ECOLOGY OF COMMON WEEDS AND THEIR ALLELOPATHIC EFFECT ON JHUMLAND CROPS IN MIZORAM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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MZU REGISTRATION NO: 5675 of 2013

Ph.D REGISTRATION NO: MZU/Ph.D/668 OF 23.05.2014

DEPARTMENT OF BOTANY

SCHOOL OF LIFE SCIENCES

FEBRUARY, 2021

Ecology of common weeds and their allelopathic effect of Jhumland crops in Mizoram

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CERTIFICATE

This is to certify that the thesis work entitled**, "Ecology of common weeds and their allelopathic effect on Jhumland crops in Mizoram"**, submitted by J.C. Angel Lalrindiki (**Regd. No. MZU/Ph.D/668 of 23.05.2014**) in partial fulfillment of the requirement of the degree of Doctor of Philosophy in Botany is a record of bonafide work carried out by her under my supervision and guidance.

Aizawl: November, 2021

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DECLARATION BY THE CANDIDATE

I, **J.C. Angel Lalrindiki**, hereby declare that the thesis entitled "**Ecology of common weeds and their allelopathic effect on Jhumland crops in Mizoram**" is a work done by me and that the contents of this thesis did not form basis of any previous degree to me or to anybody else to the best of my knowledge. This thesis has not been submitted for any research degree in any other University/Institute by me.

This is being submitted to the Mizoram University for degree of Doctor of Philosophy in Botany department.

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Preface

Seeds are generally plants that grow out of place. They compete with other plants for food, space, shelter and nutrients. Most of the weed species were found in abundant during summer where rainfall, air temperature and relative humidity were high. The increasing density and frequency of weeds corresponds to increasing environmental factors. The climatic factors along with the growth and vigour of the weed species greatly influence the density and frequency of these weeds. During the course of experiment the germination percentage and seedling length of *Zea mays* against the different weeds i.e. *Ageratum conyzoides, Chromolaena odorata* and *Mikania micrantha* remain the highest and it is least suppressed by the weeds as compared to *Brassica campestris* and *Oryza sativa*. This shows that even in the presence of weeds it can still grow abundantly. The crop that gets affected and suppressed the most by the different weeds is *Brassica campestris*. The allelopathic effects of the selected weeds greatly influenced the growth and yield of *Brassica campestris.* The qualitative screening of phytochemical compounds present in *Ageratum conyzoides, Chromolaena odorata* and *Mikania micrantha* showed that they were rich in phytochemical constituents. It shows the presence of phenols, flavonoids, alkaloids, quinones, cardiac glycosides, terpenoids and tannins except saponins & anthraquinones. The presence of these chemicals are important for their survival. These chemicals in turn, effect the agricultural crops. Many of these chemicals have antioxidant, antifungal and antibacterial properties which can be exploited in the manufacture of certain drugs. Further studies are essential for isolation and characterization of the active antioxidant agents, which can be utilised to treat various oxidative stress-related diseases. It will ensure better protection and better quality crops. Thus, the study on diversity, ecology of weed, their allelopathic effects on agricultural crops as well as phytochemical properties becomes an important field. Since, the presence of weed is a nuisance for agricultural crops as they compete for nutrition as well as growing space, thus, understanding the weed's diversity and ecology is essential for weed management as well as for developing crop management models. This thesis deals with the study of diversity, phenology, allelopathic effects and phytochemical properties of weeds on crop production with reference to jhumland of Mizoram.

The thesis can be broadly classified into five chapters. Chapter 1 deals with general introduction and chapter 2 deals with review of literature. Chapter 3 deals with the location of the experimental site i.e. Tachhip which is located about 20 km from Aizawl. This chapter includes the general knowledge of the location, weather, soil type, and cropping system. Tachhip enjoys a pleasant weather almost throughout the year. Highest temperature was recorded at 32°C at the month of April. The air temperature is lowest in the month of December with minimum temperature of 8°C. The soils are mainly loose sedimentary formations, loamy to clay-loam. The soils are brown to dark brown, poor in bases, moderately acidic with pH ranging from 5.8-6.2. The soils are rich in moderate organic carbon content, high available potash and low available phosphate. The practice of shifting cultivation is still prevalent in Tachhip and the majority of population are subsistent farmers. Traditional shifting cultivation in the hilly slopes is the main livelihood of the people. Of the total area 21% is under paddy/seasonal crops. As high as 63% of the total crop area is under shifting cultivation. The crops grown in the jhum are mixed. Chapter 4 includes detailed experimental design and methodology. Chapter 5 deals with results, discussion and conclusion. This chapter includes the different meteorological parameters of the study site, weed diversity and phenology, the classification and morphological description of selected weeds, the allelopathic effects of *Ageratum conyzoides, Chromolaena odorata* and *Mikania micrantha* on agricultural crops such as *Brassica campestris, Oryza sativa* and *Zea mays*. It also includes statistical analysis using ANOVA and Correlation Coefficient. Lastly, this chapter deals with the study of phytochemical content of selected weeds.

To the best of my knowledge, this is the first time reported the study on the diversity, phenology and allelopathic effects and phytochemical study on weeds found in Tachhip. From the study, it can be concluded that weeds have a detrimental effect on agricultural crops. It also highlighted the diversity of weeds found in Tachhip, Mizoram and its potential for production of allelochemicals present in the weeds.

Acknowledgment

I would like to express my sincere appreciation to my supervisor Prof. F. Lalnunmawia for his guidance and continued support throughout the entire work. Without his immense knowledge and motivation this work would not be possible.

I would like to thank our Head of Department for providing the laboratory facilities required to complete my work. I am also thankful to Mizoram University for providing financial assistance in the form of UGC-MZU fellowship.

I am grateful to all my lab mates and my batchmates for always being there when I need assistance. I am grateful to Lalrampani Chawngthu, R. Vanlalpeka, Lalhriatpuia and P.C. Lalremruata for their advice and friendly support. Lalmuankimi Khiangte, Alex Zohmachhuana, Lalrammuana Sailo and Remruattluanga Hnamte for their guidance in my research.

I am forever indebted to my parents, J.C. Ramthanga and Jackie Ramthansangi and my husband, Zosangliana Ralte for their unconditional love and support throughout the entire work. Without their prayers and motivation this work would not be completed. I am also grateful to my siblings and friends for their emotional support throughout my research work.

Last but not the least, I am thankful to God for blessing me with good health. Thank you Lord for your protection and guidance throughout this journey.

I dedicate this work to my children, Skylar Zorinpuii Ralte and Brandon Zomuanpuia Ralte. Thank you for being my inspiration.

J.C. Angel Lalrindiki

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ABBREVIATIONS

°C	Degree Celsius
%	Percentage
µg	Microgram
±	More or less
Anon	Anonymous

BC	Before Christ
C	Carbon
cm	Centimeter
cv	Cultivar
Ed: (eds.)	Edition: editor(s) or edited
edn.	Edition
e.g.	Example
et al.,	*et alii:* and others
etc.	etcetera or cetera: and the others
g/gms	Gram(s)
ha	Hectare
i.e	*id est* (that is)
J	Journal
K	Potassium
Kg	Kilogram
m^2	Meter square
mg	Milligram
mm	Millimeter
ml	Millilitre
N	Nitrogen
Nm	Nanometre
No	Number
P	Phosphorus

p, pp.	Pages
ppm	Parts per million
RD	Rural development
sq.km	Square kilometer
sp., spp	Species (singular); species (plural)
var.	Variety
vol.	Volume
w/v	Weight in volume

Chapter – 1

Introduction

1.1 General

Weeds are generally plants that are out of place, that adversely affect crop growth, and that for a variety of reasons are difficult to control (Rao, 2000). Since both weeds and crops are plants, they have basically the same requirements for normal growth and development. They require and compete for an adequate supply of the same nutrients, moisture, light, heat energy (temperature), carbon dioxide and growing space. Weeds compete successfully with crop plants by (i) being more aggressive in growth habits; (ii) obtaining and utilising the essentials of growth at the expense of the crop plants and (iii) in some cases, secreting chemicals that adversely affect the growth and development of the crop plants. The reduction in yield due to weed-crop competition mainly depends on weed species and their densities as well as crop species. As the distribution and infestation intensity of each weed is different, so the extent of crop yield reduction will mainly depend on the number and kind of weeds found in the field (Frisbie *et al*., 1989). Competition and the presence of vegetative and reproductive parts of weeds at or near to harvest have the greatest adverse affect on crop quality (Anderson, 1983).

1.2 Weeds infestation in Jhumland

In Northeast India, it is locally called jhum (meaning 'to group or work together'). Shifting cultivation, also known as Jhuming has become a way of life and it is deeply associated with many cultural activities in N.E India in general and Mizoram in particular. In their traditional practice, farmers slash an area of forest and burn the vegetation in situ after it dries. This is followed by manual seeding and cultivation of agricultural crops, mostly for one or occasionally two years, and then abandonment of the land to allow the restoration of soil fertility through natural processes.

About 60% of the population in Mizoram is believed to depend on shifting cultivation for their livelihood (Anonymous, 2004). Shifting cultivation in Mizoram is characterized by steep slopes; about half of the total land area has slopes of 40% to 100%. It therefore stands out from the other northeast Indian states in the need to perform the many activities of shifting cultivation, like slashing, burning, sowing, weeding and harvesting, on these steep slopes. The state also suffers huge losses, of about 60 tons per hectare, of fertile soils every year through erosion – a problem that requires meticulous scientific understanding (Tripathi *et al*., 2018). Selecting forest patches and clearing vegetation from it, takes place generally in the months of December and January. The herbs, shrubs, twigs and branches are burnt in February and March. In the months of April and May, seeds are shown, prior to the onset of monsoon. Generally, seeds include cereals, vegetables and oil seeds (Sati and Rinawma, 2014). Weeding takes place three times a year and on each occasion it is given a specific name in Mizo language. They are *hnuhlâk, hnuhhram* and *pawhchhiat.* Harvesting begins in the month of July and lasts till December, depending upon the crops. In Mizoram, the predominant practice is to crop a *jhum* for one year. The forefathers of the Mizo people lived a nomadic lifestyle characterized by the practice of Jhuming. This practice has been passed down from generation to generation. It continues today because of the transfer of knowledge and cultural tools from earlier generations, providing the opportunity for the pursuit of agrilculture with no initial cost. There has been lack of productive and economic alternatives. Due to these reasons, shifting cultivation has a deep impact on the socio-economic culture of the Mizo society. Many traditional festivals are named and observed on the basis of various stages of shifting cultivation, and of the 12 months of the lunar calendar, six months are named for different stages of swidden farming (Tripathi *et al*., 2018).

Several cultural practices to control weed include delayed crop seeding, tillage, black fallow, crop rotation, hand weeding and competitive crops. Effective cultural methods are cost efficient, easy to adopt and no technical skill is required. It maintained crop-weed ecosystem. However, a farmer's final choice of weed control practice will include available equipment, time, market and soil erosion in addition to potential weed resistance (John D. Nalewaja, 1999). Cultural methods alone cannot control weeds, but help in reducing weed population.

1.3 Phenology of weeds

Phenology is the study of the seasonal timing of life cycle events (Rathcke and Lacey, 1985). The timing of emergence, growth and sexual reproduction is highly important for the success of invasive weeds. The phenology of a weed is mediated by the interaction of internal factors with external environmental signals such as temperature, day length or drought (Godoy *et al*., 2009; Dincer *et al*., 2010). Therefore, understanding the factors that control phenological variability is crucial for the design of durable weed management practices (Dincer *et al*., 2010). Alm *et al*., (1991) defined phenology as the study of periodic biotic events that can occur at different levels, such as organ, tissue, or cell. Phenology is essentially the study of the dynamics of development, with emphasis on the inherent schedule of events rather than on the (preceding) processes causing the events (Alm *et al*., 1991). As for most plants, weeds and crops have a high degree of phenotypic plasticity, therefore plants with the same genotype at the same growth stage may appear with different morphology, depending on their environmental history during growth. In many instances, apparent variability among plants is reduced when developmental stages are expressed in terms of accumulated environmental factors rather than chronological (calendar) time. The implication of such behavious is that phenology is largely regulated by environment and therefore may be quantified.

This characteristic of growth rates emphasizes the need to record phenological events during the early stages of development, particularly when trying to account for direct causal effects, and implies that predictions of the outcome of early differences will have large errors (Alm *et al*., 1991). Temperature and light are probably the major factors regulating plant phenological response; thus, most responses focus on thermal time accumulation, day length and vernalization (Hodges, 1991; Hodges & Ritchie, 1991; Cousens *et al*., 1993a). Invasive weeds can be non-indigenous and indigenous species that can become overly abundant in a plant community (Booth, 2003). Biological processes and characteristics that are most important for weeds to thrive are dependent on reproduction, dispersal, phenology and etc. (Bryson and Carter, 2004).

Plants vary widely in their growth and phenological behaviour. Such differences can be attributed partly to innate species traits (Grime and Hunt, 1975). Many studies have demonstrated the plant attributes explaining growth and phenology variation, such as physiology (Walters *et al*., 1993), morphology (Cornelissen *et al*., 1996), anatomy (Van Arendonk and Poorter, 1994), nutrient partitioning (Cornelissen *et al*., 1997), chemical composition (Van Arendonk and Poorter, 1994) and stem xylem traits (Castro-Diez *et al*., 1998).

Phenological studies provide information on functional rhythms of plants and plant communities (Ralhan *et al*., 1985), where various phenological events may be timed to biotic and/or abiotic environmental conditions (Estabrook *et al*., 1982). Many plant processes are a function of the phenological stage of the plant. Assimilate partitioning, leaf distribution, leaf area development, plant height and leaf duration, for example, are in□uenced by phenological phase (Wall and Morrison, 1990; Tworkoski, 1992; Ghersa and Holt, 1995). In turn, the effect of phenological phase on these processes in□uences the outcome of weed crop competition (Deen *et al*., 1998).

1.4. Allelopathic effects of weeds

Rice (1974) defined allelopathy as any direct or indirect harmful effect by one plant to another through the production of chemical compounds, which escape into the environment. Hans Molish (1937) used the term to describe biochemical interactions that inhibit the growth of neighbouring plants. He refered allelopathy to biochemical interactions between all types of plants including microorganisms. His discussion indicated that he meant the term to cover both detrimental and beneficial reciprocal biochemical interactions. Molisch's used the term and defined allelopathy as any direct or indirect harmful effect by one plant (including microorganisms) on another through production of chemical compounds that escape into the environment. Rice (1984) defined allelopathy as any direct or indirect (harmful or beneficial) effect of a plant, including microbes, or another plant through release of chemicals that escape into the environment. It includes both inhibitory and stimulatory effects (Rice 1986).

According to Harper (1977), allelopathy is an interference mechanism, in which live or dead plant materials release chemical substances, which inhibit or stimulate the associated plant growth. The plant may exhibit inhibitory or rarely stimulatory effects on germination and growth of other plants in the immediate vicinity. Plants may compete with one another by biochemical interactions which may occur as a result of one species of plant secreting a growth inhibitory or stimulatory substance into its environment which is absorbed by another. Such interaction results in the inhibition of crop seed germination, formation of abnormal crop seedlings, prevention or reduction of root elongation, and cellular disorganization in roots, among other adverse effects. Allelopathy is an interference mechanism in which live or dead plant materials release chemical substances, which inhibit or stimulate the associated plant growth (May and Ash, 1990). In North-East Himalaya, agricultural crop fields are extensively been invaded by weeds. As the phytotoxic studies of weeds on agricultural crops have not been documented in a vast scale from this part of the world, an attempt has been made to study the phytotoxic influences of some dominant weeds on growth of some agricultural crops.

Most of the weed species have inhibitory effects on crops; yet, some weed species also exhibited stimulatory effects on the seed germination, growth and yield of crops. The weeds influence the crop plants by releasing phytotoxins from their seeds, decomposing residues, leachates, exudates and volatiles (Narwal, 2004). Even reduction in photosynthetic rate due to reduced leaf may also lead to reduction in root length and shoot length (Meissner *et al*., 1979). Most research on allelopathy has focused on the effect of interaction among weed species (Narwal, 1994), weed and crop (Rice, 1984), and crop species (Chung and Miller, 1995).

Weeds are known to exhibit allelopathy by releasing water soluble allelochemicals from leaves, stems, roots, rhizomes, flowers, fruits and seeds (Batish *et al*., 2007). Allelochemicals emancipated as residues, exudates and leachates by many plants from leaves, stem, roots, fruit and seeds reported to interfere with growth of other plants (Asgharipour and Armin, 2010). These chemicals products mainly affect plants at seed emergence and seedling levels (Alam and Islam, 2002; Hussain *et al*., 2007; Naseem *et al*., 2009). The allelopathic potential of several weeds have been studied in the laboratory by Bhowmik & Doll, 1984. Batish *et al*., (2007) conducted experiment using residue of *Chenopodium murale* on the growth of

chickpea and pea and found that their root and shoot length significantly decreased. Several workers have shown that allelopathy plays an important part in weed and weed interaction (Tajuddin *et al*., 2002) and weed crop interaction (Colton & Einhellig, 1980). There are several reports that some weed species have allelopathic effects on seed germination and seedlings growth of economically important crop plants (Mulatu *et al*., 2009). However, Anderson (1983) stated that allelopathic influences on crops will ensure better crop production.

1.5 Phytochemical contents of weeds

Phytochemicals are non-nutritive plant chemicals that have protective or disease preventive properties. Plant produces these chemicals to protect itself but recent research demonstrates that many phytochemicals can protect humans against diseases. The roles of plants in maintaining health is well documented (Moemann, 1996). Plants produce a large variety of secondary metabolites like phenols, tannins, terpenoids, alkaloids, polyacetylenes, fatty acids and steroids, which have an allelopathic effect on the growth and development of the same plant or neighboring plants. Considerable knowledge has been obtained concerning the chemicals involved in allelopathy (Rice 1984; Narwal and Tauro 1994).

Rice (1984) and Putnam (1983) observed that chemicals with allelopathic potential i.e. allelochemicals are present in the root, rhizome, stem, leaves, flowers, inflorescence, pollen, fruits and seeds of plants. They further stated that leaves are the major sources of these allelochemicals. Rice (1984) stated that allelochemicals are known to affect numerous physical and biochemical processes in plants. According to Gniazdowska and Bogatek (2005), the effects of allelochemicals action are detected at molecular, structural, biochemical, physiological and ecological levels of plant organization. The phytochemicals like flavonoids, alkaloids, amino acids, glycosides, saponins, steroids, tannins and many others present in the plants are the great reservoirs of many new and potential drugs. Screenings for biological activity using simple bioassays have now been added to give a better identification of the usefulness of weeds. The phytochemicals like alkaloids, saponins, flavonoids and phenolic compounds present in plants are responsible for many biological activities (Saswade, 2019).

1.6 Weed management

Anthropogenic disturbance of natural ecosystems is one of the biggest threats to biodiversity (Vitousek *et al*., 1994, 1997; Zhang and Fu, 2009), and impacts are often aggravated when disturbance facilitates invasion by weedy exotic species (Mack *et al*., 2000). Weedy exotic plants and other aggressive early successional species are important barriers to reforestation. Such species can delay or prevent succession from continuing to a desired restoration end point (Aide and Cavelier 1994; Aide *et al*., 1995, 2000; Chazdon 2003; Guariguata and Ostertag, 2001; Hobbs and Huenneke, 1992; Nepstad *et al*., 1996). Reducing the abundance of invasive grasses is then critical to decrease fuel loads and allow the establishment of trees in the system. Since mechanical or chemical weed control can be prohibitively expensive, successful restoration may sometimes depend on the ability of planted species themselves to suppress weeds (Hooper E. *et al*., 2002; Jones *et al*., 2004; Wishnie *et al*., 2007).

Certain functional traits may be key to the success of restoration species. Trees that rapidly produce deep shade may outcompete shade-intolerant exotic species (Jones *et al*., 2004; Joo Kim *et al*., 2008). Some planted trees can also affect growth of understory plants through their effects on nutrient availability (Ashton *et al*., 2008; Dakora and Phillips, 2002; Pearson and Vitousek, 2001) and soil pH (Haynes 1983). Less explored, however, is whether some tree species produce allelochemicals that inhibit germination or growth of plants. Native species that produce allelopathic compounds may be useful to control exotic weeds as part of forest restoration efforts. Agroforestry is an approach to sustainable land management that integrates trees with agricultural crops and/ or livestock (Rizvi *et al*., 1999). Inhibition of understory growth in the absence of competition for light, water, or nutrients suggests that allelopathy may play a role in suppressing growth of some plants in agroforestry (Bhatt *et al*., 1997, 2010; Chou and Kuo, 1986; Lodhi and Rice, 1971). In addition to the interspecific allelopathic effects of agroforestry trees on crops, some studies have documented inhibitory allelopathic effects of trees on weed germination and growth (Babu and Kandasamy, 1997; Chou and Kuo, 1986; Kaur *et al*., 2011; Matok *et al*., 2009; Williams and Hoagland, 2007; Wu *et al*., 2011).

