Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)

by

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(2014–11-114)

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695522

KERALA, INDIA

2016

DECLARATION

I, hereby declare that this thesis entitled **"Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

First and foremost, praises and thanks to the Lord Jesus, the Almighty, for giving me the courage, confidence and his showers of blessings to complete my research work successfully.

I am pleased to place my profound etiquette to ***Dr. Jacob John****, Professor and Head, Cropping Systems Research Centre, Karamana and the Chairman of my Advisory Committee. I am extremely grateful for his valuable guidance, suggestions, constructive criticism, support and dedication amidst his busy schedule without which this piece of work was never been possible. I feel immense pleasure in expressing my thankfulness for his help and unfailing patience throughout my research work and preparation of the thesis.*

I wish to express my heartfelt gratitude to ***Dr. Sheela, K. R.,*** *Professor and Head, Department of Agronomy and Member of my Advisory Committee for her critical suggestions and timely advice throughout the course programme.*

I am extremely grateful to ***Dr. P. Shalini Pillai****, Professor, Department of Agronomy and Member, Advisory Committee for her authentic advice, inspiring guidance, periodic suggestions and critical evaluation during the course of this work. I also convey my heartfelt thanks for her friendly approach, compassionate heart and timely help throughtout the post graduate programme.*

I greately acknowledge with sincere gratitude to ***Dr. Roy Stephen,*** *Professor, Department of Plant Physiology and Member of my Advisory Committee for his transcendent suggestions and valuable guidance throughout the course of investigation.*

I express my sincere thanks to my teachers ***Dr. Elizabeth K. Syriac, Dr. M. Meerabai and Dr. V. L. Geethakumari*** *for their mental support and motherly affection throughout the post graduate programme.*

I am thankful to ***Dr. K. Umamaheswaran*** *(Dept. of Plant pathology),* ***Dr. Vijyaraghavakumar*** *(Dept. of Agricultural Statistics)* ***Dr. Babu Mathew*** *(Professor and Head, Instructional farm),* ***Dr. G. S. Sreekala*** *(Dept. of Plantation crops and Spices),* ***Dr. R. Vijayan*** *(Dept. of Animal husbandry) and* ***Dr. B. Aparna*** *(Dept. of Soil science) for their valuable suggestions and timely help rended throughout my period of work.*

I am greatful to ***Kerala Agricultural University*** *for getting me the junior research fellowship during the tenure of the M. Sc. (Ag.) programme.*

My heartfelt thanks to ***JP chetan, Ajay chetan, Safeer ikka, Seejithettan, Achuettan, Sruthi chechi, Anjana chechi, Arya chechi, Gayathri chechi, Pintu chechi, Atul chetan, Sheeja mam, Bindhu mam and Devi mam*** *who have helped me at various stages of my work.*

I also wish to place on record my appreciation and thanks to dear seniors ***B. Renjan and G. Sreekanth*** *for their valuable guidance throughout the post graduate programme.*

I express my love and affection to my beloved classmates ***Arya Nath, Dona, Ishrath, Anjali K., Amala, Anjali Hari, Elsa, Sheeba and Vinod Mavarkar*** *for their help, companionship and generous assistance throughout my M. Sc. tenure.*

I convey my heartiest gratitude to my dear chank brothers ***Jithin, Athul, Mridul, Vinod Alur, Unnikuttan and Rajesh*** *for their care and unfalling moral support during the hardtimes and assistance throughout the period of work.*

No words are enough to express my feelings and affection towards my ***Mother, Father, Sister and Ponnuz*** *for their love, constant encouragement and moral support which enabled me to pursue this endeavour successfully.*

Eldhose Abraham

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LIST OF ABBREVIATIONS

%	-	per cent
@	-	at the rate of
°C	-	Degree Celsius
µg TPF $g^{-1}h^{-1}$	-	microgram of Triphenyl tetrazolium formazan per gram per hour
CD	-	Critical difference
CRD	-	Completely randomized design
CSRC	-	Cropping Systems Research Centre
cm	-	Centimetre
cm^3	-	Centimetre cube
C: N ratio	-	Carbon Nitrogen ratio
e.g.	-	Example
et al.	-	Co-workers/ co- authors
Fig.	-	Figure
g	-	Gram
g $plant^{-1}$	-	Gram per plant
HCl	-	Hydrochloric acid

ha^{-1}	-	per hectare
h	-	Hour
i.e.	-	that is
K	-	Potassium
KAU	-	Kerala Agricultural University
KOH	-	Potassium hydroxide
kg	-	Kilogram
kg ha^{-1}	-	Kilogram per hectare
MAP	-	Months After Planting
max	-	Maximum
min	-	Minimum
mm	-	millimetre
mg	-	milligram
mg 100 g^{-1}	-	milligram per 100 gram
m mol m^{-2} s^{-1}	-	millimol per metre square per second
mol kg^{-1}	-	millimol per kilogram
ml L^{-1}	-	millilitre per litre
MOP	-	Muriate of Potash

N	-	Nitrogen
NS	-	Not significant
pH	-	Negative logarithm of hydrogen ion concentration
P	-	Phosphorus
POP	-	Package of practices
S	-	Significant
SC	-	Suspension Concentrate
SPAD	-	Soil Plant Analysis Development
SE m	-	Standard error of mean
t	-	tonnes
t ha^{-1}	-	tonnes per hectare
UV	-	Ultra Violet
var.	-	variety
viz.	-	Namely
w/v	-	weight by volume

Introduction

1. INTRODUCTION

Excess pressure of the ever increasing human population on land for producing more food and wood has made it necessary to search for other alternatives to maximise the use of agricultural land. This has led to the concept of crop mixtures and multi-storey agroforestry systems, which are common in Kerala. Trees are key components in several agroecosystems and when trees and crops are grown together, plant-plant interactions involving allelopathy are presumed. The low productivity of crops in homesteads is often attributed to competition for nutrients, water and light. Allelopathy has been often ignored as a possible mechanism in tree-crop interaction studies.

Allelopathy encompasses all biochemical interactions, both stimulatory and inhibitory, among plants as well as microorganisms (Molisch, 1937; Rice, 1984). Allelopathy is derived from two Greek words, "allelon or allelo" meaning "mutual" and "pathos or patho" meaning "suffering". International Allelopathy Society (IAS, 1996) defines allelopathy as any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influence the growth and development of agricultural and biological systems.

Allelopathic interaction by a plant is possible through leaching, volatilization from aerial parts, decay of fallen parts and / or exudation in the rhizosphere. Rice (1974) described the influence of allelochemicals on metabolic changes of receiver plants. Trees form an integral part of agroforestry systems. Allelopathic interference results from leaching of natural products from tree canopy and root exudations. Most trees produce substantial quantum of leaves and litter, which serves as potent sources of allelochemicals.

Allelochemicals, defined as 'biocommunicators', may be produced by any part of the plant *viz.*, roots and leaves, pollen, seed or fruits, although leaves and roots

are the main sources (Horsley, 1977). Quantitatively and qualitatively, production of allelochemicals depends on the stage of the plant and is modified by environmental stresses like soil temperature, drought, flooding or poor drainage, sunlight, micro-organisms, soil salinity, diseases, herbicides, minerals and even growth regulators or hormones. The allelochemicals released are primarily secondary metabolites, which are evolved as by-products during various physiological processes in plants (Bhadoria, 2011).

The negative influence of these allelochemicals must be accounted when designing new systems, while positive effects must be exploited, especially for eco-friendly agriculture. Systematic screening of trees, crops and its combinations has to be done to reduce the harmful allelopathic interactions.

Trees produce a substantial quantum of litter, which are potential source of allelochemicals. But researchers had not paid any attention on allelopathic properties of agroforestry species. Detailed information on the effect of agroforestry species on other crops is limited. Such information is needed to identify the alleopathically compatible agroforestry species and incompatible ones with inhibitory effect. This will enable to formulate the suitable agroforestry-crop combinations for higher yield.

Ginger (*Zingiber officinale* Roscoe), a commercial crop of great importance in the tropics and subtropics, has been cultivated as a spice since thousands of years. In Kerala, the area under ginger during 2012-13 was 4538 ha with a total production of 21521 tons. The productivity in 2012-13 was 4742 kg ha^{-1} (FIB, 2016). Ginger is a shade tolerant crop and is hence, suitable for intercropping under the shaded conditions existing in multistorey home gardens.

Mulching ginger after planting with green leaves at the rate of 15 t ha^{-1} and thereafter twice at 44-60 days and 90-120 days @ 7.5 t ha^{-1} is also recommended (KAU, 2011). The allelopathic effect of mulching tree leaves and the compatibility of these trees beneath with which ginger is planted is lacking.

Hence, the present investigation entitled "Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)" was taken up with the objective of investigating the allelopathic effect of trees commonly planted in the homesteads of southern Kerala on sprouting, growth and yield of ginger.

Review of Literature

2. REVIEW OF LITERATURE

Homestead farming, the predominant land use system in Kerala, where agricultural crops and trees are grown in close association, has been practiced by farmers, since time immemorial. Even though trees are rich sources of allelochemicals, the allelopathic interactions between trees and the associated crops have often been overlooked. Ginger is a major and common tropical spice crop that is cultivated in home gardens of Kerala. Mulching is a compulsory agronomic requirement for ginger, which helps to improve the soil physical, chemical and biological properties thereby resulting in increased productivity. The present study entitled "Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)" was aimed to identify the allelopathic effect of trees commonly planted in the homesteads of southern Kerala on sprouting, growth and yield of ginger. In this chapter, an effort has been made to review the available literature on allelopathic effect of leaf leachates, extracts and fresh leaf loppings of various multipurpose trees on agricultural crops.

2.1 ALLELOPATHY DEFINED

The term allelopathy, in general, refers to the damaging effects of plants of one species on the germination, growth or development of plants on another species. The term allelopathy was coined by Molisch (1937) to refer to all chemically mediated interactions among plants (microbes and higher plants), stimulatory and inhibitory. It includes interspecific as well as intraspecific chemical co-action (Bonner, 1950). IAS (1996) defines allelopathy as any process involving secondary metabolites produced by plants, algae, bacteria and fungi that influence the growth and development of agricultural and biological systems. The chemicals through which allelopathic effect is imposed are known as allelochemicals or allelochemics (Whittaker, 1970).

2.2 ALLELOPATHY IN AGROFORESTRY SYSTEMS

Agroforestry includes land use systems in which woody perennials are deliberately combined with agricultural crops and/or animals on the same land management unit in some form of arrangement over space or time (TNAU, 2016). The success of an agroforestry system depends on the allelopathic compatibility between the tree species and the agricultural crops. Trees are rich sources of allelochemicals, which exerts environmental stress on other plants growing nearby known as "tree allelopathy" (Nandal *et al.*, 1994). Several phytochemicals have been identified in various parts of test trees, some of these may be inhibitory (Nandal *et al.*, 1994).

Most of the trees remain part of the agroecosystem for a substantial time and consequently add considerable amount of litter. Therefore, it is desirable to identify trees species with positive and negative allelopathic effects on the companion crops. If wisely exploited, allelopathy could play a main role in improving the production and productivity of agroforestry systems (Singh *et al.*, 2012). The co-existence of perennial plants with agricultural crops and their allelopathic compatibility may be vital in ensuring the success of an agroforestry system (Hossain *et al.*, 2012).

Systematic evaluation of crop and woody plant combinations for allelopathic interactions will provide useful information to design new systems.

2.3 ALLELOCHEMICALS, THE POTENTIAL SOURCE

Allelochemicals, defined as 'biocommunicators', may be produced by any part of the plant viz., roots and leaves, pollen, seed or fruits, although leaves and roots are the main sources (Horsley, 1977). Quantitatively and qualitatively, production of allelochemicals depends on the stage of the plant and is modified by environmental stresses like soil temperature, drought, flooding or poor drainage, sunlight,

microorganisms, soil salinity, diseases, herbicides, minerals and even growth regulators or hormones. Allelochemicals thus released are mainly secondary metabolites or by-products produced during different physiological processes in plants (Bhadoria, 2011).

Some trees are rich sources of secondary metabolites (allelochemicals), which play a crucial role in patterning of vegetation, distribution of plants in communities, nitrification, nitrogen fixation and ecosystem balance. Trees form an integral part of agroforestry systems. Most trees produce substantial quantum of leaves and litter, which serves as potent sources of allelochemicals. The negative influence of these allelochemicals must be accounted, while designing new systems, while positive effects must be exploited, especially for eco-friendly agriculture.

In addition to the direct effects of allelochemicals on plant growth and development their indirect effects have influence on by microbial activity. Meier and Bowman (2008) suggest that phenolic compounds can inhibit root growth directly as well as indirectly affect growth by reducing pools of plant available N by stimulating soil microbes.

According to Reigosa *et al.* (1999), allelopathy can affect distribution pattern of plants and biodiversity. They further explained that in a climax forest, germination and growth of understorey species must cope with allelochemicals released by the dominant trees. Those trees could release different chemicals, producing differences in the species composition. Similarly, Carballeira and Reigosa (1999) also indicated that monocultures (pure stands) allow the accumulation of particular allelochemicals affecting species composition.

Phenolics, alkaloids, salicylates, brassinosteroids, terpenoids, hydroxamic acids, jasmonates, momilactone flavonoids, glucosinolates, carbohydrates and amino acids are some of the major secondary metabolites recognized as allelochemicals

(Kruse *et al.*, 2000; Jabran and Farooq, 2012). The effect of allelochemicals present in the soil on crop plants is modified by factors such as soil moisture and soil temperature (Einhelling and Eckrich, 1984). Some of allelochemicals like terpenoids and polyacetylenes function in volatile state while most of current research in allelochemicals follows in water soluble compounds.

The presence of several phytochemicals in trees were reported (Duke, 1992). *Ailanthus altissima* contains ailanthin, ailanthinone, ailanthone, beta-sitosterol, gallic-acid, isoquercetin, isoquercitrin, linuthin, quassiin, quercetin, scopoletin and tannin. *Anacardium occidentale* contains alpha-linolenic acid, anacardic acid, anacardol, beta-sitosterol, capric acid, caprylic acid, cardanol, cardol, gadoleic acid, gallic acid, lauric acid, limonene, naringenin, palmitic acid, squalene, tannin and threonine. *Artocarpus heterophyllus* contains betulinic acid and tannin. Kaempferol-3-alpha-rhamnoside, quercetin-3-alpha-araboside, luteolin-3', 4'-dimethoxy-7 beta-rhamnoside, kaempferol-3-betadirhamnoside, quercetin-3-beta-glucoside is present in *Casuarina equisetifolia*. *Gliricidia sepium* contains gallic acid, protocatechuic acid, p-hydroxybenzoic acid, gentisic acid, beta-resorcyclic acid, vanillic acid, syringic acid, p-coumaric acid, m-coumaric acid, o-coumaric acid, ferulic acid, sinapinic acid (trans and cis forms), coumarin, and myricetin. Alanine, alpha-pinene, beta-pinene, gallic acid, gallotannic acid, isoleucine, isomangiferolic acid, kaempferol, lauric acid, limonene flower, linoleic acid, linolenic acid, mangiferic acid, mangiferine, mangiferol, mangiferolic acid, mangiferonic acid, myristic acid, p-coumaric acid, palmitic acid, quercetin, tannin and threonine are present in *Mangifera indica*. Alpha terpineol, cinnamaldehyde, ethyl cinnamate, galacturonic acid, geranial essential oil, geraniol essential oil, limonene, linoleic acid, myristic acid, oleic acid, palmitic acid, pantothenic acid, phenol, pipecolinic acid, tannin and tartaric acids found in *Tamarindus indica*. *Tectona grandis* contains betulin and betulinic acid. *Strychnos nux-vomica* has arachidic acid, brucine, chlorogenic acid, cycloartenol, linoleic acid, myristic acid, palmitic acid, strychnicine and strychnine.

The composition nut shell liquid (CNSL) contains anacardic acid (71.7%), cardol (18.7%), cardanol (4.7%), novel phenol (2.7%) and two unknown minor ingredients (2.2%) (Tyman and Morris, 1967).

Subabul (*Leucaena leucocephala*) contains 10 phytotoxins like mimosine, quercetin, gallic, protocatechuic, p-hydroxybenzoic, p-hydroxyphenylacetic, vanillic, ferulic, caffeic and p-coumaric acids (Chou and Kuo, 1986).

Ramamoorthy and Paliwal (1993) identified 15 toxic compounds from *Gliricidia sepium*, including gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, gentisic acid, β-resorcyclic acid, vanillic acid, syringic acid, 3-coumaric acids, ferulic acid, sinapinic acids, coumarin and myricetin.

Lin *et al.* (1996) identified the active constituents in *Ailanthus altissima* including Ailanthone and chaparrinone.

From the leaves of *Acacia leucopholea* different phenolic acids *viz.*, hydroquinone, salicylic acid, trans-cinnamic acid, gentisic acid, vanillic acid, protocatechuic acid, p-coumaric acid and trans-ferulic acid were identified. Different functional groups of tannins were also identified (Jayakumar and Manikandan. 2005).

John *et al.* (2007b) reported that leaf extracts of ailanthus contains triterpenes, cashew contains terpenoids, triterpenes and saponins, jack contains flavonoids and terpenoids, mango contains terpenoids and triterpenes, tamarind contains flavonoids and terpenoids and teak contains triterpenes.

Macias *et al.* (2010) isolated a new compound, abeograndinoic acid, from *T. grandis*, which has an unusual carbon skeleton. A further 21 known terpenoids including four sesquiterpenoids, eight diterpenes and nine triterpenes were also isolated. Two new quinones (an isoprenoid quinone, and a dimeric anthraquinone)

named naphthotectone and anthratectone respectively were isolated from bioactive leaf extracts of *Tectona grandis*.

Total phenolic content was higher in new mango leaves as compared to old ones. The compounds identified in mango leaves were 4-hydroxybenzaldehyde, *m*-coumaric, *p*-coumaric, 4-hydroxy benzoic, vanillic, caffeic, gallic and protocatechuic acids (Saleem *et al.*, 2014).

Oxalic and tartaric acids are the major allelochemicals in tamarind (*Tamarindus indica*) leaves (Syed *et al.*, 2014). The *Artemisia annua* produces artemisinin (Jessing *et al.*, 2014).

Phenolic acids *viz.*, salicylic acid, p-hydroxy benzoic acid, chlorogenic acid, tannic acid, caffeic acid, vanillic acid are reported to occur in teak with inhibitory or stimulatory effect (Mandal *et al.*, 1998; Tripathi *et al.*, 1999).

Khan and Mlungwana (1999) identified that the extract of the root heart wood of teak exhibited cytotoxic effect due to lapachol and 5-hydroxylapachol. The teak bark extract contains 5-hydroxy-1, 4-naphthalenedione (Juglone) which inhibited the *Listeria monocytogenes* and *Staphylococcus aureus* (Neamatallah *et al.*, 2005).

2.4 MODE OF ALLELOPATHIC INTERACTIONS IN AGROFORESTRY SYSTEMS

The major requisite of allelopathy is that an organic substance or alleochemical be transferred from one plant to another plant. So the way in which this transfer occurs has an important role in the expression of effects. The various organic and inorganic substances, secondary metabolites, allelochemicals or ecochemicals present in any plant is released through processes like leaching, volatilization, root exudation, extraction and decomposition. The allelopathic potential of leachates, extracts and

decomposed residues depends on the type and quantity of allelochemicals existing in them. The allelopathic stimulation or inhibition in recipient plants and their response also depends on the way in which they are exposed to the allelochemicals.

2.4.1 Volatilization

Volatilization is the release of natural products into the atmosphere. Numerous plants either secrete metabolic products into trichomes and glands or into intercellular spaces and canals, or onto leaf surfaces. Terpenoids and monoterpenoides when present in large quantities in plants may be released in hot, dry weather to the atmosphere, where they may be adsorbed onto soil surface or directly absorbed by plants (Horsley, 1991). Besides, they may also be absorbed as vapour by neighbouring plants, from dew or may reach the soil and be taken up by the roots (Muller, 1966). The plants which release volatiles are *Artemisia, Eucalyptus, Parthenium* and *Salvia* (Rice, 1984).

2.4.2 Leaching

Leaching is the removal of water soluble substances from plants by the action of rain, dew, mist and fog. Phytochemicals leach out from all plants, but the amount and quality of leachable products varies greatly with species. It depends on the physiological age of the plant part, growth stage, plant health, light, temperature, nutritional conditions, and the intensity and volume of the leaching solution (Tukey, 1970). Radioisotope studies before leaching have revealed that substantial amounts of both inorganic and organic natural products are leached from plant tissue (Tukey, 1970). The major allelochemicals released *via* leaching include many different organic and inorganic compounds such as phenolic compounds, terpenoids, alkaloids etc. (Rice, 1984). The secondary compounds released depends on the crop that is being subjected to leaching (Guenzi and McCalla, 1962; 1967). In order to identify

allelopathic activity, the procedure for leachate preparation should be similar to that existing under natural situations (Horsley, 1991).

2.4.3 Root Exudation

The release of chemicals into the surrounding medium by healthy, intact plant roots is called as root exudation. Even though their volume is small (i.e. 2-12% of the total gross photosynthates), these contribute greatly to allelopathy (Rice, 1974). A variety of natural products has been found in plant root exudates, but when compared to leaves, the amounts of organic materials are much smaller (Rovira, 1969). Factors such as plant species, growth stage, temperature, light, nutritional conditions, soil moisture and root damage, microbial activity around the roots and the nature of medium supporting roots affect the quantum and quality of the released material (Rovira, 1969). Similarly, exudation in soils can be expected to vary with soil properties. Wilting and root-damage of plants stimulates exudation (Clayton and Lamberton, 1964). Many of the compounds released *via* roots are known to reduce seed germination, root and shoot growth, nutrient uptake, and nodulation (Rice, 1984). Studies of allelopathic activity of aggressor plant roots could not distinguish the natural products originating from root exudates or dead root tissue or microbial rhizosphere products (Horsley, 1991).

In multi-storey cropping systems, there is very high root density of component plant species (trees + crops), it seems that roots of component plant species intermingle with each other leading to allelopathic interaction through root exudates. Moreover, despite the deep rooting characteristics of trees, most of the fine feeder roots are found within the top 20 cm of the soil. For example, the rubber tree has its fine feeder roots concentrated in the top 15-30 cm soil layer and spreading up to several meters. These roots are continuously sloughed off. Substances exuding from

the roots may affect adjacent species directly or may influence them indirectly through decomposition of such biomass (John and Nair, 2000).

2.4.4. Decomposition of Crop Residues

Plant residues, on decomposing, contribute large amount of allelochemicals to the rhizosphere. Litter, including leaves and twigs, is one of the main decomposing residue present in agroforestry systems. The adverse effects of decomposing residues include suppression of seed germination, stunted growth, reduced nutrient absorption, chlorosis, slow maturation, adverse effect on reproduction, inhibition of the primary root system and increase in the secondary root system (Patrick *et al.*, 1964). The water soluble inhibitors present in plants are quickly decomposed during decomposition. Patrick *et al.* (1964) estimated that up to 30 per cent of the plant dry matter entering decay cycle was lignin, which is formed from alcohols and acids.

Plant residues and mulches, commonly recycled in multi-storey cropping systems, may be a main source of allelochemicals that affects crop productivity. To improve nitrogen nutrition of crop plants, plant residue mulches, are usually utilized which may also lead to allelopathic interactions. In conservation tillage and during mulching, crop residues are left on the soil surface or incorporated into the soil. Consequently, large quantities of water soluble and partially water soluble products are liberated during decomposition of the residues. Soil sickness by allelopathic means is likely when substantial quantities of crop residue are left in the fields (Duke, 1985).

The plantation crops being mainly perennial crops produce a huge amount of waste biomass. It has been estimated that a coconut garden with 175 trees ha^{-1} generates biomass of 7000 kg, which comprises of dry leaves, sheathes, spadices, inflorescences and coconut husks. During monsoons, tannins oozing out of such heaps, creates problems of environmental pollution (Bidappa *et al.*, 1996). The cut oil

palm (*Elaeis guinensis*) fronds constitute a major source of organic manure yielding 10 t dry matter ha^{-1} (Varghese and Rethinam, 1994). Cardamom is a shade loving crop, hence, grown underneath the trees in the forests, generally high in fertility status due to leaf fall and its decomposition (Zachariah, 1978). On an average, 5-8 t dry leaves fall annually from shade trees in a hectare of cardamom (Korikanthimath, 1994). The wastes and surplus residues obtained from plantation crops is recycled back to the soil by various methods such as mulching, in situ incorporation and composting. The wider C: N ratio coupled with low N content, presence of soluble tannins (8-12 %), low biodegradability are some of the problems associated with coir pith (Fan *et al.*, 1982). Various measures to eliminate its phytotoxicity in the field to improve the crop productivity includes, removal of phytotoxins by flooding, crop rotation and detoxification through nutrient application (Chou, 1986). The rubber tree during its first five years of growth adds up to 5 t of leaf litter ha^{-1} (Lin *et al.*, 1996). Common trees of home gardens like jack (*Artocarpus heterophyllus*), wild jack (*Artocarpus hirsuta*), mango (*Mangifera indica*), mahogany (*Sweitania macrophylla*), bamblimass (*Citrus maxima*), nutmeg (*Myristica fragrans*), and coffee (*Coffea arabica*) annually contribute 3.51, 3.95, 2.43, 1.93, 1.73, 4.25 and 2.10 t litter ha^{-1} respectively (John, 1997). The increased amount of litter could remain active for a long time in low rainfall areas and may inhibit growth of subsequent intercrops.

When plant tissues age and die, cell membrane integrity is lost. Allelochemicals that are compartmentalized in living cells are released into the surroundings and react with other natural products resulting in qualitative changes in some of these products. Once natural products enter the soil as incorporated soil residues, additional qualitative changes occur as a result of physicochemical action of the soil and the activities of soil microorganisms (Dalton *et al.*, 1983; Kimber, 1973; Martin *et al.*, 1972). The secondary compounds released from litter or formed will be influenced by microbial populations present in the soil (Norstadt and McCalla, 1963).

