EVALUATION OF ALLELOPATHIC EFFECT OF *Lantana camara* L. LEAF EXTRACTS AND GROWTH INHIBITORY EFFECT OF SOIL FROM BENEATH ITS CANOPY ON *Lepidium sativum* L.

MSc THESIS

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Evaluation of Allelopathic Effect of *Lantana camara L.* Leaf Extracts and Growth Inhibitory Effect of Soil from Beneath its Canopy on *Lepidium sativum L.*

A Thesis Submitted to the Department of Biology College of Natural and Computational Sciences, Postgraduate Program Directorate
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MASTER OF SCIENCE IN BOTANY

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As Thesis Research advisors, we hereby certify that we have read and evaluated the Thesis Entitled **'Evaluation of Allelopathic Effect of *Lantana camara L.* Leaf Extracts and Growth Inhibitory Effect of Soil from Beneath its Canopy on *Lepidium sativum L.*'** prepared under our guidance by Likialesh Gebriyohanes and we recommend that it be submitted as fulfilling the thesis requirement.

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DEDICATION

I dedicate this thesis to my beloved Family, who had worked their best in all respects to the success of my life.

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is my own work. I have followed all ethical and technical principles of scholarship in the preparation data collection, data analysis and compilation of the write up of the thesis. All scholarly matter that is included in the thesis has been recognized through citation.

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BIOGRAPHICAL SKETCH

The author was born in Tigray, Endabaguna Zone of North west, from her father Gebriyohanes Haileslassia and her mother Brikti Gebrehiwot, in January 1995. She attended her Primary and Secondary School at Betmaria Primary and Endabaguna Secondary Schools, respectively in Shire Zone. She completed her Secondary School education in July 2013. Then, she joined Gondar University, Gondar College of Natural and Computational Science in November 2013 and completed her Bachelor of Science Degree in Biology in July 2015. After graduation, in September 2015, she joined Department of Biology, Haramaya University, to pursue her graduate studies in the field of Botany.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
CRD	Completely Randomized Design
GISIN	Global Invasive Species Information Network
IBC	Institute of Biodiversity Conservation
IUCN	International World Conservation Union
SPSS	Statistical Package for Social Science

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ABSTRACT

In most cases invasive plants have allelopathic effects on crops and other indigenous associated plants. Allelochemicals from such plants may also have negative impact on soils. This study was carried out to investigate the allelopathic effect of leaf extracts of Lantana camara *and soils invaded by it on* Lepidium sativum*. Leaf extracts of* Lantana camara *were prepared in 5, 10, 15 and 20% concentration levels while distilled water was used as control to evaluate germination parameters and growth parameters of seedlings of* Lepidium sativum *under laboratory condition. Soil seed-bed and extracts were also prepared from soils sampled from different sites of distance gradient from* Lantana camara *to evaluate germination parameters and growth parameters of L. sativum. Similarly, soils sampled from different sites in distance gradient from* Lantana camara *were also used to grow* Lepidium sativum *in greenhouse. Results showed that both hexane and ethanol leaf extracts negatively affected germination and growth parameters under laboratory conditions in a concentration dependent manner ($p<0.05$). Comparison between the two solvents extracts impact showed that hexane extract was superior to ethanol extract in negatively affecting performance of the test plant. However, soil toxicity test both under laboratory and greenhouse conditions did not negatively affect germination parameters and growth performance and seed yield ($p>0.05$). Overall, results of this study showed that* Lepidium sativum *is sensitive to allelochemicals from* Lantana camara *and should not be cultivated in areas with huge decomposition of* Lantana camara.

Key words: Allelopathy, Lantana camara, Leaf extract, Lepidium sativum, Soil

1. INTRODUCTION

Lantana camara L. belongs to the family Verbenacea; it is one of the fast-growing woody thicket-forming shrubs. It is native to tropical and sub-tropical South and Central America and widely distributed in many countries including Ethiopia (Binggeli and Desissa, 2002; Zalucki *et al*., 2007). It is among the top ten invasive weeds on earth (Sharma *et al.,* 2005). It can grow under a wide range of climate conditions and occurs on a variety of soil types reflecting its wide ecological tolerance (Day *et al*., 2003). The species may reach 3m in height within 3 to 4 years and often forms dense canopy.

Lantana camara was introduced to Ethiopia as an ornamental plant due to its good smelling aromatic flowers (Binggeli and Desissa, 2002). Presently, it has spread almost all over the country (Binggeli and Desissa, 2002). Moreover, *Lantana camara* is encroaching cultivated lands at a fast alarming rate and is considered noxious. Therefore, this weed plant is considered one of the invasive shrubs in tropical savanna rangelands. *Lantana camra* is known to suppress the regeneration of neighboring plants in the rangeland through its allelopathic effects (Fan *et al*., 2010).

Allelochemicals that inhibit the growth of some species at certain concentrations might in fact stimulate the growth of the same or different species at different concentrations (Narwal, 1996). It has been documented that allelopathy play an important role in plant-plant interaction by allelochemical compounds (Turk and Tawaha, 2005). If some of allelochemicals are released to the environment through leaching, litter decomposition, root exudation, or direct volatilization, they could affect (either positively or negatively) germination and growth of nearby by plant species. The allelopathic effects of some plants were studied including germination inhibition, plumule and radicle growth, seedling growth retardation (Oudhia, 2000a, 2000$_b$) and poor seedling survival rate.

Lantana camara have many negative impacts including potential to disrupt succession cycle, displacing native biota resulting in decreased biodiversity. Its infestations alter the structural and floral composition of native communities. The different parts of *Lantana camara* contain

allelochemicals mainly aromatic alkaloids and phenolic compounds which can interfere with seed germination and early growth of many plant species (Sahid and Sugau, 1993; Sharma *et al*., 2005). *Lantana camara* can also interfere with growth of nearby plants by outcompeting for soil nutrients (Dobhal*, et al*., 2010) and altering microenvironment (e.g. light, temperature) by forming dense thickets. Despite its recognition as being among the worst invasive alien species in the world (Sharma *et al*., 2005; Zalucki *et al*., 2007) multiple physiological effects have also commonly been observed from treatments with many allelochemicals. These effects include decreases in plant growth, absorption of water and mineral nutrients, ion uptake, leaf water potential, shoot turgor pressure, and osmotic potential caused by phenolic compounds (Barkosky and Einhellig, 2003).

As the density of *Lantana camara* in forest as well as agricultural land increases, allelopathic interactions increase and hence there is decline in species richness. It is considered a problematic weed in many of the countries to which it has been introduced. Many researchers (Day *et al.,* 2003*;* Sharma *et al*., 2005; Hossain and Alam, 2010) reported that the water soluble allelochemicals of *Lantana camara* inhibited the initial growth of both the agricultural (*Oryza sativa, Triticum aestivum, Vigna sinensis, Cucurbita pepo, Abelmoschus esculentus, Amaranthus tricolor*) and forest crops (*Acacia auriculiformis, Paraserianthes falcataria, Albizia procera).*

In Ethiopia, *Lantana camara* is an exotic species and it has wide ecological tolerance and growing successfully in various soil types (Day *et al*., 2003). The wide spread nature of this plant is facilitated by moving of seeds through running water, dispersal by birds and animals after eating and excreting undigested seeds (IBC, 2009). Some of the hotspot areas of Lantana in Ethiopia include Debre Zeit, Dire Dawa, Hararge and Somali region. Allelopathic effects of *Lantana camara* on some agricultural crops are given worldwide emphasis, but such scientific investigations are limited in Ethiopia. The agricultural society of Ethiopia is growing many agricultural crops in order to fulfill the demands of growing population.