Plant communities play an important role in sustainable managements by maintaining biodiversity and conserving the environment (Kandi *et al*., 2011). A major objective of most weed community ecology studies has been to identify patterns of species composition and distribution and to interpret these patterns in relation to known or presumed gradients in the environment (Fried *et al*., 2008). Quantitative analysis, especially quantitative classification methods and ordination techniques, has been widely used to indicate the ecological relationships between vegetation and environment (Zhang and Zhang, 2000). Moreover, floristic studies are not only important to know the variety of plants present in an area, but also socio-economically significant. They provide shelter, food, medicine and everything for the human being and other species of that area. Vegetation has been widely used to describe habitat characteristics, water quality and make predictions about the presence and composition of the surrounding communities (Appelgren and Mattila, 2005). Change in the existent components of a natural ecosystem, especially plants and soil, leads to gradual variations in the shape, composition and structure of such communities. Therefore, studying the classification and the inter-relation between the different plant communities in response to the environmental factors are in demand (Jafari *et al*., 2003). However, Zegeye *et al*., (2006) showed that the interdependency of vegetation type and soil chemical properties lead to a variety of species, vegetation types and distribution of plant communities.

Weed communities are affected by many factors such as soil characteristics (Fried *et al*., 2008, Pinke *et al*., 2010). It was found that sand, $CaCO_3$, OC, PAR, carbonates$^-$, EC and K were the most effective soil variables. Soil texture may affect soil or productivity via influence on the soil water holding capacity, infiltration rate, moisture availability for plants and consequently plant nutrition (Sperry and Hacke, 2002). Weeds are not just unwanted plants, they should be regarded as being of potential commercial value and useful in a range of ways such as food, medicine, agriculture, ornamentals, pollution control (Zimdahl, 2007). Eradication of weeds from our environment is rather difficult as it consumes much money, labour and time. Hence, combating the problem of weeds by exploiting their beneficial potentials is receiving increasing attention among the scientific community around the globe.

Weed management tactics that rely on predictions of weed germination patterns can be classified into three general groups. One tactic uses predictions of

weed germination in order to plant crops when weed germination will not occur (e.g. shifting from spring or summer crops to winter-grown crops to avoid spring germinating weeds). The second tactic uses germination predictions to improve timing of seedling management (e.g. pre-plant tillage or chemical control). The third tactic uses predictions of the major waves of weed germination in order to make use of the competitive advantage of early crop establishment e.g. early crop planting versus late planting (Ghersa and Holt, 1994).

The success of weed management programs that are based on ecological principles and weed biology depends largely upon a better understanding of how environmental factors affect life history traits, growth and competitive interactions of crops and weeds, and particularly upon the ability to predict crop and weed phenology (Ghersa and Holt, 1995). Phenological predictions would allow more accurate estimates of the timing and effects of weed competition on crop yield in particular agronomic systems and thus allow more speci□c control measures to be developed (Alm *et al.*, 1991; Ritchie, 1991).

In many cropping system where nutrients and water are supplied, light is often the only factor that becomes limiting to plant growth. In addition to regulating photosynthesis, light regulates many other aspects of plant growth and development such as seed dormancy, germination, phototropism and □owering (Radosevich *et al*., 1997). Knowledge about responses of weed growth and development to abiotic factors, and their links with biotic interactions, is needed to develop new management strategies based on ecological principles (Altieri and Liebman, 1988; Cousens *et al*., 1991).

Researchers in weed ecology have largely concentrated on biotic interactions in agricultural ecosystems, while emphasizing the high degree of variability in weed responses as a problem in achieving good weed management or as background noise (Cousens *et al*., 1991). This focus on biotic interactions and the development of current management tactics through empirical methods, mainly herbicide screening, has resulted in limited understanding of environmental variables that cause weed phenotypic variation (Wilson & Wright, 1990). Nevertheless, experimental evidence indicates that by understanding the variables that drive specific phenotypic responses, new approaches and more long-term solutions for weed problems can be

developed. Management opportunities can be found in phenotypic responses such as those related to seed germination, development of canopy architecture, flowering, and seed production and dispersal (Radosevich and Holt, 1984; Patterson, 19185; Altieri & Liebman, 1988; Ballare *et al*., 1992; Ghersa *et al*., 1994).

Competition for resources is a major factor causing reduction of crop yield by weeds (Zimdahl, 1980; Radosevich & Holt, 1984). A large body of research has been published describing the effects of weed competition on crops (Radosevich and Holt, 1984). In contrast, studies on mechanisms of weed and crop competition are few (Roush & Radosevich, 1985; Joenje and Kropff, 1987; Holt and Orcutt, 1991). The factors important in determining competitive success are biological, environmental, and proximity factors (Bleasdale, 1960; Ross and Harper, 1972; Harper, 1977). In an agricultural environment where there is a low level of environmental stress, frequent disturbance, and regular spacing of crop plants, biological factors are especially important in competition (Holt and Orcutt, 1991). Comparative studies of growth and development of weeds and crops are essential in order to quantify, predict, and manage crop yield losses caused by weeds (Cousens *et al*., 1993a). The relationship of plant characteristics to competitive inter- actions has been a focus of ecologists for many years, but quantitative approaches are not common (Austin, 1982; Grace, 1990). Prediction of different phenological aspects of crops, weeds and other pests with simple thermal equations appears to be a good tool for understanding plasticity and for providing practical solutions to crop and pest management problems.

We need to explore new innovations that reduce petrochemical, tillage, fertilizer, and pesticide inputs, while maintaining crop yields and profitability, and at the same time stimulating the formation of new opportunities for rural communities. The phenology of plant communities can be studied by dealing with particular life-history stages separately such as leafing, flowering, fruiting, seed dispersal and germination (Michael, 1998). It will help in understanding weed growth and it can be implemented on crop management. Further study of the phenology of weed is required as it has not been properly recorded in Mizoram.

Study of floristic composition, seasonal variation and phenology of weed is required as these have not been properly recorded in Mizoram though there are

numerous reports on the floristic composition and weed flora of agricultural fields with reference to other parts of the country (Pal & Bhattacharya, 1956; Chakravarty, 1957; Majumdar, 1962; Dutta & Maiti, 1964; Tripathi, 1964; Mahapatra *et al*., 1965; Bandopadhya, 1972; Neogi & Rao, 1980). For effective control and preventive measures of these unwanted plants, it is essential to have knowledge of their floristic composition, their seasonal variation and phenology. In North-east India, where majority of the population still relies on shifting agriculture as a main source of income, weeds play an important role in the economy of the region. It is more so in North-east states like Mizoram where 'Jhumming' or shifting cultivation is still prevalent and half a population of the population still relies on Jhum cultivation for their livelihood.

A number of studies were made on different aspects of weeds and its management. However, critical review of literatures suggests that there is a limited study on diversity, ecology of weed, their allelopathic effects on agricultutural crops as well as phytochemical properties with reference to jhumland of Mizoram. Since, the presence of weed is a nuisance for agricultural crops as they compete for nutrition as well as growing space, thus, understanding the weed's diversity and ecology is essential for weed management as well as for developing crop management models. Thus, it is proposed to study diversity, phenology, allelopathic effects and phytochemical properties of weeds on crop production with reference to jhumland of Mizoram.

1.7 Objectives

The specific objectives of the present study are as follows:

1. To study the diversity, density, dominance and phenology of weed in traditional jhumland of Mizoram.
2. To study the allelopathic effect of aqueous extracts of weeds on the seed germination and seedling growth of selected crops.
3. To analyse the phytochemical content of the three selected weeds.
4. To record meteorological parameters and soil physico-chemical properties of the experimental site.

Chapter – 2

Review of Literature

2.1 General

A number of research works had been carried out on the ecology of several weeds as well as its allelopathic effect at international, national and regional level. In this chapter, an attempt has been made to review the relevant literatures on weed diversity and its phenology, allelopathic effect of several weeds as well as study of phytochemical constituents of weeds and its uses are discussed below.

Weeds are the most severe and widespread biological constraint to crop production and cause invisible damage till the crop is harvested. According to Gupta and Mittal (2012) weeds are undesirable plants which compete with main crops in the growth media for nutrients, moisture, space, light and hamper the healthy growth ultimately reducing the growth and yield both qualitatively and quantitatively. They exhibit allelopathy, competition and parasitism (Hussain, 1980; 1983; Hussain *et al*., 1985; Hussain and Khan, 1987). This competition increases in the wet, hot, and humid monsoon season (July) and the ability of weeds to compete successfully with crops for light, water and nutrients depends on several interrelated factors, and these include the timing of weed emergence in relation to crop emergence, the growth form of the weeds, and the density of the weeds present in the crop (Tauseef *et al*., 2012). According to Memon *et al*., (2007), the different environmental conditions determine the specific weed spectrum, composition and population of each region.

Sati and Rinawma (2014) stated that in Northeast India, mainly in Mizoram, shifting cultivation is known as *Jhum* or *Jhuming* agriculture, the whole process of *Jhuming* agriculture is called '*Jhum* cycle' and the marginal farmers, who are involved in its practice, are called *Jhumias.* After a complete *Jhum* cycle, the *Jhumias* shift their *Jhumlands* in other forest areas, and this process has been continuing for centuries. Because, soils of *Jhum* plots are nutrient-poor, production of crops decreases significantly after a couple of years, at which point the *Jhumlands* are abandoned and new plots (fallow land) are cleared and planted. In Mizoram, Maithani in 2005 stated that about 54% rural people are engaged in practicing shifting cultivation for carrying their livelihood and about 58,000 households were

engaged in practicing shifting cultivation by 2000. Meanwhile, Govind Ballabh Pant Institute of Himalayan Environment and Development (2006) reported this figure as 50,000 households.

2.2 Phenological study in weed management

Phenological predictions of flowering, seed development and dispersal are available for some weeds and could aid in developing these management practices. One approach for these predictions has been the use of simple thermal time (DD) relations, without expressing them as equations, from which a value of accumulated DD is given for a particular event. This type of prediction was used, for example, by McCarty (1985) for prediction of the date of first bloom of large flowered taxa of *Carduus,* by Pawlak *et al*., (1990) to describe *D. stramonium* capsule age from anthesis and its relation to germination of non dormant seeds, and by Sattin *et al*., (1992) to document the beginning offlowering in *Abutilon theophrasti.*

The life-span of one weed can be several times longer than that of another. For instance, Schwerzel (1970) stated that it took *Galinsoga parviflora* only four days to germinate and less than 50 days to shed seed. *Leucas martinicensis,* on the other hand, took four times as long to germinate and from two to three times as long to shed. Mature seeds of both crop and weed species exhibit phenotypic variability depending on their environmental history during seed production and maturation. This variability becomes evident in seed germination responses during tests under homogeneous environments (Bewley & Black, 1982; Gutterman, 1985; Simpson, 1990). In addition, seeds undergo profound physiological changes during after-ripening, which are also regulated by environmental variables (Heydecker, 1973; Bewley & Black, 1982; Karssen, 1982: Egley & Duke, 1985; Ballare *et al*., 1992). Both aspects of seed phenology are relevant for management purposes, because persisence of the weed seedbank in the soil and seed germination dynamics depend on the quality (i.e., physiological behaviour) of the seeds at dispersal (Ballare *et al*., 1987). Similarly, *D. stramonium* L. seeds harvested within 4 weeks after anthesis are smaller and less viable than those harvested later. Both of these species are important weeds in (*Glycine max* (L.) Merr.) crops. In terms of management, reducing total input of weed seeds to the soil seedbank may be a more

rational practice than trying to manage quality of seed inputs (Norris, 1992). This strategy appears to be reasonable, particularly considering that for most weeds, the existence of a soil seedbank in highly disturbed arable land is dependent on yearly inputs of seeds (Cavers & Benoit, 1989).

According to Ballare *et al*., (1987), reduction in seed inputs can be achieved by curtailing seed production and/or harvesting seeds before and/or after they are shed to the ground. These objectives can be performed biologically, by reducing production through foraging, crop competition or seed predation, or culturally by mowing, combine harvesting or treatment with herbicides. In either case, reduction in both seed inputs to the soil seedbank and seed quality may be achieved simultaneously. For example, simultaneous reduction in quantity and quality would be expected for *Datura* spp. in precisely scheduled crops, with either an early harvesting date or a normal harvesting date in late sown soyabean. In these cropping systems *Datura* spp. seed input to the soil seed bank could be reduced by adequately regulating the combine harvester to prevent dispersal of mature seeds. As a result, the dispersed seeds would mostly be immature, thus lightly coloured or small with lower viability than mature seeds. Phenological relationships between flowering and seed physiological behaviour have been described for many other weed species (Gutternan, 1985; Simpson, 1990), thus expanding the potential use of this weed management strategy. In crop-weed management systems, crop genotypic and field environmental variables are manipulated in order to take advantage of crop-weed-specific phenotypic responses, which may lead to higher crop yields in weed infested fields and reduction of herbicide use (Ballare *et al*., 1992; ForceIla *et al*., 1993; Ghersa *et al*., 1993a; BenechAmold and Sanchez, 1994).

2.3 Allelopathic effect of weeds on crops

Water extracts from several species of the family Asteraceae and the soil on which they were grown have been shown to inhibit germination and growth of other plant species (Inderji & Dakshini, 1994; Kil & Yun, 1992; Maccas *et al*., 1993), Narwal *et al*., (2002) stated that the aqueous extract of the root of *Helianthus annus* delayed and inhibited the germination and seedling growth of linseed (*Linum usitatissium* L.) and mustard (*Brassica juncea* L.). Aqueous extracts from the leaves

of *Helianthus tuberosus* L. *Xanthium occidentale, Uctuca sativa* and *Cirsum japonica* all in the Asteraceae family inhibited the root growth of Lucerne (Chon *et al*., 2003). Mulatu *et al*., (2006) reported that aqueous extract of P*arthenium hysterophorus* leaves and flower inhibited seed germination of lettuce. Otusanya *et al*., (2007) reported that the growth of *Amaranthus cruentus* was inhibited by aqueous extract of *Tithonia diversifolia.* Javed and Asghari (2008) found that the leaf extract of *Helianthus annus* inhibited the rate of germination of wheat seedlings. Methanolic extract *of Xylocarpus granatum* Koen inhibited the growth of wheat rootlets by about 91.9% and shoots by 89.4%, at 250 □g/ml concentration (Shahid-Ud-Daula & Basher, 2009). Aqueous and methanol extracts of *Withania somnifera* was found to markedly suppressed the germination, root and shoot growth of *Parthenium hysterophorus* (Arshad, 2011).

The dominance of *Eupatorium riparium* Regel, a notorious weed of family Asteraceae over other plant species in nature has been attributed to its allelopathic effects (Raj and Tripathi, 1982). They stated that two annual weeds, *Galinsoga ciliata* (Raf.) Blake and *G. parviflora* Cav. (Asteraceae), showed suppressed growth and reduced population density when grown in the neighbourhood of *E. riparium.* Not only the germination of seeds of the *Galinsoga* spp. soaked with extracts and leachates of *E. riparium* was reduced but the growth of plumule and radicle emerging out of such seeds was also inhibited. *E. riparium* induced soil toxicity by releasing toxins through leaching during its active growth and during the decay of litter. As a result, the seed germination and growth of the *Galinsoga* species were reduced considerably (Raj and Tripathi, 1984).

Lantana camara is listed as one of the world's worst weeds (Holm *et al*., 1977). Its proliferation and spread are attributed to a number of factors including a large amount of seed production, reduced use of hand-weeding, high tolerance to currently available herbicides, and decreased competition from other weeds (Philips and Tucker, 1976). Leaves and seed of lantana are toxic to grazing animals and also poisonous to humans (Morton, 1971; Pass, 1991). Limited research has been conducted on the allelopathic effect or phytotoxicity of lantana to other plants (Tukey, 1969). Aqueous extracts of root, stem, leaf, or inflorescence of lantana inhibited spore germination of fern (Wadhwani and Bhardwaja, 1981). *Chromolaena*

odorata (Siam weed) is a herbaceous perennial, diffuse, scrambling shrub that is mainly a weed of plantation crops. It is a heavy feeder on nutrients which are then locked up in rather large quantities of slow-rotting litter. Aqueous extracts of lantana were reported to reduce germination of milkweed vine (Achhireddy and Singh, 1984) but little is known about phytotoxicity of living Siam weed or its dead residues to other plants. Considerable amounts of phenolic compounds were identified in lantana leaves (Jain *et al*., 1989). Dry weight of Chinese cabbage (*Brassica chinensis* L) and chilli (*Capsicum frutescens* L) was reduced when these crops were grown in Siam weed-contaminated soil. Germination of Chinese cabbage, chilli, and rape (*Brassica juncea* L.) decreased progressively when exposed to increasing concentrations of aqueous lantana extract. However, the lantana extract at full strength (66.7gL $^{-1}$) did not reduce germination of spinach and cucumber seed. Siam weed extract, when applied at full strength to seed of spinach, Chinese cabbage, rape, and chilli, reduced germination by 10, 12, 21, and 19% of control, respectively. Full-strength extract of Lantana and Siam weed decreased seedling length and fresh weight of all crops (Sahid and Sugau, 1993). Growth of corn was reduced by lantana while wheat was not affected as measured by all the growth parameters. This reveals an example of species- specific growth regulating effects of allelochemicals (Mersie and Singh, 1988).

Life span of annual weeds is short compared to perennial weeds (Zimdahl, 1993). Relative timing of crop and weed emergence has also been correlated to crop yield loss (Forcella, 1993). Investigations were carried out by Inderjit and Dakshini to understand the involvement and mode of operation of allelopathy in an annual weed, *Polypogon monspeliensis*. Comparative studies of soils associated with and without the weed under field conditions revealed that there was no significant difference in toxicity of the two soils, and thus the possibility of its allelopathic effect on crops grown in the same season could be ruled out. However, soil amended with weed straw had significantly higher total phenolics including higher relative concentrations of phenolic fractions that were not detected in unamended soil. Phenolic fractions significantly affected the seedling growth of radish and cluster bean. It is likely that *P. monspeliensis* did not interfere chemically with the crops cultivated during the same season, but interfered with the following season crop through incorporated straw. These

results indicate how a monocarpic annual such as *P. monspeliensis* can be allelopathic under field conditions and allelopathic potential can be managed (Inderjit and Dakshini, 1995).

Weeds cause greater loss in soybean production than all other pests combined. Weed interference with crop plants may result from competition or allelopathy. Allelopathic effects of weeds on legume-rhizobia-symbiosis is poorly understood. Of about 60 individual weed species that commonly infest soybean fields in the USA**,** 50% of them have been demonstrated to have allelopathic potential (McWhorter and Patterson, 1979). Aqueous extracts of some weeds, root exudates, leaf-leachates and decaying plant residues were found to be toxic to rhizobia in vitro, and adversely affect nodulation and N-fixation in white clover (*Trilolium repens*), red kidney beans (*Phaseolus vulgaris*) and Korean lespedeza (*Lespedea stipulacea*) (Rice, 1964; 1971; Rice *et al*., 1981). Crop residues left on the ground have generally been found to cause phytoxicity (Cochran *et al*., 1977). However, sorghum residue incorporated into soil was found to inhibit weeds but enhanced growth of snapbean (Putnam, 1983).

The collective data presented by Mallik and Tesfai (1988) indicate that both residues and extracts of sunflower (*Helianthus annuus*) and particularly of lambsquarters (*Chenopodium album*) at certain concentrations was highly inhibitory to growth and nodulation in soybean (*Glycine max* cv. Essex). Similar inhibition of growth and nodulation in soybean and other legumes by plant residues, their extracts, leaf leachates and root exudates has been reported by others. For example, Weston and Putnam (1986) found that both living and herbicidally killed quackgrass (*Agropyron repens*) significantly reduced growth, nodulation and N-fixation in soybean and three other legumes. The same authors also found that quackgrass residue and its water extract inhibited germination and growth of three legume seedlings including soybean, and root hair formation in snapbeans (*Phaseolus vulgaris*). Putnam (1983) reported that mulching of sorghum residue stimulated growth of a soybean but inhibited the weed species. The seed germination of tobacco was influenced differently by various concentrations of two weed species (*Digera muricata* Mart. and *Chinopodium murale* L.) water extract. With increasing concentration of weed extracts the root

lengths as well as the shoot lengths were gradually decreases (Khumbar and Shah, 2012).