Soil microorganisms can modify nontoxic materials to phytotoxic ones (Patrick *et al.*, 1964; Hassan *et al.*, 1989) or reduce phytotoxicity of crop residues (Haider and Martin, 1975). Microbial metabolism of organic compounds may increase or decrease the toxicity due to release of organic carbon as CO_2, fixation into microbial biomass or transformation to other products. The soil microbial biomass has been studied in several multi-storey cropping systems. Coconut-cacao mixed cropping have shown greater microbiological activity than coconut monocropping system (Nair and Rao, 1977). The microbial biomass (bacteria, fungi, actinomycetes) was higher in arecanut-based high density multispecies cropping systems than in monocropping. The nature and activity of microorganisms associated with perennial monocrop are changed with introduction of other crops (Bopaiah, 1991). In homesteads of Kerala, the soil microflora was found to vary with the cropping intensity, crop diversity, planting pattern of crops and the management practices adopted (John, 1997).

Initial experiments to determine the involvement of allelochemicals arising from residue decomposition should concentrate on simulating field conditions as closely as possible. The same quantity, quality and age of residue described during symptom description should be used; soil moisture and aeration conditions should also be similar (Horsley, 1991). Experiments that use artificial media lacking active microbial populations may give results of little value in determining the cause of inhibition in field situations (Martin *et al.*, 1972).

2.5 ALLELOPATIC EFFECT OF TREES ON CROPS

Ovalle and Avendano (1987) reported that trees increase understorey herbaceous productivity.

The overall effect of trees on understorey vegetation depends on the balance between their positive (facilitation) and negative

(competition) effects (Callaway and Walker, 1997). Rafiqul-Hoque *et al.* (2003) have shown that certain trees contain higher levels of bioactive chemicals suggesting a large inhibitory potential.

In most of the cases, allelopathic effects are selective and vary with different tree crops (Stowe, 1979; Melkania, 1986). In general, leaves are most potent source of allelochemicals however, the toxic metabolites are also distributed in all other plants parts in various concentrations. The allelopathic effect may be so striking that competition for resources does not explain why in plant communities many species appear to regulate one another through the production and release of chemicals attractants, stimulators or inhibitors (Putnam and Tang, 1986).

2.5.1 Allelopathic Effect of Tree Leaf Leachates on Crops

2.5.1.1 Effect on Germination

Konar and Kushari (1989) reported that leaf leachates of *Mangifera indica, Shorea robusta and Tectona grandis* increased the percentage sprouting of *Costus speciosus* and shortened the sprouting time, while the leaf leachate of *Eucalyptus globulus* inhibited rhizome sprouting.

Terminalia tomentosa leaf leachate inhibited germination of cowpea and rice seeds (Gayner and Jadhav, 1992).

John and Nair (1998) reported significant inhibition of rice seed germination by leaf leachates of ailanthus, tamarind (*Tamarindus indica*), acacia (*Acacia auriculiformis*) and portia. The inhibition was less by leaf leachates of mango (*Mangifera indica*), bombax and cashew (*Anacardium occidentale*). The leaf leachates of acacia, eucalyptus, casuarina, ailanthus, tamarind, portia and cashew inhibited the germination of cowpea.

The leaf leachates of *Acacia auriculiformis, Casuarina equisetifolia, Bambusa arundinacea* and *Tectona grandis* significantly inhibited germination of tomato, aubergine and chilli (Krishna *et al.*, 2003).

Morus alba, Melia azedarach and Albizzia lebbek leaf leachates inhibited seed germination of *Brassica juncea* (Abdulla *et al.*, 2005).

Krishna *et al.* (2005) recorded the adverse allelopathic effects of *Acacia auriculiformis, Casuarina equisetifolia, Eucalyptus* hybrid and *Mangifera indica* on the germination of kasthuri bendi (*Abelmoschus moschatus*) and sanka pushpa (*Clitoria ternatea*). The adverse effect of the four multipurpose trees differed with each medicinal plant. However, maximum adverse effect was recorded with *M. indica*, while minimum adverse effects were observed in *Eucalyptus* hybrid. Sanka pushpa showed the greatest sensitivity compared to the other species tested.

Leaf leachates of *Gliricidia sepium* and *Acacia auriculiformis* significantly decreased germination percentage and increased mean germination time of maize (*Zea mays*) (Oyun, 2006).

The leaf leachates of *Tectona grandis* inhibited the seed germination of cowpea. Gliricidia, cashew and mango showed strong inhibitory effect on germination of brinjal. Teak, jack and casuarina also inhibited seed germination (John *et al.*, 2007a).

El-Khawas and Shehata (2005) reported that leaf leachates of *Acacia nilotica* and *Eucalyptus rostrata* inhibited germination of *Zea mays* and *Phaseolus vulgaris*.

With increasing teak leachate concentration the inhibitory effect on germination and growth of wheat seedlings increased (Patil *et al.*, 2003).

2.5.1.2 Effect on Growth

Konar and Kushari (1989) reported that the leaf leachates of trees like *Mangifera indica, Shorea robusta and Tectona grandis* promoted the growth of *Costus speciosus*, while the leaf leachate of *Eucalyptus globulus* inhibited the growth.

Leaf leachate of *Terminalia tomentosa* stimulated growth of cowpea (Gayner and Jadhav, 1992).

John and Nair (1998) observed that the leachates of acacia, ailanthus (*matty*), tamarind and portia caused maximum suppression of plumule growth in rice. The degree of inhibition was still greater in radicle length. The leaf leachates of acacia, ailanthus, tamarind and portia proved most harmful. The inhibition was minimal from leaf leachates of bombax and jack. In cowpea, the tree leaf leachates of ailanthus and subabul caused maximum inhibition of plumule growth. The inhibition by jack leaf leachate was least. Maximum reduction of root growth in cowpea was caused by ailanthus, tamarind, cashew, albizzia and eucalyptus.

Aqueous leachates of *Eucalyptus globulus* reduced the chlorophyll content in the leaves of *Costus speciosus* and finger millet (Konar and Kushari, 1995; Padhy *et al.*, 2000).

Mango leaf leachate decreased germination, root length and seedling fresh weight of Gobhi sarson (Sharma *et al.*, 2000).

The leaf leachates of *Acacia auriculiformis, Casuarina equisetifolia, Bambusa arundinacea* and *Tectona grandis* significantly inhibited growth of tomato, aubergine and chilli. Response indices revealed that inhibition of radical and plumule growth was more pronounced (Krishna *et al.*, 2003).

All the seedling growth parameters, including seedling vigour index of maize (*Zea mays*) decreased significantly with leaf leachates of both *Gliricidia sepium* and *Acacia auriculiformis* (Oyun, 2006).

John *et al.* (2007a) reported the allelopathic effect of leaf leachates of *Artocarpus heterophyllus*, *Mangifera indica*, *Ailanthus triphysa*, *Anacardium occidentale*, *Tamarindus indica*, *Tectona grandis*, *Thespesia populnea*, *Casuarina equisetifolia*, *Gliricidia sepium* and *Strychnos nux-vomica* on the growth of cowpea, bitter gourd and brinjal. The leaf leachates of *Gliricidia sepium*, *Strychnos nux-vomica* and *Tamarindus indica* significantly inhibited the plumule growth of cowpea. Gliricidia, tamarind, strychnos, *Anacardium occidentale* and *Casuarina equisetifolia* were most inhibitory to cowpea. Strychnos, portia, mango and tamarind were most inhibitory. Leaves of *Tectona grandis*, *Thespesia populnea* and gliricidia caused maximum inhibition. Leaf leachates of casuarina, *Mangifera indica* and strychnos did not suppress root growth, whereas, gliricidia, tamarind and teak were most inhibitory. The inhibitory effects of the leaf leachate were more prominent in brinjal. Casuarina and strychnos adversely decreased the plant height at 2 MAP of cowpea. Casuarina leaf leachate inhibited the leaf production. *Ailanthus*, casuarina and gliricidia leachates inhibited the root growth. Leaf leachate of teak, casuarinas, tamarind, and strychnos caused severe inhibition of cowpea, hence were incompatible. All trees, except gliricidia, portia and tamarind, reduced the leaf production of bitter gourd at 2 MAP. Strychnos, mango, portia and tamarind also suppressed the root growth. Cashew, tamarind and teak significantly reduced the plant height of brinjal. Irrigation with *Ailanthus*, cashew, jack, strychnos, tamarind and teak leaf leachate severely inhibited the root growth in brinjal. Gliricidia, portia, tamarind, teak and cashew were incompatible.

John *et al.* (2010) reported that guinea grass plants treated with sapota, *matty*, wild jack, neem (*Azadirachta indica*) and tamarind (*Tamarindus indica*) leachates

had greater height compared to control. Tiller production was promoted by sapota and gliricidia leachates. Leaf production was severely affected by cocoa and mahogany leachates.

The aqueous leaf leachate of *Mangifera indica* suppressed growth and development of *Capsicum annum* (chilli), *Glycine max* (soybean), *Zea mays* (maize), *Oryza sativa* (rice) and *Abelmoschus esculentus* (bhindi) (Sahoo *et al.*, 2010).

Pot culture and field studies were undertaken to assess the allelopathic compatibility between pepper (var. Panniyur 1) and 21 multipurpose trees *viz.*, *Achras sapota*, *Ailanthus triphysa*, *Anacardium occidentale*, *Artocarpus heterophyllus*, *Artocarpus hirsute*, *Azadirachta indica*, *Bombax malabaricum*, *Casuarina equisettifolia*, *Coffea arabica*, *Erythrina indica*, *Gliricidia sepium*, *Hevea brasilensis*, *Leucaena leucocephala*, *Macaranga peltata*, *Mangifera indica*, *Psidium guajava*, *Swietania macrophylla*, *Tamarindus indica*, *Tectona grandis*, *Theobroma cacao* and *Thespesia populnea*. It was inferred that, due to inhibitory effects of the leaf leachates, caution should be exercised while green manuring or mulching pepper plants continuously with leaves of the trees. From the field studies it was revealed that, besides coconut, trees such as wild jack, jack, erythrina, teak, neem and mango can be safely recommended as suitable alternate standards for trailing pepper (John *et al.*, 2011).

Shoot and root growth and fresh and dry weight in gram (*Cicer arietinum*) was remarkably reduced by the leaf leachates of *Acacia auriculiformis*, *Anacardium occidentale*, *Albizia lebbeck*, *Eucalyptus citriodora*, *Emblica officinalis*, *Shorea robusta* and *Tectona grandis* (Das *et al.*, 2012).

2.5.1.3. Effect on Yield

Literature on the allelopathic effect of leaf leachate of trees found in tropics on crop yield is meager.

John (2007a) reported that seed yield of cowpea was significantly reduced by leaf leachates of *Tamarindus indica, Tectona grandis, Casuarina equisetifolia* and *Strychnos nux-vomica.* The effects of *T indica* and *T. grandis* leachate was lethal.

Field studies were conducted to assess the effect of leaf leachates of *Achras sapota, Ailanthus triphysa, Anacardium occidentale, Artocarpus heterophyllus, Artocarpus hirsute, Azadirachta indica, Bombax malabaricum, Casuarina equisettifolia, Coffea arabica, Erythrina indica, Gliricidia sepium, Hevea brasilensis, Leucaena leucocephala, Macaranga peltata, Mangifera indica, Psidium guajava, Swietania macrophylla, Tamarindus indicus, Tectona grandis, Theobroma cacao and Thespesia populnea* on yield of crops. In maize, yield was reduced by nearly 20 per cent by *A. occidentale, B. malabaricum, C. equisettifolia, G. sepium* and *T. grandis.* Despite the inhibitory effect on root growth, yield was unaffected by *A. triphysa.* In cowpea, pod formation was totally inhibited in plants grown under *A. sapota.* Substantial yield reduction was noticed in groundnut under *G. sepium* and *T. cacao.* Yield of groundnut was reduced by leaf leachates of *A. sapota, G. sepium* and *T. cacao* but compatible with *T. grandis* (KAU, 2009).

John *et al.* (2010) reported that fodder yield of guinea grass at 3 MAP was drastically reduced by leaf leachate of mahogany and rubber. A significantly higher yield was obtained with sapota and matty leachates.

2.5.2 Allelopathic Effect of Tree Leaf Extracts on Crops

2.5.2.1 Effect on Germination

The effects of extracts of dried powdered leaves of *Tectona grandis* were tested on the germination of rice (*Oryza sativa*) and cowpea (*Vigna unguiculata*). Germination was significantly reduced in the early stages (Jadhav and Gaynar, 1994).

Leaf and bark extracts of almond inhibited seed germination and root elongation of cress and fenugreek (Astaraei and sampietro, 2008).

Litter extracts of *C. equisetifolia* inhibited germination of wheat, maize, pea and mustard (Joshi and Prakash, 1992).

Litter extracts of *Bombax ceiba, Syzygium cumini, Albizia lebbeck and Dalbergia sissoo* stimulated germination of wheat, maize, pea and mustard (Joshi and Prakash, 1992).

Leaf extracts of rubber (*Hevea brasiliensis)* at lower concentrations promoted germination of tea (*Camellia sinensis*) and inhibited at higher concentrations (Pan Rong and Yuan Hui, 1977).

Kamara *et al.* (2000) observed that the most drastic reduction of maize seed germination was caused by *Gliricidia sepium, Tetrapleura tetraptera, Senna siamea* and *Leucaena leucocephala.*

Channal *et al.* (2000) recorded that leaf extracts of Azadirachta *indica, Acacia nilotica, Eucalyptus tereticornis, Tamarindus indica, Tectona grandis, Samanea saman* and *Syzygium cumini* stimulated germination of sorghum. However, *A. indica* and *A. arabica* alone promoted germination in rice.

The leaf extracts of *Tectona grandis* and *Eucalyptus tereticornis* reduced the germination of green gram while, *Syzygium cumini, Acacia arabica* (*Acacia nilotica*), *Tamarindus indica, Samanea saman* and *Azadirachta indica* promoted. *A. indica* was most stimulatory followed by *A. arabica* and *T. indica*. The leaf extracts of all trees, except *S. cumini, A. arabica* and *T. indica* enhanced germination at lower concentration (Channal *et al.*, 2002a).

Germination of sunflower was stimulated by *Tectona grandis, Tamarindus indica* and *Samanea saman*, while it was suppressed by *Eucalyptus tereticornis* and *Acacia arabica*. Soybean germination was promoted by *A. arabica, T grandis, S. saman* and *Azadirachta indica* at both lower and higher concentrations, while it was inhibited by *T. indica* (Channal *et al.*, 2002b).

Leaf extracts of *Populus deltoids* inhibited seed germination of green gram (Mandal *et al.*, 2005).

The aqueous leaf extracts of *Acacia leucopholea* showed inhibitory effects on seed germination of *Arachis hypogaea* (groundnut) and *Sorghum vulgare* (sorghum) (Jayakumar and Manikandan, 2005)

Tectona grandis and *Leucaena leucocephala* leaf extracts inhibited the seed germination of maize (Sahoo *et al.*, 2007).

Extracts from *Spina Christi* (*Ziziphus spina-christi*), *Sesbania sesban* and *Tamarindus indica* significantly reduced germination of seeds of maize (*Zea mays*) and sorghum *(Sorghum bicolor*). Extracts forced maize seeds to germinate earlier, while the opposite was observed for sorghum seeds (Mubarak *et al.*, 2009).

The aqueous extracts of eucalyptus (*Eucalyptus camaldulensis*) inhibited wheat seed germination (Khan *et al.*, 2009).

Dry leaf extract of *Dalbergia sissoo* severely suppressed the germination of pearl millet and rice and caused considerable reduction in maize also (Akhtar *et al.*, 2010).

The aqueous leaf extracts of *Mangifera indica* had both stimulatory and inhibitory action on germination and initial growth parameters of *Capsicum annum* (chilli), *Glycine max* (soybean), *Zea mays* (maize), *Oryza sativa* (rice) and *Abelmoschus esculentus* (bhindi). The inhibitory effect was much more pronounced at higher concentrations, while the lowest concentration showed stimulatory effect in some cases. The most affected crop was bhindi (Sahoo *et al.*, 2010).

Leaf extracts of *Senna siamea, Albizia lebbeck, Azadirachta indica, Cedrela odorata, Leucaena leucocephala, Gliricidia sepium, Eucalyptus grandis, Terminalia superba and Tectona grandis* significantly reduced germination of *Abelmoschus esculentus* seeds (Abugre *et al.*, 2011).

Aqueous extract of *Acacia auriculiformis*, *Anacardium occidentale*, *Albizia lebbeck*, *Eucalyptus citriodora*, *Emblica officinalis*, *Shorea robusta* and *Tectona grandis* reduced the frequency of seed germination of *Cicer arietinum* (Das *et al.*, 2012).

Mango leaf extract significantly inhibited germination of cress (*Lepidum sativum*), lettuce (*Lactuca sativa*) and alfalfa (*Medicago sativa*). The inhibition by the extracts was correlated to the concentration of the extract (Khan *et al.*, 2014). *Moringa olifera* leaves aqueous extract inhibited the seed germination of chickpea (Mangal *et al.*, 2014).

Leaf extract of old mango leaves enhanced the germination of wheat moderately (Saleem *et al.*, 2014).

Azadirachta indica leaf extract decreased the rate of germination of *Abelmoschus esculentus* (Vaithiyanathana, 2014).

Akkaya *et al.* (2006) suggests that higher amounts of extracts of pine and walnut leaves may decrease wheat grain yield.

Tectona grandis leaf extract inhibited germination and seedling growth of *Vigna mungo* (Evangeline *et al.*, 2012).

The germination and extension of root and shoot of *Z. mays* and *O. sativa* were suppressed by the extracts of leaf of *T. grandis* (Lalmuanpuii and Sahoo, 2011).

Hossain *et al.* (2012) observed that increasing concentration of the extract of plants parts of *Moringa oleifera* reduced the rate of germination of *V. radiata.*

Leela and Arumugam (2014) recorded that *Tectona grandis* leaf extract significantly reduced seed germination, seedling growth, biomass, chlorophyll a, chlorophyll b and carotenoids, protein and amino acid contents in green gram and chilli. The inhibition increased with concentration of the teak leaf extracts.

The teak leaf extracts inhibited germination and seedling growth of *Casuarina equisetifolia, Oryza sativa, Vigna unguiculata* and sorghum (Jadhav *et al.*, 1994; Balasubramanian *et al.*, 1996; Mandal and Brahmachary, 1998; Channal *et al.*, 2002a).

Alrababah *et al.* (2009) studied the allelopathic effects of leaf extracts of *Pinus halepensis* and *Quercus coccifera* on the reduced seed germination of wheat, barley, lentil, chickpea, and fababean.

2.5.2.2 Effect on Growth

Leaf extract of bamboo inhibited growth of ground nut (Eyini *et al.*, 1989). *Ailanthus altissima* leaf extract inhibited growth of garden cress (Heisey, 1990).

The effects of extract of dried powdered leaves of *Tectona grandis* were tested on the seedling growth of rice (*Oryza sativa*) and cowpea (*Vigna unguiculata*). Plumule and radicle growth in rice were inhibited. In cowpea, plumule growth was more inhibited than radicle growth and radicle growth was stimulated by short soaking time (Jadhav and Gaynar, 1994).

Water extracts of rubber (*Hevea brasiliensis)* leaves at lower concentrations promoted growth of tea (*Camellia sinensis*) seedlings and inhibited at higher concentrations (Pan Rong and Yuan Hui, 1977).

Aqueous extracts of dry teak leaves inhibited root and shoot growth of rice seedlings (Mandal and Brahmachary, 1998).

Kamara *et al.* (2000) reported that *Terminalia superba, Tetrapleura tetraptera, Gliricidia sepium* and *Senna siamea* significantly reduced maize root growth at the lowest extract concentration, while shoot length was most significantly reduced by *Gliricidia sepium, Leucaena leucocephala, Alchornea coordifolia (A. cordifolia), Terminalia superba* and *Tetrapleura tetraptera.*

Seedling growth of sorghum was suppressed by leaf extracts of *Syzygium cumini, Tectona grandis* and *Eucalyptus tereticornis* and in rice by *E. tereticornis* and *Tamarindus indica.* Seedling length remarkably increased in sorghum by *A. arabica* and in rice by *A. indica, S. saman* and *A. arabica.* Leaf extracts resulted in reduced seedling dry matter in sorghum and rice at all concentrations. Seedling length of green gram and pigeon pea was less when treated

with leaf extracts of all trees except *S. cumini, S. saman* and *A. indica.* In pigeon pea, seedling length, vigour index and seedling dry matter were increased by *A. arabica, T. indica, E. tereticornis, S. saman* and *A. indica.* All the tree leaf extracts at lower concentration enhanced seedling length (except *S. cumini, A. arabica* and *T. indica*), vigour index (except *S. cumini, T. indica, S. saman* and *A. indica*) and seedling dry matter (except *S. saman*) (Channal *et al.*, 2000; Channal *et al.*, 2002a).

Tamarind leaf extract strongly inhibited radicle and hypocotyl growth of radish and lettuce (Parvez *et al.*, 2003).

The aqueous leaf extracts of *Acacia leucopholea* inhibited shoot length, root length, leaf area of *Arachis hypogaea* (groundnut) and *Sorghum vulgare* (sorghum) (Jayakumar and Manikandan., 2005).

Prosopis juliflora and *Eucalyptus camaldulensis* leaf extracts inhibited seedling length of *Triticum aestivum* and *Brassica campestris* (Khan *et al.*, 2005).

Leaf extracts of *Populus deltoids* reduced shoot and root length of green gram (Mandal *et al.*, 2005).

John *et al.* (2007b) reported the effects of the leaf extracts of *Ailanthus triphysa,* cashew, *Casuarina equisetifolia, Gliricidia sepium, Artocarpus heterophyllus, Strychnos nux-vomica, Mangifera indica, Thespesia populnea, Tamarindus indica* and *Tectona grandis* on bitter gourd (*Momordica charantia*) and brinjal (*Solanum melongena*). Among the trees, *C. equisetifolia, T populnea, T. indica* and *T. grandis* leaf extracts reduced the number of leaves of bitter gourd (*Mamordica charantia*) at 2MAP. In brinjal, all extracts, except those of *Ailanthus triphysa* and cashew, reduced plant height at one MAP. The number of leaves were also reduced by the trees, except *A. triphysa*, cashew and *M. indica.* At 4 MAP, *T.*

indica extract alone reduced plant height. Leaf production was reduced by most of the extracts.

Leaf extract of *Acacia nilotica* significantly increased the radicle length of maize and sorghum seedlings. Higher survival of maize and sorghum seedlings was noticed when treated with extracts of *Khaya senegalensis*, *Peltophorum pterocarpum*, *Prosopis africana*, *Eucalyptus camaldulensis* and *Spina christi*. In both crops *A. nilotica* had least effect on the hypocotyl length (Mubarak *et al.*, 2009).

Leaf extracts of *Eucalyptus camaldulensis* significantly reduced fresh and dry weight of wheat seedlings. The inhibitory effects increased with increase in extract concentration (Khan *et al.*, 2009).

Allelopathic effects of *Dalbergia sissoo* fresh and dry leaves extract on growth of maize (*Zea mays*), pearlmillet (*Pennisetum glaucum*) and rice (*Oryza sativa*) were investigated.

Fresh and dry leaves extracts of *Dalbergia sissoo* did not inhibit growth of pearl millet and rice. On the contrary, it slightly promoted growth. Dry leaf extract increased dry matter production of maize. Dry leaf water extract was more inhibitory than fresh leaves (Akhtar *et al.*, 2010). Plumule and radicle extension of seedlings of *Zea mays* (maize), *Vigna unguiculata* (cowpea), *Lycopersicon esculentum* (tomato) and *Abelmoschus esculentus* (okra) were significantly reduced by the leaf extracts of *Senna siamea, Albizia lebbeck, Azadirachta indica, Cedrela odorata, Leucaena leucocephala, Gliricidia sepium, Eucalyptus grandis, Terminalia superba and Tectona grandis* with the exception of *Zea mays* where plumule and radicle development was increased by *E. grandis* leaf extracts (Abugre *et al.*, 2011).

Tectona grandis leaf extract inhibited seedling growth of *Vigna mungo* (Evangeline *et al.*, 2012).

Mango leaf extracts significantly inhibited seedling growth of cress (*Lepidum sativum*), lettuce (*Lactuca sativa*) and alfalfa (*Medicago sativa*). The inhibiton was directly proportional to the extract concentrations (Khan *et al.*, 2014). Saleem *et al.* (2014) suggested that old leaf extract of mango could be used to enhance wheat growth.

Lower concentrations of dry leaf extract of *T. grandis* significantly promoted seedling growth in black gram (*Vigna mungo*) and green gram (*Vigna radiata*). Higher concentrations severely reduced seedling dry weight of the crops (Manimegalai and Manikandan, 2010).

Mangal *et al.* (2014) reported the presence of water soluble allelochemicals in the leaf extract of *Moringa olifera*, which could inhibit the seedling growth of chickpea crop.

The growth and developmental parameters of rice seedlings were significantly reduced by leaf extracts of *Casuarina equisetifolia*. But, at lower concentration the seedling growth was slightly enhanced (Leela *et al.*, 2013).

The crude leaf extract of tamarind reduced radicle growth in lettuce more adversely than hypocotyl (Syed *et al.*, 2014).

Siddiqui *et al.* (2009) reported aqueous leaf extracts of *Ficus infectoria*, *Emblica officinalis* and *Acacia leucophloea* inhibiting the germination and root elongation in *Cicer arietinum*.

The leaf, bark and fruit pulp aqueous extract of of *Zanthoxylum armatum* reduced the germination and growth of *Triticum aestivum*, *Hordeum vulgare*, *Brassica compestris*, and *Lens culminaris* (Singh *et al.*, 2007).

Manimegalai and Manikandan (2010) found that aqueous leaf extract of teak increased the antioxidants like catalase, peroxidase and polyphenol oxidase content of black gram.

Thapaliyal *et al.* (2008) studied the phytotoxic effects of leaf and bark extracts of *Terminalia bellirica, Terminalia chebula, Aegle marmelos* and *Sapindus mukorossi* on reduced germination, radicle and plumule growth of crops *Amaranthus caudatus, Echinochola frumentaceae, Lens culinaris* and *Triticum aestivum.*

2.5.2.3 Effect on Yield and Yield Attributes

Sundramoorthy and Kalra (1991) reported a reduction in yield of pearl millet, sesame and cluster bean by the aqueous leaf extracts of *Acacia tortilis.*

The aqueous leaf extracts of *Acacia leucopholea* reduced the yield of *Arachis hypogaea* and *Sorghum vulgare* (Jayakumar and Manikandan, 2005).

Akkaya *et al.* (2006) suggested that higher amounts of leaf extracts of pine (*Pinus* sp.) and walnut (*Juglans regia*) leaves may decrease wheat (*Triticum aestivum*) grain yield, while lower amounts may contribute to grain yield.