Among the agricultural crops *Lepidium satvium* also one of the important medicinal crop in Ethiopia. Moreover, information on the ecological interference of *Lantana camara* on the growth

of native plants, especially on agronomic crops such as *Lepidium sativum* is scanty in Ethiopia. Therefore, the research was initiated with the following general and specific objectives.

General objective:

To evaluate the allelopathic effects of *Lantana camara* leaf extracts and growth inhibitory effect of soil from beneath its canopy on the germination and seedling growth of *Lepidium sativum*

Specific objectives were to:

- measure the impact of leaf extracts of *Lantana camara* on germination and seedling growth of *Lepidium sativum* under Laboratory condition.
- examine the influence of *Lantana camara* soil under canopy toxicity on *Lepidium sativum*
- evaluate the impact of *Lantana camara* invasion on soil chemical features

1. LITERATURE REVIEW

2.1. Description of *Lantana camara*

Lantana camara (Verbenaceae) is a thorny multi-stemmed, deciduous shrub with an average height of 2m. *Lantana* stems are square in outline, covered with bristly hairs when green, often armed or with scattered small prickles. *Lantana camara* possesses a strong root system. Leaves are opposite, simple, with long petioles, oval blades which are rough and hairy and have blunt toothed margins. The leaves of *Lantana camara* have a strong aroma. Its flowers are small, multi-colored, in stalked, dense in flat-topped clusters with a corolla having narrow tube with four short spreading lobes. Their flowers undergo color change subsequent to anthesis. These flowers occurs in cluster which includes white-pink-lavender or yellow-orange-red mix. The yellow coloration of the flower provides visual cue to pollinators and change in color is initiated on the act of pollination. Berries of *Lantana camara* are round, fleshy, 2-seeded drupe with initially green in color and turning purple and finally to blue-black color. However, the berries are very poisonous in nature though these are attractive to insects and birds. Seeds germination is easy and faster in *Lantana camara.* The roots even after repeated cuttings give new flush of shoots. (GISIN, 2011).

2.2. Global Distribution of *Lantana camara*

Lantana camara is established and spread in its introduced range worldwide at the cost of native species and habitats so much that the International World Conservation Union (IUCN) considers it to be among the world's 100 most invasive species (Lowe *et al*., 2004). It now exists in many different varieties throughout the world and invades pastureland in Australia, East Africa, Fiji, Hawaii, India, the Philippines, South Africa, Zimbabwe, Zambia and among others (Thomas and Ellison, 2000). The species was ranked the most significant weed of non-agricultural areas in southeastern Queens land (Day *et al*., 2003).

In Africa it is also widespread south of the Sahara Desert and particularly severe in South Africa, Kenya, Uganda, Tanzania, Zambia, Zimbabwe and Mozambique but also occurs in Ghana, Nigeria and Angola (Day *et al*., 2003). *L. camara* is currently rated the fourth most widespread invasive alien plant in South Africa occupying some 2.2 million hectares of forest and plantation margins, watercourses and savannas where it out competes and replaces other native vegetation (Simelane, 2002). In Zimbabwe it is threatening the moist evergreen rain forests of the Eastern Highlands (Timberlake and Musokonyi, 1994).

According to Day *et al*. (2003) and Sharma *et al*. (2005), the distribution of *L. camara* is still increasing, with many of the countries and islands that were listed in 1974 as not having *L. camara* being infested more recently (e.g. Galapagos Islands, Solomon Islands, Palau, Saipan, Tinian, Yap and Futuna Islands). They also highlighted that even in areas such as South Africa, India and larger islands such as New Zealand, where *L. camara* has been established for long periods of time, there is evidence that it is still spreading. Day *et al*. (2003) also pointed out that not only is the geographic range of *L. camara* still expanding in many areas, but also the density of infestations within its range is increasing and this has been recognized as a future threat to ecosystems in Australia, the Solomon Islands and Vanuata, and probably in many other countries.

In Ethiopia, the research finding of Hailu *et al*. (2004) showed the wide spread of this invasive plant species becoming a great concern in national parks, lakes, rivers, power dams and urban green spaces causing huge economic and ecological losses. They have become major threats to biodiversity loss and socioeconomic welfare of the Ethiopians. *Lantana camara* was introduced to Ethiopia as an ornamental plant due to its beautiful aromatic flowers (Binggeli and Desissa, 2002). However, because of prolific seed production and easy dispersal, it escaped cultivation and become a pest in the social, ecological and economic concerns. Presently, it has spread almost all over the country, but still it is not much perceived as a chronic environmental problem, except in few parts of Ethiopia, such as Oromia and Somali regions (Binggeli and Desissa, 2002).

2.3. Impact of *Lantana camara* on Soil Physical and Chemical Properties

There are various mechanisms whereby invasive alien plants can alter soil ecosystems (Tererai *et al*., 2015). Invasive alien plants alter the soil nutrient regimes by shifting species composition in favor of mono-stands (Jeddi *et al*., 2009). They alter the soil nutrient regimes through their ability to uptake nutrients faster than native species (Ehrenfeld, 2003). They also modify the quality and quantity of the litter entering the soil (Yelenik *et al*., 2004) or indirectly through the activity of roots and the alteration of microclimates and biological communities in soils (Castro-Díez *et al.,* 2011). Changes to soil properties, in turn affect the structure, function and composition of plant communities in invaded areas.

In most cases, changes in the soils are associated with changes in the litter fall and decomposition (Ehrenfeld, 2003). Litter decomposition is an important process that connects many above- and below-ground processes (Pandey *et al*., 2014). Some previous studies have shown that invasive alien plants, such as *Lantana camara*, Eucalyptus and Acacias, increase the amount of soil nutrients (especially soil N, P and C), soil pH and decomposition rates (Ehrenfeld, 2003; Fan *et al*., 2010; Ruwanza *et al.,* 2013; Tererai *et al*., 2015). However, in some cases, they may decrease the above-mentioned soil properties (Ehrenfeld, 2003; Tererai *et al*., 2015). For example, Kerr and Ruwanza (2015) reported that *Eucalyptus grandis* invasion in the Eastern Cape Province of South Africa caused varying effects on the soil physico-chemical properties, an increase in the soil pH and P, whilst decreasing the total soil N and C. Many of the observed soil property changes following invasion can be site- or even region-specific. Dassonville *et al*. (2008) reported that the site characteristics influence the nature and magnitude of the effects that alien plants can have on the soil physico-chemical properties. Therefore, there is the need to assess the generality of the observed impacts across a variety of environments in order to develop more predictive capacity across varying contexts (Ehrenfeld, 2003; Osunkoya and Perrett, 2011).