The reduction of crop yield by weedy species has long been attributed to competition for available water, nutrients, etc. Little work has been done showing allelopathic effects of weeds on crop plants. However, there is considerable evidence that some crop plants are inhibited by known phenolic compounds (Floyd and Rice, 1967; Einhellig, 1971; Kuan, 1971; Olmsted and Rice, 1971). *Rumex cripus* strongly inhibit grain, sorghum and corn (Einhellig and Rasmussen, 1973). It is important to note the effectiveness of the low concentrations of phytotoxins used in the seed germination bioassays. This inhibition of relatively large seeds seems to justify the conclusion that *R. crispus* can be inhibitory even if small quantities of the phytotoxins are released by leaching.

2.4 Role of phytochemical constituents in weeds

Several studies were made on the phytochemical constituents of weeds and its uses. Qualitative analysis of *Eichhornia crassipes* (Mart) Solms commonly known as water hyacinth have revealed the presence of various components of medical importance including tannins, phlobatanin, steroid, terpenoid, alkaloid, flavonoid, phenolic contents, quinone, anthraquinone and cardiac glycosides. Because of the rich diversity of this aquatic plant it is expected that screening and scientific evaluation of plant extracts may prove beneficial for the mankind along with the management of the weed. The result obtained indicates that though the plant is an aquatic weed is good services of phytochemicals needed for maintenance of good health and can also be exploited in the manufacture of drug (Dubey V *et al*., 2010).

The usefulness of the plant materials medicinally is due to the presence of bioactive constituents such as alkaloid, tannin, flavonoid and phenolic compounds (Cowan, 1999). Alkaloids play some metabolic role & control development in living system (Edeoga and Eriata, 2001). They are also involved in protective function in animals and are used as medicine especially the steroidal alkaloids (Stevens *et al*., 1992). Tannins are known to inhibit pathogenic fungi (Burkill, 1985). Studies by Kim *et al*., and Okwu (Kim *et al*., 1994; Okwu, 2004) revealed that flavonoids apart from their antioxidant protective effects, inhibits the initiation, promotion and progression

of tumors. Saponins are a class of chemical compounds which may serve as antifeedants and to protect the plant against microbes and fungi. The antifungal and antibacterial properties of saponins are important in cosmetic applications in addition to their emollient effects (Cheeke, 1998). They help to prevent cancer and increase the efficiency of vaccines. Terpenoids have a large and diverse role in antibacterial activity. They defend many species of plants, animals and microorganisms against predators, pathogens and competitors (Gershenzon and Dudareva, 2007). Tannins are polyphenolic compounds and are widely distributed in many species of plants, where they play a role in protection from predation, and perhaps also as pesticides, and in plant growth regulation (Ferrell and Thorington, 2006). Anthraquinone is an organic compound which acts as an effective repellent. The activity reported for coumarins includes anti-HIV, antitumour, anti-hypertension, anti-inflammatory, antiseptic, analgesic and is also used in the treatment of asthma (Moreland and Novitzky, 1985). Flavonoids extent antimicrobial activity in the healing of wounds and in the treatment of skin diseases (Barnabas and Nagarajan, 1988). They also play significant role as hypoglycaemic, antioxidant, anti-inflammatory and anticarcinogenic activity (Anila and Vijayalekshmi, 2002). *Dracaena manni* contains a variety of phytochemicals–alkaloids, glycosides, flavonoids and tannins (Banso and Adeyemo, 2007). These phytochemicals also reported to have growth inhibitory effect on *Eschericha coli, Proteus vulgaris, Staphylococcus aureus and Streptococcus pyrogenes,* thereby making the plant a potential antimicrobial agent. Phytochemical screening of fruit peel of Musa paradisiacal revealed that the extract contains alkaloids, flavonoids, phenols, saponins and tannins (Okechukwu *et al*., 2012).

Tithonia diversifolia (Hemsl) A. Gray commonly referred to as Mexican sunflower is a member of the family Asteraceae. It is a perennial broad-leaved weed which grows to about a height of five meters or more and varies from highly branched low population variety to unbranched high population variety. Imeokpara and Okusanya (1994) observed that most farmers find it difficult to manage *Tithonia diversifolia* infestation in most crop fields particularly rice and maize field. *T. diversifolia* has been reported to contain some allelochemicals and therefore suggested as being capable of posing a serious phytotoxicity threat to agricultural crops. The phytochemical analyses indicated the presence of bioactive substances

such as alkaloids, saponins, glycosides, flavonoid, tannins, terpenoid and phenols in the methanolic extract and the later five allelochemicals in the water extract. The allelochemicals were of higher concentrations in the methanolic extract than in the water extract. The methanolic extract was found to be more phytotoxic than the water extract since the reduction of the germination percentage of the test crop was in the order of 100% methanolic extract > 50% methanolic extract > 100% water extract. The germination and seedling growth inhibition was then extract concentration dependent and significant at $P < 0.05$. Both methanolic and water extracts have greater inhibitory effects on the growth of the radicle than on the plumule growth at 100% extract concentrations (Otusanya and Ilori, 2012).

Analysis of water extracts of different crops showed the presence of natural/organic chemical substances such as alkaloids, tannins, phenolics, coumarins, terpenes, cyanates, glycosides, quinines and coumarins. Goffin *et al*., (2002) isolated tagitinin C a known sesquiterpene lactone (Pal *et al*., 1977; Baruah *et al*., 1979) from the aerial parts of the *T. diversifolia.* According to Ayeni *et al*., (1997) several studies have indicated that these allelochemicals and their derivatives are toxics and may inhibit shoot/ root growth, and nutrient uptake.

The phytochemical analysis of methanolic extract of *Ageratum conyzoides, Eupatorium odoratum and Mikania micrantha* done by Borkataky *et al*., (2013) revealed the presence of alkaloids, saponins, flavonoids, phenolics and tannins, steroids and glycosides. Alkaloids, phenolics and tannins, steroids and glycosides were present in all the three plants whereas saponins were present only in *E. odoratum*. Also, flavonoids were present in *A.conyzoides* and in *E. odoratum* and absent in *M. micrantha.* The methanol extract of the three plants inhibited both the bacterial and fungal test strains with different efficacies at a concentration of 200 mg/mL. Alkaloids, phenolics and tannins, steroids and glycosides were present in all the three plants whereas saponins were present only in *E. odoratum*. Also, flavonoids were present in *A.conyzoides* and in *E. odoratum* and absent in *M. micrantha.* Weeds, like any other plant, are a reservoir of many types of phytochemicals. As the literature suggests, the phytochemicals, which are the different kinds of secondary metabolites, are often the reason for the various protective properties of plants. (UdayaPrakash *et al*., 2011; Suriyavathana *et al*., 2012; Siddiqui *et al*., 2009; Deokule *et al*., 2012; UdayaPraskash *et al*., 2012a; UdayaPrakash *et al*., 2012b). The

presence of flavonoids and saponins has been shown to be responsible for antifungal activity of the plant (UdayaPrakash *et al*., 2012b). In the present study, similar observations have been made where the *E. odoratum* extract shows the presence of both flavonoids and saponins and exhibits highest bioactive principles responsible for their activities. Herbs rich in tannins have been used for treating intestinal disorders such as diarrhoea and dysentery (UdayaPrakash *et al*., 2012b; Dharmananda *et al*., 2003).

Malva parviflora L. is an annual medicinal herb is a weedy invader in many orchards and vineyards (Dennis and Michael, 2009). Its wide geographical distribution is likely due to its ability to compete with and displace many other annuals, in addition to its effects on a number of plant species by reducing their germination rates and seedling growth (Zahedi and Ansari, 2011). The results from the phytochemical screening done by Shehata and Galal (2014) showed that leaves, stems and roots of *M. parviflora* contain phenol, alkaloids, flavonoids and saponin, with significant higher concentrations in the leaves than the other organs. This result was confirmed by other studies (Farhan *et al*., 2012a,b). The traditional use of *M. parviflora* as a wound- healing herb may partly be attributed to flavonoids present in its extract, since only low phenol content was observed (Afolayan *et al*., 2008). However, leaves and stems of *M. parviflora* have exerted high antioxidant power at different concentrations (Farhan *et al*., 2012a). Finally, it can be concluded that both wild and cultivated *M. parviflora* plants would seem to be a promising for pharmaceutical purposes and is a renewable natural resource with cosmopolitan phytogeographical distribution.

The invasive weed *Amaranthus spinosus* was rich in secondary metabolites which exhibited antibacterial and antifungal activity and can be effectively exploited for controlling the strains under investigation and as a biocontrol agent against pathogenic microbes (Sheeba *et al*., 2013). Phytochemical screening of fruit peel of *Musa paradisiacal* revealed that the extract contains alkaloids, flavonoids, phenols, saponins and tannins (Okechukwu R. I. *et al*., 2012).

3.1 Geographical location

3.1.1 Mizoram

Mizoram is a hilly state lying between 92°15′ and 93°29′E longitude and 21°58′ and 24°35′N latitude. Mizoram is bounded by the states of Assam and Manipur in the north, by Myanmar's Chin state and Arakan Hills in the east and south, by the Chittagong Hill Tracts of Bangladesh in the west and by the state of Tripura in the northwest. Mizoram's total geographical area is 21,087 km². The tropic of cancer (23°30′N latitude) divides the region into two equal parts (Pachuau, 1994).

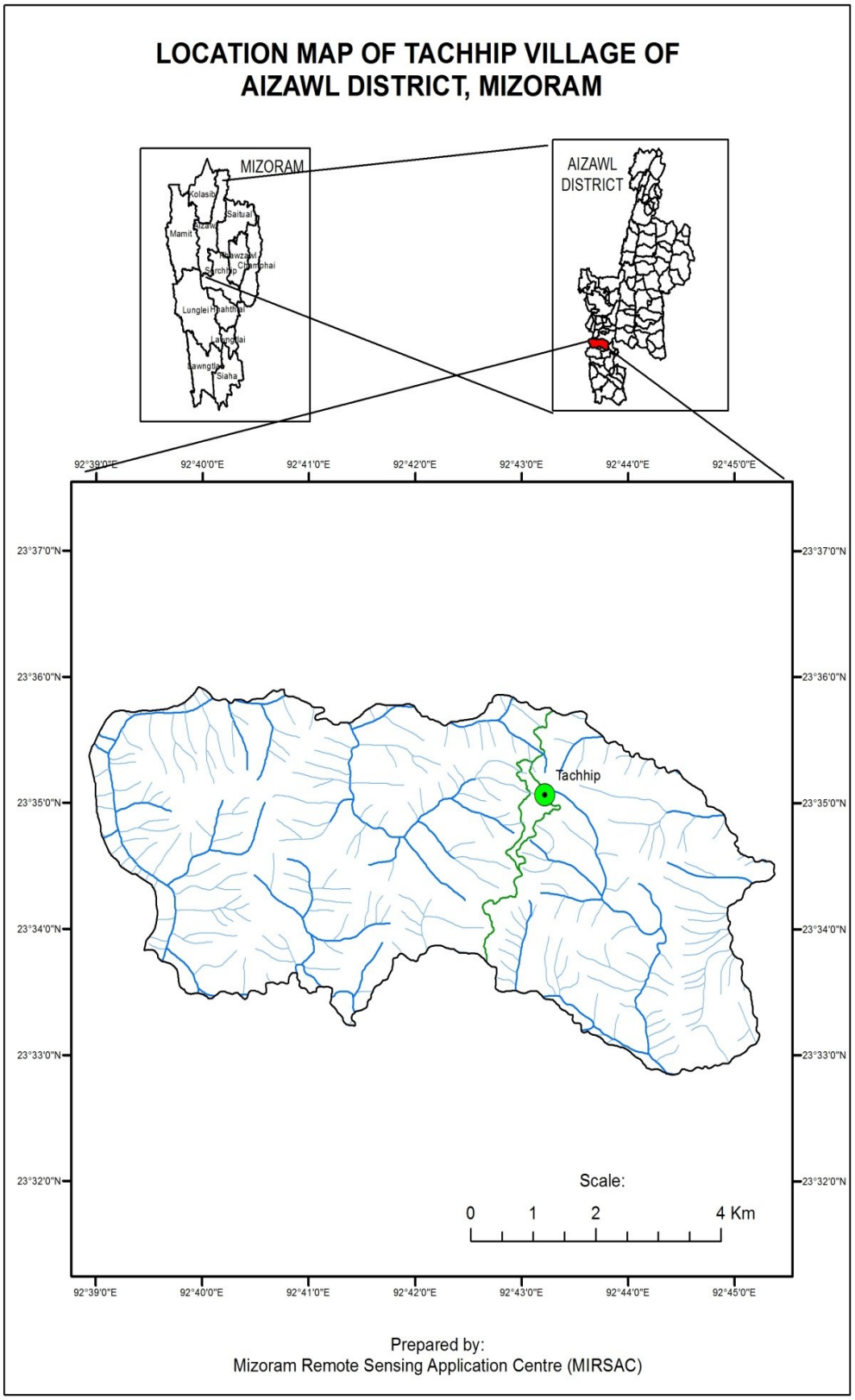
3.1.2 Location of the experimental site

The experimental site is about 20 km from Aizawl at Tachhip (Aibawk RD Block) at 23° 34' 58" N Latitude and 92° 43' 14" E Longitude. The elevation is 48 meters above sea level (Map 1).

3.2 Climate and weather

Mizoram enjoys a moderate and pleasant climate. The mean temperature varies from 9°C to 24°C in winter, and in summer from 24°C to 32°C. The entire state comes under the direct influence of the southwest monsoon, receiving an annual average rainfall between 1926mm and 2479mm (Anon., 2011). It occurs mostly between June and September by the southwest monsoon. The winter (Oct-Jan) is a cool dry season with few rainy days. Summer (March-May) is largely hot and dry with occasional thundershowers and pre-monsoon rains in April-May. Temperature accedes to 32°C during April and May and after occurrence of monsoon rain, temperature recedes slowly. During winter, average temperature remains 9°C.

Map 1: Map of Aizawl district showing location of the experimental site (Tachhip).



The study area i.e. Tachhip falls under sub-tropical climate with hot and wet summer and moderately cold and dry winter. It enjoys a pleasant weather almost throughout the year. Highest temperature was recorded at 32°C at the month of April during the study. The air temperature is lowest in the month of December with minimum temperature of 8°C. The mean Relative Humidity (RH%) increases from April to August reaches maximum humidity with the on-set of Northeast monsoon and the RH is lowest during dry period of January to March.

3.3 Soils

The soils of Mizoram are dominantly loose sedimentary formation. They are found to be young, immature and sandy soil (Pachuau, 1994). There are three types of soil in Mizoram. They are ultisols, inceptisols and entisols (Sarkar and Nandy, 1976; Singh and Dutta, 1989). The soils in the foot hills are collocium deposit and in plain areas alluvial deposits are predominant. The soils in general have low inherent fertility viz. Bases and mineral reserves. The soils in the hills are strongly acidic whereas the soils in alluvial deposits are less acidic in nature (Anon, 1991). The surface soils of the hilly region of Mizoram are dark, leached and poor in bases, rich in iron and mostly acidic and Ph ranges between 4.5 to 6.0. The soils are well drained, rich in carbon, potassium and low in available phosphorus content. The soil surface is loam to clay loam with clay content increasing with depth. The percentage of clay, silt and sand within 50cm of the surface in most cases are 25-45% respectively. The pH and organic carbon decreases and clay increases with depth (Anon, 1991). The soils are mainly loose sedimentary formations, loamy to clay-loam. The soils are brown to dark brown, poor in bases, moderately acidic with pH ranging from 5.8-6.2. The soils are rich in moderate organic carbon content, high available potash and low available phosphate.

3.4 Landuse pattern and cropping system of the study site

Out of the total geographical area (21087 km²), 75.6% area is forest cover. Total cropped area is 5.5%. Net sown area is registered only 4.9%. Irrigated area is 0.5%. Area under horticulture is 1.9%. Fallow land other than current fallow is 8.1% whereas current fallows (*Jhum* land) is 1.9 only. Land not available for cultivation is 6.6%. Land under miscellaneous tree-crops (not included in net sown area) is 2.5%. Cultivable waste land is 0.5% (Sati and Rinawma, 2014).

Agriculture is the mainstay for about 60% of the population of Mizoram. Of the total area 21% is under paddy/seasonal crops. As high as 63% of the total crop area is under shifting cultivation. The crops grown in the jhum are mixed. The principal crop is paddy and others are maize, cucumber, beans, ginger, mustard, sesame, cotton etc. Tapioca, sugarcane, cotton, pulses and oilseeds are also cultivated in the state. Oilseeds crops are sesame, mustard and soybean are growing well. Paddy occupies almost 50% of the total crop area and more than 88% of the total crop area is occupied by food grains (Anon, 2010).

The practice of shifting cultivation is still prevalent in Tachhip and the majority of population are subsistent farmers. Traditional shifting cultivation in the hilly slopes is the main livelihood of the people. The crop productivity per unit area is low due to technical know-how.

4.1 General

The investigations reported in this thesis were carried out in the year 2014 and 2015. In the first year of experiment, pre-monsoon started as early as February and the monsoon season occurred during June to October. In the second year of the experiment, pre-monsoon started in the month of April and the monsoon season occurred from June to October.

4.2 Calculation of Density, Frequency, Abundance and IVI of weed species

The sub-plots were marked for study of seasonal variation in density and frequency of weed species. Within the sub-plots, a quadrat of $1m^2$ was laid and used for estimating the density and frequency of weed species. The number of quadrats varied depending upon the area of the fields. All the seasons were studied using the same number of quadrats and from the same fields. Frequency and density of the weeds were calculated according to Odum (1971).

$$\text{Frequency (\%)} = \frac{\text{No. of sampled areas where species occurred}}{\text{No. of total sampled areas}}$$

$$\text{Density (Plants/m}^2\text{)} = \frac{\text{Total no. of individual species}}{\text{Total sampled area}}$$

Importance Value Index (IVI) is a reasonable measure to assess the overall significance of a species since it takes into account several properties of the species in the vegetation. The IVI was calculated as per Curtis and McIntosh (1950). The parameters assessed for the purpose were density, frequency, and dominance, while importance value index (IVI) was calculated as: IVI = Relative Frequency + Relative Density + Relative Dominance.

4.3 Details of collection of Data

4.3.1 Weed sample collection

Among the weeds collected from the quadrats, a total of 10 most dominant weeds were selected to study their phenology and seasonal variations. The phenological events like germination (G), vegetative (V), flowering (Fl), fruiting (Fr), seeding (S) and death (D) of 10 commonest weeds were noted. For phenological study, information from fields as well as from herbarium was gathered. Though considerable variation in the phenological pattern existed, a generalised picture is presented. Among the dominant weeds found in the plots, *Ageritum conyzoides, Chromolaena odorata* and *Mikania micrantha* were randomly selected to study the germination and seedling growth of the selected agricultural crops *Brassica campestris, Oryza sativa* and *Zea mays*. The leaves were collected and washed to remove soil particles, cut into pieces and air dried and the dried leaves were made into powder by grinding with mortar and pestle and passed through 2mm mesh sieve, and then stored in air tight glass bottles.

10 gm of air dried weed plant material was taken by Digital Electronic Weighing Machine in 100 ml of distilled water and kept for 24 hours at room temperature around 25°C. It was then filtered through Whatman filter paper no.1 and the volume of the filtrate was made to 1000ml. Different dilutions such as 2%, 4%, 6%, 8% and 10% of the extract were prepared from the stock solution. The seeds *of Brassica campestris, Oryza sativa* and *Zea mays* were soaked separately in a petri plates in distilled water overnight. The next day, the seeds were surface sterilized with 0.1% of mercuric chloride solution for two minutes and washed twice with distilled water and kept for germination. The petridishes were autoclaved before use in order to prevent any type of contamination or infection. Paper towels were used for germination tests and the towel was wrapped with the tissue paper. Each paper towel was moistened with approximately 10ml. of respective extracts. The soaked seeds were then placed in the petri dishes with the respective concentration and the number of seeds placed were counted. After placing the seeds they were then covered with a layer of moistened paper towel. In each set of treatment two replicates were kept containing the same number of seeds. Observation of germination percentage and seedling length was done after an interval of one week.

4.3.2 Growth parameters of agricultural crops

a) Seedling length: In each petri-dish, 20 seeds are placed randomly. After a week of incubation, the seeds that showed germination are recorded and their seedling length is measured. Using a ruler, the length of the radicle is measured and expressed in cm.
b) Germination %: The number of seeds that shows germination is counted and the percentage is calculated.

4.3.3 Soil sample collection

Soil samples were collected from 6 random locations of the study site for two consecutive years 2014-2015. Using a spade, it is dug out from a depth of 30cm and packed in polythene bags.

4.3.4 Processing of soil samples

The samples were air dried and crushed and passed through sieves of finer mesh size (Ghosh *et al*., 1983).

4.3.5 Determination of pH

The pH of the soil samples was measured by the methods of soil water ratio of 1:2. Soil sample of 20g was taken in a 100ml beaker to which 40ml of water was added. The suspension was stirred at regular intervals for 30 minutes and the pH was recorded with the help of electronic digital pH meter.

