. Leaves show more phytotoxicity than bark.

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CHAPTER VII

ANNEXURE

1. ANOVA Table (*Eucalyptus camaldulensis*- Leaf)

ANOVA Table for Germination Percentage

Source	DF	SS	MS	F	P
Replication	2	2903.4	1451.71		
Treatment	5	31155.0	6231.00	947.91	0.0000
Variety	4	11538.9	2884.72	438.85	0.0000
Treatment*Variety	20	10916.8	545.84	83.04	0.0000
Error	58	381.3	6.57		
Total	89	56895.4			

Grand Mean 67.353

CV 3.81

ANOVA Table for Plumule length

Source	DF	SS	MS	F	P
Replication	2	0.5687	0.28437		
Treatment	5	17.2909	3.45819	792.83	0.0000
Variety	4	14.7464	3.68660	845.19	0.0000
Treatment*Variety	20	3.3160	0.16580	38.01	0.0000
Error	58	0.2530	0.00436		
Total	89	36.1750			

Grand Mean 0.9487

CV% 6.96

ANOVA Table for Radicle Length

Source	DF	SS	MS	F	P
Replication	2	1.2272	0.61360		
Treatment	5	39.9967	7.99935	846.76	0.0000
Variety	4	29.4028	7.35071	778.10	0.0000
Treatment*Variety	20	7.8779	0.39390	41.70	0.0000
Error	58	0.5479	0.00945		
Total	89	79.0526			

Grand Mean 1.3844

CV% 7.02

ANOVA Table for Dry weight

Source	DF	SS	MS	F	P
Replication	2	0.00068	3.400E-04		
Treatment	5	0.00896	1.792E-03	264.69	0.0000
Variety	4	0.00357	8.919E-04	131.77	0.0000
Treatment*Variety	20	0.00127	6.355E-05	9.39	0.0000
Error	58	0.00039	6.769E-06		
Total	89	0.01487			

Grand Mean 0.0334

CV% 7.79

2. **ANOVA Table (*Eucalyptus camaldulensis*-bark)**

Factorial AOV Table for germination percentage

Source	DF	SS	MS	F	P
Replication	2	2600.7	1300.37		
Treatment	5	37066.7	7413.34	1024.37	0.0000
Variety	4	11300.6	2825.16	390.38	0.0000
Treatment*Variety	20	10649.1	532.46	73.57	0.0000
Error	58	419.7	7.24		
Total	89	62036.9			

Grand Mean 63.746

CV% 4.22

Factorial AOV Table for Plumule length

Source	DF	SS	MS	F	P
Replication	2	0.5361	0.26805		
Treatment	5	18.7485	3.74970	868.46	0.0000
Variety	4	13.1964	3.29910	764.09	0.0000
Treatment*Variety	20	3.2451	0.16226	37.58	0.0000
Error	58	0.2504	0.00432		
Total	89	35.9766			

Grand Mean 0.9219

CV% 7.13

Factorial AOV Table for Radicle Length

Source	DF	SS	MS	F	P
Replication	2	1.1291	0.56456		
Treatment	5	42.6119	8.52238	909.07	0.0000
Variety	4	26.4944	6.62360	706.53	0.0000
Treatment*Variety	20	7.2506	0.36253	38.67	0.0000
Error	58	0.5437	0.00937		
Total	89	78.0298			

Grand Mean 1.3320

CV% 7.27

Factorial AOV Table for Dry Weight

Source	DF	SS	MS	F	P
Replication	2	0.00052	2.615E-04		
Treatment	5	0.01059	2.118E-03	327.02	0.0000
Variety	4	0.01245	3.114E-03	480.84	0.0000
Treatment*Variety	20	0.00234	1.170E-04	18.07	0.0000
Error	58	0.00038	6.475E-06		
Total	89	0.02628			

Grand Mean 0.0289

CV% 8.81

3. ANOVA Table (*Eucalyptus camaldulensis*- leaf in field condition)

Factorial AOV Table for Germination Percentage

Source	DF	SS	MS	F	P
Replication	2	1021.9	510.93		
Treatment	10	38623.9	3862.39	1310.19	0.0000
Variety	4	11268.2	2817.04	955.59	0.0000
Treatment*Variety	40	9832.4	245.81	83.38	0.0000
Error	33	97.3	2.95		
Total	89				

Note: SS are marginal (type III) sums of squares

Grand Mean 55.122

CV% 3.11

Factorial AOV Table for Plumule Length

Source	DF	SS	MS	F	P
Replication	2	1.1679	0.58394		
Treatment	10	87.7214	8.77214	1416.83	0.0000
Variety	4	27.3280	6.83199	1103.47	0.0000
Treatment*Variety	40	8.2324	0.20581	33.24	0.0000
Error	33	0.2043	0.00619		
Total	89				

Note: SS are marginal (type III) sums of squares

Grand Mean 1.3521

CV% 5.82

Factorial AOV Table for Radicle Length

Source	DF	SS	MS	F	P
Replication	2	4.924	2.4621		
Treatment	10	211.966	21.1966	992.68	0.0000
Variety	4	186.296	46.5740	2181.17	0.0000
Treatment*Variety	40	27.012	0.6753	31.63	0.0000
Error	33	0.705	0.0214		
Total	89				

Note: SS are marginal (type III) sums of squares

Grand Mean 3.1758

CV% 4.60

Factorial AOV Table for Dry weight

Source	DF	SS	MS	F	P
Replication	2	0.00147	7.335E-04		
Treatment	10	0.06825	6.825E-03	653.72	0.0000
Variety	4	0.00408	1.019E-03	97.63	0.0000
Treatment*Variety	40	0.00523	1.309E-04	12.53	0.0000
Error	33	0.00034	1.044E-05		
Total	89				

Note: SS are marginal (type III) sums of squares

Grand Mean 0.0561

CV% 5.76

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