Mandal and Joshi (2014) concluded that *L. camara* improves soil fertility and influences nutrient cycling, which presumably make the soils more suitable for its own growth and invasion. However, Osunkoya and Perrett (2011) showed that not all soil nutrients are

significantly elevated by *L. camara* invasion; some nutrients, such as sodium, chloride, iron and manganese, were reduced. This suggests a lack of uniform impacts on soils, which could be triggered by invasion intensity or simply site effects (Osunkoya and Perrett 2011).

Most studies on the effects of invasive plants on soils have adopted a comparative approach by examining paired invaded and uninvaded sites (Sharma and Raghubanshi 2009; Fan *et al*., 2010; Osunkoya and Perrett, 2011; Tererai *et al.,* 2015). This approach (which was used in this study) can help to identify the potential effects of invasive species on soil properties, thus providing valuable information for the management of invasive species. This is an inferential approach and more direct approaches, such as measuring the soil properties after invasion or conducting experimental introduction studies that introduce invasive species, is more robust. However, direct approaches are often unviable due to the long time frames that are required for the effects to manifest and the inappropriateness of introducing invasive alien plants (Hejda and Pyšek, 2006). According to Hussain*, et al.* (2011) Soil analysis indicated that CaCO3 and organic matter were low in control soil compared with *Lantana* affected soil. Among major elements only P was higher in control soil than *Lantana* affected soil. Other two elements N and K were low in control soil. pH for both the soil samples was similar.

2.4. Allelopathy Effect

Allelopathy is defined as the positive or negative effects of one plant (as well as microorganisms) on the growth of another plant via the active release of chemical compounds into the environment through root exudation, leaching, volatilization as well as passive release through decomposition. These chemical compounds are defined as allelochemicals (Inderjit and Duke, 2003) and include secondary metabolites and phytochemicals belonging to the following classes; flavonoid, terpenoid, phenolic compound, organic cyanide, glucosinolate, saponin, alkaloid and long chain fatty acid structures. Allelochemicals differ among species, organs and tissues and the structure and concentration of allelochemicals varies with the biological and non-biological cues, therefore, their targets and functions are different (Bais, 2003).

Allelopathy and autotoxicity can play significant roles under both natural and manipulated ecosystems (Rice, 1984), mainly by adversely affecting seed germination and seedling growth.

Allelopathy plays a key role in weed control, crop protection, and crop re-establishment. Suitable manipulation of allelopathy towards improvement of crop productivity and environmental protection through eco-friendly control of weeds, pests, crop diseases, conservation of nitrogen in crop land, and synthesis of novel agrochemicals based on natural products have gained prominent attention of scientists engaged in allelopathic research. The allelochemicals can affect physiological functions like respiration, photosynthesis and ion uptake. However, scientific attention has also been drawn to exploit the positive significant roles of allelopathy and what role this phenomenon can play in enhancing crop productivity. A serious problem of modern agriculture is crop loss caused by weeds. Worldwide, weeds alone cause a 10% loss of agriculture production (Altieri and Liebman, 1988). Yet, allelopathic principles of crops can be used as an alternative mean of weed control based on natural products.

Although allelopathy is often considered a problem for agriculture, there is now considerable evidence to suggest that it might be exploited to help manage weed problems in a variety of agroecosystems. In agroecosystems, several weeds, crops, agroforestry trees and fruit trees have been shown to exert allelopathic influence on associated or subsequent crops, thus, affecting their germination and growth adversely (Kohli *et al*., 1993). Most allelopathic evidence has been associated with the effect of weeds on crops and crops on crops, and crops on weeds. Of these, an important economical potential of allelopathy may be the ability of crops to suppress weeds.

Allelopathic weeds also can affect crops by a number of ways like delaying or preventing seed germination and reducing seedling growth. Alternatives to synthetic chemical herbicides need to be developed, especially for organic or eco-friendly farming operations, landscape management systems, home gardens, and for situations where public policies mandate reduced pesticide use. Most studies on allelopathy have focused on interference and allelopathic effects of several important weeds on crop yields. Several weeds have been shown to have allelopathic

potentials and others are suspected to have allelopathic potential in agro-ecosystems (Rice, 1984). Several researchers have studied the impact of allelochemicals on different plants in crop and agro forestry systems (Kruse *et al*., 2000). Verma and Rao (2006) showed the effect of extract of weeds on germination, survival and protein content of varieties of *Glycine max*. These researches indicated the possibility of using allelochemicals to promote sustainable agriculture and improving the ecological environment.

2.5. Allelopathy Effect of *Lantana camara* on Crop Plants

The different parts of *Lantana camara* contain allelochemicals mainly aromatic alkaloids and phenolic compounds (Ambika *et al*., 2003) which can interfere with seed germination and early growth of many plant species (Sharma *et al*., 2005; Ahmed *et al*., 2007). Lantana can also interfere growth of nearby plants by outcompeting for soil nutrients (Dobhal *et al*., 2010) and altering microenvironment (e.g. light, temperature) by forming dense thickets (Sharma and Raghubanshi, 2007).

The importance of allelopathy has been examined for the ability of the exotic, invasive, woody weed *Lantana camara*, to invade, establish and form dominant components within certain susceptible ecosystems including various types of Australian forests (Gentle and Duggin, 1997). In an experiment by Gentle and Duggin (1997) it was attempted to distinguish between suppressed seedling growth caused by possible phytotoxins and density dependent resource competition respectively. The results provided evidence that *L.camara* is capable of interrupting the regeneration processes by decreasing germination, reducing early growth rates, and reducing survival of two indigenous species by allelopathy. These changes are expected to lead to disruption of community development because *L. camara* can also aggressively compete with indigenous seedlings.

The principle of density-dependent-effect (DOE) has been used under field conditions, by Gentle and Duggin (1997) to verify that allelopathy is an important factor for the ability of *Lantana camara* to invade different forest ecosystems. Both the density of the allelopathic plant and the density of the susceptible species have been documented to influence the degree of allelopathic inhibition. In field studies, seedling growth of two susceptible species was negatively related to increasing density of *Lantana camara*. When the densities of the two susceptible species were increased, the average seedling biomass for both species increased (Gentle and Duggin, 1997).

The effect of leaf extracts and leaf leachates of *Lantana camara* was studied on the germination behavior, growth and metabolism of *Vigna radiata* (mung bean). Percentage seed germination, speed of germination, seed viability and field emergence capacity was significantly reduced along with enhancement of both leaf extracts and leaf leachates of donor plant on the test species. The inhibition of germination behavior was associated with decreased level of protein as well as activities of catalase and dehydrogenase enzymes, with concomitant increase of amino acids, soluble carbohydrates and amylase activity of mung bean. Both the leaf extracts and leaf leachates showed pronounced inhibition of root, shoot and internode lengths, number of leaves, fresh and dry weight per plant of the test species. The inhibitory effect was strictly concentration-dependant. The inhibition of plant growth was correlated with the decrease in chlorophyll content, level of proteins and the activity of catalase enzyme in leaves. The effect of leaf extracts was found to be pronounced than that of leaf leachates (Maiti *et al*., 2008).