4.3.6 Estimation of Organic Carbon (Walkley and Black, 1934)

Walkley and Black (1934) method was used to estimate Organic Carbon. Soil samples were grounded and passed through 0.2mm sieve. 1g of soil sample was placed at a 500ml conical flask. 10 ml of $K_2Cr_2O_7$ solution was pipetted into the flask. The flask was rotated to mix them thoroughly. Then 20ml of concentrated H_2SO_4 was added gently into the flask. The flask was allowed to stand for about 30 minutes. After 30 minutes, 200ml of distilled water was added after which 10ml of H_3PO_4 was added. The burette was filled with 0.5N ferrous iron solution upto 50ml mark. 1.5ml of diphenylamine was added and titrated till dull green colour appears. Simultaneously, a blank was run without soil.

The result was calculated by:

$$Organic\ Carbon\ (\%) = \frac{10\ (B-T)}{B} \times 0.003 \times \frac{100}{S}$$

Where,

B= Volume of ferrous ammonium sulphate required for blank titration in ml

T= Volume of ferrous ammonium sulphate needed for soil sample in ml

S= Weight of soil in gram

4.3.7 Estimation of Available Nitrogen content (Kjeldahl, 1883)

20g of soil sample was taken in a 800ml kjeldahl flask. Few glass beads and 1g paraffin was also taken in the flask. The kjeldahl nitrogen distillation was assembled. 20ml of 2% boric acid-mixed indicator A solution was taken in a 250ml conical flask. The flask was placed under the condenser tube (i.e receiver tube). The outlet of condenser tube was dipped into the boric acid-mixed indicator A solution. The feeding funnel was filled with 10ml distilled water. The rod shaped stopper was lifted to let the distilled water into the kjeldahl flask. 100ml of freshly prepared 0.32% $KMnO_4$ solution was taken into the feeding funnel. In the same way, 100ml 2.5% NaOH solution was taken in the kjeldahl flask. 20ml of distilled water was added into the feeding funnel to remove the NaOH solution from the drain hole. The heating unit was switched on to boil the contents in the kjeldahl flask. It is continued till 100-120ml of distillate is collected in the receiving conical flask. Then the heater was switched off. Similarly, a blank without soil content was conducted following the same procedure. The sample distillate was titrated by adding standard acid (0.02N H_2SO_4 or 0.02%N HCL) in a burette until the colour of the solution (blue/green) disappears. One drop in excess turns the solution pink. Again, blank distillate was titrated following the same procedure. The N content is calculated by the formula,

$$The\ N\ content\ of\ soil\ (Kg\ ha^{-1}) = \frac{N \times (S-B) \times 31360}{W}$$

Where, N=Normality of acid (strength of acid), S=Soil titre in ml, B=Blank titre in ml, W=Weight of the soil

4.3.8 Estimation of Available Phosphorus (Olsen *et al*., 1954)

2.5 g of dried soil and 50 ml of sodium bicarbonate solution in a flask was mixed and shake for 30 minutes with a suitable shaker. The suspension was filtered through Whatman filter paper No.40 and activated carbon was added to obtain a clear filtrate. 5 ml of the extract was taken in a 25 ml volumetric flask to which 5 ml of Dickman and Bray's reagent was added drop by drop with constant shaking till the effervescence due to CO_2 evolution ceases and 1 ml of diluted $SnCl_2$ was added. The volume was then made up to the mark. The colour is stable for 24 hrs and maximum intensity was obtained in 10 minutes. The absorbance was read with a spectrophotometer (Dynamica Halo DB-20) at 660 nm and calculated by the following formula

$$Available\ Phosphorus\ \left(\frac{Kg}{ha}\right) = R \times \frac{V}{v} \times \frac{1}{S} \times \frac{(2.24 \times 10^6)}{10^6}$$

Where,

V= total volume of extractant (ml)

v= volume of aliquot taken for analysis (ml)

S= weight of soil (g)

R= weight of phosphorus in the aliquot in µg (from standard graph)

4.3.9 Estimation of Available Potassium (Ghosh *et al*., 1983)

The method developed by Ghosh *et al*., (1983) was used to estimate available Potassium using Flame Photometer. 5g of soil sample was shaken with 25ml of 1N ammonium acetate (pH 7) for 5 minutes and filtered immediately through a dry Whatman no.1 filter paper. First few ml was discarded. Potassium concentration in the extract was determined using the flame photometer and calculated according to the following

$$Exchangeable\ Potassium\ \left(\frac{Kg}{ha}\right) = R \times \frac{V}{W} \times 224 \times \frac{10^6}{10^6}$$

Where, R= ppm of K in the extract (obtained from standard graph), V= Volume of the soil extract in ml, W= Weight of dry sample taken for extraction in gram.

4.4 Quantification of Total Phenol Content (TPC) (Ainsworth *et al*., 2007)

The total phenol content (TPC) was estimated by Folin-Ciocalteu reagent method following Ainsworth *et al*., 2007. Gallic acid was used as a reference standard for plotting calibration curve. It was prepared by using 2.5, 5 and 20 mg/ml solutions of Gallic acid. To determine the total phenol content in the plant extract, an aliquot of 0.5 ml plant extract was added along with 5 ml of Folin-Ciocalteu reagent. This solution was neutralized by adding 4 ml of sodium carbonate (Na_2CO_3) solution (7.5 % w/v) and incubated at 25°C for 30 minutes with intermittent shaking. The development of blue color chromophore was read with a spectrophotometer (Cary 60) at 765 nm against prepared blank sample. The total phenol content was expressed as mg/g of dry weight.

4.5 Quantification of Total Flavonoid Content (TFC) (Kaufman *et al*., 1999)

The total flavonoid content (TFC) was estimated by Aluminium chloride colorimetric methods describe by Kaufman *et al*., 1999 with minor modification. Quercetin solutions of various concentrations was used to make the standard curve.10 mg of quercetin was dissolved in 100 ml methanol and then diluted to 1, 2, 5, 10 and 20 □g/ml using methanol. To estimate the total flavonoid content in the plant extract, 0.5 ml of each plant extract along with 1.5 ml methanol and 0.1 ml of 10 % alluminium chloride ($AlCl_3$) solution was added to test tubes. To this, 0.1 ml of 1 M potassium acetate (CH_3CO_2K) solution and 2.8 ml distilled water were added. The solution was mixed well and filtered through Whatman No.1 filter paper. Similarly, sample blank was prepared by replacing aluminium chloride solution with distilled water and the absorbance was read in a spectrophotometer (Cary 60) at 415 nm against prepared blank sample. The total flavonoid content in the plant extract was expressed as mg/g of dry weight.

4.6 Quantification of Alkaloids (Luyang Li *et al*., 2014)

Total alkaloid content was estimated by using method developed by Luyang Li *et al*., (2014). The extract samples were dissolved in 2 N of Hydrochloric acid (HCl) and then filtered. Phosphate buffer solution (pH 4.7) was prepared by adjusting the pH of 2 M sodium phosphate (71.6 g Na2HPO4 in 1 L distilled water) to 4.7(4.5 to 4.9) with 0.2 M citric acid (42.02 g citric acid in 1 L distilled water.

Bromocresol green solution (BCG) (10-4M) was prepared by heating at 50°-60°C, 10-15 min of 69.8 mg bromocresol green with 3 ml of 2N NaOH and 5 ml distilled water until completely dissolved and the solution was diluted to 1000 ml with distilled water. 1 ml of extract was transferred to separating funnel and add 5 ml of phosphate buffer pH 4.7 and 5 ml of bromocresol green (BCG) solution. The mixture was shaken and complex formed was extracted with 5 ml of chloroform. Chloroform layer was collected in 10 ml of volumetric flask and make the volume up to mark with chloroform. Absorbance was taken at 415 nm against blank.

4.7 Qualitative Phytochemical Analysis (Krishnaiah *et al*., 2009; Sofowora, 1982): The phytochemical screening of the samples was carried out as described by Krishnaiah *et al*., (2009) and Sofowora (1982) with slight modification. The samples were screened for tannins, saponins, flavonoids, alkaloids, quinones, cardiac glycosides, terpenoids, phenols and anthraquinones.

a) Tannin test: 1 ml of the plant extract was taken in a test tube. To this, 2 ml of 0.7 M Sodium bicarbonate ($NaHCO_3$) and a few drops of Folin's reagent were added. Formation of greenish black or dark blue indicates the presence of tannin.

b) Saponin test: 2 ml of distilled H_2O was mixed with 2 ml of plant extract in a test tube and it was mixed vigorously. The formation of foam layer indicates the presence of saponin.

c) Flavonoid test: 2 ml of plant extracts was mixed with 5 ml of dilute ammonia and concentrated sulphuric acid (H_2SO_4). White precipitate appearance indicates the presence of flavonoid.

d) Alkaloid test: A few drops of Dragendorff's reagent was added to 1 ml of plant extract. Orange red precipitate form indicates the presence of alkaloid.

e) Quinone test: 1 ml of plant extracts was mixed with 1 ml of concentrated sulphuric acid (H_2SO_4). The presence of quinone was indicated by the formation of red colour.

f) Cardiac glycosides test: 2 ml of glacial acetic acid and a few drop of 5 % ferric chloride ($FeCl_3$) solution was mixed with 1 ml of plant extract and concentrated H_2SO_4. A brown ring formed between the layers showed the presence of cardiac glycosides.

g) Terpenoid test: 1 ml of plant extracts along with 2 ml of chloroform was mixed in a test tube. Then, concentrated sulphuric acid (H_2SO_4) was added carefully. A red brown colour ring formed between the layers showed the presence of terpenoids.

h) **Phenol test:** A few drops of 15 % sodium carbonate (Na_2CO_3) and Folin's Reagent were added to 1 ml of plant extract. The formation of blue colour indicates presence of phenol.

i) Anthraquinone test: Few drops of 10 % ammonia (NH_3) was added to 1 ml of plant extracts and shaken vigorously. The appearance of pink colour precipitate indicates the presence of anthraquinone.

4.8 Statistical Analysis

The experimental data pertaining to each parameters were analyzed statistically using SPSS16 with the help of analyses of variance technique (ANOVA) and Correlation coefficient (r). Statistical significance at p □ 0.05 was considered.

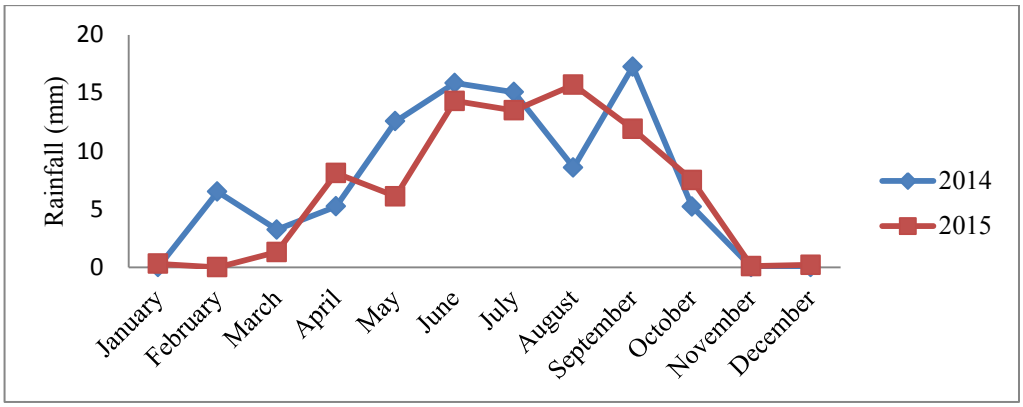
5.1 Meteorological parameters of the study site

5.1.1 Rainfall

The total averaged rainfall in the study site during the first year of study (2014) was 89.47 mm and in the second year (2015) it was 79mm (Table 1.1). In the first year of experiment, pre-monsoon started as early as February and the monsoon season occurred during June to October. In the second year of the experiment, pre-monsoon started in the month of April and the monsoon season occurred from June to October.

Table 1.1: Averaged rainfall report at the experimental site during the study period.

Month	**Rainfall(mm)**	
	2014	**2015**
January	0.0	0.3
February	6.50	0.0
March	3.24	1.3
April	5.23	8.1
May	12.55	6.1
June	15.58	14.3
July	15.06	13.5
August	8.57	15.7
September	17.25	11.9
October	5.22	7.5
November	0.0	0.1
December	0.0	0.2
Avg. Total	**89.47**	**79**



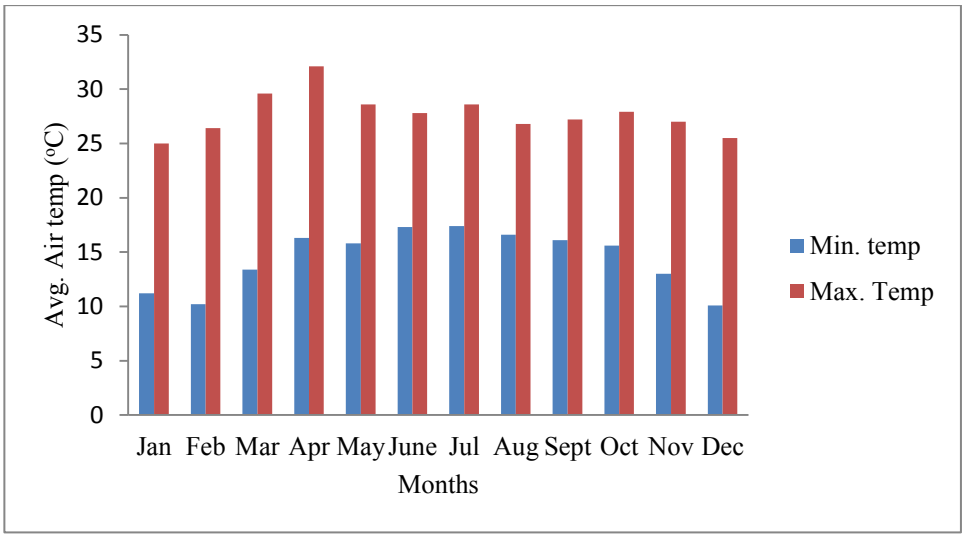
Graph 1.1: Averaged rainfall at the experimental site during the study period.

5.1.2 Air Temperature

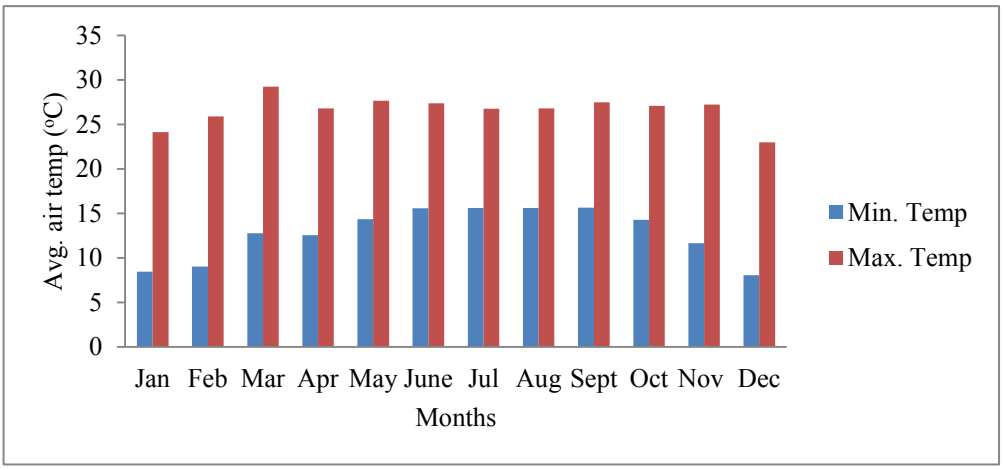
The maximum air temperature during the first year of study (2014) was recorded in April (32.1°C) and minimum air temperature in December (10.1°C). During the second year of study (2015), the maximum air temperature was recorded in the month of March (29.22°C) and the minimum air temperature was recorded in December (8.05°C) as shown in Table 1.2.

Table 1.2: Averaged air temperature at the experimental site during the study period.

Months	1st year (2014)		2nd year (2015)	
	Min	Max	Min	Max
January	11.2	25.0	8.44	24.14
February	10.2	26.4	9.04	25.90
March	13.4	29.6	12.77	29.22
April	16.3	32.1	12.56	26.80
May	15.8	28.6	14.35	27.64
June	17.3	27.8	15.57	27.36
July	17.4	28.6	15.60	26.75
August	16.6	26.8	15.62	26.78
September	16.1	27.2	15.64	27.48
October	15.6	27.9	14.26	27.08
November	13.0	27.0	11.66	27.23
December	10.1	25.5	8.05	22.97



Graph 1.2: Averaged air temperature at the experimental site in the first year (2014).



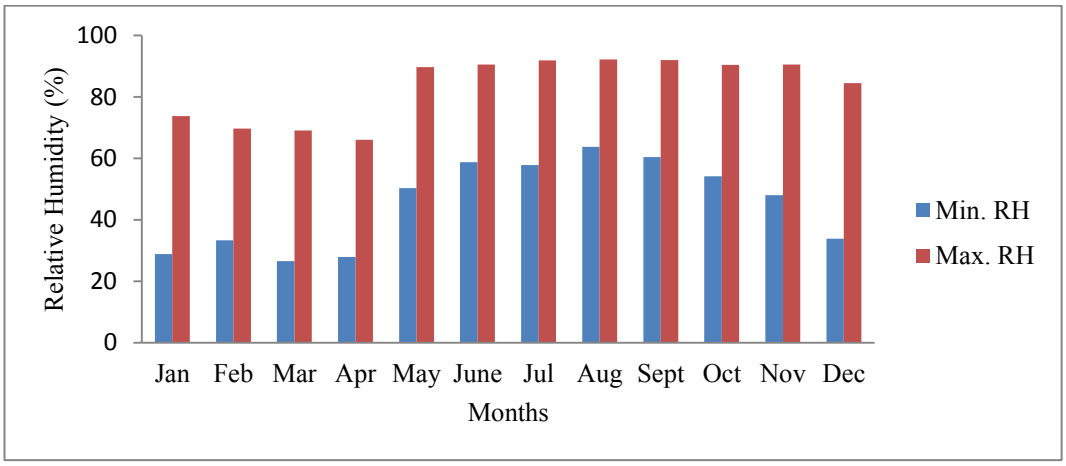
Graph 1.3: Averaged air temperature at the experimental site in the 2nd year (2015).

5.1.3 Relative humidity (RH%)

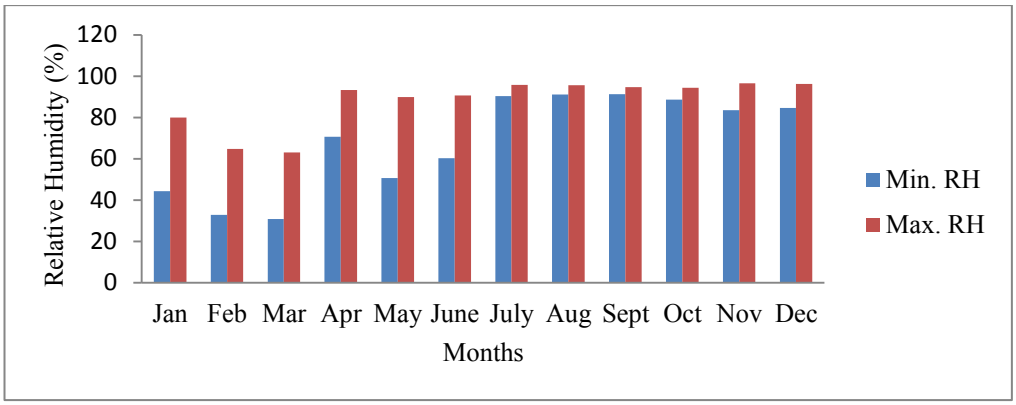
The mean Relative Humidity (%) of the experimental site during the first year of study (2014) ranged from 26.5 to 91.9%. It was highest during the month of September (91.9%). During the second year of study (2015), the Relative Humidity was highest in the month of November (96.6%) and lowest in the month of March (30.8%) as shown in Table 1.3.

Table 1.3: Averaged Relative Humidity (%) at the experimental site during the study period.

Months	1st year (2014)		2nd year (2015)	
	Min. RH	Max. RH	Min. RH	Max. RH
January	28.8	73.7	44.3	79.9
February	33.3	69.6	32.8	64.8
March	26.5	69	30.8	63.1
April	27.9	66	70.7	93.3
May	50.3	89.6	50.7	89.9
June	58.7	90.5	60.3	90.7
July	57.8	91.8	90.4	95.7
August	63.7	92.1	91.1	95.6
September	60.4	91.9	91.3	94.7
October	54.1	90.4	88.7	94.4
November	48	90.5	83.5	96.6
December	33.8	84.4	84.6	96.2



Graph 1.4: Averaged Relative Humidity (%) at the experimental site during the first year (2014).