Young leaf extracts of mango induced some reduction in grain weight of wheat (Saleem *et al.*, 2014).

2.5.3 Allelopathic Effect of Fresh Tree Leaf Loppings and Leaf Litter on Crops

2.5.3.1 Effect on Germination

John and Nair (1999) recorded that leaf litter of *Tamarindus indicus, Albizia lebbeck, Casuarina equisetifolia, Leucaena leucocephala, Artocarpus heterophyllus,* Acacia *auriculiformis* and *Mangifera indica* inhibited germination of rice remarkably.

Leaf litter of *Eucalyptus camaldulensis* inhibited germination of wheat (Khan *et al.*, 2008).

Bhatt and Singh (2009) reported that leaf litter of *Aquilaria malaccensis* (Syn. *A. agallocha), Michelia champaca, Tectona grandis and Trema orientalis* reduced the germination of rice, maize, green gram, rice bean, groundnut and cabbage.

The top soil extracts transferred from *Tectona grandis* plantation affected the seed germination and seedling growth of *Lycopersicon esculentum* (Mensah *et al.*, 2015).

Leela *et al.* (2013) observed that leaf extracts of *Casuarina equisetifolia* reduced seed germination, seedling length, biomass, chlorophyll a , chlorophyll b, carotenoids, starch, protein and amino acid contents of rice (*Oryza sativa*).

2.5.3.2 Effect on Growth

The leaf litter of *Mangifera indica, Casuarina equisetifolia, Tamarindus indica* and *Artocarpus heterophyllus* remarkably inhibited growth of rice (John and Nair, 1999).

Sapota, casuarina, coffee, rubber, gliricidia, subabul and guava had deleterious effects on pepper establishment and growth under field conditions (John *et al.*, 2011).

Divya and Yassin (2003) reported the reduction in dry matter production of cowpea, sesame, horse gram and sorghum when mulched with crushed dry leaves of *Azadirachta indica.*

Leucaena leucocephala and *Tectona grandis* leaf litter had inhibitory effect on the growth of maize (Sahoo *et al.*, 2007).

The leaf litter of *Eucalyptus camaldulensis* adversely affected growth of wheat (Khan *et al.*, 2008).

Bhatt and Singh (2009) reported that leaf litter of *Aquilaria malaccensis* (Syn. *A. agallocha*), *Michelia champaca, Tectona grandis and Trema orientalis* reduced growth and dry matter production of rice, maize, green gram, rice bean, ground nut and cabbage.

2.5.3.3. Effect on Yield and Yield Attributes

Ramamoorthy and Paliwal (1993) reported that mulching with leaves of *Gliricidia sepium* increased the yield of *Sorghum vulgare*.

The grain yield of maize increased with increasing levels of applied mulch of *L. leucocephala* (Larbi *et. al.*, 1993). A five year field experiment to evaluate the effect of *Leucaena* dead mulches revealed that it improved yield of maize (Caamal *et. al.*, 2001).

Kamara (1998) reported highest yields of maize (*Zea mays*) when mulched with leaves of *Gliricidia sepium* and *Leucena leucocephala*.

Sidhu and Dhillon (1998) recorded that grain yields of wheat (*Triticum aestivum*) generally increased with increasing leaf litter rates of *Eucalyptus tereticornis* in plots without NPK fertilizer, but decreased with leaf litter incorporation in plots with fertilizer.

Mango litter biomass increased the yield of forage crops. The combined application of 75 per cent N as urea fertilizer along with 25 per cent N as tree litter biomass resulted in higher forage yield of sorghum, sudan grass (*Sorghum sudanense*) and maize than when N was applied as urea alone or litter alone (Lal, 1999).

Divya and Yassin (2003) reported the suppression of grain yield of cowpea, sesame, horse gram and sorghum when mulched with crushed dry leaves of *Azadirachta indica.*

Leucaena leucocephala and *Tectona grandis* leaf litter had negative effect on the yield of maize (Sahoo *et al.*, 2007).

The leaf litter of *Eucalyptus camaldulensis* adversely affected yield of wheat (Khan *et al.*, 2008).

The effect of leaf loppings of *Anacardium occidentale*, *Artocarpus heterophyllus*, *Artocarpus hirsuta*, *Gliricidia sepium*, *Hevea brasilensis*, *Mangifera indica*, *Tamarindus indicus* and *Tectona grandis* on yield of crops was investigated through field studies. Leaf loppings of all trees, except *M. indica*, reduced the seed yield of cowpea. The greatest yield reduction was caused by *A. occidentale* (84%), followed by *T. grandis* and *H. brasilensis.* All trees, except *M. indica*, significantly reduced groundnut yield. *H. brasilensis* leaves reduced yield considerably. The yield reduction in groundnut caused by *A. occidentale* was notable. Leaf loppings of all the trees significantly reduced maize yield. Development of grains on the cob was severely affected (KAU, 2009).

The leaf loppings of *Aporosa octandra, Anthocephallus chinensis and Albizzia procera* inhibited the growth and development of *Oryza sativa, Glycine max, Brassica campestris* (Kumar *et al.*, 2008).

Bhatt *et al.* (1997) revealed that dried leaves of *Terminalia* spp. in agroforestry system depressed the germination, growth and dry matter production of agriculture crops like *Hordeum vulgare, Eleusine coracana, Glycine max* and *Brassica campestris.*

Combined application of tree litter of ipil-ipil (*Leucaena leucocephala*) and recommended fertilizer dose produced good rice yield (Arifin *et al.*, 2012)

Thakur (2014) reported that mulberry, plum and pomegranate leaf leachate and mulch reduced the seed germination, germination relative index, vigour index, root length, shoot length and dry matter production of soybean.

Mulching with mango leaves resulted in significantly lower yield in turmeric while jack, cashew and teak enhanced the yield (Lakshmi and John, 2015).

Sengupta *et al.* (2009) reported that mulching ginger with dry leaves resulted in plants with maximum height, greater number of pseudostems per clump, leaves per clump and highest yield.

2.6 ALLELOPATHIC EFFECT OF TREES ON PHYSIOLOGICAL PROCESS IN PLANTS

Leaf extracts of bamboo reduced chlorophyll development and protein content of groundnut (Eyini *et al.*, 1989).

The diosgenin concentration in rhizomes of *Costus speciosus* increased on treating with *Mangifera indica* leaf leachate and decreased with *Eucalyptus globulus* leachate but was unaffected by *Shorea robusta* and *Tectona grandis* leachates (Konar and Kushari, 1989).

Experiments were conducted to assess the effect of aqueous leaf extracts of *Eucalyptus globulus, Melia azedarach* and *Moringa oleifera* on mineral uptake by sorghum. The uptake of Zn, Ca and Mg were more affected than K, P, Fe or Mn by extract exposure and the extracts reduced uptake of these minerals. *E. globulus* caused the greatest reduction in Ca absorption, while *M. oleifera* and E. *globulus* caused marked reductions in Mg uptake (Pawar and Chavan, 1999).

The allelopathic potential of aqueous leaf extract of *Eucalyptus camaldulensis* was investigated on mitotic index in the root apical meristem of *Allium cepa*, Hill reaction in isolated spinach (*Spinacia oleracea*) chloroplast and radicle growth and peroxidase activity in *Lepidium sativa*, *Avena fatua*, *Zea mays* and *Lycopersicon esculentum*. The presence of different concentrations of aqueous leaf extract decreased the mitotic index. Aqueous extract decreased the mitotic index and number of cells in prophase, metaphase and anaphase, affected Hill reaction, decreased the enzyme activity significantly, inhibited peroxidase activity in *L. sativum* and suppressed the radicle growth in all the plant species. These results suggest that *Eucalyptus* species suppresses the growth of other plant species by affecting several biochemical and physiological processes (Moradshahi *et al.*, 2003)

Phenolic allelochemicals have been observed in both natural and managed ecosystems, where they cause a number of ecological and economic problems such as decline in crop yield due to soil sickness, regeneration failure of natural forests and replanting problems in orchards. Phenolic allelochemical structures and modes of action are diverse and may offer potential lead compounds for the development of future herbicides or pesticides. Allelopathic effects of phenolics includes changes in membrane permeability, inhibition of plant nutrient uptake, inhibition of cell division and elongation, effects on plant photosynthesis and respiration, effects on various enzyme functions, synthesis of plant endogenous hormones and protein synthesis. (Li *et al.*, 2010).

The yield of essential oils and total phenolics and the anti-oxidant activities of basil seedlings increased with increasing concentrations of aqueous leaf extracts of walnut (*Juglans regia*) whereas the relative water content, leaf water potential, as well as the total chlorophyll and carotenoid content of basil leaves decreased significantly (Dadi *et al.*, 2014).

Tamarind leaf extract (crude extract) hindered the normal physiological growth process resulting in weak and curly seedlings and necrosis of their tips in lettuce seedlings (Syed *et al.*, 2014).

From the above review it is evident that leaf leachates, leaf extracts, leaf loppings and leaf litter of trees exert significant allelopathic effect on crops. The effects may be on germination, growth or yield. The effects are mostly inhibitory while some instances of stimulatory influences are also reported. The manifestation of the inhibitory effects is mainly a consequence of the multifarious physiological processes in plants which may be affected. It is also revealed that several phytochemicals are present in plants which may be causing these allelopathic effects. However, it is apparent that the allelopathic of certain trees which have been selected in the present study, have not been investigated till date. Moreover, the allelopathic influence of the test trees on ginger have not been studied till date.

Mulching with tree leaves is a recommended in ginger cultivation. The farmers are doubtful about the tree leaves to be used for mulching. Hence, the present study which aims to probe into the allelopathic compatibility of certain trees, commonly found in homesteads of Kerala, with ginger is of great relevance and practical utility.

Materials and Methods

3. MATERIALS AND METHODS

The investigation entitled "Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)" was undertaken at the College of Agriculture, Vellayani during the period from February 2015 to December 2015. The primary aim of the study was to investigate the allelopathic effect of certain common trees planted in the homesteads of Kerala on sprouting, growth and yield of ginger.

The study involved two bioassays, which were carried out at the Cropping Systems Research Centre (CSRC), Karamana and two pot culture experiments, which were conducted at the Instructional Farm, College of Agriculture, Vellayani. The materials utilized and the methods employed for carrying out the experiments are presented in this chapter.

3.1 EXPERIMENTAL SITE

The bioassays were undertaken at CSRC, Karamana situated at 8° 28' 25'' North latitude and 76° 57' 41'' East longitude at an altitude of 3.3 m above mean sea level. The weather data are presented in Appendix I. The pot culture experiments were carried out in an open field area in the Instructional Farm of the College of Agriculture, Vellayani, Thiruvananthapuram located at 8° 25' 78'' North latitude and at 76° 59' 28'' East longitude and an altitude of 29 m above mean sea level.

3.2 CLIMATE AND SEASON

The experimental site has a humid tropical climate. The bioassays were carried out from February to April 2015. The mean maximum and minimum temperature during the period ranged from 30.34°C to 33.08°C and 20.45°C to 24.53°C respectively.

The pot culture experiment was conducted from February to December, 2015. The data on weekly mean maximum and minimum temperature, relative humidity,

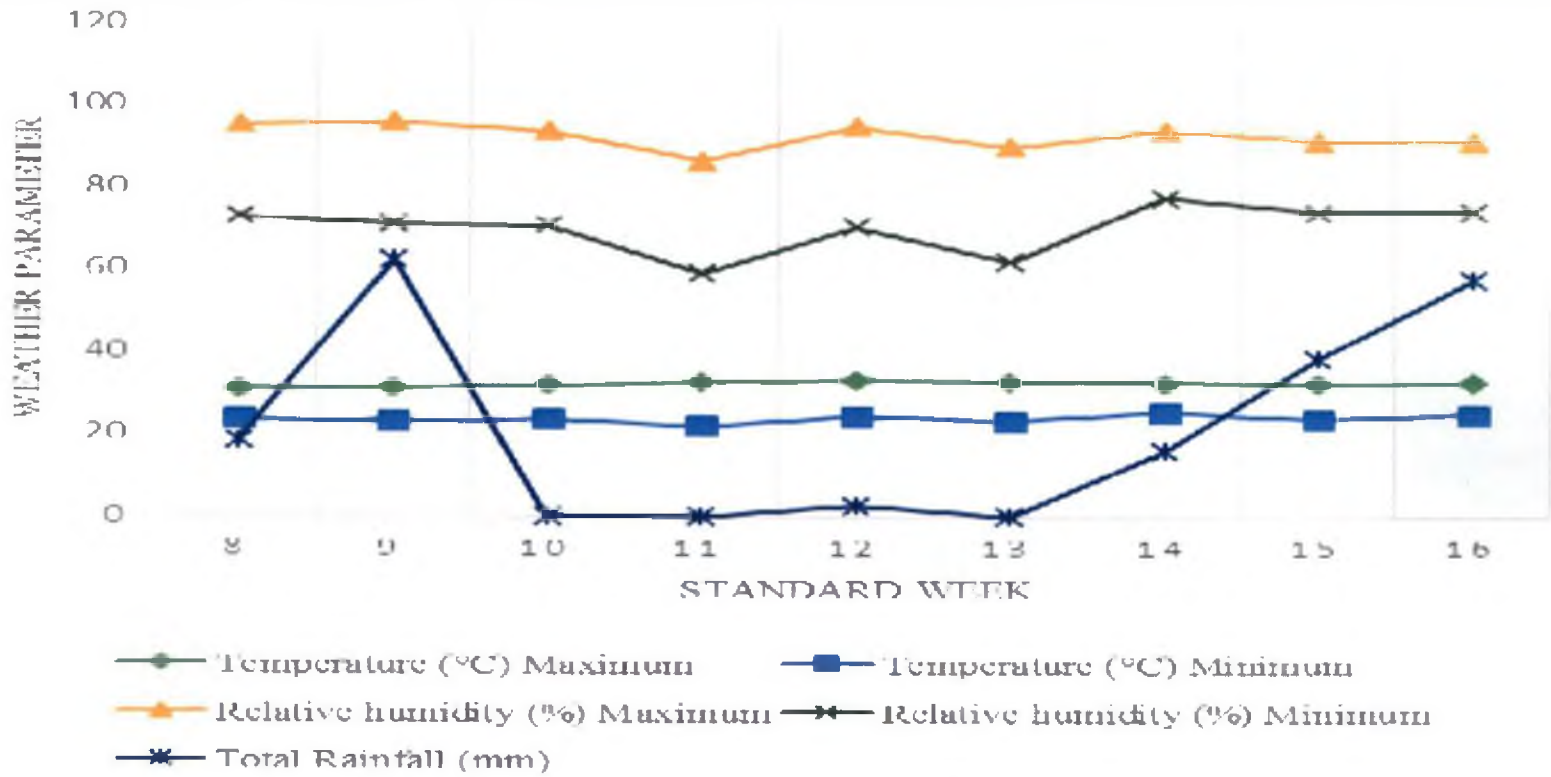

Fig. 1. Weather data during the cropping period of bioassay experiment

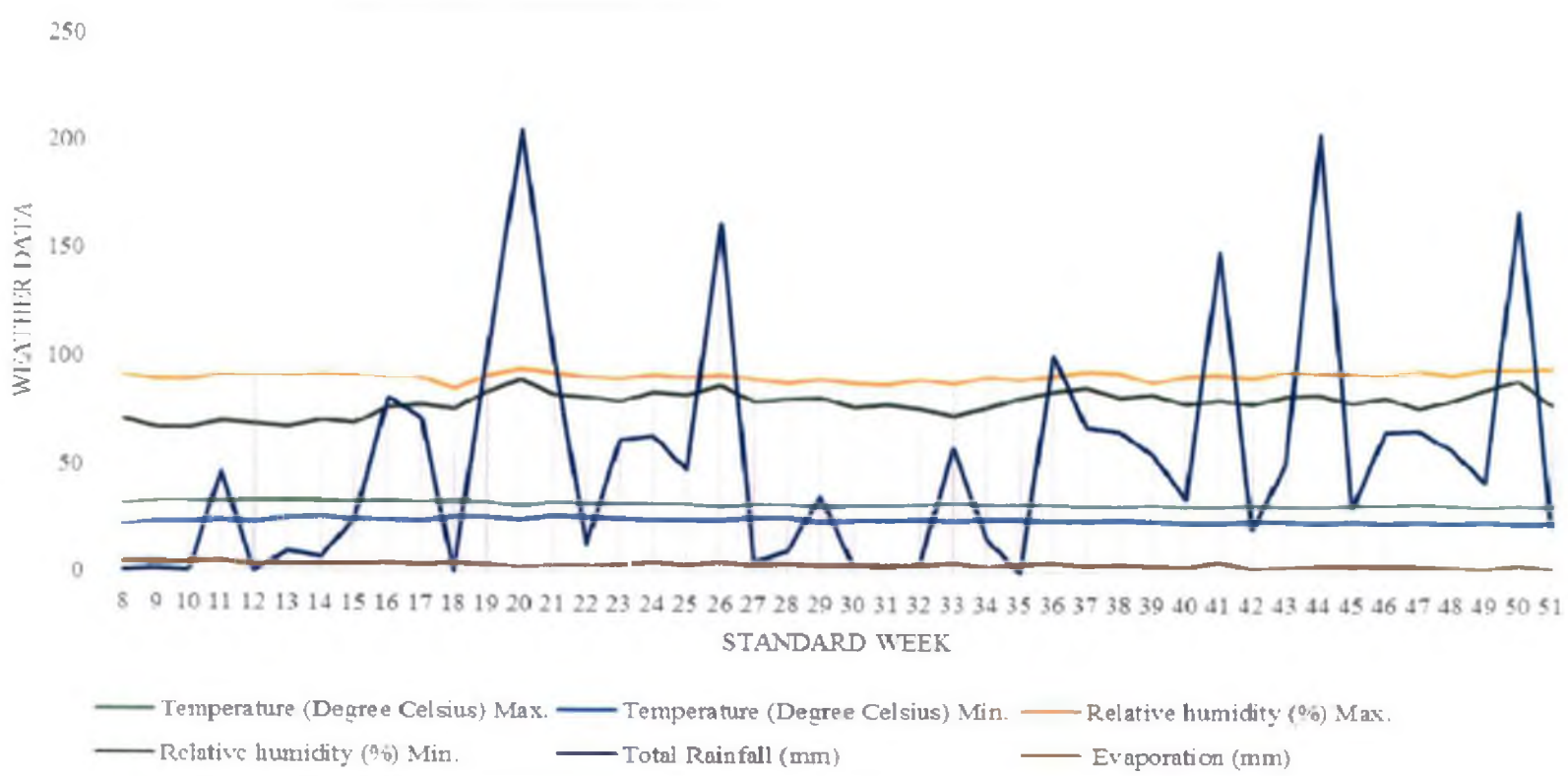

Fig. 2. Weather data during the cropping period of pot culture experiment

total rainfall, and evaporation during the study period were obtained from Class B Agromet Observatory of College of Agriculture, Vellayani. The data are presented in Appendix 2 and illustrated graphically in Figure 1. The mean maximum temperature during the cropping period ranged from 30.4°C to 33.2°C and the mean minimum temperature raged between 21°C to 26.1°C. A total rainfall of 2327.6 mm was recorded during the crop period.

3.3 TEST CROP

Ginger variety, Karthika, was used for the study. Karthika is a selection from somaclones of cultivar Maran. It was released from College of Horticulture, Kerala Agriculture University (KAU), Vellanikkara, Thrissur in 2010. The characters of the variety includes, medium duration (220-240 days), suited for raising both as pure and intercrop, ideal for fresh and dry ginger and tolerance to bacterial wilt and soft rot disease. The rhizomes are medium bold. Mean fresh yield of rhizome is 19 t ha^{-1}. Dry recovery is 21.6 per cent with 22.87 per cent zingiberene content, 7.2 per cent oleoresin and 3.7 per cent crude fibre.

3.4 TEST TREES

The following trees were investigated

Table 1. Tree species used in the experiment

Sl. No.	Common name	Scientific name	Family
1.	Jack	*Artocarpus heterophyllus* Lamk.	Moraceae
2.	Mango	*Mangifera indica* L.	Anacardiaceae
3.	Tamarind	*Tamarindus indica* L.	Fabaceae
4.	Matty	*Ailanthus triphysa* (Dennst) Alston	Simaroubaceae
5.	Wild Jack	*Artocarpus hirsuta* Lamk.	Moraceae
6.	Teak	*Tectona grandis* L. f.	Lamiaceae
7.	Rubber	*Hevea brasiliensis* Mull. Arg.	Euphorbiaceae
8.	Panal	*Glycosmis pentaphylla* (Retz.)	Rutaceae

The study comprised of four different experiments to examine the allelopathic effect of trees on ginger.

3.5 EXPERIMENT I (BIOASSAY I)

This experiment was undertaken to assess the allelopathic effect of fresh leaf leachates of test trees on sprouting and early establishment of ginger. The bioassay was conducted during February 2015 to April 2015.

3.5.1 Materials

3.5.1.1 Planting Material

Rhizomes of ginger variety, Karthika, were procured from the Department of Plantation Crops and Spices, College of Horticulture, KAU, Vellanikkara, Thrissur. Rhizome bits weighing 10 g were treated with Mancozeb (0.3 %) and Quinalphos (0.1 %) for 30 minutes before planting.

3.5.1.2 Containers

Protrays with cells having 3.5 cm diameter were used for planting the rhizome bits of ginger.

3.5.1.3 Preparation of Growing Media

The protrays were filled with growing media composed of soil exposed to sunlight for one week, sand and compost in 1:1:1 proportion.

3.5.2 Manures and Fertilizers

The general recommendation for ginger is organic manure @ 30 t ha^{-1} and N: P_2O_5: K_2O @ 75:50:50 kg ha^{-1} as per the Package of Practices Recommendations for Crops (KAU, 2011). The quantity of organic manure (full dose) and fertilizers to supply the basal dose of 50 kg P_2O_5 and 25 kg K_2O was worked out for growing

media and applied at the time of planting. The quantity of cow dung, Rajphos and MOP for 15 kg growing media was 200 g, 1.85 g and 0.55 g respectively.

3.5.3 Methods

3.5.3.1 Design and Layout

The experiment was laid out in completely randomized design (CRD) with 17 treatments. The treatments were replicated thrice. The treatments are listed in Table 2.

3.5.3.2 Treatments

The first bioassay comprised of 17 treatments as detailed below.

Table 2. Treatment details of Bioassay I

Sl. No.	Treatments	Concentration of leaf leachate (w/v)
1.	t_1c_1	Jack 1 : 10
2.	t_1c_2	Jack 1 : 15
3.	t_2c_1	Mango 1 : 10
4.	t_2c_2	Mango 1 : 15
5.	t_3c_1	Tamarind 1 : 10
6.	t_3c_2	Tamarind 1 : 15
7.	t_4c_1	Matty 1 : 10
8.	t_4c_2	Matty 1 : 15
9.	t_5c_1	Wild Jack 1 : 10
10.	t_5c_2	Wild Jack 1 : 15
11	t_6c_1	Teak 1 : 10
12.	t_6c_2	Teak 1 : 15
13.	t_7c_1	Rubber 1 : 10
14.	t_7c_2	Rubber 1 : 15
15.	t_8c_1	Panal 1 : 10
16.	t_8c_2	Panal 1 : 15
17.	Control	Distilled water

3.5.3.2.1 Collection of Leaves

The leaves were collected from different parts (lower, middle and top portions) of fully mature trees so as to get a representative sample of the entire tree canopy. Dead, senescent and ready to shed leaves were avoided.

3.5.3.2.2 Cleaning

Contaminants like soil/dust, which may influence the chemical composition of leachate were removed from the leaves. The adhering particles were removed by wiping with a dry soft brush/cloth.

3.5.3.2.3 Drying and Storing of Sample

As the tree leaves collected from different parts were of varying moisture content, they were air dried (in shade) to uniform moisture content. Whenever the material was to be stored for later use, it was kept in polythene bags in refrigerator (for use as fresh).

3.5.3.2.4 Preparation of Leachate

Leachate was prepared from the intact leaves without subjecting it to destruction according to the standard procedures (John *et al.*, 2006). In order to identify the presence of allelopathic activity, the protocol for preparing leachate must be similar to that existing under natural situation. Hence, distilled water (ambient temperature) was used as solvent, as in nature, allelochemicals are released into the environment in a water soluble form. Moreover, this ensured a natural release of toxins. Aqueous leachate was prepared by soaking the fresh leaves in distilled water in the ratio 1:10 (w/v) and 1:15 (w/v) respectively. The leaves were soaked for 24 h, as within that period it was expected to leach out most of the allelochemicals. The ratio 1:15 was tried to explore the possibility of alleviation of allelopathic effects, if any, through dilution.

3.5.3.2.5 Filtration

The tree leaf leachates were filtered through muslin cloth.

3.5.3.2.6 Measurement of pH

The pH of the leaf leachates were measured using pH meter. The pH of the leaf leachates was adjusted to range between 6-7 by adding either alkali (KOH) or acid (HCl) as needed.

3.5.3.2.7 Storing of Leachates

The leachates were stored in refrigerator at 4°C to prevent decay, breakdown by bacterial and fungal development.

3.5.3.2.8 Setting up of the Bioassay with Leaf Leachate

Growing media were filled in protrays with cell size of 3.5 cm diameter and uniformly sized healthy rhizome bits of ginger were planted. Uniform and adequate moisture was maintained in all the treatments during the period of study by adding equal quantity of the leachate, daily or on alternate days.

The control consisted of protray cells set up similarly but watered with distilled water. All the treatments and control in bioassays were replicated thrice. Each replication comprised of ten protray cells. The observations were recorded at two months after planting (2 MAP).

3.6 EXPERIMENT II (BIOASSAY II)

This bioassay aimed to examine the allelopathic effect of fresh leaf extracts of test trees on sprouting and early establishment of ginger. The bioassay was conducted during February to April 2015.

3.6.1 Materials

Same as for bioassay I (sections 3.5.1.1. to 3.5.3.1.)

3.6.3.2 Treatments

The first bioassay comprised of 17 treatments as detailed below.