The allelopathic effects of different concentrations of aqueous leaf extracts and leaf leachates from leaves of *L. camara* were inhibitory to seed germination and metabolism of mung bean seeds (Maiti *et al*., 2010). Leaf extract of *Lantana camara* showed a wide variation in the reduction of the germination rate of seeds of both the vegetable species, radish (*Raphanus sativus* L.) and spinach (*Spinacia oleracea* L.) over the control. The 100% concentration of leaf extract showed maximum inhibition followed by 50% leaf extract. Aqueous extracts of all parts of *Lantana camara* have strong allelopathic effect on the germination of *Pennisetum americanum, Lactuca sativa* (L.) and *Setaria italica* (L.) (Hussain *et al*., 2011). Maiti *et al*. (2008) found that the leaf extracts of *L. camara* rendered adverse effects on mung bean seeds with respect to the physiology and biochemistry of seed germination.

2.6. Allelochemicals of *Lantana camara*

Allelochemicals of *Lantana* have already been isolated and documented by many scientists. Allelochemicals such as β-pinene, β-sitosterol, Betulonic acid, Caffeic acid, Calceolarioside, Camaraside, Camarinic acid, Campesterol, 1,8-Cineole and Cinnamic acid are present in leaves, stem, roots, fruits and flowers of *Lantana camara* (Gopie-shkhanna and Kannabiran, 2007). The chemical compounds present in *Lantana camara* extracts include mono and sesquiterpenes, flavinoids, iridoid glycoside, furanonaphoquinones, sthsteroids triterpenes and diterpenes.

Yi *et al*. (2005) reported the presence of several phenolic compounds in *Lantana* leaf extract identified by HPLC as salicylic, gentisic, β-resorcylic acid, vanillic, caffeic, ferulic, phydroxybenzoic acids, coumarin and 6- methyl coumarin. Lantadene A and lantadene B as more potent allelochemicals. Allelopathic chemicals from *Lantana camara* are able to repel other plant. Lantadene A and B are the most common and salicylic acid is recorded as one the major toxins.

1.7. Description of *Lepidium sativum* L.

The plant *Lepidium sativum Linn*. (commonly known as Garden cress) belonging to the family Brassicaceae is an erect, glabrous annual, 15-45cm in height, cultivated as a salad plant throughout India, Europe and United States. It is an annual plant reach a height of 60cm (~24 inches), with many branches on the upper part. The local name of *Lepidium sativum* is *Feto*. The cauline leaves are sessile and usually entire. It has small white flowers in long recemes. The pods are obovate or broadly, elliptic rotundate, emarginated, notched at apex and winged. The plant thrives on any good light soil, but does best on moist loam. It can be grown at all elevations, all the year round, but the best crop is obtained in the winter season. The herb is an important medicinal plant since the Vedic era (Wealth of India, 1962).

2.8. Bioassay Techniques for Allelopathy Research

In allelopathy research, different bioassay techniques such as the tube method, modified sponge-dish method, filter paper method, plant root box method, field method, pot culture method, agar culture method etc., (Fujii *et al*., 2007) are widely used. Researchers have further improved on these approaches, including co-culture in a hydroponic system, in sand as well as other substrates and nevertheless, have also utilized co-culture in field experiments, which could better simulate the natural state (Xiao *et al*., 2013).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in botany laboratory and *Rarre* green house, in Haramaya University (HU). Haramaya University is located between latitudes of 9° 24' 53.13"N and 9° 24' 51.34"N, and between longitudes of 42° 01'55.69"E and 42° 01' 56.62"E at a distance of 14 km and 508 km from west of Harar and east of Addis Ababa, respectively. The altitude in the campus varies from 1980 to 2000 meter above sea level.

3.2. Plant Materials and Soil Samples

Lantana camara leaves and soils affected by it were collected from sites supporting thickets of *Lantana camara* in Haramaya university campus. Leaves were collected in fresh and air dried in the laboratory. Soils from the upper 20cm were collected from four sites in distance gradient starting from beneath *Lantana camara* canopy, edge of *Lantana camara* canopy, and away from the edge of *Lantana camara* canopy at 1m and 2m distance. The test plant (*Lepidium sativum*) was grown in green house from seeds obtained from Haramaya university agricultural institute.

3.3. Experimental Design

The experiment was conducted in Completely Randomized Design (CRD) which includes four treatments and one control for the test crop seeds. The four treatments were considered as 5%, 10%, 15% and 20% and control group denotes 0%. The control group plants were grown in distilled water without mixing the *Lantana camara* leaf extract where as the four treatments plants were grown with 5, 10, 15 and 20% of *L. camara* leaf extract concentration levels. The experiment was replicated twice. However, in green house four treatment sites (beneath *L. camara* canopy, edge of *Lantana camara* canopy, and away from the edge of *Lantana camara* canopy at 1m and 2m distance) were used. For each experiment, ten seeds were sown and allowed for germination. The experiment was done in four replication and performed from October 2016 to January 2017.

3.4. *Lantana camara* Leaf Extractions

Lantana camara leaves were first thoroughly washed with distilled water and air dried in the laboratory at room temperature. Air dried leaves were then powdered using mortar and pestle. The powder (100 gram) was mixed with 300 ml of organic solvents (Ethanol and Hexane separately) and left on the table in the laboratory for 24 hours with intermittent stirring with glass rod (Meseret *et al*., 2010). After 24 hours of extraction, extract was filtered under

suction using Whatmann no 1 filter paper and stored in the refrigerator until bioassay. Organic solvent extracts were then made to dry in order to completely remove the solvents under rotary evaporator. There after the crude extracts were dissolved in distilled water (100 ml) to have 5, 10, 15, 20% concentrations.

3.5. *Lantana camara* Leaf Extracts Phytotoxicity Bioassay

In order to test the impact of *Lantana camara*'s leaf extract, seeds of *Lepidium sativum* were first surface sterilized using 15% Sodium hypochlorite for 20 min and rinsed in distilled water. Thereafter, 10 seeds were placed on Whatmann No.1. filter paper that received 5 ml of 5, 10, 15 and 20% extracts in Petri dishes of 9cm diameter. Distilled water of equal volume to the extract was used as negative control. The Petri dishes were arranged on a table in the laboratory in a completely random design with three replicates and incubated for days to complete germination. Petri dishes were made to get more or less the same amount and types of light throughout the incubation period and moved around to avoid position effect. Moisture in the Petri dishes was maintained by adding 2 ml of the extract for the treated seeds or distilled water for the control every 2 days. After days of incubation, percent germination, plumule and radicle growth were measured. The seeds were considered germinated up on the emergence of the radicle. Germinated seeds were counted daily and the lengths of the roots and shoots were measured at the end of the experiment. Data on germinated seeds (number of seedlings with visible radicle and plumule growth were collected daily from the third to fifteen days after planting. Shoot and root length (cm) were recorded on the fifteenth day by taking all the germinated seedlings and took the average length.

Germination percentage: determined from counts of normal germinated seedlings and the total seeds placed on Petridishes.

Germination percentage (GP) = number of germinated seeds/total number of seeds *100

Plumule and radicle length: measured daily from the third days after planting by using ruler.

Shoot Length: of the germinated seeds with normal seedlings were measured from the tip region to the point of attachment to the cotyledon and the average shoot length (cm) was calculated.