Graph 1.5: Averaged Relative Humidity (%) at the experimental site in the 2nd year (2015).

5.2 Soil physico-chemical properties of the study site:

The soil nutrient status of the study site (pH, OC, N, P and K) was recorded for the two years of study (2014 and 2015). The soil nutrient status was recorded randomly from the experimental site during the course of two years. The results are presented in Table 1.4 and 1.5. The soil nutrient status during the two years are shown in graphs 1.4.1 to 1.4.5.

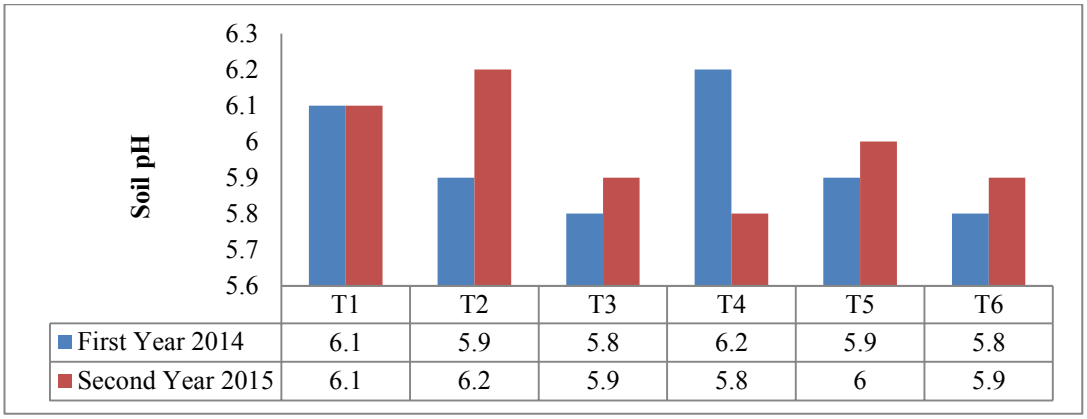
The pH value ranges between 5.8 to 6.2 shows that the soil is acidic to neutral. This shows that the soil is rich in nutrients and both agricultural crops as well as weeds can thrive well in the experimental site. The experimental result of the analysis of soil during the First and Second year showed that the organic carbon content is quite low as well as available Phosphorus found in the experimental site. Available Nitrogen and Potassium was found in moderate amount during both years. The nutrient condition of the soil is maybe because of leaching during heavy rain, water runoff, denitrification etc.

Table 1.4: Soil nutrient status of experimental plot during the First Year 2014.

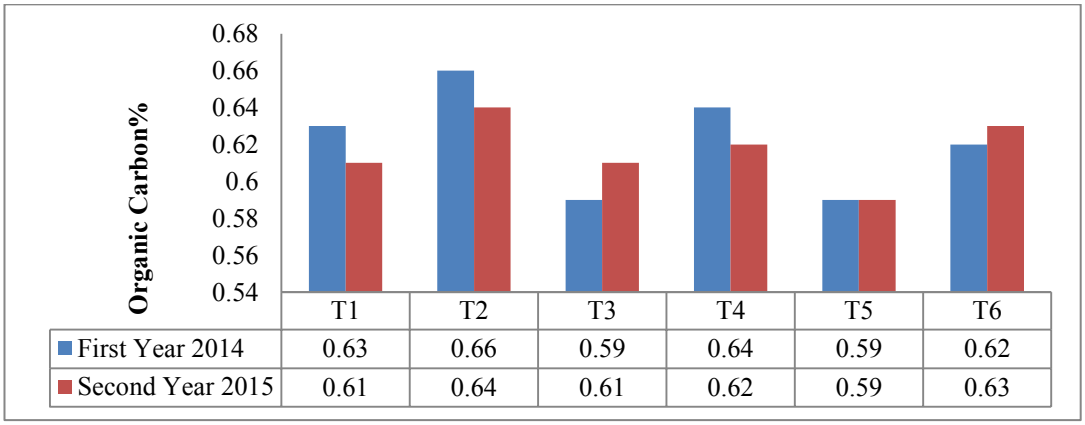
Sample no	pH	Org C (%)	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
T-1	6.1	0.63	263	11.8	241
T-2	5.9	0.66	275	12.2	219
T-3	5.8	0.59	288	10.5	118
T-4	6.2	0.64	398	13.1	211
T-5	5.9	0.59	274	12.5	175
T-6	5.8	0.62	342	11.4	125

Table 1.5: Soil nutrient status of experimental plot during the Second Year 2015.

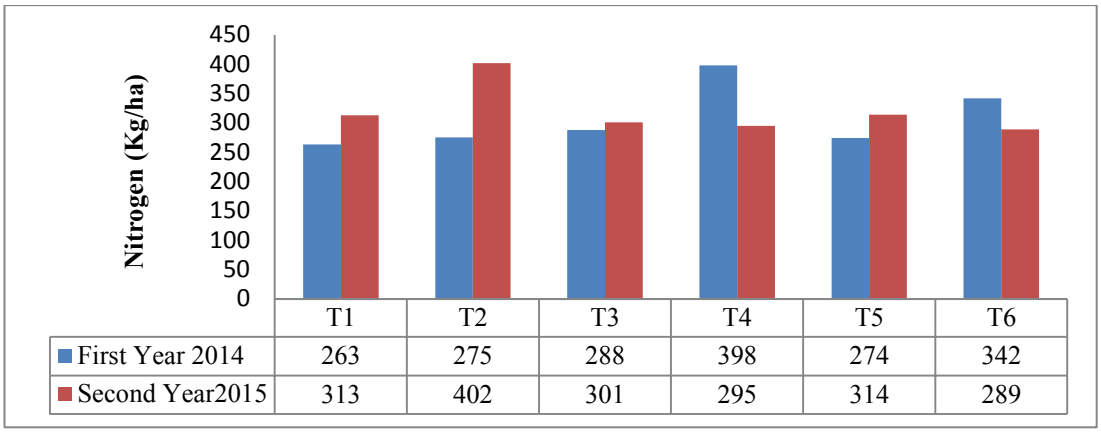
Sample no	pH	Org C (%)	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)
T-1	6.1	0.61	313	12.3	175
T-2	6.2	0.64	402	12.8	148
T-3	5.9	0.61	301	10.5	175
T-4	5.8	0.62	295	11.2	178
T-5	6.0	0.59	314	10.5	184
T-6	5.9	0.63	289	12.4	189



Graph 1.6.1: Soil pH of the experimental site during the First and Second year.

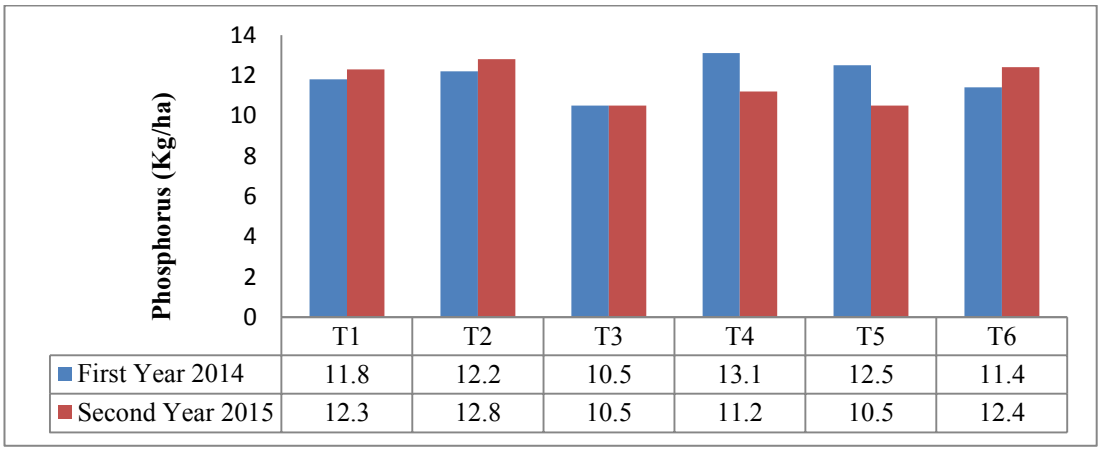


Graph 1.6.2: Soil Organic Carbon of the experimental site during the First and Second year.



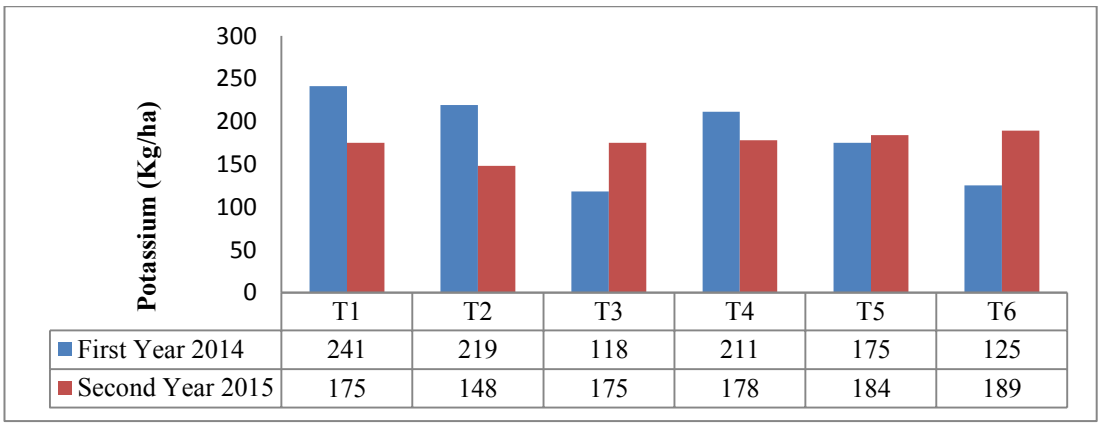
	T1	T2	T3	T4	T5	T6
First Year 2014	263	275	288	398	274	342
Second Year2015	313	402	301	295	314	289

Graph 1.6.3: Soil Available Nitrogen of the experimental site during the First and Second year.



	T1	T2	T3	T4	T5	T6
First Year 2014	11.8	12.2	10.5	13.1	12.5	11.4
Second Year 2015	12.3	12.8	10.5	11.2	10.5	12.4

Graph 1.6.4: Soil Available Phosphorus of the experimental site during the First and Second year.



	T1	T2	T3	T4	T5	T6
First Year 2014	241	219	118	211	175	125
Second Year 2015	175	148	175	178	184	189

Graph 1.6.5: Soil Available Potassium of the experimental site during the First and Second year.

5.3 Weed diversity and Phenology

A detailed survey of the weed flora in jhumland fields yields 37 weed species belonging to 24 families were found (Table 2.1). The dicot species were found to be more in abundant than the monocots. Among the dicots, the Asteraceae family with 9 species were the dominant family. Among the common species were *A. conyzoides, C. odorata*, *M. micrantha* and *A. oleracea.* Among the monocots, the Poaceae family with 4 species were the dominant family. They were *Croix lacryma-jobi, C. accrescens, D. distachya* and *I. cylindrica. A. conyzoides* (187.7 individuals/m²) has the highest density (Table 2.1). The other species having high density were *S. media* (Linn.) Villars (59.9 individuals/m²) and *I. cylindrica* (Linn) Raeuschel (30.3 individuals/m²). The number of individuals was found to be highest during summer due to high temperature and abundant moisture with moderate rainfall. *A. conyzoides* was found to be the most dominant species with highest IVI (166) in all the seasons followed by *S. media* (Linn.) Villars. (IVI=107.7). The other dominant species were *C. odorata* (IVI=86.7), *I. cylindrica* (Linn) Raeuschel. (IVI=68.3), *O. corniculata* (IVI=66.6) and *A. oleracea* (IVI=64) (Table 2.1). Weed species like *A. conyzoides* are an invasive weed. They grow abundantly in presence of rainfall and moisture. They are found throughout the year.

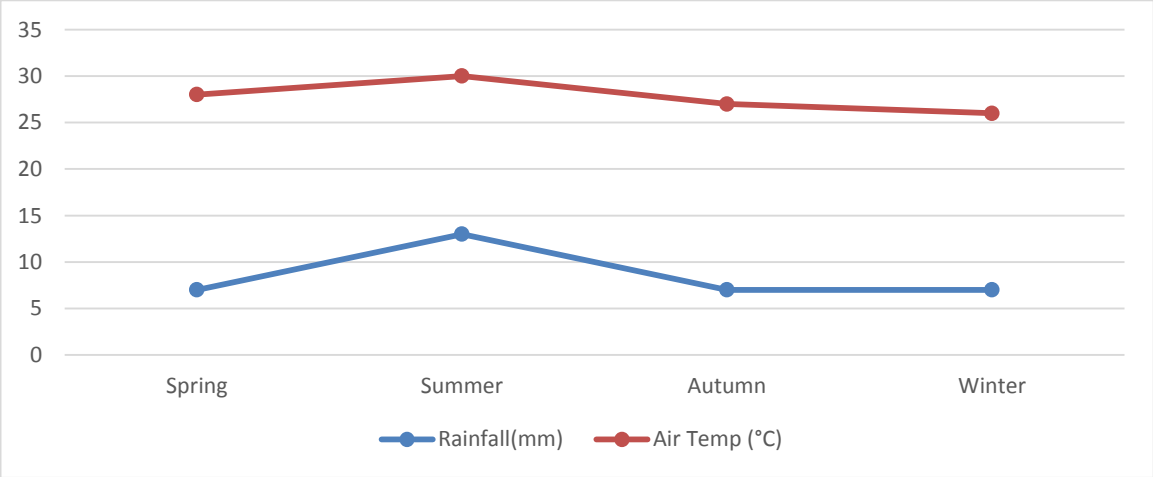
There is a distinct phenological pattern seen in different weeds. In Table 2.2, the phenological events of 10 most dominant weeds are shown. Most of the weeds germinate during the month of March-May such as *A. conyzoides, A. lunulatum* and *C. accresens*. Most of the weeds flower and fruit during June to December. Otherwise the seeds of weeds produced would be disseminated and buried in the soil. As winter approaches, the weeds population decreases. Most of the weeds were found to have died after completing their life cycle during winter and the weed population diminished. They are mostly found throughout the year. Most of the density of weeds like *A. lunulatum, A. conyzoides, C. accrescens, C. odorata, I. cylindrica, A. oleracea* and *S. media* increases from winter to summer. Whereas *M. micrantha* and *O. corniculata* increases from summer to winter. The density of *B. pilosa* is negligible during winter.

Table 2.1: Density and IVI of weed species in different seasons.

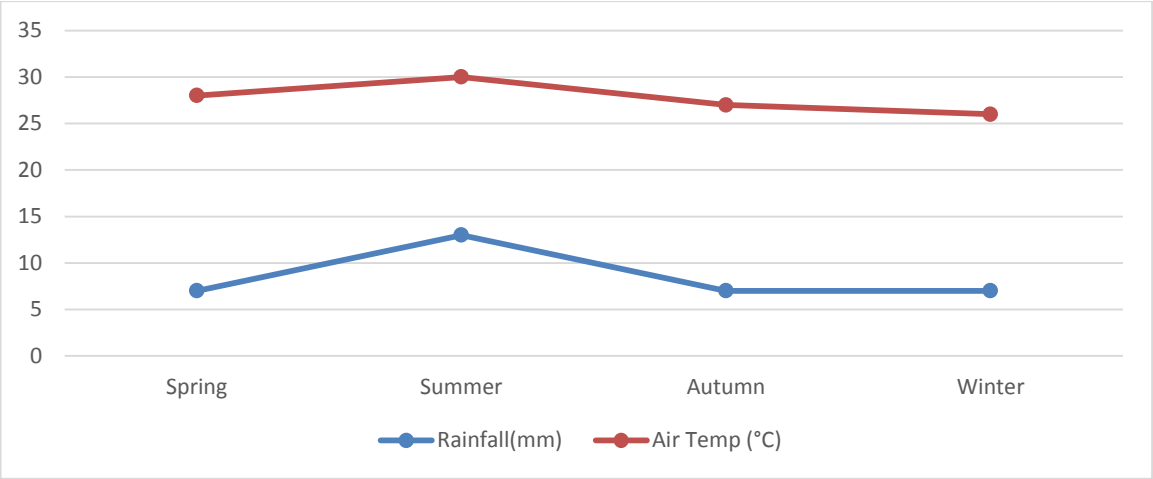
Name of the species/Accession no	Summer		Autumn		Winter	
	Density	IVI	Density	IVI	Density	IVI
1.Ageratum conyzoides L./MZUBOT0357	102.7	33.8	71	77.6	14	54.6
2 Stellaria media (L.) Vill./MZUBOT0358	29.9	27.3	19.9	34.5	10.1	45.9
3.Imperata cylindrica (L.) Raeusch./MZUBOT0359	13.3	14	9.5	18.3	7.5	18.3
4.Oxalis corniculata L./MZUBOT0360	7.5	9.6	13	20.9	8	36.1
*5.Acmella oleracea (*L.) R.K. Jansen/MZUBOT0361	12.3	13.3	10.2	18.8	5.3	31.9
6.Chromolaena odorata (L.) R.M.King & H.Rob./MZUBOT0362	7.9	10.5	7.1	14	5.3	27.1
7.Adiantum lunulatum Burm.f./MZUBOT0363	6.7	8.9	10.8	19.3	3.5	20.6
8.Mikania micrantha Kunth./MZUBOT0364	2	5.5	6	14	3.5	25.7
9.Bidens pilosa L./MZUBOT0365	21.9	22.5	1.7	5.8	0	0
10.Cyrtococcum accrescens (Trin.) Stapf./MZUBOT0366	3.6	5.8	0.7	4	1.1	10.3
11.Byttneria pilosa Roxb./MZUBOT0367	6.5	9.8	10	6.9	0	0
12.Conyza bonariensis (L.) Cronq./MZUBOT0368	2.2	5.2	0.9	4.9	0.2	3.8
13.Clerodendrum infortunatum L./MZUBOT0369	1.3	5.8	0.3	7.8	0	0
14.Croix lacryma-jobi L./MZUBOT0370	11	12.6	0	0	0	0
15.Lobelia angulata G. Frost./MZUBOT0371	5.6	5.3	0.8	3.6	0	0
*16.Polygonum barbatum*L./MZUBOT0372	3.8	6.7	1	4.4	0	0
17.Torenia violacea (Azaola ex Blanco)./MZUBOT0373	0	0	4.7	10.8	0	0
18. Dioscoria bulbifera L./MZUBOT0374	2.2	5.7	0.6	3.7	0	0
19. Lygodium flexuosum(L.) Sw./MZUBOT0375	0.6	5.3	0.3	3.6	0	0
20. *Triumfetta pilosa* Roth./MZUBOT0376	1.9	4	0.8	4.7	0	0
21.Plantago major L./MZUBOT0377	0.4	2.4	1	5	0	0
22. Digitaria distachya (L.) Pers./MZUBOT0378	2.7	7.2	0	0	0	0
23. Ipomoea batatas (L.) Lam./MZUBOT0379	1.7	4.2	0.2	2.2	0	0
24.Amaranthus spinosus L./MZUBOT0380	0.7	3.3	0.5	3	0	0
25.Centella asiatica (L.) Urb./MZUBOT0381	4.4	5.1	0.1	1.2	0	0
26. Lindernia ruellioides (Colsm.) Pennell./MZUBOT0382	0.3	3.3	2.8	1.8	0	0
27. Conyza stricta Willd./MZUBOT0383	1	4.2	0	0	0	0
28. Solanum nigrum L./MZUBOT0384	0.8	2.9	0.1	1.2	0	0
29. Spermacoce ocymoides Burm. f./MZUBOT0385	0.8	3.5	0	0	0	0
30.Costus speciosus (J. Koeing) Sm./MZUBOT0386	0.8	2.5	0	0	0	0
31. Ipomoea hederifolia L./MZUBOT0387	0.6	2.5	0	0	0	0
32.Mimosa pudica L./MZUBOT0388	0.4	2.4	0	0	0	0
33.Mucuna exserta C.E.C.Fisch./MZUBOT0389	0.6	2.2	0	0	0	0
34.Gynura bicolor (Roxb. ex Willd.) D.C./MZUBOT0390	0	0	0.2	1.7	0	0
35. Alchornea tiliaefolia (Benth.) Muell./MZUBOT0391	0.3	1.4	0	0	0	0
36. Inula cappa (Buch.-Ham. ex D. Don)/MZUBOT0392	0	0	0.1	1.2	0	0
37.Celosia argentea L./MZUBOT0393	0.2	1.1	0	0	0	0

Table 2.2: Phenology of 10 most abundant weeds in the study site.