Table 3. Treatment details of Bioassay II

Sl. No.	Treatments	Concentration of leaf extract (w/v)
1.	t_1c_1	Jack 1 : 10
2.	t_1c_2	Jack 1 : 15
3.	t_2c_1	Mango 1 : 10
4.	t_2c_2	Mango 1 : 15
5.	t_3c_1	Tamarind 1 : 10
6.	t_3c_2	Tamarind 1 : 15
7.	t_4c_1	Matty 1 : 10
8.	t_4c_2	Matty 1 : 15
9.	t_5c_1	Wild Jack 1 : 10
10.	t_5c_2	Wild Jack 1 : 15
11	t_6c_1	Teak 1 : 10
12.	t_6c_2	Teak 1 : 15
13.	t_7c_1	Rubber 1 : 10
14.	t_7c_2	Rubber 1 : 15
15.	t_8c_1	Panal 1 : 10
16.	t_8c_2	Panal 1 : 15
17.	Control	Distilled water

3.6.3.2.1 Collection of Leaves

Same as described under section 3.5.3.2.1.

3.6.3.2.2 Cleaning

Same as described under section 3.5.3.2.2.

3.6.3.2.3 Drying and Storing of Sample

Same as described under section 3.5.3.2.3.

3.6.3.2.4 Preparation of Leaf Extract

Leaf extract was prepared from the intact leaves by subjecting it to destruction according to the standard procedures (John *et al.*, 2006). Aqueous extracts were

prepared by blending the tree leaves with distilled water in the ratio 1:10 (w/v) and 1:15 (w/v) respectively.

3.6.3.2.5 Filtration

Same as described under Section 3.5.3.2.5

3.6.3.2.6 Measurement of pH of Leaf Extracts

Same as described under section 3.5.3.2.6

3.6.3.2.7 Storing

Same as described under section 3.5.3.2.7

3.6.3.2.8 Setting up of the Bioassay with Leaf Extract

Growing media were filled in protrays with cell size of 3.5 cm diameter and uniformly sized healthy rhizome bits of ginger were planted. Uniform and adequate moisture was maintained in all the treatments during the period of study by adding equal quantity of the extract, daily or on alternate days.

The control consisted of protray cells set up similarly, but watered with distilled water. All the treatments and control in bioassays were replicated thrice. Each replication comprised of ten protray cells. The observations were recorded at two month after planting (2 MAP).

3.7 EXPERIMENT III (POT CULTURE 1)

This experiment was undertaken to assess the effect of irrigating with fresh tree leaf leachates of test trees on growth and yield of ginger.

3.7.1 Season

The experiment was conducted during February to December 2015.

3.7.2 Materials

3.7.2.1 Plant Material

Rhizomes of ginger variety, Karthika, was purchased from the Department of Plantation Crops and Spices, College of Horticulture, KAU, Vellanikkara, Thrissur. Rhizome bits weighing 10 g each were treated with Mancozeb (0.3%) and Quinalphos (0.1%) for 30 minutes before planting.

3.7.2.2 Containers

Ultra Violet (UV) stabilized grow bags of 25 cm height and 30 cm diameter capable of holding up to 15 kg of growing media were used for raising the crop.

3.7.2.3 Preparation of Growing Media

Growing media was prepared by mixing soil sand and cow dung in 1:1:1 ratio and exposed to sunlight for one week.

3.7.2.5 Manures and Fertilizers

Organic manure and NPK fertilizers were applied, as per the Package of Practices Recommendations for Crops (KAU, 2011).

3.7.3 Methods

3.7.3.1 Design and Layout

The pot culture experiment was laid out in completely randomized design and comprised of 17 treatments as detailed in section 3.7.3.2. All the treatments were replicated thrice.

3.7.3.2 Treatment Details

3.7.3.2.1 Treatments

This experiment comprised of 17 treatments as detailed below

Table 4. Treatment details of Pot culture I

Sl. No.	Treatments	Concentration of leaf leachate (w/v)
1.	t_1c_1	Jack 1 : 10
2.	t_1c_2	Jack 1 : 15
3.	t_2c_1	Mango 1 : 10
4.	t_2c_2	Mango 1 : 15
5.	t_3c_1	Tamarind 1 : 10
6.	t_3c_2	Tamarind 1 : 15
7.	t_4c_1	Matty 1 : 10
8.	t_4c_2	Matty 1 : 15
9.	t_5c_1	Wild Jack 1 : 10
10.	t_5c_2	Wild Jack 1 : 15
11	t_6c_1	Teak 1 : 10
12.	t_6c_2	Teak 1 : 15
13.	t_7c_1	Rubber 1 : 10
14.	t_7c_2	Rubber 1 : 15
15.	t_8c_1	Panal 1 : 10
16.	t_8c_2	Panal 1 : 15
17.	Control	Tap water

3.7.3.2.2 Collection of leaves

Same as described under section 3.5.3.2.1

3.7.3.2.3 Cleaning

Same as described under section 3.5.3.2.2

3.7.3.2.4 Drying and Storing of Sample

Same as described under section 3.5.3.2.3

3.7.3.2.5 Preparation of Leaf Leachate

Same as described under section 3.5.3.2.4. However, in order to simulate natural conditions the pH of the leaf leachates were adjusted to range 6-7.

3.7.3.2.6 Filtration

Same as described under section 3.5.3.2.5

3.7.3.2.7 Storing

The prepared leachates were stored in refrigerator to prevent decay and breakdown by bacteria.

3.7.3.2.8 Setting up of the Pot Culture with Leaf Leachate

The study was conducted using UV stabilized grow bags of 25 cm height and 30 cm diameter capable of holding upto 15 kg of growing media. The grow bags were filled with potting mixture containing sand, soil and cow dung in the ratio 1:1:1 exposed to sunlight for one week to eliminate the presence of any allelochemicals. Organic manure and NPK fertilizers were applied, as per the Package of Practices Recommendations for Crops (KAU, 2011). The healthy ginger sprouts of uniform growth (at 2 leaf stage) were planted in grow bags. The tree leaf leachates were prepared using distilled water as described earlier in 3.7.3.2.5 and uniformly applied to each grow bag (@ 100 ml per pot) immediately after planting and subsequently twice in a week. On all other days excluding rainy days the grow bags were irrigated with tap water to maintain adequate moisture, throughout the experimental period. A control was maintained, in which the plants were irrigated with tap water alone. All the treatments were replicated thrice and each replication comprised of four grow bags.

3.7.4 Details of Cultivation

3.7.4.1 Nursery

Ginger rhizomes were planted in protrays with cells of 3.5 cm diameter filled with growing media prepared using sand, soil and cow dung in the ratio 1:1:1 to get uniform and healthy seedlings for the pot culture studies. Rhizomes were sown on 19th February 2015.

3.7.4.2 Transplanting

Single bud sprouts of rhizome were raised in portrays for 30-40 days and these were transplanted @ one seedling per grow bag.

3.7.4.3 Manures and Fertilizers

Organic manure and NPK fertilizers were applied as per the Package of Practices Recommendations for Crops (KAU, 2011). The recommended rates of organic manure (30 t ha^{-1}) and N: P_2O_5: K_2O (75:50:50 kg ha^{-1}) were calculated for each grow bag containing 15 kg potting mixture. The organic manure was applied as basal dose (200 g for each grow bag). Full dose of P_2O_5 and half dose of K_2O were applied as basal. Half the quantity of N was applied at 60 DAP. The remaining quantity of N and K_2O were applied at 120 DAP. A total of 1.08 g urea, 1.85 g Rajphos and 0.55 g MOP were applied in each grow bag as split doses.

3.7.4.4 After Cultivation

The weeds were removed from the grow bags by hand weeding as and when they appeared. The plants were irrigated as and when required.

3.7.4.5 Plant Protection

There was incidence of soft rot and leaf spot in ginger. Spraying of Bordeaux mixture (1%) was done at regular intervals for controlling the diseases. Shoot borer (*Conogethes punctiferalis*) occurrence was noticed during September-October. It was effectively controlled by spraying Chlorantraniliprole 18.5 SC @ 0.03 ml l^{-1}.

3.7.4.6 Harvesting

Harvesting was done after the crop attained full maturity at 270 days after planting.

Plate 1. General layout of the experiment 3 (Pot culture I)

Plate 2. General layout of the experiment 4 (Pot culture II)

3.8 EXPERIMENT IV (POT CULTURE II)

This experiment was carried out to investigate the effect of mulching with fresh leaf loppings of test trees on the growth and yield of ginger.

3.8.1 Season

The experiment was conducted during February to December 2015.

3.8.2 Materials

3.8.2.1 Planting Material

Ginger variety, Karthika, from the Department of Plantation Crops and Spices, College of Horticulture, KAU, Vellanikkara, Thrissur, was used for the experiment. Rhizome bits weighing 10 g were treated with Mancozeb (0.3%) and Quinalphos (0.1%) for 30 minutes before planting.

3.8.2.2 Containers

The crop was raised in UV stabilized grow bags of 25 cm height and 30 cm diameter capable of holding up to 15 kg of growing media.

3.8.2.3. Preparation of Growing Media

Growing media was prepared using various components such as soil, sand and cow dung in 1:1:1 ratio, exposed to sunlight for one week.

3.8.2.4. Manures and Fertilizers

Organic manure and NPK fertilizers were applied, as per the Package of Practices Recommendations for Crops (KAU, 2011).

3.8.3. Methods

3.8.3.1. Design and Layout

The experiment was laid out in completely randomized design and comprised of nine treatments as detailed in section 3.8.3.2.1. All the treatments were replicated thrice.

3.8.3.2 Treatment Details

3.8.3.2.1 Treatments

The experiment comprised nine treatments as detailed below

Table 5. Treatment details of Pot culture II

Sl. No.	Treatments	Tree leaves used
1.	M_1	Jack
2.	M_2	Mango
3.	M_3	Tamarind
4.	M_4	Matty
5.	M_5	Wild Jack
6.	M_6	Teak
7.	M_7	Rubber
8.	M_8	Panal
9.	M_9	Control (Newspaper)

3.8.3.2.2 Collection of Leaves

Same as described under section 3.5.3.2.1

3.8.3.2.3 Setting up of Pot Culture with Fresh Leaf Loppings

The growbags were filled with potting mixture as explained in *3.7.3.2.8.* Organic manures and NPK fertilizers were applied as per the Package of Practices Recommendations for Crops (KAU, 2011). Healthy ginger sprouts of uniform growth (at 2 leaf stage) were planted in grow bags. Fresh leaf loppings were applied as mulch

@ 15 t ha^{-1} immediately after planting. Mulching with green leaves was repeated twice @ 7.5 t ha^{-1}, first 55 days and second 110 days after planting (KAU, 2011). The equivalent quantity of tree leaf loppings applied in a single grow bag used for the study was 100 g as basal and repeatedly with 50 g @ 55 days and 110 days after planting. A control was also maintained in which mulching was done with newspaper. All the treatments were replicated thrice and each replication comprised of four grow bags.

3.8.4 Details of Cultivation

3.8.4.1 Manures and Fertilizers

Same as described under section 3.7.4.3

3.8.4.2 After Cultivation

Same as described under section 3.7.4.4

3.8.4.3 Plant Protection

There was incidence of soft rot and leaf spot in ginger. Spraying of Bordeaux mixture (1%) was done at regular intervals for controlling the diseases. Severe shoot borer (*Conogethes punctiferalis*) occurrence was noticed during September-October. It was effectively controlled by spraying Chlorantraniliprole 18.5 SC @ 0.03 ml l^{-1}.

3.8.4.4 Harvesting

Harvesting was done when the crop attained full maturity (270 days after planting).

3.9. OBSERVATIONS

3.9.1 Bioassay

3.9.1.1 Percentage Sprouting

Percentage sprouting was calculated by comparing the total number of rhizomes germinated in each treatment and the total number of rhizomes planted.

3.9.1.2 Days to Sprouting

The number of days required for the germination of seed rhizomes was observed and expressed in days.

3.9.1.3 Shoot Length

Plant height was measured from the base to the growing tip (top most leaf bud) at two month after planting (2 MAP) and the mean values were computed and expressed in cm.

3.9.1.4 Root Length

The seedlings were uprooted at 2 MAP and the maximum length of the roots was measured and mean length expressed in cm.

3.9.1.5 Number of Roots

The seedlings were uprooted at 2 MAP and the total number of roots were counted.

3.9.1.6 Response Index

The degree of inhibition or stimulation in the bioassays was evaluated through the Response Index (RI), determined as follows, where T is the treatment mean (number of rhizomes germinating or mean shoot / root length of germinated seeds) and C is the control mean (Williamson and Richardson, 1988).

If T > C the RI = 1 -(C/T)

If T = C then RI = 0

If T < C then RI = (T/C) - 1

A positive Response index signifies stimulation, while negative indicates inhibition.

3.9.1.7 pH of Leachates and Extracts

The pH of tree leaf leachates and extracts was measured using pH meter with glass electrode (Jackson, 1973).

3.9.1.8 Phenol Content of Leachates and Extracts

Phenol content in tree leaf leachates and extracts was estimated using Folin-Ciocalteu method (Malick and Singh, 1980).

3.9.1.9 Tannin Content of Leachates and Extracts

Tannin content of tree leaf leachates and extracts were assessed using Folin-Denis reagent (Schanderl, 1970).

3.9.2 Pot culture

3.9.2.1 Growth Characters

3.9.2.1.1 Plant Height

Plant height was measured, at bimonthly intervals from 2 MAP, from the base of the pseudostem to the tip of the topmost leaf and height was expressed in cm.

3.9.2.1.2 Number of Tillers

The number of aerial shoots arising around each plant was counted at bimonthly intervals from 2 MAP.

3.9.2.1.3 Number of Leaves

Number of leaves produced at bimonthly intervals from 2 MAP was recorded by counting the number of leaves of the tillers from each sample plant.

3.9.2.2 Rhizome Characters

3.9.2.2.1 Rhizome Spread

The horizontal spread of rhizome was measured at the time of harvest and the mean value expressed in cm.

3.9.2.2.2 Rhizome Thickness

The diameter of the rhizome was measured by using a thread through the centre portion and expressed in cm.

3.9.2.3 Root Characters

3.9.2.3.1 Root Length

The root length was recorded at the time of harvest by measuring the maximum length of roots and mean length expressed in cm.

3.9.2.3.2 Root Spread

Root spread was measured at the time of harvest by spreading the root system on a marked paper and measuring the spread of the root system at its broadest part. It is expressed in cm.

3.9.2.3.3 Root Weight per Plant

Roots were separated from individual plants at the time of harvest and dried in hot air oven at 70±5°C and its weight taken and expressed in g plant^{-1}.

3.9.2.3.4 Root Volume per Plant

Root volume per plant was determined at the time of harvest by displacement method and expressed in cm^3 $plant^{-1}$.

3.9.2.4 Physiological Parameters

3.9.2.4.1 SPAD Reading

SPAD value was recorded using chlorophyll meter (Konica Minolta Model SPAD 502) which represents the greenness of the leaf, an indication of the leaf chlorophyll content.

3.9.2.4.2 Canopy Temperature

Canopy temperature was measured using steady state porometer (Spectro Analytical) and expressed as °C.

3.9.2.4.3 Stomatal Conductance

Stomatal conductance was measured using steady state porometer (Spectro Analytical) and expressed as m mol m^{-2} s^{-1}.

3.9.2.5 Visual Observation on Yellowing

Since the variety used was tolerant to soft rot and bacterial wilt, there was no yellowing observed in plants.

3.9.2.6 Yield and Yield Components

3.9.2.6.1 Rhizome Yield

The yield of fresh rhizome from each treatment was recorded and expressed as g $plant^{-1}$.

3.9.2.6.2 Top yield

The yield of above ground portion (pseudostem, leaves and inflorescence) was recorded from the individual treatments at 9 MAP on dry weight basis and expressed as g plant^{-1}.

3.9.2.6.3 Dry Ginger Yield

From each treatment, 100 g of fresh rhizomes were taken and dried in a hot air oven at 70±5°C till constant weight were attained. The weight was then taken and expressed as recovery percentage on dry weight basis.

3.9.2.7 Chemical Analysis

3.9.2.7.1 Nutrient (major) Content of the Fresh Tree Leaves

Nutrient (major) content of the fresh tree leaves in terms of total N, P and K was analyzed using standard analytical methods as follows.

Table 6. Analytical methods used for the chemical characterization of plant sample

Chemical parameter	Method	Reference
Total N (%)	Modified microkjeldhal method	Jackson (1973)
Total P (%)	Vanado-molybdo phosphate yellow colour method	Jackson (1973)
Total K (%)	EEL flame photometry	Jackson (1973)

3.9.2.7.2 Available NPK (kg ha^{-1}) and Organic Carbon Content (%) of Media Before and After the Experiment (in pot culture 2)

Table 7. Analytical methods used for the chemical characterization of soil sample

Sl. No.	Properties	Method	Reference
1.	Organic carbon	Walkley and Black rapid titration method	Jackson (1973)
2.	Nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
3.	Phosphorus	Bray colorimetric method	Jackson (1973)
4.	Potassium	Ammonium acetate method	Jackson (1973)

3.9.2.8 Enzyme Studies

3.9.2.8.1 Dehydrogenase (before and after the experiment in pot culture 2)

The effect of leaf lopping treatments on the soil microbial activity was studied by analysing the soil dehydrogenase enzyme activity before and after the crop following the procedure outlined by Casida *et al.* (1964).

3.9.3 Statistical Analysis

The data generated from the experiment were statistically analysed using Analysis of Variance technique for completely randomised design (CRD) and factorial CRD (Panse and Sukhatme, 1985) and significance was tested by 'F' test (Snedecor and Cochran, 1967). The data after statistical analysis were used for interpretation.

Results

4. RESULTS

The results of the experiments conducted in the Cropping Systems Research Centre, Karamana and College of Agriculture, Vellayani to assess the allelopathic effect of trees grown in homesteads of Kerala on sprouting, growth and yield of ginger are presented in this chapter under the following sections.

4.1 Experiment I: To study the effect of fresh tree leaf leachates on sprouting of ginger

4.2 Experiment II: To study the effect of fresh tree leaf extracts on sprouting of ginger

4.3 Experiment III: To study the effect of irrigating with fresh tree leaf leachates on growth and yield of ginger

4.4 Experiment IV: To study the effect of mulching with fresh tree leaf loppings on growth and yield of ginger

4.1 EXPERIMENT I (BIOASSAY I)

This experiment was carried out to examine the allelopathic effect of fresh leaf leachates of test trees on sprouting and early establishment of ginger (*Zingiber officinale* Roscoe).

4.1.1 Percentage Sprouting

Data on percentage sprouting recorded at 2 MAP are presented in Table 8. Tree leaf leachates and its concentration significantly influenced the sprouting of ginger rhizomes. The treatment T_8 resulted in the highest sprouting. The treatments T_6 and T_3 severely inhibited the sprouting of seed rhizomes. But T_6 was on par with T_4. Among the concentrations, C_1 caused more inhibition action. The interaction effects

Table 8. Effect of tree leaf leachates and concentrations on percentage sprouting and days to sprouting of ginger seed rhizomes

Treatments	2 MAP	
	Percentage sprouting	Days to sprouting
Tree leaf leachates (T)		
T_1 (Jack)	49.43	20.50
T_2 (Mango)	52.26	22.83
T_3 (Tamarind)	42.02	22.63
T_4 (Matty)	45.19	20.00
T_5 (Wild Jack)	52.25	21.33
T_6 (Teak)	44.14	22.33
T_7 (Rubber)	54.55	22.00
T_8 (Panal)	69.38	16.16
SEm (±)	01.16	0.74
CD (0.05)	2.380	1.508
Concentrations (C)		
C_1 (1:10)	49.69	21.66
C_2 (1:15)	52.61	20.33
SEm (±)	0.58	0.37
CD (0.05)	1.190	0.754

MAP-Months After Planting

Table 9. Interaction effect of tree leaf leachates and concentrations on percentage sprouting and days to sprouting of ginger seed rhizomes

Treatments	2 MAP			
	Percentage sprouting	Response index	Days to sprouting	Response index
Interaction (TxC)				
t_1c_1	46.72	-0.38	21.33	-0.14
t_1c_2	52.15	-0.27	19.66	-0.07
t_2c_1	49.99	-0.31	24.66	-0.26
t_2c_2	54.54	-0.22	21.00	-0.13
t_3c_1	40.38	-0.51	23.66	-0.23
t_3c_2	43.92	-0.44	22.00	-0.17
t_4c_1	43.66	-0.45	20.66	-0.11
t_4c_2	46.92	-0.37	19.33	-0.05
t_5c_1	52.94	-0.25	21.66	-0.15
t_5c_2	51.56	-0.37	21.00	-0.13
t_6c_1	41.74	-0.48	22.33	-0.18
t_6c_2	46.53	-0.28	22.33	-0.18
t_7c_1	53.95	-0.23	23.33	-0.21
t_7c_2	55.15	-0.38	20.66	-0.11
t_8c_1	68.36	+0.01	15.66	+0.17
t_8c_2	70.40	+0.04	16.66	+0.10
SEm (±)	1.65	-	1.04	-
CD (0.05)	NS	-	NS	-
Treatment mean	51.15	-	21.00	-
Control mean	85.33	-	18.33	-
Control *Vs.* Treatments	S	-	S	-

S: Significant at 5% level NS: Not significant at 5% level

were not significant (Table 9). The maximum sprouting was observed in t_8c_2 (70.40 percent) and minimum was in t_3c_1 (40.38 percent). The percentage of inhibition of sprouting as evident from response index was highest in t_3. The positive response index was observed in t_8. The comparison between treatments and control revealed that there was significant difference. The control showed the highest percentage of sprouting (85.33).

4.1.2 Days to Sprouting

The leaf leachates and its concentrations significantly influenced the number of days for sprouting (Table 8). The maximum days (22.83) to sprouting was recorded under T_2, which was on par with T_3, T_5, T_6 and T_7. Earlier sprouting was observed under T_8 (16.16). More days were required for sprouting under higher leachate concentration (C_1). With respect to days to sprouting, positive response index was noted in t_8. The interaction effects were not significant (Table 9).

4.1.3 Shoot Length

The tree leaf leachates and concentration significantly influenced the shoot length. The results are presented in Table 10. Seedlings under T_7 (21.48 cm) recorded the highest shoot length closely followed by T_5 (20.51 cm), but was on par with T_8 (19.53 cm). The treatment T_2 (14.80 cm) was found to be the poorest performing treatment. The concentration significantly influenced shoot length with C_2 (20.04 cm) resulting in more shoot length than C_1 (15.76 cm). The interaction effects were not significant. Maximum inhibition was caused by t_3 (55%) at 1:10 concentration. Significant difference was observed in the shoot length between the treatments and the control (Table 11).

Table 10. Effect of tree leaf leachates and concentrations on shoot length, root length and number of roots of ginger seedlings

Treatments	2 MAP		
	Shoot length (cm)	Root length (cm)	Number of roots
Tree leaf leachates (T)			
T_1 (Jack)	16.73	9.85	5.08
T_2 (Mango)	14.80	9.16	4.08
T_3 (Tamarind)	16.06	9.98	4.05
T_4 (Matty)	15.78	9.75	5.26
T_5 (Wild Jack)	20.51	11.81	4.73
T_6 (Teak)	18.36	10.90	4.81
T_7 (Rubber)	21.48	12.00	5.10
T_8 (Panal)	19.53	12.16	5.98
SEm (±)	1.13	0.43	0.29
CD (0.05)	2.305	0.885	0.607
Concentrations (C)			
C_1 (1:10)	15.76	10.08	4.61
C_2 (1:15)	20.04	11.32	5.16
SEm (±)	0.56	0.21	0.14
CD (0.05)	1.152	0.442	0.303

MAP-Months After Planting

Table 11. Interaction effect of tree leaf leachates and concentrations on shoot length, root length and number of roots of ginger seedlings

Treatments	2 MAP					
	Shoot length (cm)	Response index	Root length (cm)	Response index	Number of roots	Response index
Interaction (TxC)						
t_1c_1	14.93	-0.41	8.30	-0.44	4.76	-0.27
t_1c_2	18.53	-0.27	11.40	-0.23	5.40	-0.18
t_2c_1	12.40	-0.51	8.40	-0.43	4.02	-0.39
t_2c_2	17.20	-0.32	9.93	-0.33	4.50	-0.31
t_3c_1	11.40	-0.55	9.16	-0.38	3.66	-0.44
t_3c_2	20.73	-0.19	10.80	-0.27	4.44	-0.32
t_4c_1	13.53	-0.47	9.23	-0.37	5.03	-0.23
t_4c_2	18.03	-0.29	10.26	-0.30	5.50	-0.16
t_5c_1	18.23	-0.28	11.50	-0.22	4.50	-0.31
t_5c_2	22.80	-0.10	12.13	-0.18	4.96	-0.24
t_6c_1	16.43	-0.35	10.36	-0.30	4.66	-0.29
t_6c_2	20.20	-0.21	11.43	-0.23	4.96	-0.24
t_7c_1	20.80	-0.18	11.30	-0.23	4.90	-0.25
t_7c_2	22.16	-0.13	12.70	-0.14	5.30	-0.19
t_8c_1	18.40	-0.28	12.40	-0.16	5.70	-0.13
t_8c_2	20.66	-0.19	11.93	-0.19	6.26	-0.05
SEm (±)	1.60	-	0.61	-	0.42	-
CD (0.05)	NS	-	NS	-	NS	-
Treatment mean	17.90	-	10.70	-	4.88	-
Control mean	25.43	-	14.77	-	6.56	-
Control *Vs.* Treatments	S	-	S	-	S	-

S: Significant at 5% level NS: Not significant at 5% level

4.1.4 Root Length

Root length was significantly influenced by tree leaf leachates (Table 10) with T_8 recording significantly greater root length, but on par with T_7 and T_5 (12.16, 12.00 and 11.81 cm respectively). Root length was significantly lower in T_2 (9.16 cm). Concentration had significant effect with C_2 (11.32 cm) recording more root length than C_1 (10.08 cm). Root length was inhibited most by t_1 (RI-0.44). Interaction effects were not significant (Table 11).

4.1.5 Number of Roots

The number of roots as influenced by the leaf leachates, concentration and their interaction are presented in Tables 10 and 11. The number of roots was significantly greater under T_8 (5.98). It was significantly less in T_3 (4.05) and was on par with T_2 (4.08). Concentration had significant effect on number of roots, with C_2 recording greater number of roots (5.16) than C_1 (4.61). Root number was inhibited most by t_3, which resulted in a response index of 0.44. The interaction effects were not significant. .

4.1.6 pH of Tree Leaf Leachates

The data on the pH of leaf leachates used are furnished in Table 12. All leaf leachates were acidic. Tamarind leaf leachate at 1:10 and 1:15 concentrations had the lowest pH of 3.48 and 3.76 respectively.