Root Length: of the germinated seeds with normal seedlings were measured from the collar region up to the tip of the primary root and was expressed as mean root length in cm. All the lengths measured by using a ruler

3.6. Phytotoxicity and Quality of Soils Invaded by *Lantana camara*

In order to investigate *Lantana camara* soil residual toxicity on test plants and the quality, i.e., chemical features of soils affected by *Lantana camara*, soils were sampled in four distance gradient from four *L. camara* individuals. For this, four places that serve as replicates having *L. camara* individuals with 100% canopy coverage, but edges with no *Lantana camara* individuals was selected. Then, 4 treatment sites; the site beneath the *Lantana camara* canopy, on the edge of *L. camara* canopy, one meter away from *L. camara* canopy, and two meters away from *L. camara* canopy were considered for soil sampling. After that a 1×1m plot was laid beneath the canopy of *Lantana camara* (selected individuals of *L. camara* in four replicates) and soils (upper 20 cm) were taken from each corner and center of the plot and made into composite. Similar plots were laid at the edge of the canopy and then at 1 m and 2 m distance from the canopy edge to have a distance gradient. Part of the sampled soils were brought to the laboratory for soil residual toxicity bioassay and chemical analyses while the rest were used to cultivate the test plant in pots in green house as described below.

Soil residual toxicity was determined in soil bed and soil extract bioassays as follows.

Soil bed bioassay: First**, s**oils from the four treatment sites (n=4), i.e., beneath the *L. camara* canopy, on the edge of *L. camara* canopy, 1m away from *L. camara* canopy, and 2m away from *L. camara* canopy were collected and dried at room temperature. One gram of *Lantana* collected soils were then used as seed-bed in Petri dish in the laboratory. Soil was topped with

a single sheet filter paper and moistened with 15 ml distilled water. After 3 days, seeds of test species were placed on filter papers and incubated at room temperature for germination. The experiment was done in a completely randomized design with three replications.

Soil extract bioassay: In this case**,** five gram of soil from the four treatment sites and four distance gradients were dissolved in 100 ml of distilled water and filtered after 24 hrs. The filtrate was used against the same test species as used in the case of leaf extracts in Petri dishes in the laboratory. For both assay types, soils were sieved through 2 mm sieve to remove non-soil materials. After days of incubation germination parameters (percent germination, plumule, radicle, shoot and root growth) were recorded.

3.7. Use of *Lantana camara* Soils for Cultivation of Test Plant

Seeds (10) of the test plant were sown in pots filled with soils obtained from four sites of Lantana thickets in four distance gradient as indicated above. Eight pots (2 pots having soils from each treatment) were arranged on a table in three replicates in greenhouse. The plants were watered with tap water regularly to keep soils always moist, but were not fertilized. Data collected included germination percentage and growth performance such as shoot length, shoot fresh and dry weights and yield and yield related parameters (Patnaik, 1998).

Shoot dry and fresh weight: After the completion of experiment, plants were harvested and the biomass of shoots was measured. The fresh weight of the sample was calculated immediately after harvest and dry weight was calculated by keeping the plants in oven at 70°C for 48 h.

Weight of seed per pot: This parameter was estimated from the total weight of seeds per pot in each treatment sites.

1000 seed weight: sample of seeds from the bulk in each treatment was taken and 1000 seeds were manually counted and weighed using a sensitive balance.

3.8. Analyses of *Lantana camara* Soil Chemical Properties

Soil samples were analyzed by the methods described in Page *et al.* (1982).

Soil pH: was determined with a pH meter (pH rex-2 lei-ci, Shanghai) with a 1: 2.5 w/v (soil: distilled water) ratio.

Soil organic matter (SOM): was measured using the K2Cr2O7–H2SO4 oxidation method (Nelson and Sommers, 1982).

Total phosphorus (P) and available P: were determined using the colorimetric Molybdenum-blue-method (Olsen and Sommers, 1982).

Total nitrogen: was determined using *kjeldahi digestion* method.

Each analysis was replicated three times.

3.9. Data Analysis

The data collected from the experiments were subjected to descriptive statistics to calculate germination percentage, radicle, plumule, root, shoot lengths and growth performance by one-way ANOVA using statistical package SPSS version 16. Differences between means were considered statistically significant at $P<0.05$.

4. RESULTS AND DISCUSSION

4.1. Impact of *Lantana camara* Leaf Extracts on Percent Germination, Plumule and Radicle Length of *Lepidium sativum*

The present study indicates that Leaf extract of *Lantana camara* have strong allelopathic effect on the germination and growth of the test species. The analysis of variance showed significant effect of *L.camara* leaves extracted by using polar (ethanol) and non polar (hexane) organic solvents on seed germination and seedling growth of *Lepidium sativum*. The mean germination percentage, plumule and radicle lengths of *Lepidium sativum* grown on the petridish were presented in Table1.

Compared to the control, percent germination, plumule and radicle lengths of *Lepidium sativum* were significantly ($P<0.05$) reduced by both ethanol and hexane leaf extracts at all concentration levels. Reduction in percent germination, plumule and radicle lengths were also found to increase with increasing extract concentration in both solvent cases (Table 1). Mishara (2015) recently reported similar result that germination inhibitory effect of plants increase with increasing extract concentration. Comparison between the two solvents showed that hexane extract more negatively affected percent germination, plumule and radicle lengths than ethanol extracts in all concentrations considered (Table 1).

That is, complete failure of seed germination was recorded as a result of application of 10, 15 and 20% Hexane extracts. This result showed that *Lantana camara* has allelopathic effect on *Lepidium sativum* germination and seedling growth. Previously, Ahmed *et al*. (2007) reported the allelopathic effect of *L. camara* in different crops. The present finding is also in agreement with the reports of Narwal (1996) and Hossain and Alam (2010) who reported that *Lantana camara*

is allelopathic weed and hinders the seedling recruitment and growth of other plants due to the presence of phenolic acids and phytotoxic chemicals released from the leaf litter and roots.

In other related research Jabeen and Ahmed (2009) and Hossain and Alam (2010) suggested that *L. camara* leaf extracts have allelopathic effects on germination behavior of agricultural crops such as *Triticum aestivum* and *Cucurbita pepo.* In addition to this Sahid and Sugau (1993) reported that Germination of Chinese cabbage, chili and rape decreased progressively when exposed to increasing concentration of aqueous *Lantana* extract. Desalegn (2014) also reported that aqueous leaf extract of *L. camara* significantly reduced germination of tef (*Eragrostis teff*) seed. The phytotoxicity of leaf extract may be attributed to secondary compounds mainly to complex interaction of the phenolic compounds (Jain *et al.*, 1989). In addition to phenolics, a recent report indicates that lantadene A and B are more potent allelochemicals. These two allelochemicals are triterpenes cholestatic poisons in *Lantana camara (*Kong *et al.*, 2006). From this allelochemicals present in leaf were better extractable in hexane than in ethanol and that the allelochemicals were differentially extractable in both solvents. The fact that the two organic solvents showed varying effects suggests that solvents of different polarity have different potential to extract compounds of different profile showing different activities (Meseret *et al*., 2010).

Table 1. Effect of Ethanolic and Hexane leaf extracts of *Lantana camara* on some germination parameters.