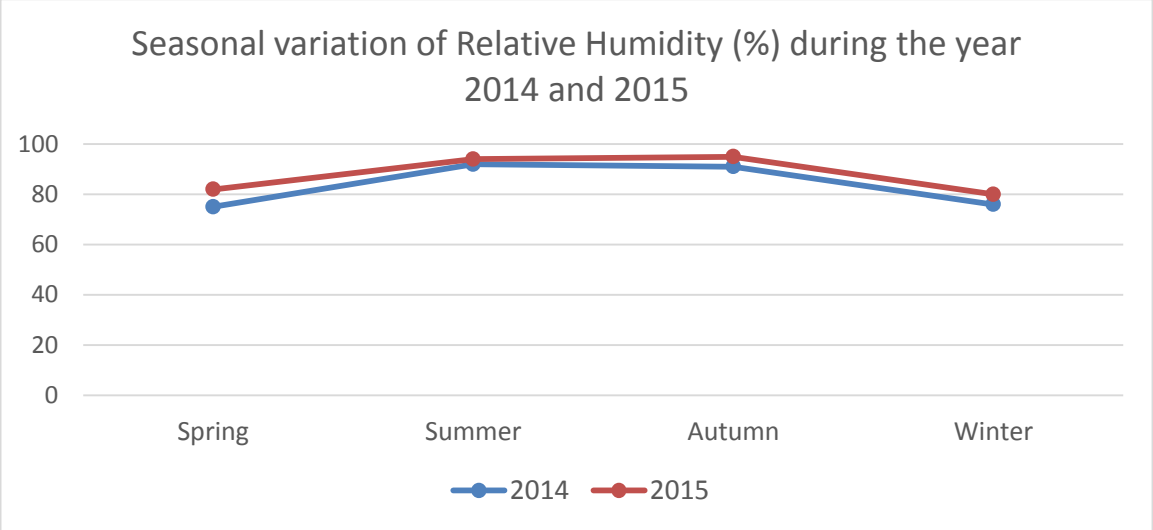
Sl	Name of species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	*Acmella oleracea*	S	S,D	G	G	G,V	Fl,Fr	Fl,Fr	Fl,Fr	Fl,Fr	Fl,Fr	Fl,Fr	Fr,S
2	*Adiantum lunulatum*	Fr,S	S,D	G	G	G	V	V	V	Fl	Fl	Fl	Fl,Fr
3	*Ageratum conyzoides*	S,Fr	S,D	G	G	V	V	V	Fl	Fl	Fl	Fl,Fr	Fr,S
4	*Bidens pilosa*	S	S,D			G	V	V	V	Fl	Fl	Fl, Fr	S
5	*Chromolaena odorata*	S,D		G	G	G	Fl	Fl	Fl	Fl,Fr	Fl,Fr	Fl,Fr	Fr,S
6	*Cyrtococcum accrescens*	S	S,D	G	G	V	V	V, Fl	Fl	Fl	Fl, Fr	Fl, Fr	S
7	*Imperata cylindrica*			G	G,V	G,V	Fl,Fr	Fl,Fr	Fl,Fr	Fl,Fr	Fr,S		
8	*Mikania micrantha*	Fl,Fr	Fl,Fr	Fr,S	S,D		G	G	G,V	V	Fl,Fr	Fl,Fr	Fl,Fr
9	*Oxalis corniculata*	S,D		G	G	G,V	Fl	Fl	Fl	Fl,Fr	Fl,Fr	Fl,Fr	Fr,S
10	*Stellaria media*	Fl,Fr	Fl,Fr	Fr,S	S,D	G	G	V	V	Fl,Fr	Fl,Fr	Fl,Fr	Fl,Fr



Graph 1.6.6: Seasonal variation of Rainfall and Air Temperature during the First year.



Graph 1.6.7: Seasonal variation of Rainfall and Air Temperature during the Second year.



Graph 1.6.8: Seasonal variation of Relative Humidity (%) during the First and Second year.

The seasonal variations in meteorological parameters are presented in Tables 1.1, 1.2, 1.3 and Graphs 1.6.6, 1.6.7, 1.6.8, and correlations between these meteorological parameters and the phenological changes are explained as follows. Most of the weeds started to germinate at the beginning of spring (March-May) except for *B. pilosa, M. micrantha* and *S. media* (Table 2.2). Flowering and fruiting occurs during summer (June-Aug) till autumn (Sept-Nov) when the air temperature as well as relative humidity is high as compared to spring and winter. The weed

population decreases during winter when the temperature and humidity decreases. By December many weeds have died after completing their life cycle. The study of the phenological pattern helps in understanding seed production and seed dispersal for an effective weed management.

5.3.1 Classification and morphological description of the common weeds

Scientific classification of *Acmella oleracea* (L.) R.K. Jansen

Kingdom- Plantae

Order- Asterales

Family- Asteraceae

Genus- *Acmella*

Species- *A. oleracea*

Binomial name-*Acmella oleracea* (L.) R.K. Jansen

Synonyms-*Spilanthes oleracea* L.

Common name- Toothache plant.

Figure 1: A. Habitat; B. Inflorescence of *A. oleracea*

Occurrence and distribution: *Acmella oleracea* is a genus comprising of over 60 species that are widely distributed in tropical and subtropical regions of the world, such as Africa, America, Borneo, India, Sri Lanka and Asia (Sahu *et al*., 2011; Tiwari *et al*., 2011). *A. oleracea* is native to Brazil and is cultivated throughout the year as ornamental or medicinal plant.

Morphology of the plant: Annual erect or ascending stout herbs, 20-50 cm high. Leaves are opposite, petiolate, broadly ovate, narrowed at base, acute or obtuse at apex. Stems are glandular hairy with pungent taste. The whole plant is acrid in taste. It has striking cone-like flowers.

Reproduction: Germination occurs early March. Flowering and fruiting is found to occur during the month of June till early winter season.

Scientific classification of *Adiantum lunulatum* Burm.f.

Kingdom- Plantae

Order- Polypodiales

Family- Pteridaceae

Genus- *Adiantum*

Species- *A. lunulatum*

Binomial name- *Adiantum lunulatum* Burm.f.

Figure 2: Habitat of *A. lunulatum.*

Synonyms- *Adiantum philippense* L.

Common name- Walking maidenhair fern

Occurrence and distribution: *Adiantum* is popularly known as 'Maiden hair fern' because of the shiny black rachis of the leaves. It is one of the most widely distributed genera of the family growing luxuriantly in both tropical and sub topical regions. It grows ubiquitously wherever nature offers a moist, shaded locality. Widely distributed in the tropics through Africa, Asia, Australia, Central America and Northern S. America.

Morphology of the plant: It is an evergreen, perennial fern producing fronds up to 40cm tall from a shortly-creeping rhizome. The sporophytic plant body consists of an underground rhizome from which are produced leaves and roots. The rhizome is covered with chaffy scales (Paleae). The leaves show circinate vernation typical of ferns. The rachis of the leaf is hard, wiry, shiny and black or dark brown in colour. Glandular hairs may also be present.

Reproduction: Vegetative propagation is brought about by buds produced at the leaf tips. The buds enter the ground when the leaf bends and touches the soil. There they develop into a new individual. Germination starts as early as March. Vegetation propagation starts from June. Flowering and fruiting is found to occur from September till early January. Their entire life cycle ends at February. Their population decreases during winter due to dry condition.

Scientific classification of *Ageratum conyzoides* L.

Kingdom- Plantae

Order- Asterales

Family- Asteraceae

Genus- *Ageratum*

Species- *A. conyzoides*

Binomial name- *Ageratum conyzoides* L.

Synonyms- *Ageratum ciliare* L.

Common name- Billygoat weed

Figure 3: A. Habitat; B. Inflorescence of *A. conyzoides.*

Occurrence and distribution: *Ageratum conyzoides* L. is a tropical plant found in some regions of Africa, Asia and South America. This species is commonly known as billy goat weed. It is a terrestrial, annual, erect herb, upto 120cm tall. It is an annual aromatic weed of cultivated fields, however, it is also invasive of pastures, vacant lots and even of forest areas.

Morphology of the plant: *A. conyzoides* have fasciculate root, weakly fixed to the soil. The stem is classified as aerial, has cylindrical shape and is covered by trichomes. The leaves are simple, opposite, oval shape, acute tip, attenuated base and toothed margin, covered with whitish trichomes. The terminal inflorescence bears about fifteen purple flower-head. The flower head is surrounded by two or three rows of oblong bracts which are green with pale or reddish-purple tops.

Reproduction: Seeds are dispersed by wind and water. Flowering all the year round, usually starts in August due to favourable wet and humid condition and may produce up to 40,000 seeds per plant. The seeds also germinate in response to light (are photoblastic) and are often no longer viable within 12 months. Germination occurs during early March. Eventually, their population diminishes with decrease in temperature and rainfall.

Scientific classification of *Bidens pilosa* L.

Kingdom- Plantae

Order- Asterales

Family- Asteraceae

Genus- *Bidens*

Species- *B. Pilosa*

Binomial name- *Bidens pilosa* L.

Synonyms- *Bidens alba* (L.) DC.

Common name- Farmers' friends.

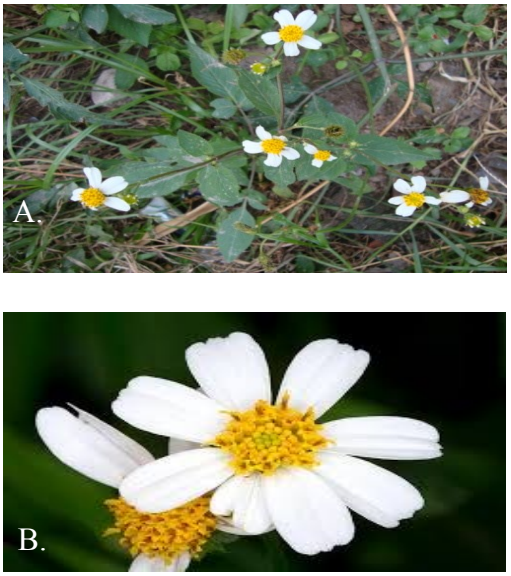


Figure 4: A. Habitat; B. Inflorescence of *B. pilosa.*

Occurrence and distribution: *Bidens pilosa* is an erect herb, slightly branched, and strong smelling, usually high of 20 to 60 cm, but can reach up to 1.5 m. It is a native to tropical America. The species is a cosmopolitan weed common in tropical and subtropical regions worldwide.

Morphology of the plant: The leaves are soft and light green in color. They are opposite and arranged crosswise in pairs. The lamina is deeply divided into three to five-segments whose edge is serrated. The petiole is long and lined with tiny white hairs. The flowers are grouped terminally in globular heads or at the base of the leaves. Each head consists of a few white flowers spread at the periphery and many yellow flowers in the centre. The inflorescence is surrounded by two rows of small green spatula shaped pieces. When ripe, the fruits form black balls studded with spikes.

Reproduction: The numerous seeds (3000 to 6000 per individual) are capable of germinating immediately after dispersal. They usually germinate during the month of May. They dispersed via air, water and wind. All the species of *Bidens* produces large quantity of seed due to humid and moist condition, which can germinate immediately after being shed. With *B. pilosa* it has been shown that, if conditions are not suitable for germination for about 8 weeks, the seed becomes dormant and can

remain viable for a considerable period. Flowering and fruiting occurs during the month of September till onset of winter.

Scientific classification of *Chromolaena odorata* (L.) R.M. King & H. Rob.

Kingdom- Plantae

Order- Asterales

Family- Asteraceae

Genus- *Chromolaena*

Species- *C. Odorata*

Binomial name- *Chromolaena odorata* (L.)

R.M. King & H. Rob.

Synonyms- *Eupatorium odoratum* L.

Common name- Jack in the bush.

Figure 5: A. Habitat; B. Inflorescence of *C. odorata.*

Occurrence and distribution: It is a fast growing shrubby perennial that forms dense bushes about 2.5 to 6 m (8.2 to 19.6 ft.) tall when climbing on other plants. *C. odorata* is a very widely distributed tropical shrub that is still expanding its range, and is considered one of the world's worst weeds. It continues to spread due to its effective short- and long-distance dispersal. *C. odorata* is often noted as a native of tropical Central and South America, from Mexico and the Caribbean to Brazil.

Morphology of the plant: The leaves are lanceolate, pubescent, with a serrate margin, and grow opposite. The stems branch freely and develop lateral branches in pairs. The older parts of the stems are brown and woody near the base; the tips and

young shoots succulent with a green to purplish brown colour. The root system is fibrous and does not penetrate beyond 30cm in moist soils. The flower heads are borne in terminal corymbs of 20 to 60 heads on all stems and branches. The flowers are white or pale lilac and when dry they have a feathery aspect.

Reproduction: The seeds have small spines that can adhere to clothes, fur and feathers, especially when these are wet. They dispersed through air, wind and water. It is known to reproduce vegetatively. Seed production is very prolific with up to 87,000 seeds per mature plant or about 400,000/sq/m. Some seeds survive for up to 5 years. A plant can germinate and set seed within a 12 month period. They usually germinate on the onset of spring during abundant rainfall and temperature. Flowering is usually seen from the month of June till early winter.

Scientific classification of *Cyrtococcum accrescens* (Trin.) Staph

Kingdom- Plantae

Order- Poales

Family- Poaceae

Genus- *Cyrtococcum*

Species- *C. Accrescens*

Binomial name- *Cyrtococcum accrescens*

(Trin.) Staph

Synonyms- *Cyrtococcum patens*

var. *latifolium* (Honda) Ohwi

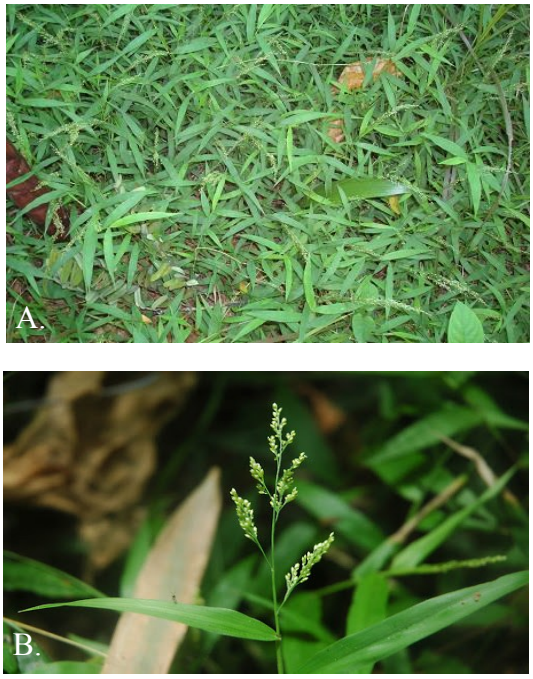


Figure 6: A. Habitat; B. Inflorescence of *C. accrescens.*

Occurrence and distribution: It is a creeping, annual grass. It is distributed throughout the Himalayas, tropical Asia.

Morphology of the plant: Culms are 15-55 cm long, creeping or trailing, rooting at the lower nodes. Leaves are ovate-lanceolate, base cuneate, apex acuminate; sheaths

softly villous, margins ciliate; ligules ovate. Panicles are 5-14 cm long. Spikelets are long, ovate or obovate, purplish-green.

Reproduction: Plants are bisexual, all with bisexual spikelets; with hermaphrodite florets. Inflorescence are paniculate; open, or contracted. Rachilla terminated by a female-fertile floret. Hairy callus absent. Two glumes are present; more or less equal; shorter than the spikelets; shorter than the adjacent lemmas. Fruits are small; compressed laterally. Hilum is short and embryo is large. Germination starts as early as March. Fruiting and flowering occurs during July till early winter. Their population increases with increase in humidity and rainfall but deceases with temperature.

Scientific classification of *Imperata cylindrica* (L.) Raeusch.

Kingdom- Plantae

Order- Poales

Family- Poaceae

Genus- *Imperata*

Species- *I. cylindrica*

Binomial name- *Imperata cylindrica* (L.) Raeusch.

Synonyms- *Imperata latifolia* (Hook. f) L. Liou

Common name- Spear grass.

Figure 7: A. Habitat; B. Inflorescence of *I. cylindrical.*

Occurrence and distribution: It is a perennial rhizomatous grass commonly known as cogongrass or speargrass. It is native to Southeast Asia and is a widespread invader in many subtropical and tropical regions. It is an extremely aggressive invader with the capability of invading a range of sites. It forms dense, usually circular infestations that exclude all other vegetation. It can grow upto 6 feet tall.

Morphology of the plant: Leaves have an off-center, whitish midrib and finely serrated margins. Leaves are up to 6 ft. (1.8 m) long, 0.5-0.75 in. (1.3-1.9 cm) wide,

stiff, and have a sharp, pointed apex. Rhizomes are whitish, branched, scaly and sharp at the tips. Flower heads are 2-8 in. (5.1-20.3 cm) long, silvery-white and cylindrical. *Imperata cylindrica* is best identified in the spring by the large fuzzy panicle of flowers and seeds, giving the plant a cottony or silky look.

Reproduction: Seeds are dispersed by wind over long distances to colonize cleared or previously uninfested land. It can produce as many as 3000 seeds per plant (Holm *et al*., 1977) and 95% of the seeds can germinate within one week of being harvested but can also retain viability for atleast one year (Santiago, 1965). Germination occurs from the month of March, when temperature starts to increase and the condition becomes ideal for germination. *I. Cylindrical* is not capable of self-pollination (Gabel, 1982) and produces viable seeds only through cross-pollination (McDonald *et al*., 1996). Flowering occurs during summer. It is variable between individual plants and can occur in response to stress from slashing, grazing, burning, mowing, or the addition of nitrogen (Holm *et al*., 1977; Willard, 1988).

Scientific classification of *Mikania micrantha* Kunth.

Kingdom- Plantae

Order- Asterales

Family- Asteraceae

Genus- *Mikania*

Species- *M. micrantha*

Binomial name- *Mikania micrantha* Kunth.

Synonyms- *Mikania denticulata* (Vahl) Wild.

Common name- Bitter vine.

Figure 8: A. Habitat; B. Inflorescence of *M. micrantha.*

Occurrence and distribution: M*ikania micrantha* Kunth is an extremely fast-growing, sprawling, perennial vine belonging to the family Asteraceae and native to tropical America (Day *et al*., 2016). The vine is listed as one of the top 100 worst invasive species by the International Union for Conservation of Nature (IUCN) (Lowe *et al*., 2000). It was introduced in India in the 1940s as ground cover in tea plantations (Prabu, Stalin & Swamy, 2014). It produces thousands of lighweight seeds that are wind-dispersed and also has the ability to reproduce vegetatively through its roots, resulting in rapid and widespread invasion by this weed in any disturbed area.

Morphology of the plant: Leaves are simple, opposite, stalked. Leaf blade 3 to 13 cm wide and from 3 to 10 cm wide, oval or triangular. Its apex is acute and its base shortly acuminate. Inflorescence formed by small whitish or greenish-white flower heads arranged in panicles, twigs bearing composite cymes, dense, terminal and lateral. The flower stalk is 5 mm long, each having at its top a subinvolucrale bract, narrowly elliptic to obovate, acuminate, glabrous to more or less pubescent, about 2 mm long. The flowers contain only 4 flowers. The involucral bracts are arranged in 2 rows. The flowers are white, all tubular, corolla ends with 5 triangular lobes. The fruit is a black achene, oblong to obovate, ribbed, pentagonal section.

Reproduction: It germinates early in the summer season in presence of humidity and rainfall; grows extremely fast with a maximum mean growth rate of 20 □cm day$^{\square 1}$ (Li *et al*., 2012); roots from each vine node has a smothering habit; produces very large numbers of widely dispersed seeds of about 170,000 □m$^{\square 2}$ (Kuo *et al*., 2002) which are very small (8.92 □× □10$^{\square 5}$ □g 1000 grains$^{\square 1}$); and has an ability to survive harsh conditions (Hu and But, 1994; Yang *et al*., 2003). Flowering starts during the month of October when the temperature starts to decline.

Scientific classification of *Oxalis corniculata* L.

Kingdom- Plantae

Order- Geranials

Family- Oxalidaceae

Genus- *Oxalis*


A.

Species- *O. corniculata*

Binomial name- *Oxalis corniculata* L.

Synonyms- *O. Albicans* Kunth.

Common name- Creeping woodsorrel.

Figure 9: A. Habitat; B. Inflorescence of *O. corniculata.*

Occurrence and distribution: *Oxalis corniculata* is an annual or short-lived perennial herb growing only 5 - 10cm tall but spreading at the roots to form a mat of growth 30cm or more wide. They are found in grassland. It is commonly known as creeping wood sorrel. It is a native primarily to southern Africa and tropical and South America.