4.1.7 Phenol Content of Leachates

The data on phenol content in the leaf leachates are presented in Table 12. Among the trees, phenol content was very low in jack (0.58 and 0.38 mg $100g^{-1}$ at 1:10 and 1:15 concentrations respectively). It was relatively high in teak leaf leachate

Table 12. The pH, phenol and tannin content of leaf leachate of trees

Tree	pH		Phenol content (mg $100g^{-1}$)		Tannin content (mg $100g^{-1}$)	
	1:10	1:15	1:10	1:15	1:10	1:15
Jack	5.90	6.15	0.58	0.38	71.33	62.42
Mango	4.70	4.83	2.01	1.71	65.39	55.49
Tamarind	3.48	3.76	2.14	1.92	76.28	68.36
Matty	5.74	5.88	1.94	1.81	77.27	67.37
Wild Jack	5.45	5.60	1.98	1.84	45.60	34.71
Teak	5.41	5.56	2.27	2.01	74.30	64.40
Rubber	5.13	5.41	1.86	1.79	78.26	69.35
Panal	5.69	5.70	1.78	1.66	58.46	48.56
Tap water	6.50	6.50	-	-	-	-

(2.27 and 2.01 mg $100g^{-1}$ at 1:10 and 1:15) followed by tamarind and mango leaf leachates.

4.1.8 Tannin Content of Leachates

The tannin content in the leaf leachates are given in Table 12. The maximum tannin content was in rubber leaf leachate (78.26 and 69.35 mg $100g^{-1}$ at 1:10 and 1:15 concentrations respectively) and minimum in wild jack.

4.2 EXPERIMENT II (BIOASSAY II)

This bioassay was undertaken to examine the allelopathic effect of fresh leaf extracts of trees on sprouting and early establishment of ginger (*Zingiber officinale* Roscoe).

4.2.1 Percentage Sprouting

Observations on percentage sprouting was recorded at 2 MAP are presented in Table 13. Tree leaf extracts and its concentration significantly influenced the sprouting of ginger rhizomes. The treatment T_3 significantly and severely inhibited the sprouting (40.67 percent) of rhizomes. Significantly higher sprouting was noticed under T_8 which was on par with T_7 (53.84 and 53.67 percent respectively). Among the concentrations, inhibition was significantly more under C_1. The degree of inhibition of sprouting varied from 20-54 as evident from response index. The interaction effects did not have any significant influence on percentage sprouting (Table 14).

4.2.2 Days to Sprouting

The data pertaining to number of days required for sprouting of rhizomes as influenced by the leaf extracts and concentrations are presented in Table 13. The leaf

Table 13. Effect of tree leaf extracts and concentrations on percentage sprouting and days to sprouting of ginger seed rhizomes

Treatments	2 MAP	
	Percentage sprouting	Days to sprouting
Tree leaf extracts (T)		
T_1 (Jack)	48.76	19.83
T_2 (Mango)	50.31	21.16
T_3 (Tamarind)	40.67	20.83
T_4 (Matty)	44.13	19.50
T_5 (Wild Jack)	49.90	20.50
T_6 (Teak)	44.61	21.33
T_7 (Rubber)	53.84	18.66
T_8 (Panal)	53.67	14.83
SEm (±)	1.15	0.57
CD (0.05)	2.359	1.163
Concentrations (C)		
C_1 (1:10)	46.64	20.37
C_2 (1:15)	49.83	18.79
SEm (±)	0.57	0.28
CD (0.05)	1.179	0.581

MAP-Months After Planting

Table 14. Interaction effect of tree leaf extracts and concentrations on percentage sprouting and days to sprouting of ginger seed rhizomes

Treatments	2 MAP			
	Percentage sprouting	Response index	Days to sprouting	Response index
Interaction (TxC)				
t_1c_1	45.38	-0.41	20.66	-0.11
t_1c_2	52.15	-0.30	19.00	-0.04
t_2c_1	47.87	-0.36	23.00	-0.20
t_2c_2	52.75	-0.26	19.33	-0.05
t_3c_1	39.02	-0.54	22.66	-0.19
t_3c_2	42.31	-0.47	19.00	-0.04
t_4c_1	42.69	-0.46	20.33	-0.10
t_4c_2	45.57	-0.40	18.66	-0.02
t_5c_1	49.22	-0.33	20.33	-0.10
t_5c_2	50.57	-0.30	20.66	-0.11
t_6c_1	44.04	-0.43	21.66	-0.15
t_6c_2	45.19	-0.41	21.00	-0.13
t_7c_1	53.15	-0.25	19.66	-0.07
t_7c_2	54.53	-0.22	17.66	+0.04
t_8c_1	51.76	-0.28	14.66	+0.25
t_8c_2	55.59	-0.20	15.00	+0.22
SEm (±)	1.63	-	0.80	-
CD (0.05)	NS	-	1.645	-
Treatment mean	48.24	-	19.58	-
Control mean	85.33	-	18.33	-
Control *Vs.* Treatments	S	-	S	-

S: Significant at 5% level NS: Not significant at 5% level

extracts and its concentrations significantly influenced the number of days to sprout. Rhizomes under the treatment T_6 took significantly more number of days (21.33) to sprout and was on par with treatments T_5, T_2 and T_3. However, the treatment T_8 resulted in significantly earlier sprouting. The concentration C_1 (20.37) had significantly more inhibitory effect than C_2 (18.79). With respect to days to sprouting, a positive response index was obtained with t_8 and at lower concentration (C_2) of t_7. The interaction effect was significant. The treatment combination t_8c_1 (14.66) took significantly less days for sprouting and was on par with t_8c_2, while rhizomes under t_2c_1 (23.00) took significantly more days and was on par with t_3c_1 (22.66) (Table 14).

4.2.3 Shoot Length

The tree leaf extracts and its concentrations significantly influenced the shoot length and are presented in Table 15. Seedlings had significantly higher shoot length under T_7 (18.95 cm), which was on par with T_8 (18.45 cm), T_5 (18.33 cm) and T_6 (17.28 cm). Shoot length was significantly lower under the treatment T_2 (13.31 cm). The concentrations significantly influenced shoot length with C_1 (14.43 cm) being more inhibitory. Shoot length was inhibited most by t_3 at higher concentration (C_1) and resulted in response index as high as -0.59. The interaction effects did not have any significant effect on shoot length (Table 16).

4.2.4 Root Length

Root length was significantly influenced by tree leaf extracts (Table 15). Significantly greater root length was recorded in T_7 (11.33 cm), while significantly lower length was observed under T_2 (5.51 cm), which was on par with T_6 (5.93 cm). Concentration had significant effect with C_2 (8.76 cm) resulting in greater root length than C_1 (7.66 cm). The magnitude of inhibition of root length was considerably greater than the shoot length as evident from higher values of response index. Interaction effect on root length was not significant (Table 16).

Table 15. Effect of tree leaf extracts and concentrations on shoot length, root length and number of roots of ginger seedlings

Treatments	2 MAP		
	Shoot length (cm)	Root length (cm)	Number of roots
Tree leaf extracts (T)			
T_1 (Jack)	15.01	7.60	4.01
T_2 (Mango)	13.31	5.51	3.96
T_3 (Tamarind)	15.05	6.93	3.61
T_4 (Matty)	14.46	9.16	4.48
T_5 (Wild Jack)	18.33	10.10	4.18
T_6 (Teak)	17.28	5.93	4.36
T_7 (Rubber)	18.95	11.33	4.95
T_8 (Panal)	18.45	9.15	5.26
SEm (±)	0.82	0.43	0.45
CD (0.05)	1.674	0.894	NS
Concentrations (C)			
C_1 (1:10)	14.43	7.66	4.06
C_2 (1:15)	18.27	8.76	4.64
SEm (±)	0.41	0.21	0.22
CD (0.05)	0.837	0.447	0.458

MAP-Months After Planting

Table 16. Interaction effect of tree leaf extracts and concentrations on shoot length, root length and number of roots of ginger seedlings

Treatments	2 MAP					
	Shoot length (cm)	Response index	Root length (cm)	Response index	Number of roots	Response index
Interaction (TxC)						
t_1c_1	12.53	-0.51	6.80	-0.54	4.33	-0.34
t_1c_2	17.50	-0.31	8.40	-0.43	5.03	-0.23
t_2c_1	11.36	-0.55	4.76	-0.68	3.70	-0.43
t_2c_2	15.26	-0.40	6.26	-0.58	4.23	-0.35
t_3c_1	10.40	-0.59	6.60	-0.55	3.46	-0.47
t_3c_2	19.70	-0.23	7.26	-0.51	3.76	-0.42
t_4c_1	11.90	-0.53	8.63	-0.41	4.23	-0.35
t_4c_2	17.03	-0.33	9.70	-0.35	4.73	-0.28
t_5c_1	17.20	-0.32	9.40	-0.36	4.13	-0.37
t_5c_2	19.46	-0.24	10.80	-0.27	4.23	-0.36
t_6c_1	15.40	-0.39	5.40	-0.63	4.26	-0.35
t_6c_2	19.16	-0.25	6.46	-0.56	4.46	-0.32
t_7c_1	18.86	-0.26	10.86	-0.26	4.66	-0.29
t_7c_2	19.03	-0.25	11.80	-0.20	5.23	-0.20
t_8c_1	17.83	-0.30	8.86	-0.40	5.06	-0.23
t_8c_2	19.06	-0.25	9.43	-0.36	5.46	-0.17
SEm (±)	1.16	-	0.62	-	0.63	-
CD (0.05)	2.368	-	NS	-	NS	-
Treatment mean	16.35	-	8.21	-	4.35	-
Control mean	25.43	-	14.77	-	6.56	-
Control *Vs.* Treatments	S	-	S	-	S	-

S: Significant at 5% level NS: Not significant at 5% level

4.2.5 Number of Roots

The number of roots as influenced by the leaf extracts, concentration and their interaction are presented in Tables 15 and 16. The number of roots was not significantly influenced by the tree leaf extracts. Concentration had significant effect on number of roots with C_2 resulting more number of roots (4.64) than C_1 (4.06). Maximum inhibition (47%) was caused by t_3 at higher concentration (C_1) and the response index value was -0.47. The interaction effects were not significant.

4.2.6 pH of Tree Leaf Extracts

The pH of the tree leaf extracts used are given in Table 17. All leaf extracts were acidic. Rubber leaf extract had the lowest pH of 3.63 and 3.78 at 1:10 and 1:15 concentrations respectively.

4.2.7 Phenol Content of Leaf Extracts

The data on phenol content in the leaf extracts are presented in Table 17. The phenol content was very low in jack (1.67 and 1.63 mg $100g^{-1}$ at 1:10 and 1:15 concentrations respectively) while it was relatively high in tamarind leaf extract (4.26 and 4.08 mg $100g^{-1}$ at 1:10 and 1:15) followed by mango.

4.2.8 Tannin Content of Leaf Extracts

The tannin content in the leaf extracts used are furnished in Table 17. The maximum tannin content was in rubber leaf extract (110.20 and 101.93 mg $100g^{-1}$ at 1:10 and 1:15 concentrations respectively) followed by tamarind (108.36 and 101.01 mg $100g^{-1}$ at 1:10 and 1:15). It was least in wild jack.

Table 17. The pH, phenol and tannin content of leaf extract of trees

Tree	pH		Phenol content (mg $100g^{-1}$)		Tannin content (mg $100g^{-1}$)	
	1:10	1:15	1:10	1:15	1:10	1:15
Jack	5.65	5.90	1.67	1.63	103.77	95.49
Mango	4.52	5.26	4.09	3.88	98.25	89.06
Tamarind	4.56	5.48	4.26	4.08	108.36	101.01
Matty	4.39	4.57	3.68	3.37	109.28	100.09
Wild Jack	5.88	5.48	3.47	3.15	79.86	69.75
Teak	5.16	5.23	3.66	3.42	106.53	97.33
Rubber	3.63	3.78	3.55	3.41	110.20	101.93
Panal	6.09	6.10	3.12	3.08	91.82	82.62
Tap water	6.50	6.50	-	-	-	-

4.3 EXPERIMENT III (POT CULTURE I)

This experiment was undertaken to assess the effect of irrigating with fresh tree leaf leachates of the test trees on growth and yield of ginger (*Zingiber officinale* Roscoe).

4.3.1 Growth Characters

4.3.1.1 Plant Height at Bimonthly Intervals from 2 MAP

The data on plant height as influenced by the tree leaf leachates and concentrations at 2, 4 and 6 MAP are abridged in Table 18. Plant height at 2 MAP was significantly inhibited by all trees. Plant height was significantly less under T_3 (31.26 cm), which was on par with T_2 (34.52 cm) and T_7 (35.10 cm). Maximum plant height was observed in T_5 (40.54 cm), which was on par with T_4, T_1 and T_8. At 4 MAP, plant height was significantly more under T_8 (69.04 cm). Among the concentrations, C_1 caused more significant inhibition than C_2. Neither the leaf leachate nor their concentration had significant effect on plant height at 6 MAP. The interaction effect was also not significant (Table 19).

4.3.1.2 Number of Tillers

The data on tiller production as influenced by leaf leachates, concentrations and their interaction, recorded at 2, 4 and 6 MAP are presented in Tables 18 and 19. At 2 MAP, the number of tillers produced was significantly influenced by the tree leaf leachates, with the least in T_3 (1.83) and the highest in T_7 (3.43). At 4 and 6 MAP, the tiller production was significantly affected and the highest number of tillers were produced in T_7 (9.51 and 14.56) and lowest in T_1 (6.41 and 11.41). The tiller production significantly differed between concentrations with more tiller production at C_2.Their interaction effect was not significant.

Table 18. Effect of tree leaf leachates and concentrations on plant height, number of tillers and number of leaves of ginger.

Treatments	Plant height (cm)			Number of tillers			Number of leaves		
	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
Tree leaf leachates (T)									
T_1 (Jack)	37.98	56.69	78.79	2.83	6.41	11.41	9.50	15.65	159.83
T_2 (Mango)	34.52	54.83	74.51	3.03	8.45	13.58	8.51	15.10	154.33
T_3 (Tamarind)	31.23	57.45	81.14	1.83	9.26	14.26	8.88	17.01	167.28
T_4 (Matty)	39.75	54.58	78.97	2.53	8.53	13.53	9.23	15.73	165.81
T_5 (Wild Jack)	40.54	56.16	84.28	2.83	8.23	13.23	8.81	15.00	164.61
T_6 (Teak)	36.60	52.35	84.55	3.40	8.80	13.80	7.28	13.85	154.01
T_7 (Rubber)	35.10	60.00	85.56	3.43	9.51	14.56	8.90	14.83	173.73
T_8 (Panal)	37.81	69.04	88.37	2.83	9.11	14.30	10.15	15.68	174.68
SEm (±)	1.92	2.80	4.27	0.30	0.33	0.32	0.73	0.55	3.93
CD (0.05)	3.926	5.714	NS	0.619	0.688	0.663	NS	1.128	8.021
Concentrations (C)									
C_1 (1:10)	35.01	52.95	80.64	2.35	8.23	13.25	8.44	14.86	159.66
C_2 (1:15)	38.37	62.32	83.40	3.33	8.84	13.92	9.37	15.85	168.91
SEm (±)	0.96	1.40	2.13	0.15	0.16	0.16	0.36	0.27	1.96
CD (0.05)	1.963	2.857	NS	0.875	0.344	0.331	0.753	0.564	4.010

MAP-Months After Planting

Table 19. Interaction effect of tree leaf leachates and concentrations on plant height, number of tillers and number of leaves of ginger.

Treatments	Plant height (cm)			Number of tillers			Number of leaves		
	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
Interaction (TxC)									
t_1c_1	38.50	51.27	75.43	2.33	5.73	10.73	8.66	15.30	156.33
t_1c_2	42.58	62.12	82.16	3.33	7.10	12.10	10.33	16.00	163.33
t_2c_1	31.69	47.54	73.24	2.53	7.83	12.83	8.10	14.60	149.33
t_2c_2	37.36	56.65	75.78	3.53	9.06	14.33	8.93	15.60	159.33
t_3c_1	29.63	52.56	80.13	1.33	8.83	13.83	8.43	16.73	158.23
t_3c_2	32.84	62.34	82.16	2.33	9.70	14.70	9.33	17.30	176.33
t_4c_1	35.95	50.49	78.48	2.03	8.20	13.20	9.00	15.30	164.30
t_4c_2	43.56	58.67	79.47	3.03	8.86	13.86	9.46	16.16	167.33
t_5c_1	38.35	51.47	84.45	2.33	8.10	13.10	7.76	14.30	161.23
t_5c_2	42.73	60.85	84.12	3.33	8.36	13.36	9.86	15.70	168.00
t_6c_1	34.94	46.78	83.67	2.90	8.76	13.76	6.90	13.70	151.70
t_6c_2	38.27	57.92	85.43	3.90	8.83	13.83	7.66	14.00	156.33
t_7c_1	33.56	57.87	83.67	3.00	9.36	14.46	8.33	14.66	168.13
t_7c_2	36.64	62.14	87.46	3.87	9.66	14.66	9.46	15.00	179.33
t_8c_1	37.46	65.65	86.11	2.33	9.06	14.06	8.56	14.30	168.03
t_8c_2	38.17	72.44	90.63	3.33	9.16	14.53	9.96	17.06	181.33
SEm (±)	2.72	3.96	6.04	0.42	0.47	0.46	1.04	0.78	--5.56
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment	36.69	57.63	82.02	2.84	8.54	13.58	8.91	15.35	164.28
Control mean	44.45	70.27	94.25	4.10	9.43	14.43	11.20	18.66	186.70
Control *Vs.* Treatments	NS	NS	S	S	S	S	S	S	S

S: Significant at 5% level NS: Not significant at 5% level

4.3.1.3 Number of Leaves

There was significant variation in the number of leaves with different leaf leachates and concentrations at 4 and 6 MAP (Table 18). At 4 MAP, leaf number was maximum in plants treated with T_3 (17.01) and minimum in T_6 (13.85) and T_7 (14.83), which were on par. At 6 MAP, leaf number was maximum in T_8 (174.68), followed by T_7 (173.73) and T_3 (167.28), which were on par. With regard to concentration, leaf number was significantly higher under C_2 at 2, 4 and 6 MAP. Interaction effect was not significant (Table 19).

4.3.2 Rhizome Characters

4.3.2.1 Rhizome Spread

The rhizome spread as influenced by leaf leachates, concentrations and their interactions are presented in Tables 20 and 21. The rhizome spread was not influenced by the tree leaf leachates. However, significantly greater spread was observed under C_2 (21.66 cm). The interaction effect was not significant.

4.3.2.2 Rhizome Thickness

The data on rhizome thickness of ginger are furnished in Tables 20 and 21. Neither the leaf leachates, concentrations nor their interactions had significant effect on the rhizome thickness of ginger.

Table 20. Effect of tree leaf leachates and concentrations on rhizome characters of ginger

Treatments	Rhizome spread (cm)	Rhizome thickness (cm)
Tree leaf leachates (T)		
T_1 (Jack)	20.46	1.60
T_2 (Mango)	20.29	1.64
T_3 (Tamarind)	17.20	1.40
T_4 (Matty)	22.40	1.73
T_5 (Wild Jack)	21.04	1.71
T_6 (Teak)	21.30	1.68
T_7 (Rubber)	20.83	1.68
T_8 (Panal)	22.05	1.72
SEm (±)	1.29	0.09
CD (0.05)	NS	NS
Concentrations (C)		
C_1 (1:10)	19.73	1.61
C_2 (1:15)	21.66	1.68
SEm (±)	0.64	0.04
CD (0.05)	1.314	NS

S: Significant at 5% level NS: Not significant at 5% level

Table 21. Interaction effect of tree leaf leachates and concentrations on rhizome characters of ginger

Treatments	Rhizome spread (cm)	Rhizome thickness (cm)
Interaction (TxC)		
t_1c_1	18.48	1.56
t_1c_2	22.44	1.64
t_2c_1	18.66	1.63
t_2c_2	21.92	1.66
t_3c_1	16.83	1.35
t_3c_2	17.58	1.46
t_4c_1	21.83	1.72
t_4c_2	23.00	1.75
t_5c_1	20.64	1.68
t_5c_2	21.45	1.75
t_6c_1	19.98	1.65
t_6c_2	22.61	1.71
t_7c_1	20.46	1.66
t_7c_2	21.20	1.69
t_8c_1	21.00	1.68
t_8c_2	23.10	1.76
SEm (±)	1.82	0.13
CD (0.05)	NS	NS
Treatment mean	20.70	1.65
Control mean	23.92	1.75
Control *Vs.* Treatments	S	NS

S: Significant at 5% level NS: Not significant at 5% level

4.3.3 Root Characters

4.3.3.1 Root Length

Root length was not significantly influenced by the tree leaf leachates (Tables 22 and 23). But, the effect of concentration was significant with longer roots noticed under C_2 (31.14 cm). The interaction effect was not significant.

4.3.3.2 Root Spread

The data on the effect of leaf leachates, concentration and their interaction on root spread are presented in Tables 22 and 23. Leaf leachate and its interaction with concentration were not significant with respect to root spread. However, among the concentrations, greater root spread was observed under C_2 (23.29 cm).

4.3.3.3 Root Weight per Plant

The data on root weight per plant of ginger are furnished in Tables 22 and 23. Significantly less root weight per plant was recorded in T_3 (9.00 g), while significantly greater root weight per plant was found with T_7 (13.24 g) and T_8 (13.12 g), which were on par. Significantly greater root weight was noticed under C_2 (13.05 g). The interaction effect was not significant.

4.3.3.4 Root Volume per Plant

The data on root volume per plant as influenced by tree leaf leachates, their concentration and their interaction are furnished in Tables 22 and 23. The tree leaf leachates significantly affected root volume per plant with the least with T_3 (16.81 cm^3) and maximum with T_7 (24.82 cm^3) and T_8 (24.62 cm^3), which were on par. Root volume was significantly more under C_2 (24.39 cm^3). The interaction effect t_3c_1 (14.72 cm^3) resulted in the lowest root volume and was on par with t_1c_1, t_2c_1, t_4c_1 and

Table 22. Effect of tree leaf leachates and concentrations on root characteristics of ginger

Treatments	Root length (cm)	Root spread (cm)	Root weight per plant (g)	Root volume per plant (cm^3)
Tree leaf leachates (T)				
T_1 (Jack)	30.79	21.32	12.68	23.69
T_2 (Mango)	29.74	21.98	11.68	21.80
T_3 (Tamarind)	24.80	21.29	09.00	16.81
T_4 (Matty)	30.94	23.12	11.25	20.98
T_5 (Wild Jack)	30.49	21.37	11.06	20.83
T_6 (Teak)	24.41	21.39	11.56	21.59
T_7 (Rubber)	29.64	21.40	13.24	24.82
T_8 (Panal)	27.96	23.17	13.12	24.62
SEm (±)	2.20	1.46	0.92	1.56
CD (0.05)	NS	NS	1.883	3.205
Concentrations (C)				
C_1 (1:10)	26.04	20.97	10.35	19.39
C_2 (1:15)	31.14	23.29	13.04	24.39
SEm (±)	1.10	0.73	0.46	0.78
CD (0.05)	2.245	1.487	0.941	1.602

S: Significant at 5% level NS: Not significant at 5% level

Table 23. Interaction effect of tree leaf leachates and concentrations on root characteristics of ginger

Treatments	Root length (cm)	Root spread (cm)	Root weight per plant (g)	Root volume per plant (cm^3)
Interaction (TxC)				
t_1c_1	29.12	19.47	09.12	17.18
t_1c_2	32.46	23.17	16.24	30.21
t_2c_1	26.00	20.81	10.00	18.60
t_2c_2	33.49	23.16	13.37	25.00
t_3c_1	21.28	19.47	07.87	14.72
t_3c_2	28.32	23.12	10.12	18.90
t_4c_1	29.23	22.57	09.62	17.95
t_4c_2	32.65	23.67	12.87	24.01
t_5c_1	27.97	20.35	10.12	18.96
t_5c_2	33.01	22.40	12.00	22.70
t_6c_1	23.75	20.14	10.75	20.12
t_6c_2	25.07	22.65	12.37	23.07
t_7c_1	25.35	22.17	12.12	22.59
t_7c_2	33.92	24.63	14.37	27.06
t_8c_1	25.67	22.78	13.25	25.05
t_8c_2	30.25	23.56	14.00	24.18
SEm (±)	3.11	2.97	1.30	2.21
CD (0.05)	NS	NS	NS	4.532
Treatment mean	28.59	22.13	11.70	21.89
Control mean	34.08	23.82	13.50	28.23
Control *Vs.* Treatments	S	NS	NS	S

S: Significant at 5% level NS: Not significant at 5% level

Table 24. Effect of tree leaf leachates and concentrations on physiological parameters of ginger

Treatments	SPAD reading	Canopy temperature (°C)	Stomatal conductance (m mol m^{-2} s^{-1})
Tree leaf leachates (T)			
T_1 (Jack)	42.06	30.40	105.67
T_2 (Mango)	42.30	30.25	99.72
T_3 (Tamarind)	38.70	30.28	83.74
T_4 (Matty)	42.32	30.43	85.77
T_5 (Wild Jack)	40.45	30.35	90.74
T_6 (Teak)	41.41	30.68	83.81
T_7 (Rubber)	38.05	31.01	95.43
T_8 (Panal)	44.25	30.16	111.78
SEm (±)	3.16	1.58	4.96
CD (0.05)	NS	NS	10.119
Concentrations (C)			
C_1 (1:10)	40.77	30.26	90.16
C_2 (1:15)	41.61	30.63	99.00
SEm (±)	1.58	0.79	2.48
CD (0.05)	NS	NS	5.059

S: Significant at 5% level NS: Not significant at 5% level

Table 25. Interaction effect of tree leaf leachates and concentrations on physiological parameters of ginger

Treatments	SPAD reading	Canopy temperature (°C)	Stomatal conductance (m mol m^{-2} s^{-1})
Interaction (TxC)			
t_1c_1	41.37	30.45	104.22
t_1c_2	42.76	30.36	107.13
t_2c_1	40.86	29.89	95.63
t_2c_2	43.74	30.61	103.82
t_3c_1	36.50	29.92	74.23
t_3c_2	40.90	30.65	93.25
t_4c_1	42.97	30.19	80.58
t_4c_2	41.67	30.68	90.96
t_5c_1	40.40	30.22	85.47
t_5c_2	40.51	30.49	96.02
t_6c_1	42.11	30.26	80.27
t_6c_2	40.71	31.11	87.36
t_7c_1	37.24	30.88	90.31
t_7c_2	38.87	31.15	100.56
t_8c_1	44.74	30.32	110.62
t_8c_2	43.76	30.01	112.94
SEm (±)	4.46	1.58	7.02
CD (0.05)	NS	NS	14.310
Treatment mean	41.19	30.45	94.58
Control mean	41.28	30.63	84.46
Control *Vs.*	NS	NS	NS

S: Significant at 5% level NS: Not significant at 5% level

t_5c_1. While t_1c_2 and t_7c_2 (30.21 and 27.06 cm^3 respectively) had the highest root volume per plant.