Solvent	Germination parameters	0%	5%	10%	15%	20%	F-value	p-value
Ethanol	Germination %	100.00±0.00 a	77.50±8.54b	50.00±4.10 c	42.50±4.79 c	37.50±4.79 c	25.915	0.001
	Radicle length	2.67±0.00a	1.16± 0 .12b	0.86±0.07c	0 . 6 2 ± 0 .09d	0.49±0.05 d	126.508	0.001
	Plumule length	1.94±0.00a	0.91±0.07b	0.68±0.02b	0.64±0.01b	0.54±0.02b	214.582	0.005
Hexane	Germination%	100.00±0.00 a	30.00±4.08b	NG	NG	NG	409.364	0.00
	Radicle length	2.67±0.00a	0.60±0.18b	NG	NG	NG	54.043	0.002
	Plumule length	1.94±0.00a	0.48±0.18b	NG	NG	NG	34.518	0.001

Note: 0%, 5%, 10%, 15%, 20% represents extract concentration; NG= No growth; Values are mean±SE(n=5). Differences between means were considered statistically significant at *P<0.05;* Values followed by different small letters in a row are significantly different while those with the same letters are not statistically vary. Radicle and plumule length was expressed in centimeter.

4.2. Shoot and Root Growth of *Lepidium sativum* Treated with Ethanol and Hexane Leaf Extracts of *Lantana camara*

The average shoot and root length (cm) recorded from the germinated seedlings 15 days after planting are presented in Table 2. The allelopathic effects of the Ethanolic and hexane leaf extract of *Lantana camara* on shoot and root length of the test crop species was demonstrated as that shoot and root length of *L. sativum* was significantly affected upon applying the different concentrations of *Lantana camara* leaf extracts. According to the results recorded all the extract concentrations of *Lantana camara* had significant effect on shoot and root length of *Lepidium sativum*.

When compared with the control, shoot and root lengths of the seedlings were significantly ($P<0.05$) reduced by both ethanol and hexane leaf extracts at all concentration levels. Reduction in growth increased with increasing extract concentration in both solvent cases (Table 2). However, the maximum reduction of the length was observed at 20% leaf extract as compared to all the treatments. Similar to the present result, several studies also indicated growth inhibitory effect of *Lantana camara* on a variety of crops (e.g., Ahmed *et al.*, 2007; Maiti *et al.*, 2008). The results of the present study is in agreement with the finding of Hossain and Alam (2010) who observed that increased application of *L. camara* leaf extracts completely inhibits shoot elongation of *Abelmoschus exculantus.* Abiyu and Nagappan (2015) also reported that the shoot and root length of wheat and maize was significantly inhibited by the increasing amount of *L. camara* leaf powder.

Table 2. Shoot and root elongation (cm) of *Lepidium sativum* treated with Ethanolic and Hexane *Lantana camara* leaf extracts.

Solvent	Germination parameters	0%	5%	10%	15%	20%	F-value	p-value
Ethanol	Root length	15.65±0.00 a	6.12±0.80 b	3.48±.33c	2.68±0.52 d	2.29±0.5d	122.445	0.008
	Shoot length	3.63±0.00a	3.52±0.13 a	3.25±0.28 b	2.76±0.32 c	1.95±0.37 d	7.331	0.002
Hexane	Root length	15.65±0.00 a	2.54±0.38 b	NG	NG	NG	666.220	0.001
	Shoot length	3.63±0.00a	1.21±0.10 b	NG	NG	NG	143.211	0.000

Note: 0%, 5%, 10%, 15% and 20% represents extract concentration; Values are mean ± SE (n=5); Differences between means were considered statistically significant at *P<0.05;* Values followed by different small letters in a row are significantly different while those with the same letters are not statistically vary. Root and shoot length was expressed in centimeter.

4.3. Soil Residual Toxicity Bioassay

4.3.1 Soil bed

Results of seed germination experiment done on soil bed obtained from different sites in a distance gradient from *L. camara* showed no significant (P>0.05) allelopathic effect difference (Table 1). However, though value was not statistically significant, that of beneath *L. camara* more reduced germination percentage as compared to soils sampled at the edge, one and two meters away from *L.camara* (Table 3). Similarly, plumule length showed no significant difference between soils sampled in distance gradient from *L. camara*.

The root and shoot lengths were measured 15 days after planting and the result showed that root length was significantly reduced when grown in soil sampled 2 m far away from *L. camara* (Table 3). Previously, similar result was noted by Hussain *et al*. (2011).The fact that soils beneath *L. camara* showed relatively greater allelopathic effect on germination percentage of Lactuca as compared to the rest of distance gradient implies that allelochemical from leachates, root exudtes and tissue decomposition are more concentrated under the canopy, but less diffuse to areas away from the canopy. It is also possible that chemicals may decompose as exposed to open light out of the canopy. However distance gradient showed some significant difference in 1 m away from Lantana canopy on shoot growth. The fact that root growth was less at 2m away from Lantana than soils sampled from near *L. camara* may be attributed to the variation of either soil moisture, chemical or physical properties in distance gradient.

It is suggested that soil might have not accumulated sufficient concentration of toxins to become inhibitory. It was also true in this case as the soil was collected after rains that had reduced for leached away toxins that might have been present. Overall, the result also coincides with findings of Sahid and Sugau (1993) and Achhireddy and Singh (1984) who reported that *Lantana* affected soil did not influence the crop. Likewise, studies made by Sundaramourty *et al.*, (1992) also concluded that soil collected from beneath *Acacia tortillus* and *Prosopis cineraria* had no significant inhibition.

Table 3. Seed germination parameters grown on soil-bed of soils sample from Position of soil sample relative to *Lantana camara*

Germination parameters	Beneath	Edge	1m	2m	F-value	p-value
Germination %	85.00±0.64^{a}	90.00±0.41a	90.00±0.41^{a}	90.00±0.41^{a}	0.231	0.38
Radicle length	0.99±0.03b	1.03±0.09^{a}	1.13±0.09a	0.99±0.10^{b}	10.375	0.09
Plumule length	0.89±0.03a	0.89±0.05^{a}	0.85±0.13a	0.72±0.10^{a}	1.517	0.247
Root length	4.39±0.11a	4.60±0.08^{a}	4.50±0.08a	3.51±0.13^{b}	8.731	0.182
Shoot length	3.18±0.22b	3.28±0.16^{b}	3.56±0.25a	3.23±0.19^{b}	1.922	0.07

Note: Beneath, edge, 1m and 2m indicates Position of soil sample relative to *Lantana camara*; Values are mean ± SE (n=4); Differences between means were considered statistically significant at $P<0.05$. Values followed by different small letters in a row are significantly different while those with the same letters are not statistically varied. Radicle, plumule, root and shoot length was expressed in centimeter (cm).

4.3.2 Soil extract

Similar to soil-bed experiment, results of seed germination experiment done on extracts of soils sampled from different sites in a distance gradient from *L. camara* showed no significant allelopathic effect difference. However, though value was not statistically significant, that of beneath *L. camara* reduced germination percentage as compared to soils sampled at the edge, one and two meters away from *L.camara* (Table 4). Similarly, plumule and radicle lengths showed no significant difference between soils sampled in distance gradient from *L. camara* (Table 4). There was no significant difference between soil extracts of the different sites of distance gradient from *L.camara* in radicle and plumule lengths.