Morphology of the plant: The leaves arise from a creeping, scaly rootstock, and the flowers are borne singly on a stalk that arises from the leaf axil. The flowers have five white, purple-veined petals. The fruit is a capsule that splits open by valves. The seeds have a fleshy coat, which curls back elastically, ejecting the true seed. The leaflets, as in other species of the genus, fold back and droop at night. The flowers are 1-1.5 cm in diameter and have 5 yellow petals. The fruit is a capsule, 1-1.5 cm long, cylindric, pointed apically, and 5-ridged in cross section.

Reproduction: This wildflower can reproduce vegetatively by forming rootlets along the nodes of its creeping stolons. Small colonies of plants are often produced and is pollinated by Insects. The plant is self-fertile. Germination occurs from March. Flowering starts from June and it flowers throughout the year.

Scientific classification of *Stellaria media* (L.) Vill.

Kingdom- Plantae

Order- Caryophyllales

Family- Caryophyllaceae

Genus- *Stellaria*

Species- *S. Media*

Binomial name- *Stellaria media* (L.) Vill.

Synonyms- *Alsine media* L.

Common name- Chickweed

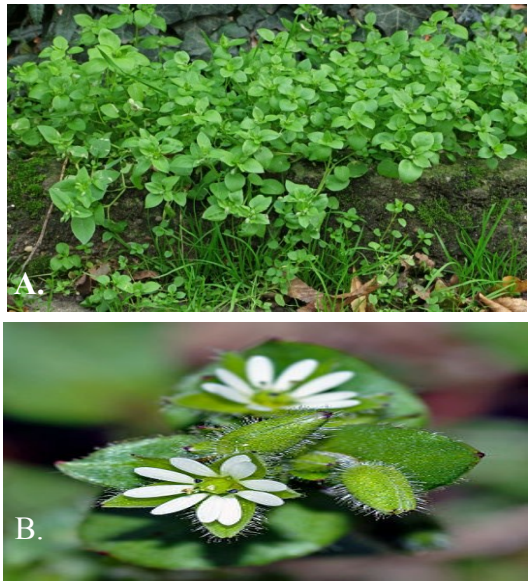


Figure 10: A. Habitat; B. Inflorescence of *S. media.*

Occurrence and distribution: *Stellaria media* commonly known as chickweed produces 1/2 inch to 1 inch stems that usually sprawl across the ground. It branches abundantly near the base. It grows almost anywhere.

Morphology of the plant: It is an erect or diffuse herb; stems are tomentose. Leaves opposite, ovate, acute, glabrous, lateral nerves form a clear intra-marginal vein. Flowers solitary, axillary and terminal; sepals oblong, hairy outside; petals 5, 2-fid to base, white; stamens 10, free; ovary 1-celled, ovules few, basal; styles 3, curved, tubercled. Capsule ovoid; seeds 4-8, reniform, tuberculate. The stems terminate in small white flowers. Each flower is consist of 5 white bifid petals (appearing to be 10 petals), 5 green sepals, 3 white styles, 2 to 10 stamens, and a light green ovary in the center.

Reproduction: It flowers all year round. Vegetation starts during the month of May when there is abundant rainfall as well as humidity. The blooming period occurs during the spring for plants that are winter annuals, and during the summer or autumn for plants that are summer annuals. A typical plant will bloom sporadically for 1-2 months.

5.4 Allelopathic effect of weed extract:

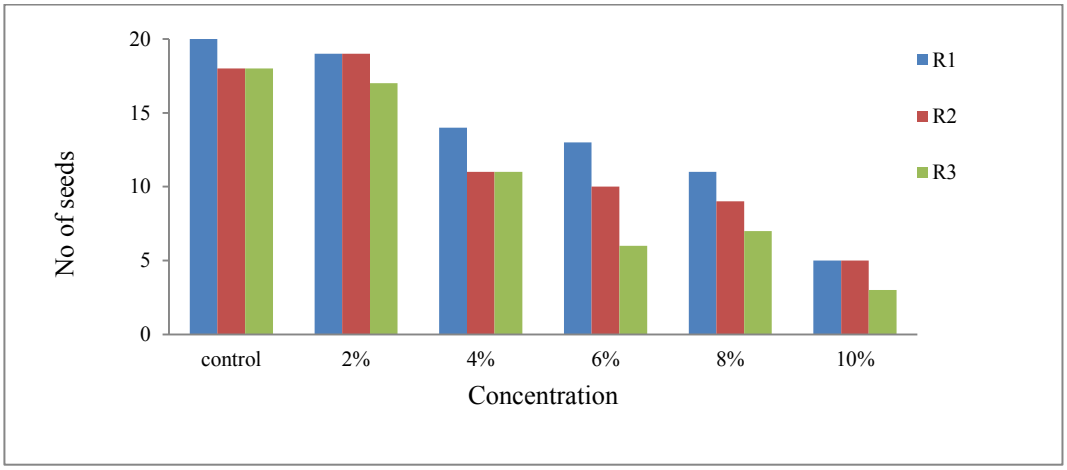
5.4.1 Allelopathic effect of *Ageratum conyzoides* on the germination% of *Brassica campestris.*

Observations on germination% under different concentrations of weed leaf extract were recorded after a week of treatment. 20 seeds of the agricultural crops were placed in the petri-dish and 3 replicates were recorded for each concentration.

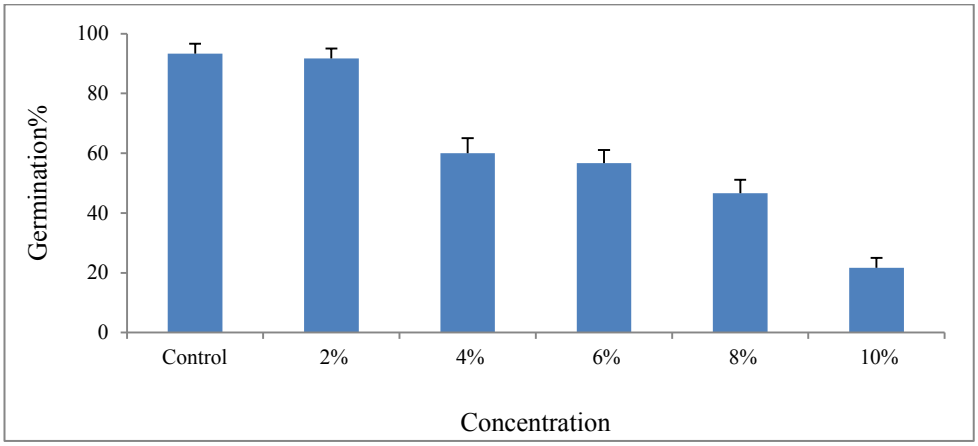
When treated with aqueous leaf extract of *A. conyzoides*, there is a gradual decrease of seed germination% in *B. campestris* (Table 3.1). There may be seed germination in the higher concentration of aqueous leaf extract of *A. conyzoides,* but the germinated seeds could not survive and they die. Germination at control is 93.3% while only 21.6% germinated at 10% concentration.

Table 3.1: Germination% of *Brassica campestris* on different concentrations of *Ageratum conyzoides*.

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	18	18	93.3%
2%	20	19	19	17	91.6%
4%	20	14	11	11	60%
6%	20	13	11	10	56.6%
8%	20	11	9	8	46.6%
10%	20	5	5	3	21.6%



Graph 2.1: No. of *Brassica campestris* seeds germinated when treated with *Ageratum conyzoides.*



Graph 2.2: Germination% of *Brassica campestris* when treated with *Ageratum conyzoides.*

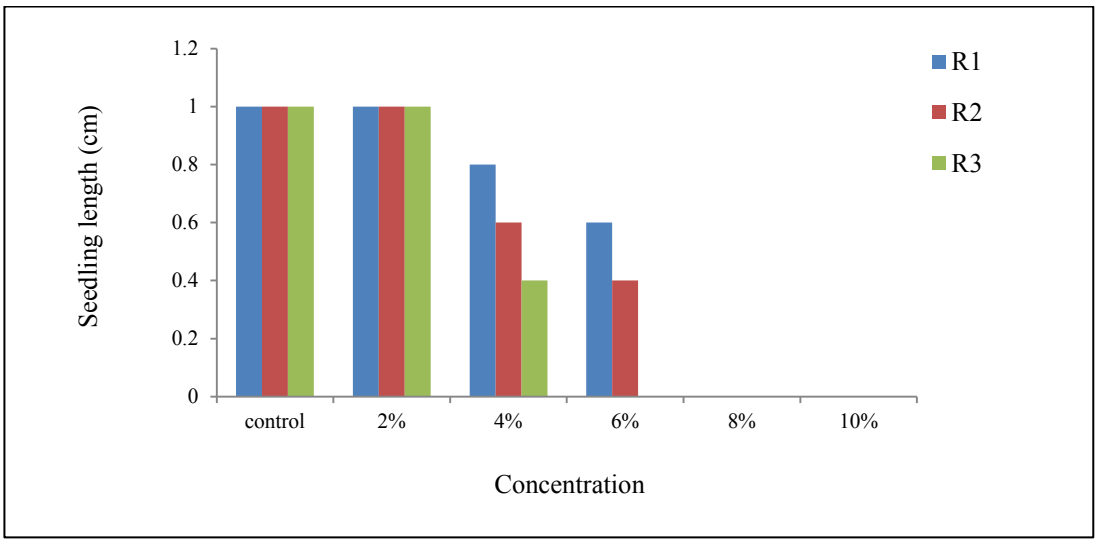
5.4.2 Alleopathic effect of *Ageratum conyzoides* on the seedling growth of *Brassica campestris.*

Observations on seedling growth under different concentrations of weed leaf extract were recorded after a week of treatment. 20 seeds of the agricultural crops were placed in the petri-dish and 3 replicates were recorded for each concentration.

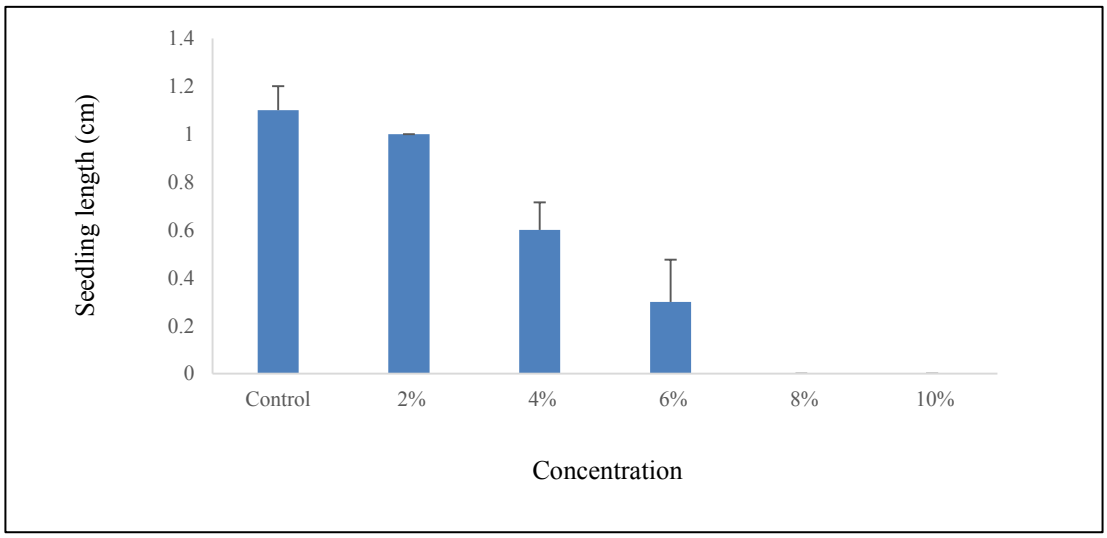
When treated with aqueous leaf extract of *A. conyzoides*, the seedling growth rate shows a gradual decline. It greatly inhibit the seedling growth of *Brassica* as most of the seeds did not germinate. The seedling length of control was found to be only 1cm (Table 3.2).

Table 3.2: Averaged seedling length of *Brassica campestris* on different concentrations of *Ageratum conyzoides*.

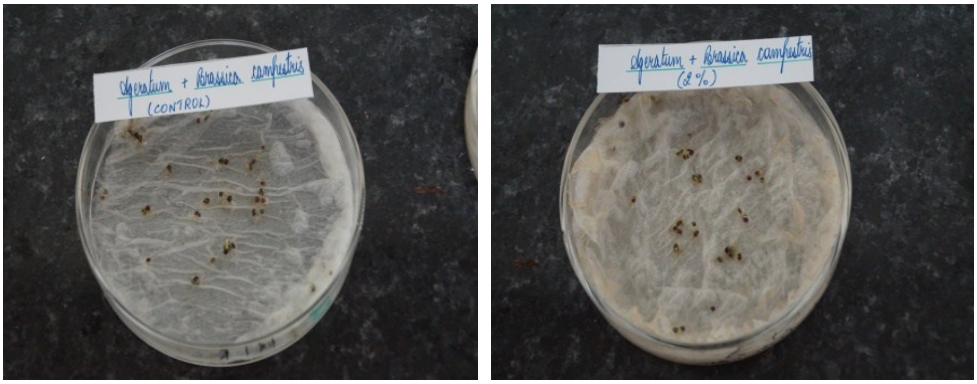
Dilutions	Seedling length			Avg. Seedling length
	R1	R2	R3	
Control	1.3	1	1	1.1
2%	1	1	1	1
4%	0.8	0.6	0.4	0.6
6%	0.6	0.4	0	0.3
8%	0	0	0	0
10%	0	0	0	0



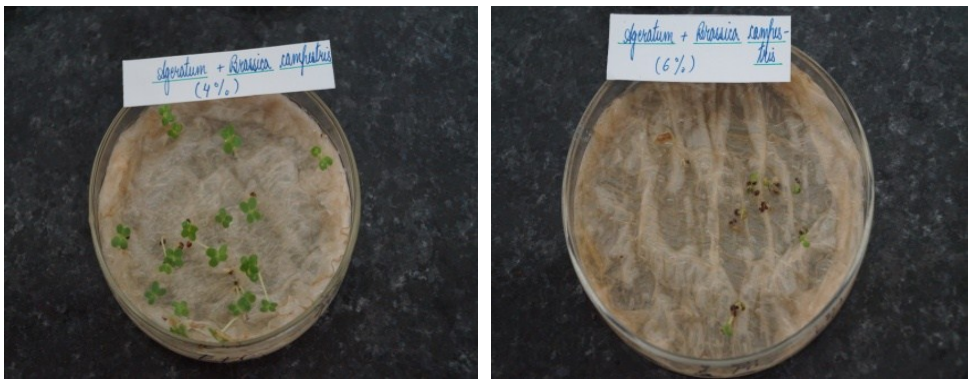
Graph 2.3: Avg. seedling length of *Brassica campestris* when treated with *Ageritum conyzoides*.



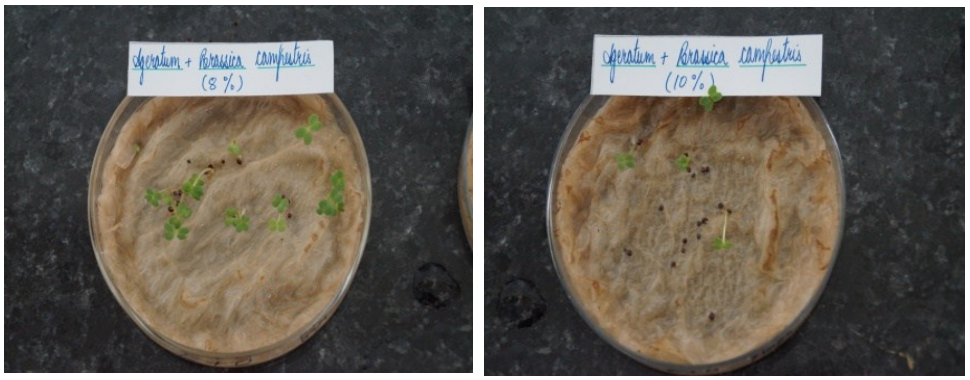
Graph 2.4: Seedling growth of *Brassica campestris* when treated with *Ageritum conyzoides*.



A. B.



C. D.



E. F.

Photoplate 1: Germination of *Brassica campestris* seeds at different concentrations of *Ageratum conyzoides.*

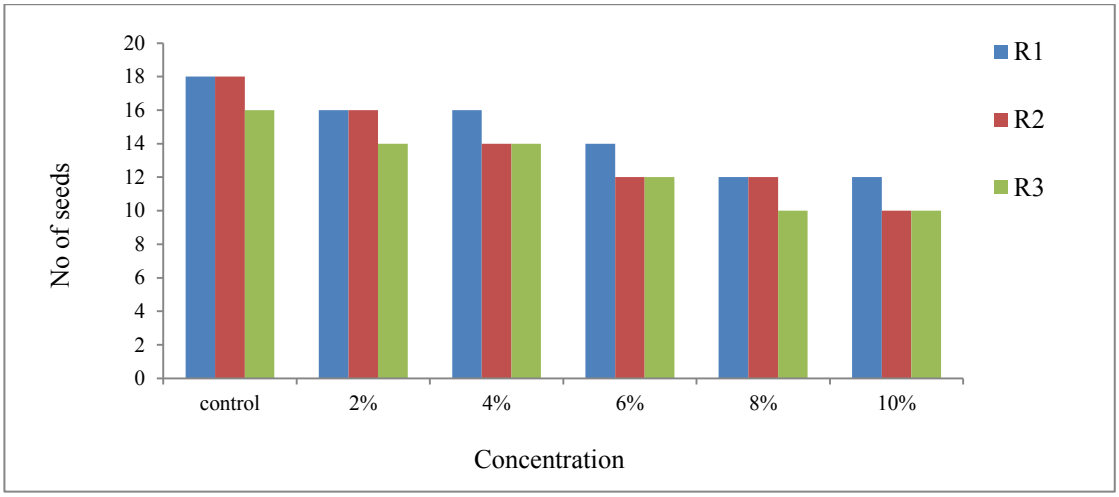
A. *B. campestris* seeds at control.
B. *B. campestris* seeds at 2% concentration.
C. *B. campestris* seeds at 4% concentration.
D. *B. campestris* seeds at 6% concentration.
E. *B. campestris* seeds at 8% concentration.
F. *B. campestris* seeds at 10% concentration.

5.4.3 Allelopathic effect of *Ageratum conyzoides* on the germination % of *Oryza sativa.*

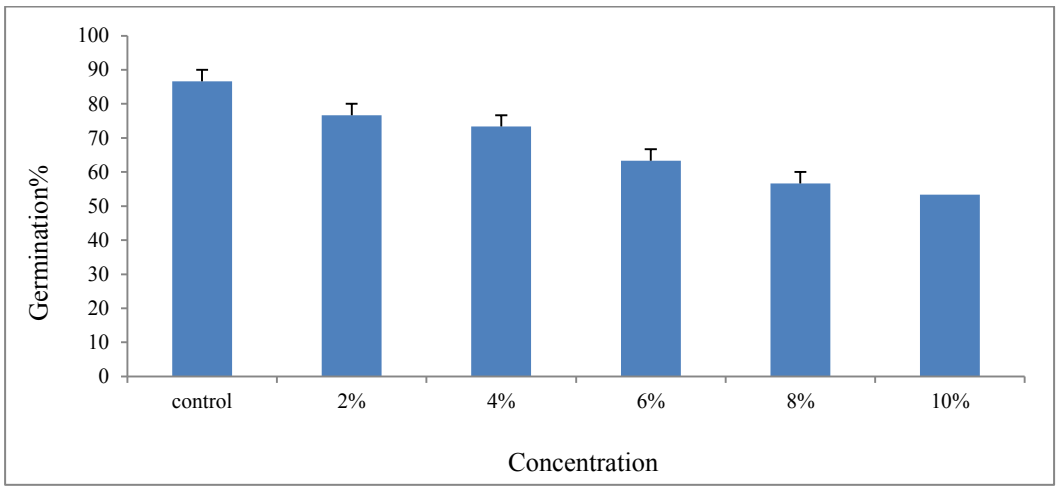
O. sativa when treated with aqueous leaf extract of *A. conyzoides* also shows decrease in the germination rate. However, it clearly shows a high percentage of germination in all concentrations. This shows that *O. sativa* can germinate even in presence of *A. conyzoides* extracts. At control, 86.6% of the seeds germinate while 53.3% of seeds germinated at 10% concentration (Table 3.3).

Table 3.3: Germination% of *Oryza sativa* on different concentrations of *Ageratum conyzoides*.