4.3.4 Physiological Parameters

4.3.4.1 SPAD Reading

The data on SPAD value are furnished in Tables 24 and 25. Neither the leaf leachates, concentrations nor their interactions had significant effect on SPAD value.

4.3.4.2 Canopy Temperature

The data on canopy temperature are presented in Tables 24 and 25. Neither the leaf leachates, concentrations nor their interactions had significant effect on canopy temperature.

4.3.4.3 Stomatal Conductance

Stomatal conductance was significantly influenced by the tree leaf leachates and their concentration (Tables 24 and 25). Stomatal conductance was significantly less in T_3 (82.74 m mol m^{-2} s^{-1}), while it was maximum in T_8 (111.78 m mol m^{-2} s^{-1}). Among the concentrations, C_2 resulted in higher stomatal conductance (99.00 m mol m^{-2} s^{-1}). The interaction effect was significant. Stomatal conductance was minimum in t_3c_1 (74.23 m mol m^{-2} s^{-1}), which was on par with t_4c_1, t_5c_1, t_6c_1 and t_6c_2 and maximum in t_8c_2 (112.94 m mol m^{-2} s^{-1}), which was on par with t_1c_1, t_1c_2, t_2c_2, and t_3c_1.

4.3.5 Yield and Yield Components

4.3.5.1 Rhizome Yield

The data related to rhizome yield are presented in, Tables 26 and 27. Significantly higher rhizome yield was observed in T_8 (632.87 g), which was on par

Table 26. Effect of tree leaf leachates and concentrations on rhizome yield, top yield and dry ginger

Treatments	Rhizome yield per plant (g)	Top yield per plant (g)	Dry ginger (recovery %)
Tree leaf leachates (T)			
T_1 (Jack)	521.60	44.59	20.56
T_2 (Mango)	532.68	32.90	19.02
T_3 (Tamarind)	443.56	32.08	19.71
T_4 (Matty)	616.59	44.97	21.58
T_5 (Wild Jack)	590.02	42.88	21.40
T_6 (Teak)	580.37	35.07	20.08
T_7 (Rubber)	611.80	40.17	18.92
T_8 (Panal)	632.87	37.15	18.98
SEm (±)	24.13	1.89	1.68
CD (0.05)	49.154	3.857	NS
Concentrations (C)			
C_1 (1:10)	530.33	35.37	19.46
C_2 (1:15)	602.04	42.08	20.60
SEm (±)	12.06	0.94	0.840
CD (0.05)	24.577	1.928	NS

S: Significant at 5% level NS: Not significant at 5% level

Table 27. Interaction effect of tree leaf leachates and concentrations on rhizome yield, top yield and dry ginger

Treatments	Rhizome yield per plant (g)	Top yield per plant (g)	Dry ginger (recovery %)
Interaction (TxC)			
t_1c_1	463.24	41.08	19.51
t_1c_2	579.96	48.11	21.61
t_2c_1	509.46	27.85	17.48
t_2c_2	555.91	37.96	20.55
t_3c_1	428.46	29.81	20.35
t_3c_2	458.67	34.36	19.06
t_4c_1	596.68	44.81	21.77
t_4c_2	636.51	45.14	21.39
t_5c_1	569.67	39.67	20.00
t_5c_2	610.38	46.10	22.81
t_6c_1	528.65	33.11	19.11
t_6c_2	632.09	37.02	21.04
t_7c_1	562.48	36.56	17.68
t_7c_2	661.12	43.79	20.15
t_8c_1	584.03	30.11	19.79
t_8c_2	681.71	44.20	18.16
SEm (±)	34.12	2.67	2.37
CD (0.05)	NS	NS	NS
Treatment mean	566.19	38.73	20.03
Control mean	693.25	48.45	20.84
Control *Vs.* Treatments	S	S	NS

S: Significant at 5% level NS: Not significant at 5% level

with T_7, T_4 and T_5. Significantly lower rhizome yield was recorded in T_3 (443.56 g). Significantly higher yield was produced under C_2 (602.04 g) than C_1 (530.33 g). The interaction effect was not significant.

4.3.5.2 Top Yield

The data related to top yield are presented in Tables 26 and 27. Significantly higher top yield was produced in T_4 (44.97 g) and it remained on par with T_5 and T_1. Top yield was lowest in T_3 (32.08 g) and was on par with T_2 and T_6. Significantly higher top yield was produced under C_2 (42.08 g) than C_1 (35.37 g). The interaction effect was not significant.

4.3.5.3 Dry Ginger Yield

The data on dry ginger recovery are furnished in Tables 26 and 27. Neither the leaf leachates, their concentrations nor the interactions had any significant effect on dry ginger recovery.

4.4. EXPERIMENT IV (POT CULTURE II)

4.4.1 Growth Characters

4.4.1.1 Plant Height at Bimonthly Intervals from 2 MAP

The data on the effect of tree leaf loppings on plant height of ginger are presented in Table 28. At 2 MAP, plant height was significantly greater under M_8 and M_9, which were on par. Plant height was significantly lower in treatments, M_2 (36.84 cm) and M_3 (34.89 cm), which were on par. At 4 MAP, plant height was significantly greater under treatment, M_8 (64.65 cm), which was on par with M_9 (58.76 cm), followed by M_7 (56.44 cm). When compared to control, plant height was significantly lower in M_2 and M_5, which were on par. At 6 MAP, there was no significant difference in plant height among the treatments.

4.4.1.2 Number of Tillers

The data on tiller production as influenced by tree leaf loppings are presented in Table 28. At 2 MAP, there was significant difference in tiller production. Maximum tillers were produced under M_8 (4.45), which was on par with control (M_9). Tiller production was significantly less and was on par under M_2 and M_4. At 4 MAP, tiller production was highest under M_8 (15.33) which was on par with M_9 and M_7. When compared to control, significantly lesser tiller production was recorded under M_2, M_4 and M_1, which were on par. At 6 MAP, more tillers were recorded under M_8 (17.49), which was on par with M_9, M_7 and M_5. The lowest number of tillers was observed under M_2, M_4 and M_1, which were on par.

Table 28. Effect of tree leaf loppings on plant height, number of tillers and number of leaves of ginger

Treatment	Plant height (cm)			Number of tillers			Number of leaves		
	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP	2 MAP	4 MAP	6 MAP
M_1 Jack	38.65	53.73	87.38	3.41	9.56	13.54	6.87	10.67	135.72
M_2 Mango	36.84	46.67	80.49	3.04	8.46	11.31	6.97	11.20	140.35
M_3 Tamarind	34.89	50.83	82.68	3.66	12.40	14.77	7.97	13.07	177.20
M_4 Matty	39.53	49.42	91.92	3.32	9.14	12.76	7.63	11.87	162.49
M_5 Wild Jack	38.43	48.42	91.70	3.66	10.19	15.45	7.87	14.23	180.62
M_6 Teak	38.17	55.91	85.73	3.67	10.66	13.57	7.50	12.67	149.23
M_7 Rubber	40.14	56.44	91.92	4.01	13.54	16.42	8.53	14.43	169.90
M_8 Panal	46.50	64.65	94.36	4.45	15.33	17.49	12.00	18.07	192.43
M_9 Control	43.16	58.76	93.41	4.13	14.66	16.92	10.00	17.63	186.09
SEm (±)	1.85	2.56	4.19	0.26	0.89	1.12	0.46	0.70	7.64
CD (0.05)	5.511	7.602	NS	0.802	2.653	3.339	1.374	2.091	22.729

S: Significant at 5% level NS: Not significant at 5%

4.4.1.3 Number of Leaves

The data presented in Table 28 indicates that leaf production was significantly influenced by the different tree leaf loppings. At 2 MAP, highest leaf production was recorded under M_8 (12.00), followed by M_9 and M_7. Leaf production was lowest under M_1 and M_2, which were on par. At 4 MAP, number of leaves produced was highest under M_8 and M_9, which were on par. This was followed by M_7 and M_5, which were on par. The lowest number of leaves were recorded under M_1 (10.67), which was on par with M_2 and M_4. At 6 MAP, maximum leaf production was recorded under M_8 and M_9, which were on par. Leaf production was significantly less under M_1 (135.72), which was on par with M_2 (140.35).

4.4.2 Rhizome Characters

4.4.2.1 Rhizome Spread

The data on rhizome spread (Table 29) indicated significant difference among the different leaf loppings. Rhizome spread was significantly greater under M_8 (28.80 cm), which was on par with M_9 (control). Rhizome spread under M_2 and M_3, were on par, and significantly less than all the other treatments.

4.4.2.2 Rhizome Thickness

Rhizome thickness was significantly influenced by the tree leaf loppings. Rhizome thickness was significantly higher under M_8 (2.03 cm), M_9 and M_7, which were on par. Rhizome thickness was significantly lower and were on par in M_3, M_1 and M_2, when compared to the other treatments.

Table 29. Effect of tree leaf loppings on rhizome characters

Treatment	Rhizome spread (cm)	Rhizome thickness (cm)
M_1 Jack	22.07	1.72
M_2 Mango	17.97	1.73
M_3 Tamarind	17.37	1.56
M_4 Matty	25.67	1.80
M_5 Wild Jack	24.63	1.78
M_6 Teak	25.67	1.75
M_7 Rubber	26.23	1.92
M_8 Panal	28.80	2.03
M_9 Control	28.16	1.98
SEm (±)	0.72	0.07
CD (0.05)	2.159	0.229

S: Significant at 5% level NS: Not significant at 5% level

4.4.3 Root Characters

4.4.3.1 Root Length

The results on root length are presented in Table 30. The treatment M_8 (53.52 cm) resulted in the maximum root length and was on par with M_9 and M_7. The minimum root length were observed under M_2 (31.52 cm) and M_3 (35.85 cm), which were on par.

4.4.3.2 Root Spread

The data on root spread are presented in Table 30. Root spread was significantly greater under M_8 (28.45 cm), which was on par with M_9, M_7 and M_5. Root spread was significantly less under M_2 (19.34 cm) and it was on par with M_3, M_1, M_4 and M_6.

4.4.3.3 Root Weight per Plant

Root weight per plant was significantly affected by the different tree leaf loppings (Table 30). Significantly higher root weight was recorded under M_9. It was on par with M_4 and M_5. The treatment M_3 (7.79 g) resulted in significantly lesser root weight and was on par with M_1, M_2 and M_7.

4.4.3.4 Root Volume per Plant

The data on root volume (Table 30) indicated significant difference among treatments. Root volume was significantly higher under M_9 (25.88 cm^3). It was on par with M_4 and M_5. Significantly lower root volume were observed under M_3 (16.03 cm^3) which was on par with M_2 and M_1.

Table 30. Effect of tree leaf loppings on root characteristics of ginger

Treatment	Root length (cm)	Root spread (cm)	Root weight per plant (g)	Root volume per plant (cm^3)
M_1 Jack	40.52	20.13	8.75	17.30
M_2 Mango	31.52	19.34	9.00	16.09
M_3 Tamarind	35.85	19.42	7.79	16.03
M_4 Matty	45.18	22.47	12.75	25.15
M_5 Wild Jack	41.18	26.32	11.50	22.71
M_6 Teak	40.85	20.72	9.50	18.76
M_7 Rubber	47.18	27.14	9.13	17.76
M_8 Panal	53.52	28.45	10.38	20.46
M_9 Control	47.52	27.42	13.13	25.88
SEm (±)	2.47	1.33	0.75	1.39
CD (0.05)	7.360	3.950	2.232	4.143

S: Significant at 5% level NS: Not significant at 5% level

Table 31. Effect of tree leaf loppings on physiological parameters of ginger

Treatment	SPAD reading	Canopy temperature (^{0}C)	Stomatal conductance (mol m^{-2} s^{-1})
M_1 Jack	41.58	30.67	72.56
M_2 Mango	40.27	30.11	78.23
M_3 Tamarind	44.63	30.14	68.46
M_4 Matty	42.20	30.41	75.49
M_5 Wild Jack	41.60	30.44	83.17
M_6 Teak	42.38	30.47	79.61
M_7 Rubber	38.72	30.28	92.46
M_8 Panal	43.64	30.90	112.85
M_9 Control	46.20	30.94	93.57
SEm (±)	1.94	1.43	4.03
CD (0.05)	NS	NS	11.988

S: Significant at 5% level NS: Not significant at 5% level

4.4.4. Physiological Parameters

4.4.4.1 SPAD Reading

The data on SPAD value are furnished in Table 31. There was no significant difference in the SPAD values among the treatments.

4.4.4.2 Canopy Temperature

The data on canopy temperature are furnished in Table 31. There was no significant difference in the canopy temperature among the treatments.

4.4.4.3 Stomatal Conductance

The data on stomatal conductance are furnished in Table 31. Stomatal conductance was significantly higher under M_8 (112.85 m mol m^{-2} s^{-1}). This was followed by the treatments M_9 (control), M_7 and M_5, which were on par. Compared to the other treatments, stomatal conductance was significantly less under M_3, M_1, M_4 and M_2, which were on par.

4.4.5 Yield and Yield Components

4.4.5.1 Rhizome Yield

The tree leaf loppings significantly influenced rhizome yield. Rhizome yield was significantly less under M_3 (512.09 g) and M_2 (521.19 g), which were on par. Rhizome yield under the other treatments, including control, were significantly higher and on par (Table 32).

Table 32. Effect of tree leaf loppings on rhizome yield, top yield and dry ginger

Treatment	Rhizome yield per plant (g)	Top yield per plant (g)	Dry ginger (recovery %)
M_1 Jack	601.11	29.24	20.02
M_2 Mango	521.19	20.04	20.34
M_3 Tamarind	512.09	19.38	19.73
M_4 Matty	613.60	32.64	21.16
M_5 Wild Jack	607.11	32.52	21.35
M_6 Teak	617.32	28.47	21.75
M_7 Rubber	621.40	36.64	20.56
M_8 Panal	653.50	32.70	20.48
M_9 Control	637.01	33.12	21.02
SEm (±)	20.81	1.36	0.98
CD (0.05)	61.854	4.060	NS

S: Significant at 5% level NS: Not significant at 5% level

Table 33. Available N, P, K, organic carbon and dehydrogenase content of media before the experiment

Organic carbon (%)	N	P	K	EC	pH	Dehydrogenase ($\mu g\ TPF\ g^{-1}h^{-1}$ media)
0.91	325.79	48.18	261.57	0.9	5.7	163.12

Table 34. Available N, P, K, organic carbon and dehydrogenase content of media after the experiment

Treatments	Organic carbon (%)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	Dehydrogenase ($\mu g\ TPF\ g^{-1}h^{-1}$ media)
M_1 Jack	0.81	181.44	52.67	258.71	181.89
M_2 Mango	0.93	208.32	50.40	248.43	208.84
M_3 Tamarind	0.65	145.60	38.60	240.75	145.96
M_4 Matty	0.95	212.80	50.03	260.45	213.33
M_5 Wild Jack	1.15	257.60	54.87	256.57	258.24
M_6 Teak	0.45	100.80	18.20	270.15	101.05
M_7 Rubber	0.66	147.84	29.00	208.89	148.21
M_8 Panal	0.74	165.76	22.28	240.47	166.17
M_9 Control	0.29	63.84	16.96	200.74	64.00

4.4.5.2 Top Yield

The treatments significantly affected top yield per plant. Top yield was significantly higher in M_7 (36.64 g), which was on par with M_9, M_8 and M_4. When compared to control (M_9), top yield was significantly less in M_3 and was on par with M_2 (Table 32).

4.4.5.3 Dry Ginger Yield

There was no significant difference among the treatments in dry ginger recovery (Table 32).

4.4.6 Available N, P, K and Organic Carbon Content of Media Before and After the Experiment (Pot culture II)

The data recorded on organic carbon, N, P and K before the experiment are presented in Table 33. The data on nutrient status of the media after the experiment are furnished in Table 34. The treatment M_5, resulted in higher organic carbon (1.15 %), nitrogen (257.60 kg ha^{-1}) and phosphorus (54.87 kg ha^{-1}). Potassium was found to be more in M_4 (260.45 kg ha^{-1}). However, the lowest nutrient status was found in the treatment, M_9 (Control).

4.4.7 Dehydrogenase Content of Media Before and After the Experiment (Pot culture II)

The observations on the dehydrogenase enzyme analysis done before and after the experiment are presented in Tables 33 and 34 respectively. Soil dehydrogenase enzyme activity was higher under M_5 (258.24 µg TPF $g^{-1}h^{-1}$media) followed by M_4. The treatments M_3, M_6 and M_9 recorded lower enzyme activity than initial activity in the growing media.

Table 35. Nitrogen, phosphorus and potassium content of fresh tree leaves

Tree	Nutrient content (%)		
	N	P	K
Jack	2.146	0.335	0.463
Mango	1.866	0.248	0.833
Tamarind	2.706	0.213	0.783
Matty	2.612	0.204	0.498
Wild Jack	2.146	0.300	0.701
Teak	2.700	0.291	0.975
Rubber	3.825	0.326	0.781
Panal	3.452	0.257	0.592

4.4.8 Nutrient (major) Content of the Fresh Tree Leaves

The content of major nutrients of the fresh tree leaves are furnished in Table 35. Nitrogen content was higher in rubber leaf (3.825 %). Phosphorus content was more in jack leaf (0.335 %) and more potassium in teak leaf (0.975 %).

Discussion

5. DISCUSSION

An experiment was conducted to assess the allelopathic effect of trees commonly planted in the homesteads of Kerala on sprouting, growth and yield of ginger. The results of the study presented in the previous chapter are discussed below.

5.1 EXPERIMENT I (BIOASSAY I)

The allelopathic effect of fresh leaf leachates of test trees on sprouting and early establishment of ginger was studied as part of the investigation. Tree leaf leachates and its concentration significantly influenced the sprouting of ginger rhizomes. There was significant reduction in sprouting of ginger rhizomes when treated with the leaf leachates of tamarind and teak. The inhibition, as indicated by the response index, was as high as 51 and 48 per cent respectively at higher concentration. The inhibition caused by matty tree leaf leachate was on par with that of teak. Sprouting was remarkably delayed when treated with mango, tamarind, wild jack, teak and rubber leaf leachates. Treating with panal leaf leachate resulted in earlier sprouting and the stimulation was 17 per cent when compared to control. The degree of inhibition increased with concentration from 1:15 to 1:10 (w/v).

The tree leaf leachates significantly influenced shoot and root growth. The leaf leachate of mango, tamarind, matty and jack caused greatest inhibition of shoot growth and the degree of inhibition was as high as 55, 51, 47, and 41 per cent respectively. A similar pattern of inhibition was observed in root growth. The number of roots was considerably less when treated with mango and tamarind leaf leachate and the magnitude of inhibition was 44 and 39 per cent respectively. However, roots produced were more when treated with panal leaf leachate. Dilution alleviated the inhibitory effects as evident from the lesser inhibition recorded at 1:15 concentration.

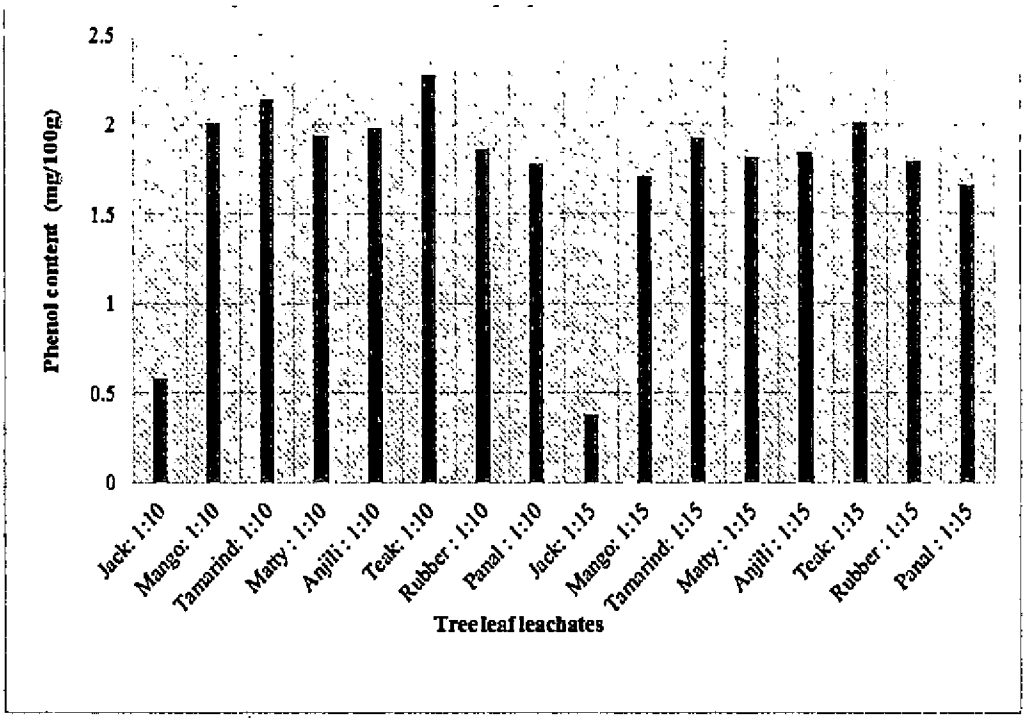

Fig. 3. Phenol content of tree leaf leachates

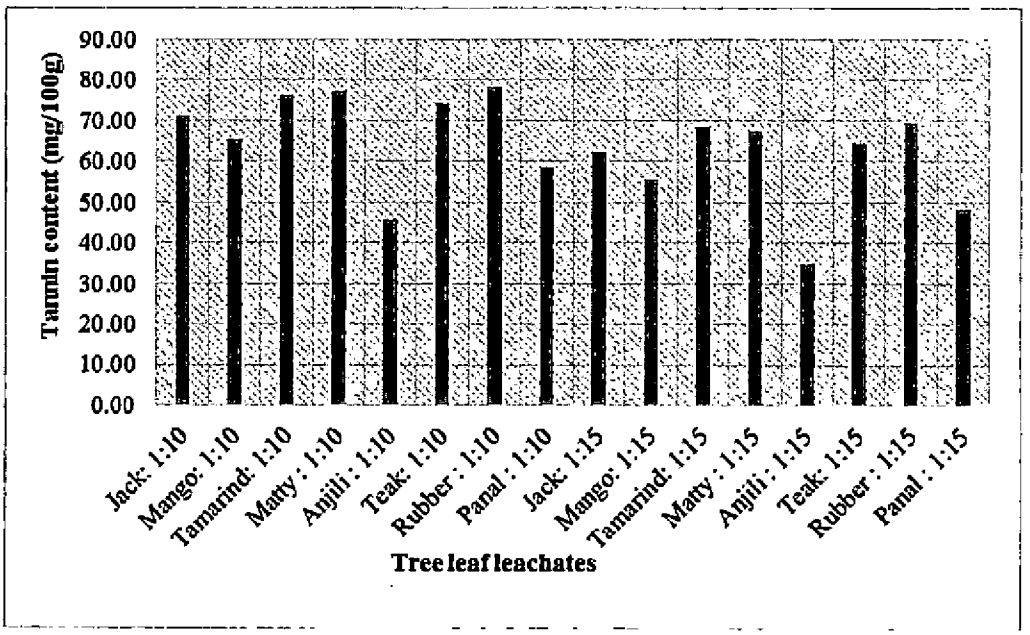

Fig. 4. Tannin content of tree leaf leachates

It can be inferred that leaf leachates of tamarind, teak and matty inhibited sprouting the most, while mango and tamarind delayed sprouting and had most deleterious effects on shoot growth, root growth and number of roots. Though all the leaf leachates were acidic and tamarind leaf leachate had the lowest pH, to avoid the adverse effects due to acidity, pH was adjusted to the neutral range by adding alkali (KOH). Hence, it is only logical to conclude that the observed effects might be due to the phytochemicals present in the leaf leachates. The highest phenol content was observed in teak leaf leachate followed by tamarind and mango. The rubber leaf leachate had the highest tannin content followed by tamarind and matty. Mango and tamarind leaf leachates were consistent in their greater inhibitory effects on growth. The presence of substantial quantities of phenol in tamarind and mango leachates might have caused the observed inhibition. Interestingly, panal leaf leachate hastened sprouting of the rhizomes.

Duke (1992) reported the presence of alanine, alpha-pinene, beta-pinene, gallic acid, gallotannic acid, isoleucine, isomangiferolic acid, kaempferol, lauric acid, linoleic acid, linolenic acid, mangiferic acid, mangiferine, mangiferol, mangiferolic acid, mangiferonic acid, myristic acid, p-coumaric acid, palmitic acid, quercetin, tannin and threonine in mango. Alpha terpineol, cinnamaldehyde, ethyl cinnamate, galacturonic acid, geranial essential oil, geraniol essential oil, limonene, linoleic acid, myristic acid, oleic acid, palmitic acid, pantothenic acid, phenol, pipecolinic acid, tannin and tartaric-acid are found in tamarind. Teak contains betulin and betulinic-acid. These phytochemicals may be present in varying amounts in the tree leaf leachates. Numerous alkaloids have been identified in the leaves of panal, some of which might be responsible for the observed stimulatory effect (Sreejith *et al.*, 2012). However, based on the present study, it is not possible to identify which of these chemicals were specifically responsible for the inhibitory or stimulatory effect.

John and Nair (1998) observed inhibition of plumule growth in rice and cowpea by tamarind leachates. John *et al.* (2007a) described the inhibitory effects of leaf leachate of teak on seed germination of cowpea. Mango leaf leachate had conspicuous inhibitory effect on germination of brinjal. The severe inhibitory effects of mango, teak and tamarind leaf leachates on sprouting and growth of turmeric have been already reported (Lakshmi, 2015).