Moreover, root and shoot lengths measured 15 days after planting has showen some significant differences between soil extracts of the different sites of distance gradient from *L.camara* (Table 4). Root and shoot growth however, appeared to lower in the beneath of *L. camara canopy* as compared to the edge, suggesting the soil microenvironment that provides some growth inhibitory chemicals in soils from beneath *L. camara* canopy. This suggested that the affectivity of toxins in soil, however, depends upon a number of factors including texture, accumulation capability and microbial activity (Hussain *et al*., 2011)

Table 4. Seed germination parameters of *Lepidium sativum* treated with soil extract sampled from *L.camara* canopy and away from its canopy

Germination parameters	Beneath	Edge	1m	2m	F-value	p-value
Germination %	87.50±4.79^{b}	90.00±4.08 b	90.00±5.77^{b}	100.00±0.00^{a}	1.686	0.223
Radicle length	1.50±0.05 a	1.21±0.07^{a}	1.26±0.14 a	1.09±0.14^{a}	7.054	0.062
Plumule length	0.71±0.09 a	0.68±0.05^{a}	0.66±0.04 a	0.63±0.07^{a}	0.237	0.913
Root length	2.25±0.21 b	2.99±0.32^{a}	2.19±0.06 b	1.96±0.15^{b}	1.106	0.08
Shoot length	3.04±0.09 b	3.58±0.19^{a}	3.09±0.08 b	3.03±0.03^{b}	2.997	0.09

Note: Beneath, edge, 1m and 2m indicates Position of soil sample relative to *L. camara*; Values are mean ± SE (n=4); Differences between means were considered statistically significant at $P<0.05$. Values followed by different small letters in a row are significantly different while those with the same letters are not statistically varied. Radicle, plumule, root and shoot length was expressed in centimeter.

4.4 Green House Experiment

Growth performance of Lepidium was not significantly affected under beneath of soil samples relative to *Lantana camara*. Germination percentage, Plant height, fresh and dry shoot weight varied non significant (P>0.05) between soils of different sites in distance gradient from *L. camara* (Table 5). At the time of maturity stage of the test seeds, the maximum plant height, shoot fresh and dry weight were recorded in plants treated with soil sample taken from beneath of canopy, whereas at the same age, the minimum was recorded in plants treated with soil taken from 2m away from its canopy of *Lantana camara*.

Similarly, Germination percentage, fresh and dry shoot weight was showed a decrease with increasing distance gradient from canopy of *Lantana camara*. This suggests that the variation of growth performance of *L. sativum* in increased distance gradient may be associated with the release of phytochemicals from the *Lantana camara* root that may stimulate the growth of the plant or may be alter the available nutrient for plant growth. That is, all parameters were found to subsequently decrease with increasing distance from *Lantana camara* canopy with the exception of seed yield per pot and weight of 1000 seeds.

However, significant difference was observed between soils of different distance gradient from *Lantana camara* in seed yield/ha and weight of 1000 seeds. This suggests that the effect of allelochemicals released by allelopathic donor plants depends upon a number of factors including accumulation capability and microbial activity. Previously, Achhireddy and Singh (1984) indicated that soil collected from under Lantana had no effect on germination and growth of milkweed vine. Contrary to this, Senarathne *et al.* (2011) demonstrated germination inhibitory effect of Lantana invaded soils on seed germination of *Lycopersicum esculentem, Crotalaria junica* and *Capsicum annuum.* The fact that it should be noted that the response of the receptor species to allelochemicals varies widely among species (Whittaker, 1970).

Table 5. Impact of soil samples relative to *Lantana camara* on *Lepidium sativum* seed germination and growth performance.

Germination parameters	Beneath	Edge	1m	2m	F	P
Germination %	95.00±2.89^{a}	90.00±4.08^{b}	90.00±4.08^{b}	87.50±4.79^{b}	0.613	0.62
Plant height	47.66±1.06^{a}	45.54±1.39^{b}	37.61±1.54^{c}	33.27±0.96^{d}	27.412	0.07
Shoot fresh weight	8.31±0.30^{a}	7.12±0.25^{b}	5.27±0.09^{c}	4.57±0.09^{c}	35.116	0.13
Shoot dry weight	3.91±0.13^{a}	2.91±0.10^{b}	2.32±0.05^{b}	1.86±0.03^{c}	1.538	0.278
Seed yield per pot	6303.92±2.47^{b}	6715.69±409.42^{a}	6696.08±2.79^{a}	5911.77±3.42^{c}	16.021	0.03
Weight of 1000 seeds	2.07±0.03^{b}	1.83±0.03^{b}	2.10±0.06^{a}	2.20±0.06^{a}	10.83	0.045

Note: Beneath, edge, 1m and 2m indicates Position of soil sample relative to *Lantana camara*; Values are mean ± SE (n=4); Differences between means were considered statistically significant at $P<0.05$. Values followed by different small letters in a row are significantly different while those with the same letters are not statistically varied. Plant height was expressed in centimeter. Shoot dry and fresh weight and weight of 1000 seeds in gram; weight of seed yield per pot in kilogram per hectare (Kg/h).

4.5. Soil Properties of the Treatment Sites

The pH value and total nitrogen did not vary between soils sampled from different sites in distance gradient from *L camara*. However, Total phosphorus was significantly higher in soils from beneath *L. camara* than soils sampled from the edge and 1-2m away from *L. camara*, whereas available phosphorus was higher in soils sampled from areas without *L. camara* invasion (Table 6). Moreover, soil organic matter was lower in soils from beneath *L. camara* as compared edge and 1-2m away from its canopy. This shows that allelochemicals input from decomposition or leachates of *L.camara* tissue may be inhibitory to microorganisms that enhance phosphorus availability and organic matter underneath its canopy. Recently, Ruwanza and Shackleton (2016) indicated that the soils from underneath *L. camara* had a higher level of total P compared to the soils in the adjacent sites that had no *L. camara*, while the soil pH showed no difference between the invaded and un-invaded sites.

Table 6. chemical properties of the soil samples taken from treatment sites

Parameters	IN	O N	OUT
pH value	7.02 ± 0.10^{a}	7.20 ± 0.12^{a}	7.21 ± 0.03^{a}
SOM (%)	1.18 ± 0.27^{b}	1.51 ± 0.10^{a}	1.29 ± 0.13^{b}
Total P (ppm)	127.04 ± 4.93^{a}	108.46 ± 24.72^{b}	107.32 ± 14.12^{b}
Available P (ppm)	14.45 ± 6.68^{b}	14.62 ± 2.25^{b}	23.62 ± 7.29^{a}
Total N (%)	0.08 ± 0.02^{a}	0.10 ± 0.03^{a}	0.09 ± 0.02^{a}

Note: IN indicates soil beneath *Lantana camara* canopy; ON=soil on the edge of Lantana individual; OUT= soil 1-2 m away from Lantana individual; Values are mean ± SE (n=3); Values followed by different small letters in a row are significantly different while those with the same letters are not statistically varied.

5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and Conclusions

Under field conditions the presence of weed is one of the major factors responsible for growth and yield reduction in crops. However, findings have shown that allelopathic interactions between crops and weeds were also partly responsible for such losses in crop yields. *Lantana camara* is one of the most invasive weeds which have allelopathic effect on other plants. But, little information is available on phytotoxicity effect of *Lantana camara*. On the other hand, in Ethiopia such as Oromia and Somali regions most of the lands are occupied by the weed *Lantana camara*.

Therefore, in this study an investigation was carried out under laboratory and greenhouse conditions at biology laboratory and *Rarre* green house, respectively with the objective of evaluating the allelopathic effects of leaf extracts of *Lantana camara* and growth inhibitory effect of soil invaded by it on *Lepidium sativum*. Laboratory bioassay on germination and seedling growth of the test crop was investigated under Ethanolic and hexane leaf extracts of different concentrations (5, 10, 15 and 20%).

The results showed that both solvents extracts of *Lantana camara* have allelopathic effect of *Lepidium sativum*. Germination parameters and growth performance of the test plant were inhibited in concentration dependent manner. Comparison between hexane and ethanol extracts showed that hexane extracts had higher effect on the measured parameter than Ethanolic extract. However, soil residual toxicity test made in the laboratory and greenhouse did not affect germination parameters and growth performance of *Lepidium sativum*.

5.2 Recommendations

Based on the current results of the finding the following recommendations are forwarded:

- Although soils invaded by *Lantana camara* showed no toxicity to *Lepidium sativum* in this particular experiment, high accumulation of chemicals from tissue decomposition can negatively influence *Lepidium sativum* and other crops too. Therefore, Decomposition of this plant on farm land should be avoided.

- Since the study considers only allelopathic potential of *Lantana camara* on Germination and growth performance of *Lepidium sativum* in greenhouse condition for one season, it is recommended to have additional investigations in field condition.

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7. APPENDICES

Appendix 1: Mean Comparison within Treatments by using Least Significance Difference (LSD)

Table 1. Results of ANOVA on comparisons of the Effect of Ethanolic leaf extracts of *Lantana camara* on Germination parameters

		Germination%		Radicle Length		Plumule length		Shoot length		Root length	
(I) TRT	(J)TRT	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.
0%	5%	22.50*	0.008	1.51*	0.000	-0.04	0.026	-0.04	0.916	9.54*	0.00
	10%	50.00*	0.000	1.81*	0.000	-0.02	0.009	0.38	0.328	12.17*	0.00
	15%	57.50*	0.000	2.05*	0.000	0.08	0.008	0.88*	0.033	12.98*	0.00
	20%	62.50*	0.000	2.19*	0.000	0.38	0.031	1.68*	0.000	13.37*	0.00
5%	10%	27.50*	0.002	0.30*	0.018	0.02	0.966	0.42	0.282	2.64*	0.002
	15%	35.00*	0.000	0.54*	0.000	0.12	0.777	0.92*	0.027	3.44*	0.000
	20%	40.00*	0.000	0.67*	0.000	0.41	0.316	1.72*	0.000	3.83*	0.000
10%	15%	7.50	0.324	0.24*	0.047	0.10	0.810	0.49	0.203	0.80	0.279
	20%	12.50	0.110	0.38*	0.004	0.39	0.337	1.29	0.003	1.19	0.116
15%	20%	-5.00	0.507	0.14	0.234	0.29	0.466	0.80*	0.049	0.39	0.592

Table 2. Results of ANOVA on comparisons of the Effect of Hexane leaf extracts of *Lantana camara* on germination parameters

		Gp%		Radicle Length		Plumule length		Shoot length		Root length	
(I) TRT	(J)TRT	M D (I -J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.
0%	5%	72.50*	0.000	2.07*	0.000	1.47*	0.000	2.42*	0.000	13.11*	0.000
	10%	100.00*	0.000	2.67*	0.000	1.94*	0.000	3.63*	0.000	15.65*	0.000
	15%	100.00*	0.000	2.67*	0.000	1.94*	0.000	3.63*	0.000	15.65*	0.000
	20%	100.00*	0.000	2.67*	0.000	1.94*	0.000	3.63*	0.000	15.65*	0.000
5%	10%	27.50*	0.000	0.60*	0.000	0.48*	0.001	1.21*	0.000	2.54*	0.000
	15%	27.50*	0.000	0.60*	0.000	0.48*	0.001	1.21*	0.000	2.54*	0.000
	20%	27.50*	0.000	0.60*	0.000	0.48*	0.001	1.21*	0.000	2.54*	0.000
10%	15%	0.000	1.000	0.00	1.000	0.00	1.000	0.00	1.000	0.00	1.000
	20%	0.000	1.000	0.00	1.000	0.00	1.000	0.00	1.000	0.00	1.000
15%	20%	0.000	1.000	0.00	1.000	0.00	1.000	0.00	1.000	0.00	1.000

Table 3. Results of ANOVA on comparisons of the effect of the *Lantana camara* soil-bed of soils sampled from *Lantana camara* canopy and away from it on *Lepidium sativum*

		Germination%		Radicle Length		Plumule length		Shoot length		Root length	
(I) TRT	(J)TRT	M D (I -J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.
B	E	-5.00	0.510	0.29*	0.045	0.005	0.968	-0.11	0.725	-0.46	0.613
	1m	-5.00	0.510	0.24	0.091	0.04	0.737	-0.38	0.214	-0.61	0.508
	2m	-5.00	0.510	0.46*	0.075	0.18	0.182	-0.06	0.853	0.63	0.491
E	1m	0.00	1.000	-0.05	0.698	0.03	0.767	-0.28	0.360	-0.15	0.873
	2m	0.00	1.000	0.16	0.242	0.17	0.194	0.05	0.867	1.09	0.242
1m	2m	0.00	1.000	0.22	0.130	0.13	0.305	0.33	0.283	1.24	0.049

Note: B, indicates beneath; E= edge; 1 m= 1 meter; 2 m= 2 meter away from canopy of *L.camara*.

Table 4. Results of ANOVA on the comparisons of the effect of the *Lantana camara* soil-extract of soils sampled from *L.camara* canopy and away from it on *Lepidium sativum*

		Germination%		Radicle Length		Plumule length		Shoot length		Root length	
(I) TRT	(J)TRT	M D (I -J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.	M D (I-J)	Sig.
B	E	-2.50	0.686	-0.03	0.791	0.04	0.701	-0.54*	0.006	-0.75*	0.025
	1m	-2.50	0.686	-0.14	0.273	0.06	0.575	-0.05	0.787	0.05	0.867
	2m	-12.50	0.041	-0.005	0.967	0.08	0.418	-0.04	0.833	0.28	0.352
E	1m	0.00	1.000	-0.11	0.398	0.02	0.857	00.49*	0.010	0.79*	0.018
	2m	-10.00	0.124	0.03	0.822	0.04	0.664	0.51*	0.009	1.03*	0.004
1m	2m	-10.00	0.124	0.13	0.290	0.03	0.798	0.01	0.952	0.23	0.441

Note: B, indicates beneath; E= edge; 1 m= 1 meter; 2 m= 2 meter away from canopy of *L.camara*.

Appendix 2: Laboratory and Greenhouse Pictures

a) Seed sowing experiment

b) Petridishes treated within extracts

c) Control

d) Measuring of shoot and root length e) Seeds treated with soil bed f) Seeds treated with soil extract



Appendix figure 1: Sample pictures while during laboratory bioassay

a) Growth of the test seeds stage

b) At flowering

c) Yielding stage

d) Measuring of above ground plant height

e) Harvesting stage

f) measuring of shoot biomass

Appendix figure 2: Sample pictures while during green house experiment