5.2. EXPERIMENT II (BIOASSAY II)

The allelopathic effect of fresh tree leaf extracts on sprouting and early establishment of ginger was studied as part of the investigation. Tree leaf extracts and its concentration significantly influenced the sprouting of ginger rhizomes. Tamarind leaf extracts inhibited sprouting severely and the magnitude of inhibition, as measured by response index, was 54 per cent. Teak and matty, which ranked next, also considerably suppressed sprouting. Sprouting was delayed most when treated with leaf extracts of teak and mango. However, earlier sprouting was observed when treated with panal leaf extract and the magnitude of stimulation was 25 per cent. The extent of inhibition by the tree leaf extracts increased with concentration of leaf extract.

Shoot and root growth were appreciably suppressed with the application of tree leaf extracts. The leaf extract of mango (55 % inhibition) and matty (53 %) severely inhibited shoot growth. Among the trees, shoot growth was more when treated with rubber, panal and wild jack. Root growth was most adversely affected by mango and teak leaf extracts. The tree leaf extracts did not influence the number of roots produced. Higher concentration of the extracts caused greater inhibition with respect to all parameters.

From this bioassay it can be concluded that the allelopathic effects on sprouting and initial growth of rhizomes varied with tree species. It was revealed that despite neutralizing the acidity, leaf extracts of tamarind, teak and matty inhibited

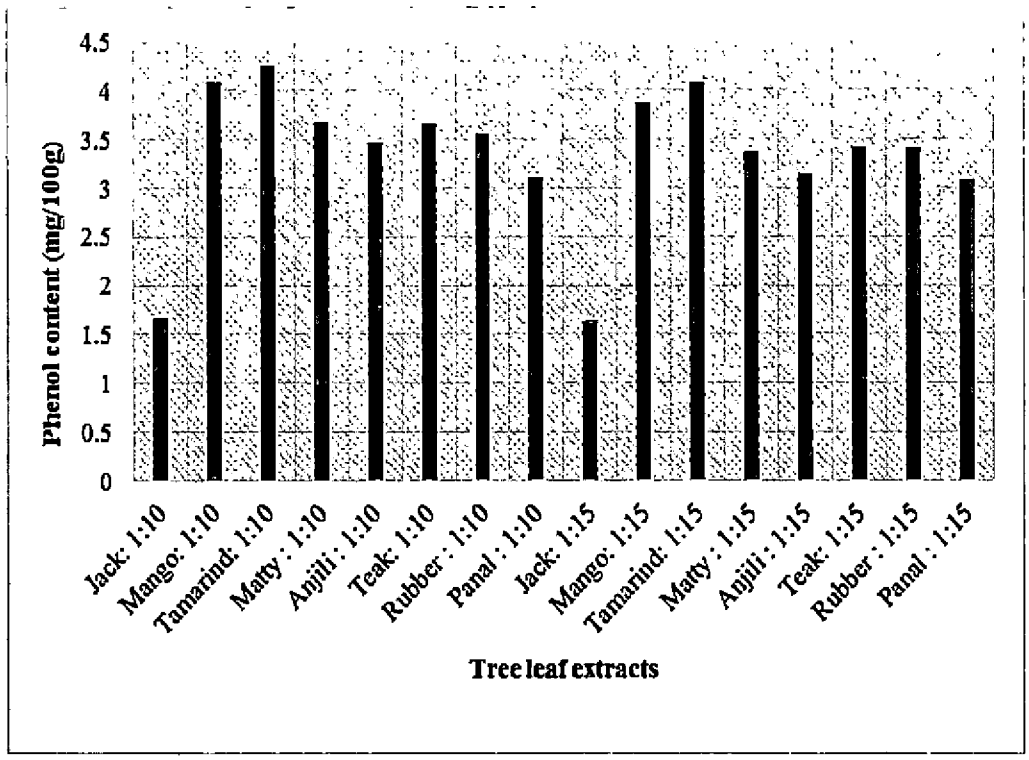

Fig. 5. Phenol content of tree leaf extracts

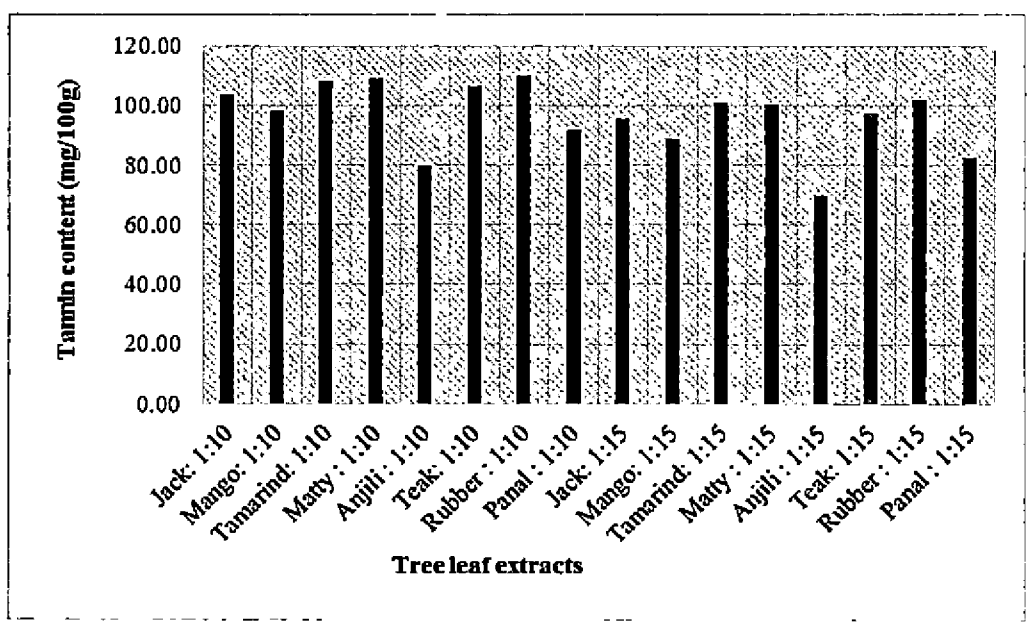

Fig. 6. Tannin content of tree leaf extracts

sprouting. Mango leaf extracts delayed sprouting and also suppressed growth. Teak, besides inhibiting, delayed sprouting and inhibited root growth. The effect of leaf extracts of panal in hastening sprouting and promoting shoot growth was notable.

The magnitude of inhibition of root growth was much more than shoot growth. Dilution was effective in alleviating allelopathic inhibition. In general, the degree of inhibition by leaf extracts was relatively greater than that by leaf leachates. As in the case of leaf leachates, the inhibitory effects of the leaf extracts cannot be attributed to acidity, as the pH of the extracts were adjusted to a neutral range before application. Leaf extracts were prepared by blending the tree leaves with water. Hence, as the leaves were subjected to crushing, the nature, number and concentration of the phytochemicals present in the extract would have been entirely different from that in leachate.

At both 1:10 and 1:15 concentration, the highest phenol content was observed in tamarind leaf extract (4.26 and 4.08 mg $100g^{-1}$ at 1:10 and 1:15) followed by mango. The tamarind leaf extract had relatively high tannin content (108.36 and 101.01 mg $100g^{-1}$ at 1:10 and 1:15 concentrations respectively). Higher phenol and tannin content might be responsible for the inhibitory effects of tamarind and mango. The inhibitory action of phenols has been attributed to their effect on membrane functions, membrane potential, mineral absorption and plant water relations (Einhellig, 1995).

A large number of phytochemicals may be present in the leaf extracts, some of which may be responsible for inhibition and certain for stimulation. John *et al.* (2007b) reported that fresh leaf extract of mango contains terpenoids and triterpenes, tamarind has flavonoids and terpenoids while teak contains triterpenes.

Reports of inhibitory effect by aqueous fresh leaf extracts of mango on germination, shoot and root growth in receptor plants are available (Sahoo *et al.*, 2010). Lakshmi (2015), based on a similar laboratory study, recorded that the leaf extract of tamarind and teak inhibited sprouting of turmeric rhizomes. Leaf extract of teak (1:10) suppressed shoot growth of turmeric severely followed by mango (1:10)

and tamarind (1:10) and the extent of inhibition was 50, 47 and 44 percent respectively. Root growth in turmeric was inhibited by the leaf extracts of tamarind, mango and teak.

5.3. EXPERIMENT III (POT CULTURE I)

The ailelopathic influence of leaf leachate of different trees on ginger was evaluated in this pot culture study.

Plant height was remarkably affected by all tree leaf leachates at 2 and 4 MAP. At 2 MAP, plants treated with leaf leachate of tamarind, mango and rubber had the minimum height. At 4 MAP, plant height was significantly greater with panal and rubber leaf leachate. Interestingly, application of panal leaf leachate resulted in maximum plant height.

At 2 MAP, tiller production was most adversely affected by tamarind leaf leachate. The highest number of tillers was recorded in plants treated with leachate of rubber at 2, 4 and 6 MAP.

At 4 MAP, leaf number was the least in plants treated with leaf leachate of teak and rubber. At 6 MAP, plants exposed to panal and rubber leaf leachate had maximum number of leaves.

Rhizome characters like rhizome spread and rhizome thickness were not conspicuously affected by the tree leaf leachates. Applying tamarind leaf leachate resulted in least root weight and root volume per plant, while maximum was recorded with rubber and panal leaf leachate.

Among the physiological parameters, there was no difference between the treatments with respect to SPAD values and canopy temperature. Stomatal conductance alone was affected by the leaf leachate of trees. It was least in plants treated with tamarind leaf leachate and maximum with panal leaf leachate.

The rhizome yield per plant was significantly influenced by the different tree leaf leachates. Application of tamarind leaf leachate resulted in least yield (443.56 g

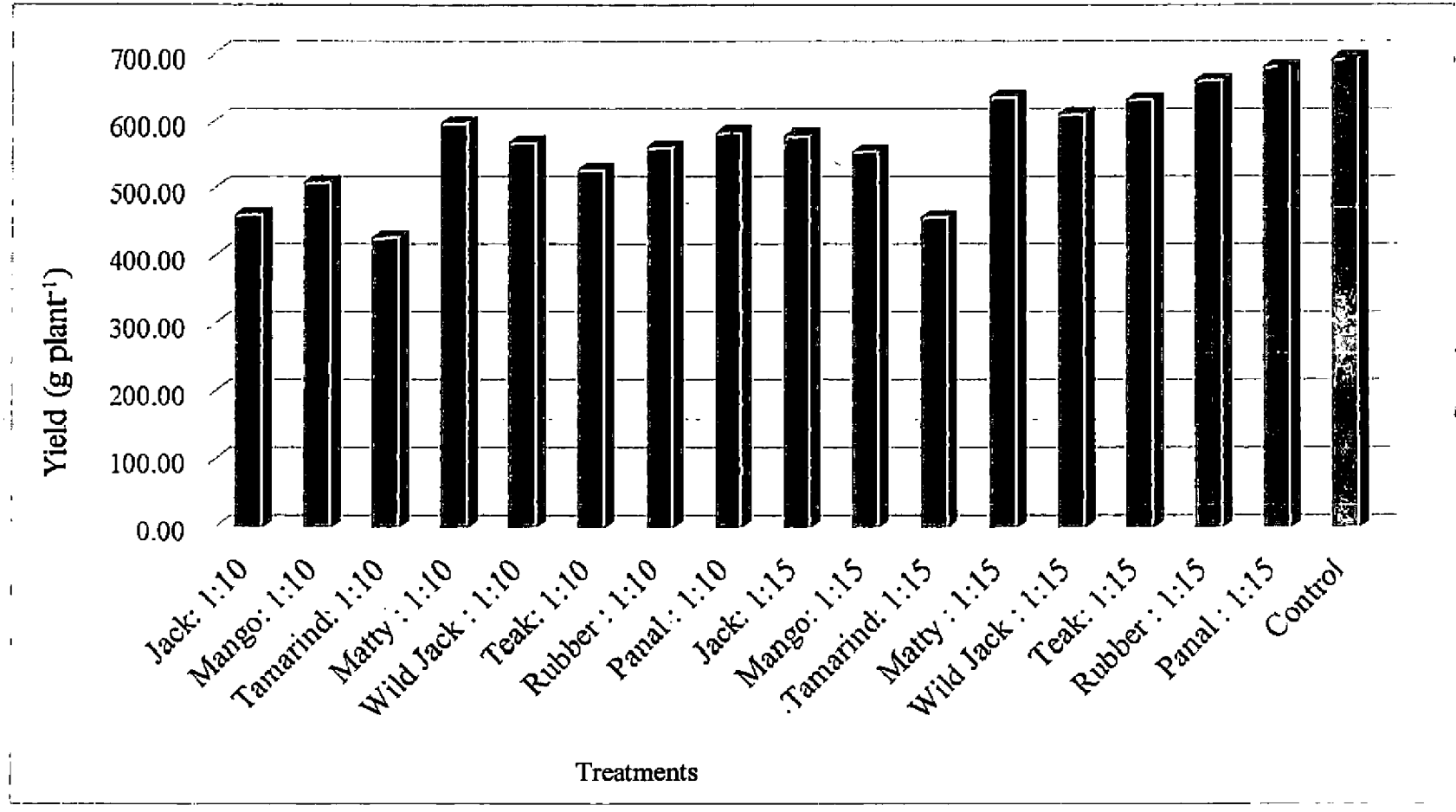

Fig. 7. Effect of tree leaf leachates on yield of ginger

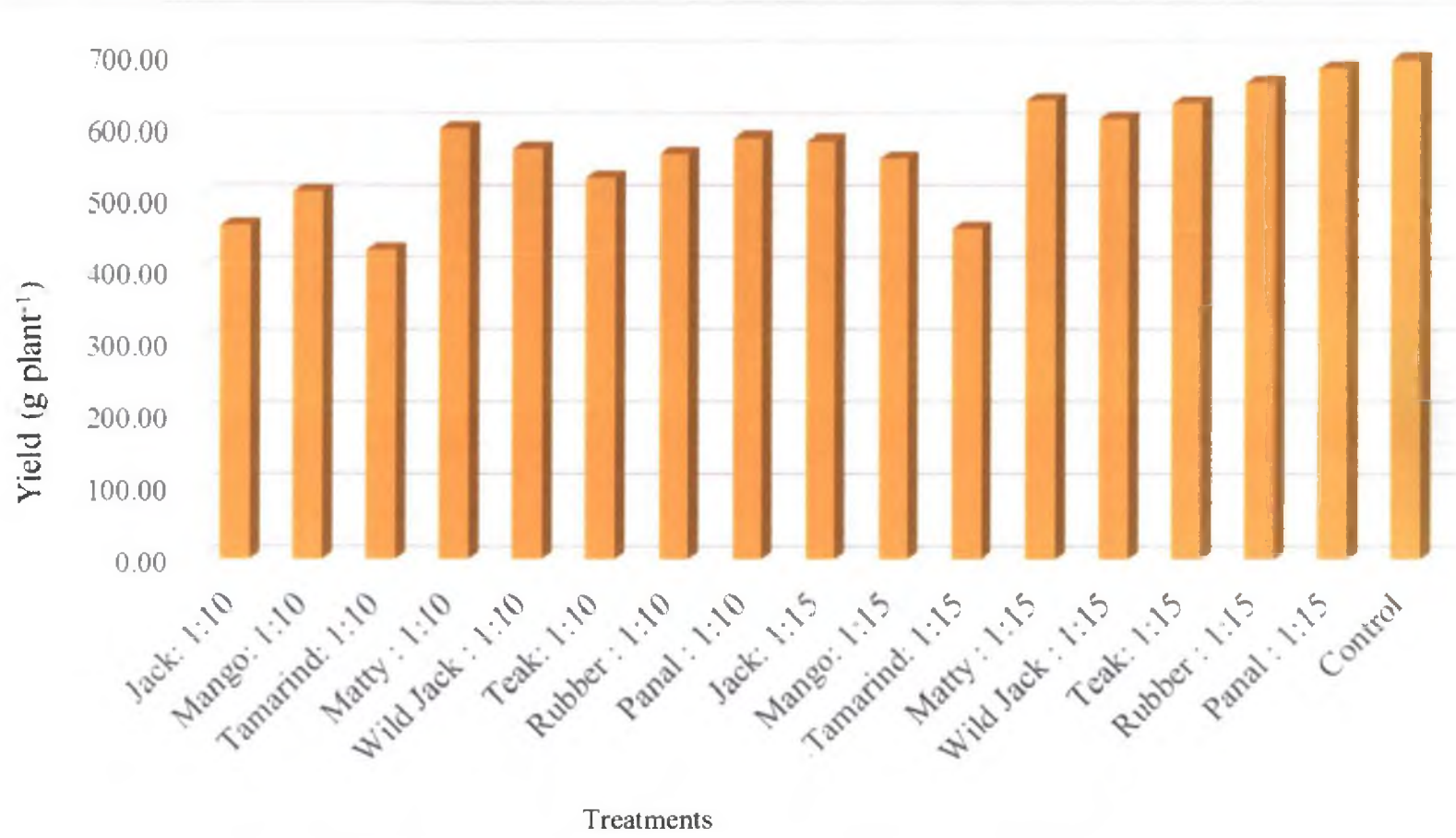

Fig. 7. Effect of tree leaf leachates on yield of ginger

plant^{-1}) followed by jack and mango. However, application of panal, rubber and matty leaf leachate produced substantially higher rhizome yield per plant.

It can be surmised that tamarind leaf leachate severely inhibited growth and reduced yield. The yield reduction caused by tamarind leaf leachate might be a consequence of the reduced tiller number, lesser root weight and root volume and, minimal stomatal conductance. The high phenol and tannin content in the tamarind leaf leachate, as evidenced from the estimation made as part of this study, may be responsible for the observed adverse effects on ginger. Phenolics are known to cause changes in membrane permeability, inhibit nutrient uptake, inhibit cell division and elongation, adversely affect plant photosynthesis and respiration, different enzyme functions, synthesis of plant endogenous hormones and protein synthesis (Li *et al.*, 2010). Studies conducted by John *et al.* (2007a) revealed severe reduction in seed yield of cowpea by tamarind leaf leachate.

Sahoo *et al.* (2010) observed the negative influence of leaf leachate of mango on growth and development of chilli, soybean, maize, rice and bhindi.

A notable fact is that panal, rubber and matty leaf leachate promoted plant growth appreciably as evidenced from the remarkably greater plant height, higher tiller and leaf production, more root volume and weight and consequently higher yield. Moreover, panal leaf leachate resulted in higher stomatal conductance. The stimulatory effect of panal, rubber and matty leaf leachates is an aspect that needs to be investigated further and the possibility of exploiting this at field level should be explored.

Another interesting inference from this study is that dilution of the leachate from 1:10 to 1: 15 (w/v) alleviated the inhibitory effects significantly. It needs to be probed through further detailed studies whether the inhibitory effects can be lessened or even avoided in the field level through copious irrigation.

5.4. EXPERIMENT IV (POT CULTURE II)

Mulching with leaves of the different trees significantly influenced the growth and yield of ginger.

At 2 MAP, when compared to control (mulched with newspaper), height was the least in plants mulched with mango and tamarind. At 4 MAP, the least plant height was recorded in plants treated with mango, wild jack, matty and tamarind. But, plant height was significantly greater when treated with panal leaves and was on par with control.

At 2 MAP, maximum tillers were produced when mulched with panal leaf loppings and was on par with control. Compared to control, tiller production was remarkably less when mulched with mango and matty leaves. At 4 MAP, number of tillers was less when mulched with mango, matty and jack. But, mulching panal and rubber leaves was on par with control. A similar trend was noticed at 6 MAP.

The effect of the tree leaves on leaf production showed a similar trend at 2, 4, and 6 MAP. Leaf production was maximum when mulched with panal leaves and was on par with the control, while it was least when mulched with mango and jack.

Rhizome spread was significantly greater in plants mulched with panal leaves and was on par with control. Rhizome spread in plants mulched with leaves of mango and tamarind was remarkably less than all the other treatments. Plants mulched with panal and rubber leaves had considerably greater rhizome thickness and was on par with control. Rhizome thickness was substantially less when mulched with tamarind, jack and mango leaves.

Root length was significantly greater when mulched with panal and rubber leaves and was on par with the control. A similar trend was observed with respect to root spread. However, root weight and root volume were considerably greater under matty, wild jack and control. Root length, root spread, root weight and root volume were conspicuously less when mulched with mango and tamarind leaves.

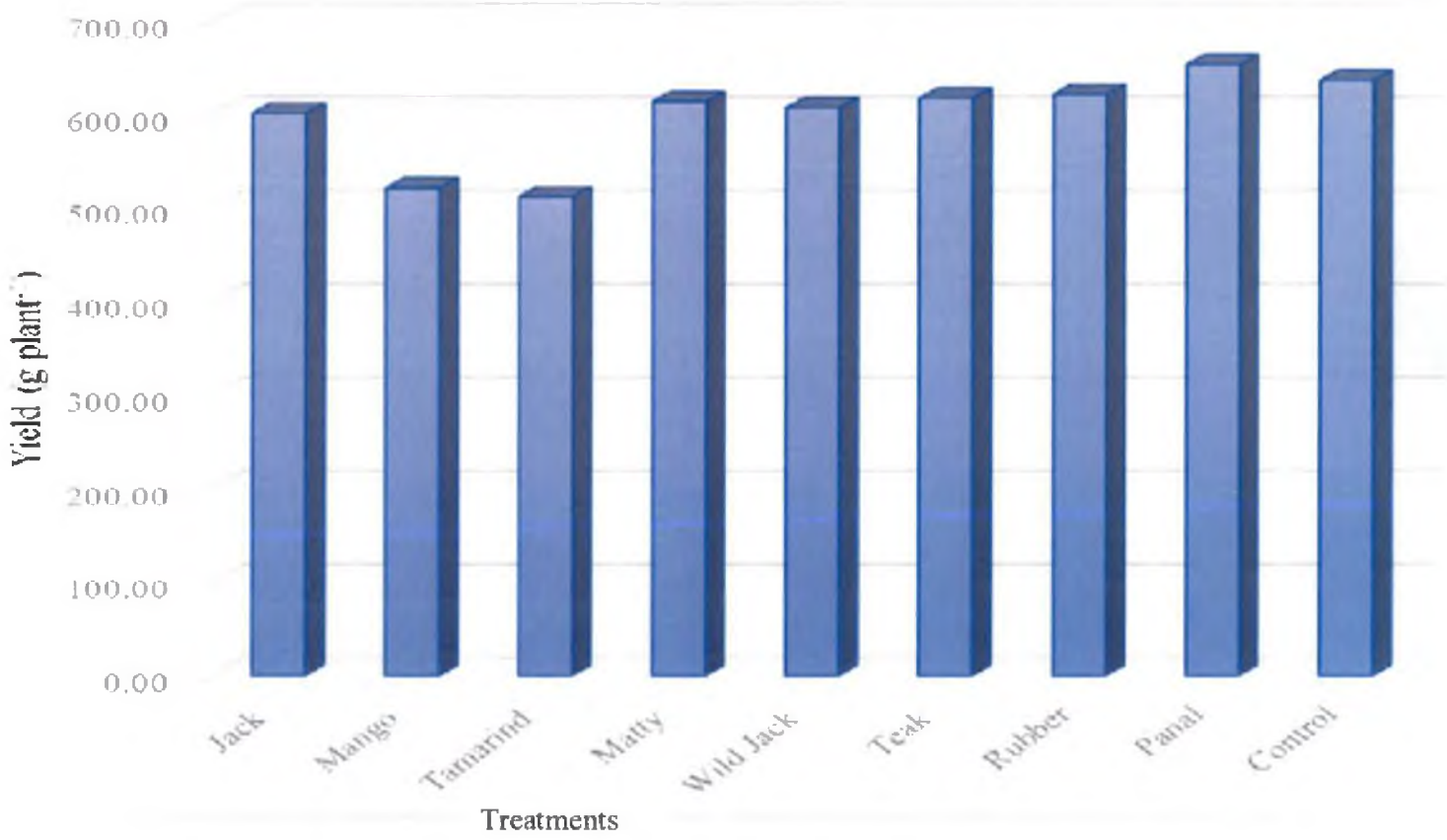

Fig. 8. Effect of tree leaf loppings on yield of ginger

Among the physiological parameters, stomatal conductance alone was affected and it was distinctly more in plants mulched with panal leaves. However, in plants mulched with tamarind, jack, mango and teak it was markedly less.

Rhizome yield was remarkably less when mulched with mango (521 g plant^{-1}) and tamarind (512 g plant^{-1}) leaves. However, mulching with all the other tree leaves and the control (newspaper) gave appreciably higher rhizome yield.

Top yield of ginger was highest when mulched with rubber and panal leaves and least with tamarind and mango.

Nitrogen content was higher in rubber leaf followed by panal. Phosphorus content was more in jack and rubber leaf, while potassium was greater in teak leaf followed by mango.

After the experiment, organic carbon (1.15 %), available nitrogen (257.60 kg ha^{-1}) and phosphorus (54.87 kg ha^{-1}) in soil were higher when mulching was done with leaves of wild jack. However, available K was more where matty leaves (260.45 kg ha^{-1}) were used as mulch. The lowest organic carbon and nutrient status was in the control where only newspaper was used as mulch. This was probably due to the fact that the nutrients removed by the crop were not compensated through organic matter.

An increased soil dehydrogenase enzyme activity was observed when mulched with leaves of wild jack (258.24 µg TPF g^{-1}h^{-1}media) followed by matty. The treatments with leaves of tamarind, teak, rubber and control recorded lower enzyme activity than the initial activity in the growing media. Dehydrogenase enzyme is an indicator of the microbial activity in soil. The higher organic matter provided *via* mulches might have served as adequate substrate for microbial growth, thereby leading to more enzyme activity.

It is clearly evident that mulching with mango and tamarind leaves had an adverse effect on growth and yield of ginger. Mulching with mango and tamarind leaves resulted in reduced yield of ginger. This was a consequence of the remarkably

lesser plant growth, tiller production, leaf production, root length, root spread, rhizome spread, rhizome thickness and stomatal conductance in ginger when mulched with tamarind and mango leaves. This is corroborated by the findings of Sahoo *et al.* (2010) who reported that water soluble leachate from the mature fresh leaves of mango has the allelopathic potential to reduce the germination as well to suppress the growth and development of the crops. They recorded that the root lengths were more sensitive to allelochemicals than the shoot length, ultimately affecting the biomass. Yield reduction in cowpea by tamarind leaf loppings has also been reported (KAU, 2009). Though plant height was less at 4 MAP when mulched with leaves of wild jack and matty, this was not reflected in any of the other growth and yield attributes.

The estimations made in the present study revealed that fresh leaf extracts of mango and tamarind contain high phenol. These also might have been released into the soil during the process of decomposition. Mango leaves are reported to contain 43 to 46.7 per cent euxanthin acid ($C_{19}H_{16}O_{10}$) and also some euxanthon ($C_{13}H_8O_4$), hippuric acid and benzoic acids and four per cent mangin (Bhatt and Todaria, 1990). An analysis revealed that caffeic acid, ferulic acid, coumaric acid, benzoic acid, vanillic, chlorogenic, gallic, hydroxybenzoic and cinnamic acid were present in mango leaf extract (El-Rokiek *et al.*, 2010). These chemicals too might have had a role in the observed effect of mango leaves. In tamarind, chemicals like alpha terpineol, cinnamaldehyde, ethyl cinnamate, galacturonic acid, geranial essential oil, geraniol essential oil, limonene, linoleic acid, myristic acid, oleic acid, palmitic acid, pantothenic acid, phenol, pipecolinic acid, tannin and tartaric acid have been identified (Duke 1992).

Better growth, yield attributes and higher ginger yield were recorded when mulched with panal and rubber leaves. The yield obtained by mulching with leaves of teak, matty, wild jack and jack also resulted in comparable high yield. Some of the main groups of compounds identified from panal include terpenoids, amides, imides, alkaloids, coumarins and flavonoids (Sreejith *et al.*, 2012). These groups may comprise many phytochemicals some of which may be stimulatory and responsible

for the positive effects on the crop. Some of the alkaloids reported from the leaves of panal include glycosine, arborine, glycosminine, arborinine (major), glycosamine, glycorine, glycosmicine, g-fagarine triterpenes, arbinol and isoarbinol, arborinone, two isomeric terpene alcohols, myricyl alcohol, stigmasterol and ß-sitosterol. Studies on the allelopathic proclivities of panal have not been undertaken and hence, supporting results are not available. However, the Kerala Agricultural University has recommended covering of the ginger rhizomes with panal leaves while storing (KAU, 2011). At field level, the use of leaves of panal, rubber, teak, matty, wild jack and jack can be recommended for mulching in ginger. Another interesting observation was that in the control where newspaper were used as mulch, the yield was high (637 g $plant^{-1}$) and comparable to mulching with panal, rubber, teak, matty, wild jack and jack leaves. Hence, for ginger grown in homesteads and terrace gardens, if available newspaper can be used for mulching.

From the experiments undertaken, it can be inferred that, in general, the trees had varied allelopathic effects on the growth and development of ginger. Dilution alleviated the inhibitory allelopathic effects.

It can be specifically concluded from the bioassays, that leaf leachates of tamarind, teak and matty inhibited sprouting the most, while mango and tamarind delayed sprouting and had the most deleterious effects on growth of ginger. The leaf extracts of tamarind, teak and matty inhibited sprouting. Mango leaf extracts delayed sprouting and also suppressed growth. Teak, besides inhibiting, delayed sprouting and inhibited root growth. Hence, caution should be exercised and measures to alleviate the inhibitory effects may be adopted while planting ginger under the canopy of these trees. The stimulatory effect of leaf leachate and extracts of panal in hastening sprouting should be exploited at field level.

In the pot culture, application of tamarind leaf leachate resulted in the least yield of ginger followed by jack and mango. Dilution of the leachate from 1:10 to 1:15 (w/v) alleviated the inhibitory effects significantly. Panal, rubber and matty leaf leachate promoted plant growth and resulted in higher yield.

Leaf loppings of panal, rubber, teak, matty, wild jack and jack enhanced yield and hence, can be recommended to farmers for applying as mulch in ginger @ 15 t ha^{-1} (100 g per grow bag of 25 cm height and 30 cm diameter, capable of holding 15 kg potting mixture comprising of soil:sand:cow dung in 1:1:1 ratio) immediately after planting and subsequently @ 7.5 t ha^{-1} (50 g per grow bag) each at 44-60 and 90-120 DAP.

Summary

6. SUMMARY

The research project entitled "Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)" was conducted at the Cropping Systems Research Centre, Karamana and College of Agriculture, Vellayani, during the period from February to December 2015. The study involved two laboratory bioassays and two pot culture experiments. The objective was to investigate the allelopathic effect of trees commonly planted in the homesteads of southern Kerala on sprouting, growth and yield of ginger.

The first bioassay was laid out in completely randomized design, with eight tree leaf leachates at two concentrations and one control totaling 17 treatments each replicated thrice *viz.*, t_1c_1 jack (1:10), t_2c_1 mango (1:10), t_3c_1 tamarind (1:10), t_4c_1 matty (1:10), t_5c_1 wild jack (1:10), t_6c_1 teak (1:10), t_7c_1 rubber (1:10), t_8c_1 panal (1:10), t_1c_2 jack (1:15), t_2c_2 mango (1:15), t_3c_2 tamarind (1:15), t_4c_2 matty (1:15), t_5c_2 wild jack (1:15), t_6c_2 teak (1:15), t_7c_2 rubber (1:15), t_8c_2 panal (1:15) and one absolute control (distilled water). The second bioassay was carried out in the same manner with leaf extract. The two pot culture experiments were laid out in completely randomized design. The first pot culture experiment was laid out with 17 leaf leachate (same as in bioassay 1) as treatments, each replicated thrice. The second pot culture experiment, was carried out to study the effect of different tree leaf mulches and comprised nine treatments with three replications *viz.* M_1 (fresh leaf loppings of jack), M_2 (mango), M_3 (tamarind), M_4 (matty), M_5 (wild jack), M_6 (teak), M_7 (rubber), M_8 (panal), M_9 (control using newspaper). Mulch was applied at the rate recommended by KAU. The ginger variety, 'Karthika', was used for the study.

The results of the first bioassay revealed that the tree leaf leachates and its concentrations significantly influenced the sprouting of ginger rhizomes. There was significant reduction in sprouting of ginger rhizomes by the leaf leachates of tamarind and teak and the inhibition, as indicated by the response index, was as high as 51 and 48 per cent respectively that too at higher concentration. Sprouting was remarkably delayed when treated with mango, tamarind, wild jack, teak and rubber leaf leachate.

Treating with panal leaf leachate resulted in earlier sprouting and the stimulation was 17 per cent when compared to control. The degree of inhibition increased with concentration from 1:15 to 1:10 (w/v).

The tree leaf leachates significantly influenced shoot and root growth. The leaf leachate of mango, tamarind, matty and jack caused greatest inhibition of shoot growth. A similar pattern of inhibition was observed in root growth. The number of roots was considerably less when treated with mango and tamarind leaf leachate. However, more roots were produced when treated with panal leaf leachate. Dilution alleviated the inhibitory effects as evident from the lesser inhibition recorded at 1:15 concentration.

All leaf leachates were acidic and tamarind leaf leachate had the lowest pH. At both concentrations, the highest phenol content was observed in teak leaf leachate followed by tamarind. The rubber leaf leachate had highest tannin content followed by matty.

In the second bioassay, tamarind leaf extracts inhibited sprouting severely and the magnitude of inhibition, as measured by response index, was 54 per cent. Teak and matty, which ranked next, also considerably suppressed sprouting. Sprouting was delayed most when treated with leaf extracts of teak and mango. However, earlier sprouting was observed when treated with panal leaf extract and the magnitude of stimulation was 25 per cent. The extent of inhibition increased with concentration of leaf extract.

Shoot and root growth were appreciably suppressed with the application of tree leaf extracts. The leaf extract of mango and matty severely inhibited shoot growth. Among the trees, shoot growth was more when treated with rubber, panal and wild jack. Root growth was most adversely affected by mango and teak leaf extracts.

Higher concentration of the extracts caused greater inhibition with respect to all parameters.

All leaf extracts were acidic and rubber leaf extract had the lowest pH. At both 1:10 and 1:15 concentrations, the highest phenol content was observed with tamarind leaf extract followed by mango. The rubber leaf extract had highest tannin content followed by tamarind.

In the first pot culture study, plant height of ginger was remarkably affected by all tree leaf leachates at 2 and 4 MAP. At 2 MAP, plants treated with leaf leachate of tamarind, mango and rubber had least height. At 4 MAP, plant height was significantly greater with panal and rubber leaf leachate. Interestingly, application of panal leaf leachate resulted in maximum plant height. At 2 MAP, tiller production was most adversely affected by tamarind leaf leachate. Highest number of tillers was recorded in plants treated with leachate of rubber at 2, 4 and 6 MAP. At 4 MAP, leaf number was least in plants treated with leaf leachate of teak and rubber. At 6 MAP, plants exposed to panal and rubber leaf leachate had maximum number of leaves.

Among the physiological parameters, there was no difference between the treatments with respect to SPAD values and canopy temperature. Stomatal conductance alone was affected by the leaf leachate of trees. It was least in plants treated with tamarind leaf leachate and maximum with panal leaf leachate.

Rhizome characters like rhizome spread and rhizome thickness were not conspicuously affected by the tree leaf leachates. Applying tamarind leaf leachate resulted in least root weight and root volume per plant, while maximum was recorded with rubber and panal leaf leachate.

The rhizome yield per plant was significantly influenced by the different tree leaf leachates. Application of tamarind leaf leachate resulted in least yield (443.56 g $plant^{-1}$) followed by jack and mango. However, application of panal, rubber and matty leaf leachate produced substantially higher rhizome yield per plant.

The second pot culture experiment revealed that mulching with leaves of the trees chosen for the study significantly influenced the growth and yield of ginger. At 2 MAP, when compared to control (mulched with newspaper), height was least in plants mulched with mango and tamarind. At 4 MAP, least plant height was recorded in plants treated with mango, wild jack, matty and tamarind. But, plant height was significantly greater when treated with panal leaves and was on par with control.

At 2 MAP, maximum tillers were produced when mulched with panal leaf loppings and was on par with control. When compared to control, tiller production was remarkably less when mulched with mango and matty leaves. At 4 MAP, number of tillers was less when mulched with mango, matty and jack. But, mulching panal and rubber leaves was on par with control. A similar trend was noticed at 6 MAP.

The effect of the tree leaves on leaf production showed a similar trend at 2, 4, and 6 MAP. Leaf production was maximum when mulched with panal leaves and was on par with the control, while it was least when mulched with mango and jack.

Rhizome spread was significantly greater in plants mulched with panal leaves and was on par with control. Rhizome spread in plants mulched with leaves of mango and tamarind was remarkably less than all the other treatments. Plants mulched with panal and rubber leaves had considerably greater rhizome thickness and was on par with control. Rhizome thickness was substantially less when mulched with tamarind, jack and mango leaves.

Root length was significantly greater when mulched with panal and rubber leaves and was on par with the control. A similar trend was observed with respect to root spread. However, root weight and root volume was considerably greater under matty, wild jack and control. Root length, root spread, root weight and root volume was conspicuously less when mulched with mango and tamarind leaves.

Among the physiological parameters, stomatal conductance alone was affected and it was distinctly more in plants mulched with panal leaves. However, in plants mulched with tamarind, jack, mango and teak it was markedly less. Top yield of ginger was highest when mulched with rubber and panal leaves and least with tamarind and mango.

Rhizome yield was remarkably less when mulched with mango (521 g $plant^{-1}$) and tamarind (512 g $plant^{-1}$) leaves. However, mulching with all the other tree leaves and the control (newspaper) gave appreciably high rhizome yield.

It can be specifically concluded from the bioassays, that leaf leachates of tamarind, teak and matty inhibited sprouting the most, while mango and tamarind delayed sprouting and had most deleterious effects on growth. The leaf extracts of tamarind, teak and matty inhibited sprouting. Mango leaf extracts delayed sprouting and also suppressed growth. Teak, besides inhibiting, delayed sprouting and inhibited root growth. Hence, caution should be exercised and measures to alleviate the inhibitory effects may be adopted while planting ginger under the canopy of these trees. The stimulatory effect of leaf leachate and extracts of panal in hastening sprouting should be exploited at field level.

In the pot culture, application of tamarind leaf leachate resulted in least yield of ginger followed by jack and mango. Dilution of the leachate from 1:10 to 1: 15 (w/v) alleviated the inhibitory effects significantly. Panal, rubber and matty leaf leachate promoted plant growth and resulted in higher yield.

Based on the results of the second pot culture experiment, it can be concluded that leaf loppings of panal, rubber, teak, matty, wild jack and jack enhanced yield and hence, can be recommended to farmers for applying as mulch in ginger @ 15 t ha^{-1} (100 g per grow bag of 25 cm height and 30 cm diameter, capable of holding 15 kg potting mixture comprising of soil:sand:cow dung in 1:1:1 ratio) immediately after

planting and subsequently @ 7.5 t ha^{-1} (50 g per grow bag) each at 44-60 and 90-120 DAP. Another interesting observation was that in the control, where newspaper were used as mulch, the yield was high (637 g $plant^{-1}$) and comparable to mulching with panal, rubber, teak, matty, wild jack and jack leaves. Hence ginger is grown in homesteads and terrace gardens, if available, newspaper can be used for mulching.

Future line of work

- The findings of the present study, especially the laboratory bioassays, are of preliminary nature. Comprehensive studies need to be undertaken by raising ginger under the canopy of the trees so as to make certain whether the inhibitory effects noticed in the lab bioassay and pot culture are expressed in the field too. Such studies should include in-depth observations on physiological parameters and biochemical studies.
- If inhibitory effects are sustained in the field trials, measures to alleviate the adverse effects should be evolved. Experiments should be undertaken to explore ways to alleviate the inhibitory effect of leaves of mango and tamarind on ginger.
- From the available literature, it is evident that numerous phytochemicals are present in tree leaf leachates and leaf loppings. But it is fundamental to identify which chemical is responsible for causing the inhibition, for which meticulous biochemical studies are required. Identifying such a phytochemical and using it at higher concentration could offer an opportunity for using it as a natural herbicide.
- It is imperative to explore the possibility in alleviating the inhibitory effect of allelochemicals through copious irrigation.
- Field investigations should be undertaken to explore the possibility of exploiting the stimulatory property of panal, rubber and matty leaf leachate in ginger and other crops.

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Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)

by

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(2014–11-114)

Abstract of the

thesis submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695522

KERALA, INDIA

2016

ABSTRACT

The research project entitled "Allelopathic effect of trees grown in homesteads of Kerala on ginger (*Zingiber officinale* Roscoe)" was conducted during the period from February to December 2015. The objective was to investigate the allelopathic effect of trees commonly planted in the homesteads of southern Kerala on sprouting, growth and yield of ginger.

The study involved two laboratory bioassays and two pot culture experiments, all laid out in completely randomized design. The first bioassay comprised eight tree leaf leachates each at two concentrations and one control totaling 17 treatments each replicated thrice [jack, mango, tamarind, matty, wild jack, teak, rubber, panal each at 1:10 and 1:15 concentration, and one absolute control (distilled water)]. The second bioassay was carried out in the same manner with leaf extract. The two pot culture experiments were laid out in completely randomized design. The first pot culture experiment was laid out with 17 leaf leachate as treatments, each replicated thrice. The second pot culture experiment, was carried out to study the effect of different tree leaf mulches and comprised nine treatments with three replications - M_1 (mulching with fresh leaf loppings of jack), M_2 (mango), M_3 (tamarind), M_4 (matty), M_5 (wild jack), M_6 (teak), M_7 (rubber), M_8 (panal), M_9 (control with newspaper). Mulch was applied as per the KAU recommendations. The ginger variety, 'Karthika', was used for the study.

The first bioassay revealed that the leaf leachates of tamarind (T_3) and mango (T_2) severely inhibited the sprouting and the shoot growth of ginger rhizome. All the leaf leachates reduced the root growth and number of roots significantly and tamarind (T_3) resulted in the highest inhibition. The inhibitory effect was alleviated with dilution.

In the second bioassay, leaf extracts of tamarind (T_3) significantly inhibited sprouting of ginger. Leaf extracts of mango and tamarind recorded significantly lower

shoot growth. Leaf extracts of mango (T_2), tamarind (T_3) and teak (T_6) inhibited the root growth and number of roots significantly. Leaf extracts of panal (T_8) had a significant stimulatory effect.

In the first pot culture study, plants treated with leaf leachate of tamarind (T_3) had least height and number of tillers at 2 months after planting (MAP), while applying panal (T_8) leaf leachate resulted in maximum plant height at 4 and 6 MAP. The number of leaves was highest in applying panal (T_8) leaf leachate, at 6 MAP. Tamarind (T_3) leaf leachate significantly inhibited the root volume and root weight. Among the physiological parameters, stomatal conductance alone was affected by the leaf leachate of trees. Application of tamarind (T_3) leaf leachate resulted in lesser yield (443.56 g plant^{-1}). However, application of panal (T_8), rubber (T_7) and matty (T_4) leaf leachates produced significantly higher rhizome yield per plant.

In the second pot culture experiment involving mulching with the tree leaf loppings, plant height was significantly less in treatments M_2 (mango) and M_3 (tamarind). Rhizome yield was significantly higher when mulched with panal (653.50 g plant^{-1}) and was on a par with newspaper (637 g plant^{-1}) and rubber (621.40 g plant^{-1}) leaves. However, mulching with mango leaves resulted in significantly lesser yield (512.09 g plant^{-1}). Another interesting observation was that in the control where newspaper were used as mulch, the yield was high (637 g plant^{-1}) and comparable to mulching with panal, rubber, teak, matty, wild jack and jack leaves. Hence ginger is grown in homesteads and terrace gardens, if available newspaper can be used for mulching.

Based on the results of the experiments, it can be concluded that leaf leachates and extracts of tamarind, mango and teak are inhibitory to sprouting and growth of ginger. Hence, when ginger is planted under the canopy of these trees care should be taken to alleviate the inhibitory effect. Leaf lopping of tamarind is not ideal for mulching in ginger. Leaf loppings of panal, rubber or matty can be recommended for mulching in ginger.

സംഗ്രഹം

കേരളത്തിലെ പുരയിടങ്ങളിൽ കണ്ടുവരുന്ന വൃക്ഷങ്ങളുടെ അലിലോപ്പതിക് സ്വഭാവം എങ്ങനെ ഇഞ്ചിയുടെ മുളപ്പൊട്ടൽ, വളർച്ച, വിളവർദ്ധനവ് തുടങ്ങിയതിനെ ബാധിക്കുന്നു എന്നതിനെപ്പറ്റി ഒരു ഗവേഷണ പഠനം വെള്ളായണി കാർഷിക കോളേജിലും ക്രോപ്പിംഗ് സിസ്റ്റം റിസർച്ച് സെന്റർ കരമനയിലുമായി 2015 ഫെബ്രുവരി മുതൽ ഡിസംബർ വരെയുള്ള കാലഘട്ടത്തിൽ നടത്തുകയുണ്ടായി.

പ്ലാവ്, മാവ്, പുളി, ആഞ്ഞിലി, പെരുമരം, തേക്ക്, റബ്ബർ, പാണൽ തുടങ്ങി എട്ടു മരങ്ങളുടെ ഇലകളാണ് പ്രസ്തുത പരീക്ഷണത്തിന് ഉപയോഗിച്ചത്. ആകെ നാലു ഘട്ടങ്ങളായി നടത്തിയ പരീക്ഷണത്തിന് 'കാർത്തിക' എന്നയിനം ഇഞ്ചിയാണ് പഠന വിധേയമാക്കിയത്.

ആദ്യ രണ്ടു പഠനങ്ങളിൽ യഥാക്രമം ഇലകളുടെ ലീച്ചേറ്റും എക്സ്ട്രാറ്റുകളും 1:10, 1:15 എന്നീ അനുപാതങ്ങളിൽ പ്രോട്രേകളിൽ നട്ട ഇഞ്ചിയിലും, മൂന്നാംഘട്ടത്തിൽ ഇലകളുടെ ലീച്ചേറ്റ് നടുന്ന സമയത്തും ആഴ്ചയിൽ രണ്ടു തവണയും ഗ്രോബാഗുകളിൽ നട്ട ഇഞ്ചിയിലും തളിച്ചു കൊടുത്തു. നാലാമത്തെ പഠനത്തിൽ മേൽപ്പറഞ്ഞ മരങ്ങളുടെ ഇലകളും, ന്യൂസ് പേപ്പർ ഉപയോഗിച്ചുള്ള ഒരു കൺട്രോളും ഉൾപ്പെടുത്തി പുതയായി ഉപയോഗിച്ചു.

ഈ പഠനത്തിൽ നിന്നും പുളി, മാവ്, പെരുമരം, തേക്ക് എന്നീ വൃക്ഷങ്ങളുടെ ഇലകളുടെ ലീച്ചേറ്റുകളും എക്സ്ട്രാറ്റുകളും 1:10 എന്ന ഗാഢതയിൽ ഇഞ്ചിയുടെ വളർച്ചയെ തടസപ്പെടുത്തുന്നതായി തെളിഞ്ഞു. അതുപോലെ പുളി, മാവ് എന്നിവയുടെ ഇലകൾ കൊണ്ടുള്ള പുത ഇഞ്ചിയുടെ വളർച്ചയെയും വിളവിനെയും ദോഷകരമായി ബാധിക്കുന്നതായും പാണൽ, റബ്ബർ, തേക്ക്, മട്ടി തുടങ്ങിയവയുടെ ഇലകളുടെ പുതയിടൽ വിളവ് വർദ്ധിപ്പിക്കുന്നതായും തെളിഞ്ഞു.

Appendices

Appendix- I

Weather data during the cropping period of bioassay experiment

(CSRC Karamana- February to April 2015)

Standard week	Period	Temperature (°C)		Relative humidity (%)		Total Rainfall (mm)
		Max.	Min.	Max.	Min.	
8	Feb 19-25	30.94	23.74	95.16	72.92	18.54
9	Feb 26-Mar 4	31.14	23.09	95.87	71.10	62.23
10	Mar 5-11	31.84	23.70	93.71	70.81	0.00
11	Mar 12-18	32.61	21.98	86.45	59.14	0.00
12	Mar 19-25	33.08	24.53	94.81	70.51	2.79
13	Mar 26-Apr 1	32.72	23.19	89.85	61.88	0.00
14	Apr 2-8	32.46	25.42	93.88	77.62	16.00
15	Apr 9-15	32.28	23.81	91.52	74.08	38.35
16	Apr 16-22	32.65	25.00	91.51	74.50	57.66

Appendix- II

Weather data during the cropping period of pot culture experiment

(COA Vellayani- Februay to December 2015)

Standard week	Period	Temperature (°C)		Relative humidity (%)		Total Rainfall (mm)	Mean Evaporation (mm)
		Max.	Min.	Max.	Min.		
8	Feb 19-25	31.2	21.0	90.3	70.1	0.0	4.4
9	Feb 26-Mar 4	32.1	23.3	88.7	66.6	1.0	4.6
10	Mar 5-11	32.1	23.3	88.6	66.3	0.0	4.4
11	Mar 12-18	32.1	23.6	91.4	69.3	45.7	4.9
12	Mar 19-25	32.7	23.3	90.7	67.9	0.0	3.1
13	Mar 26-Apr 1	33.0	24.7	90.7	67.0	9.4	4.0
14	Apr 2-8	33.1	25.2	91.9	70.0	7.0	4.1
15	Apr 9-15	32.6	24.3	91.4	68.6	23.8	3.6
16	Apr 16-22	32.9	24.3	89.7	76.5	80.8	4.4
17	Apr 23-29	32.5	23.8	89.6	77.3	71.0	3.8
18	Apr 30-May 6	33.2	25.2	85.1	75.9	0.0	4.4
19	May 7-13	32.5	25.2	91.4	83.6	103.1	4.0
20	May 14-20	30.4	24.3	94.0	89.1	205.2	2.5
21	May 21-27	32.3	26.1	92.1	82.7	97.7	3.2
22	May 28-Jun 3	31.9	25.2	90.8	81.0	13.0	3.2
23	Jun 4-10	31.9	24.7	89.7	79.6	61.5	3.5
24	Jun 11-17	31.9	24.0	91.7	83.9	63.0	5.0
25	Jun 18-24	31.6	24.4	90.3	82.7	47.8	3.8
26	Jun 25-Jul 1	30.5	24.0	92.0	86.6	161.6	5.0
27	Jul 2-8	31.6	25.3	90.1	79.6	5.0	4.0
28	Jul 9-15	31.9	25.2	88.1	80.9	10.2	4.3
29	Jul 16-22	30.6	23.8	90.1	81.1	35.1	3.5
30	Jul 23-29	31.3	24.1	87.9	76.9	3.2	4.0
31	Jul 30-Aug 5	31.3	24.5	87.6	78.1	2.3	4.1
32	Aug 6-12	31.8	24.7	90.0	76.1	4.4	4.0
33	Aug 13-19	32.4	24.5	87.9	73.4	57.6	5.0
34	Aug 20-26	31.8	24.7	91.3	76.7	15.9	3.4
35	Aug 27-Sep 2	31.9	24.7	89.9	81.1	0.0	4.4
36	Sep 3-9	31.5	24.2	91.7	84.3	101.2	5.1
37	Sep 10-16	31.2	24.0	93.4	86.4	67.3	4.1
38	Sep 17-23	31.0	24.6	93.1	81.9	66.0	4.4
39	Sep 24-30	31.8	24.5	88.9	83.0	55.3	3.9
40	Oct 1-7	31.2	23.9	91.9	79.0	34.8	3.0
41	Oct 8-14	31.3	23.8	92.6	80.6	149.1	5.6

42	Oct 15-21	31.4	24.4	91.1	78.9	20.7	2.7
43	Oct 22-28	31.2	24.2	93.3	82.4	50.9	3.1
44	Oct 29-Nov 4	31.1	23.5	92.7	83.1	204.1	3.5
45	Nov 5-11	31.6	24.1	93.1	79.4	30.6	3.8
46	Nov 12-18	31.5	23.6	92.1	81.7	65.7	3.7
47	Nov 19-25	32.0	24.0	94.1	76.9	66.6	3.8
48	Nov 26-Dec 2	31.7	23.8	92..6	80.7	57.5	3.3
49	Dec 3-9	31.1	24.2	95.0	85.7	42.7	2.7
50	Dec 10-16	31.8	23.9	94.9	89.7	168.3	4.6
51	Dec 17-23	31.1	23.4	95.7	78.7	21.5	2.7