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	18	18	16	86.6%
2%	20	16	16	14	76.6%
4%	20	16	14	14	73.3%
6%	20	14	12	12	63.3%
8%	20	12	12	10	56.6%
10%	20	12	10	10	53.3%



Graph 2.5: No. of *Oryza sativa* seeds germinated when treated with *Ageratum conyzoides.*



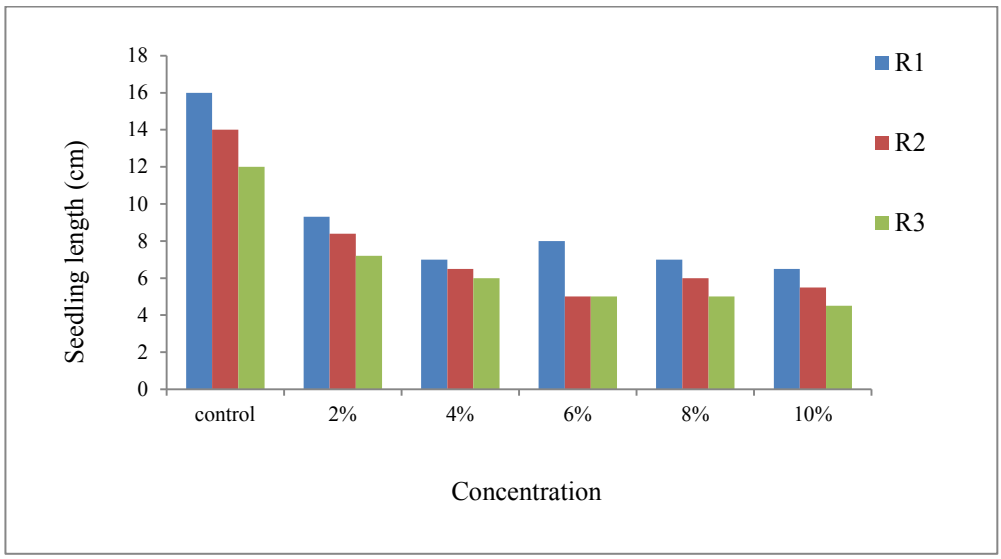
Graph 2.6: Germination% of *Oryza sativa* when treated with *Ageritum conyzoides.*

5.4.4 Allelopathic effect of *Ageratum conyzoides* on the seedling growth of *Oryza sativa.*

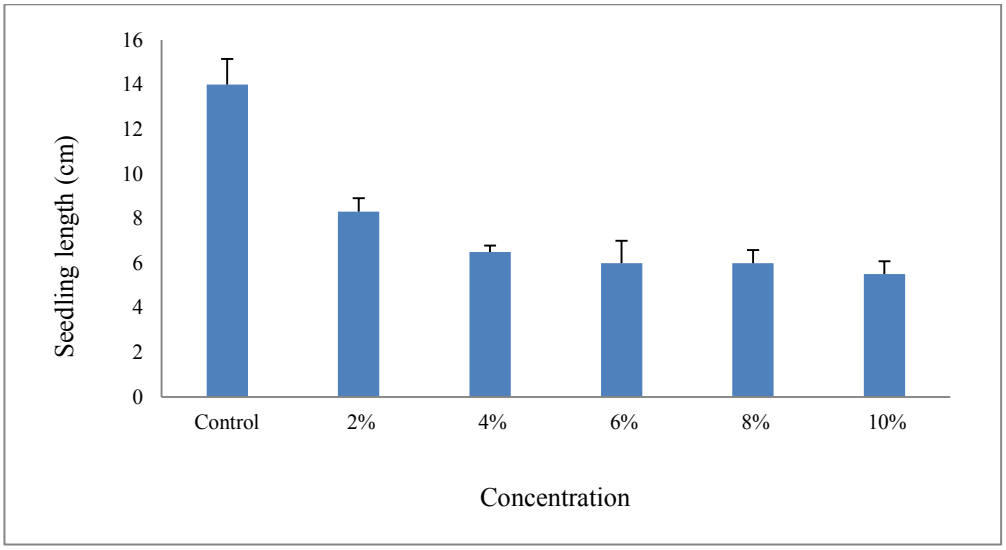
There is a gradual decline in seedling length. The seedling length of *O. sativa* is highest in control i.e. 14cm while in 10% it shows minimum length of 5.5cm. Although, *A. conyzoides* extracts decreases the growth of *O. sativa,* it does not entirely inhibit the seedling length (Table 3.4).

Table 3.4: Averaged seedling length of *Oryza sativa* on different concentrations of *Ageratum conyzoides*.

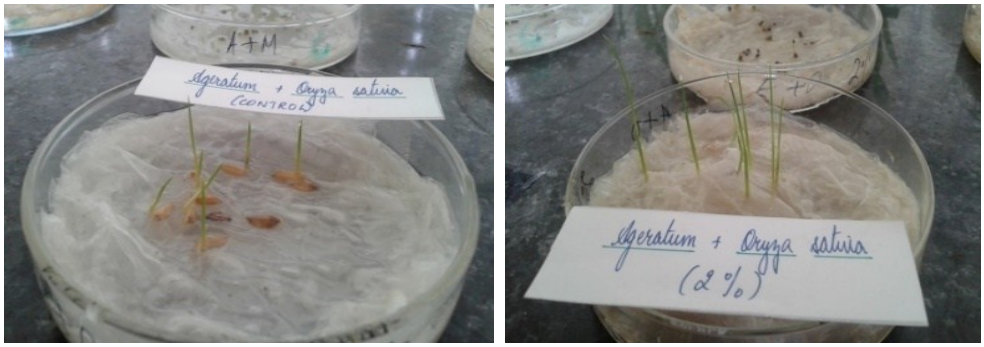
Dilutions	Seedling length			Avg. Seedling length
	R1	R2	R3	
Control	16	14	12	14.0
2%	9.3	8.4	7.2	8.3
4%	7	6.5	6	6.5
6%	8	5	5	6.0
8%	7	6	5	6.0
10%	6.5	5.5	4.5	5.5



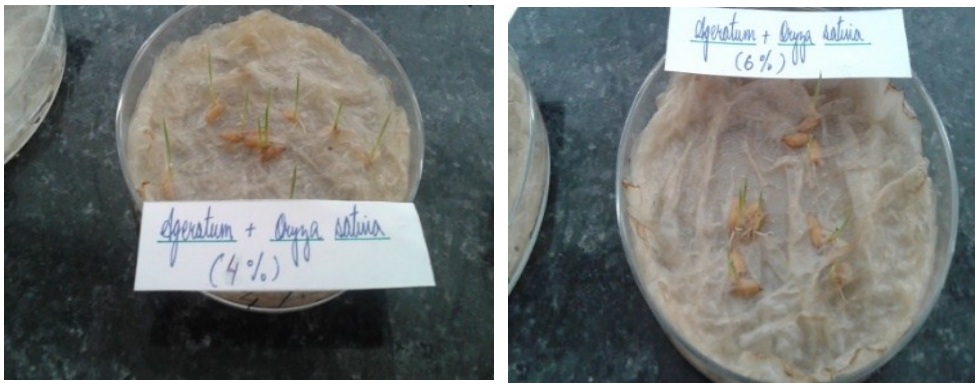
Graph 2.7: Avg. seedling length of *Oryza sativa* when treated with *Ageritum conyzoides*.



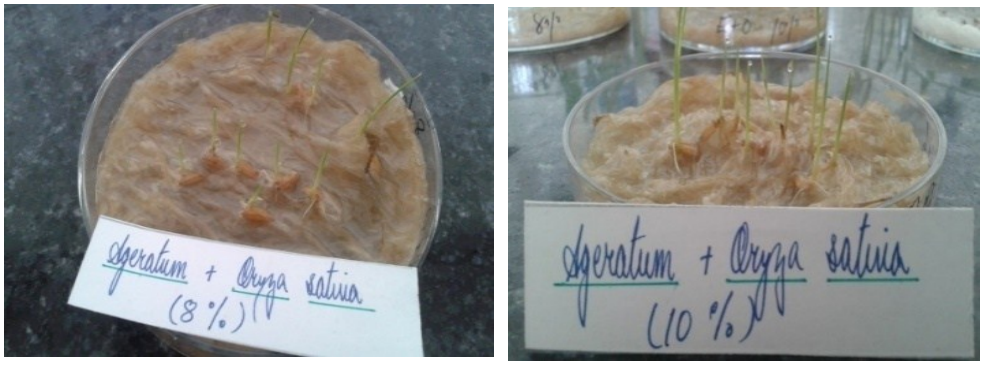
Graph 2.8: Seedling growth of *Oryza sativa* when treated with *Ageritum conyzoides*.



A. B.



C. D.



E. F.

Photoplate 2: Germination of *Oryza sativa* seeds at different concentrations of *Ageratum conyzoides.*

A. *O. sativa* seeds at control.
B. *O. sativa* seeds at 2% concentration.
C. *O. sativa* seeds at 4% concentration.
D. *O. sativa* seeds at 6% concentration.
E. *O. sativa* seeds at 8% concentration.
F. *O. sativa* seeds at 10% concentration.

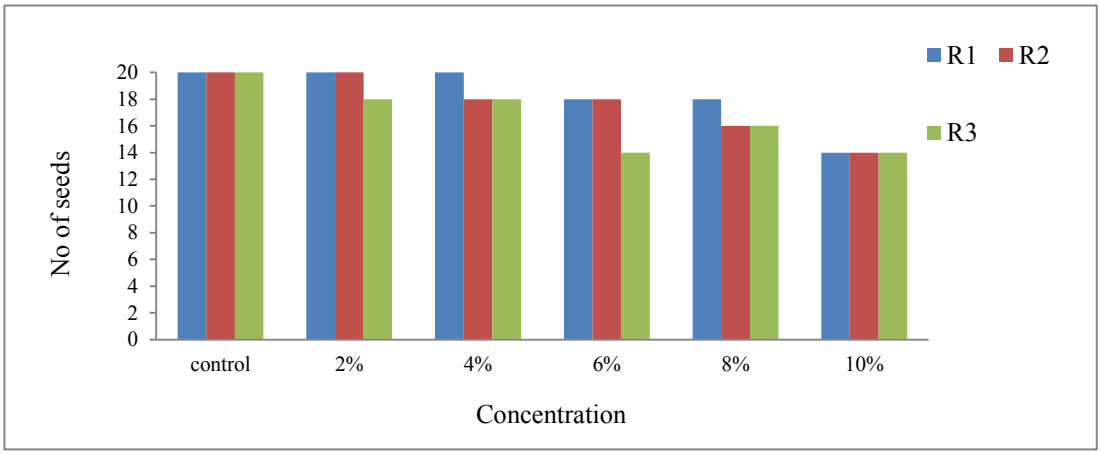
5.4.5 Allelopathic effect of *Ageratum conyzoides* on the germination % of *Zea mays.*

The Table 3.5 shows a slow but gradual decline in germination % when treated with *A. conyzoides.* All the seeds in control germinated. This indicates that the weed *A. conyzoides* has little or no effect on *Z. mays.* However, it still showed a gradual decline in the germination %.

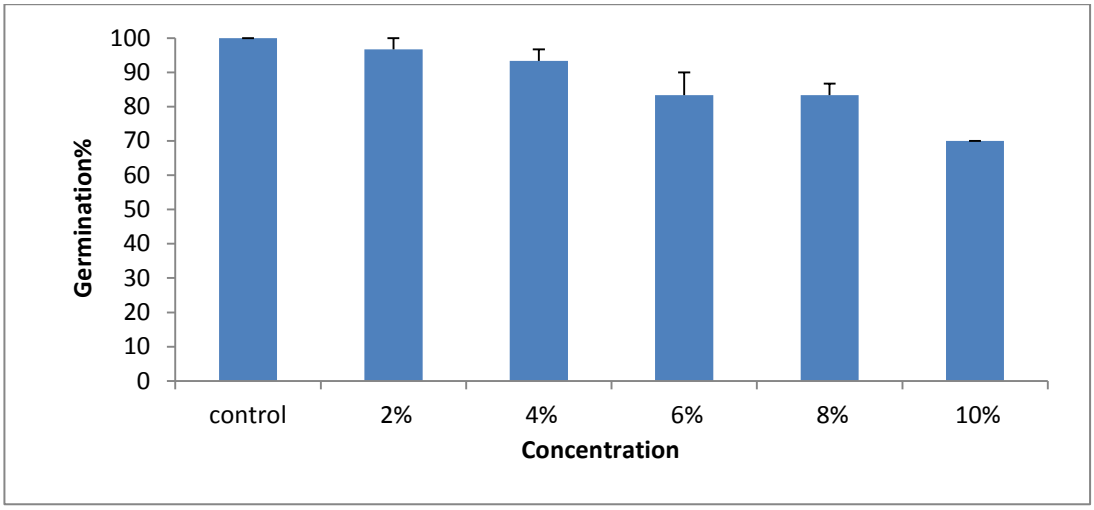
Table 3.5: Germination% of *Zea mays* on different concentrations of *Ageratum conyzoides.*

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	20	20	100%
2%	20	20	20	18	90.6%
4%	20	20	18	18	93.3%
6%	20	18	18	14	83.3%
8%	20	18	16	16	83.3%
10%	20	14	14	14	70%

.



Graph 2.9: No. of *Zea mays* seeds germinated when treated with *Ageritum conyzoides*.



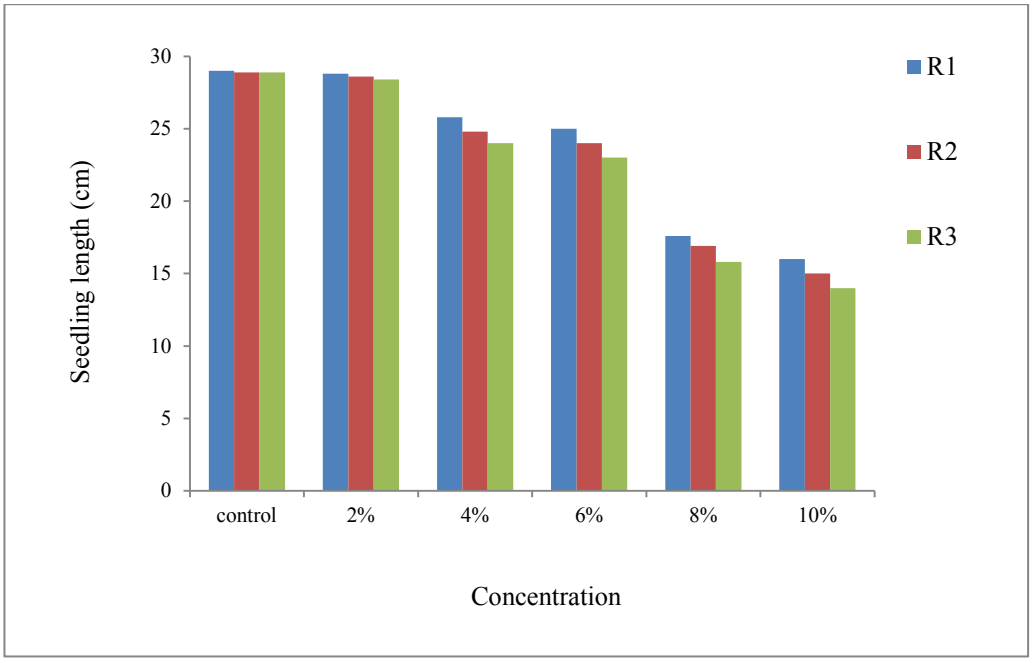
Graph 2.10: Germination% of *Zea mays* when treated with *Ageritum conyzoides.*

5.4.6 Allelopathic effect of *Ageratum conyzoides* on the seedling growth of *Zea mays.*

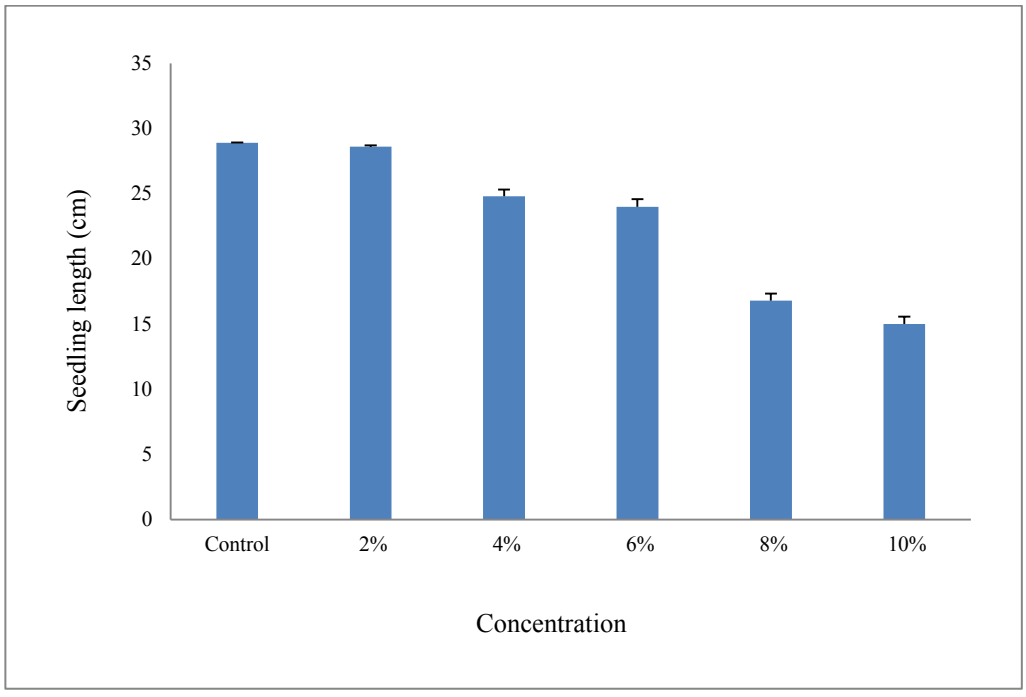
There is a slow but gradual decline in the seedling growth. However, the seedling length when measured ranges from 28cm to 15cm. This shows that the presence of *A. conyzoides* has little or no effect on the seedling growth (Table 3.6).

Table 3.6: Averaged seedling growth of *Zea mays* on different concentrations of *Ageratum conyzoides*.

Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	29	28.9	28.9	28.9
2%	28.8	28.6	28.4	28.6
4%	25.8	24.8	24	24.8
6%	25	24	23	24.0
8%	17.6	16.9	15.8	16.8
10%	16	15	14	15



Graph 2.11: Avg. seedling length of *Zea mays* when treated with *Ageritum conyzoides.*

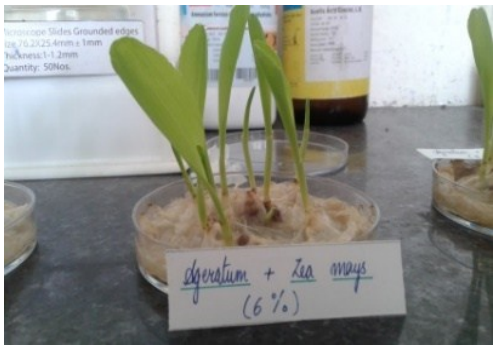


Graph 2.12: Seedling growth of *Zea mays* when treated with *Ageritum conyzoides.*

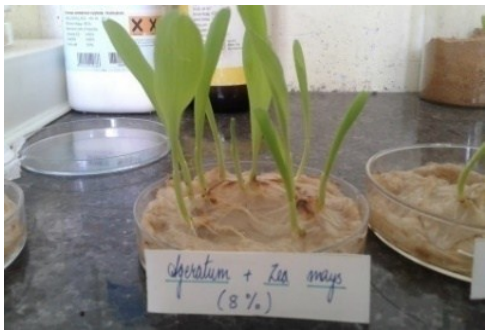
A.

B.

C.



D.



E.

F.

Photoplate 3: Germination of *Zea mays* seeds at different concentrations of *Ageratum conyzoides.*

A. *Z. mays* seeds at control.
B. *Z. mays* seeds at 2% concentration.
C. *Z. mays* seeds at 4% concentration.
D. *Z. mays* seeds at 6% concentration.
E. *Z. mays* seeds at 8% concentration.
F. *Z. mays* seeds at 10% concentration.

5.4.7 Statistical analysis

5.4.8 Germination%

The ANOVA table for the influence of different concentrations of *A. conyzoides* on the three agricultural crops are given in Table 4.1. The study revealed that the effects of the selected weed on the germination% of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p □0.05).

Table 4.1: One way analysis of variance (ANOVA) of selected agricultural crops under the influence of different concentrations of *Ageratum conyzoides* at CTRL, 2%,4%,6%,8%,10% [A(B)=*Ageratum conyzoides*(*Brassica campestris*) A(O)=Ageratum conyzoides(Oryza sativa) A(Z)=Ageratum conyzoides(Zea mays)].

Parameters	Source of variation CTRL×2%×4%×6%×8%×10%	F-value	p-value
A(B)	-do-	46.354	0.000*
A(O)	-do-	14.700	0.000*
A(Z)	-do-	9.486	0.001*

* Values are significant at p □0.05

5.4.9 Seedling growth

The ANOVA table for the influence of different concentrations of *A. conyzoides* on the three agricultural crops are given in Table 4.2. The study revealed that the effect of the selected weed on the seedling growth of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p □0.05).

Table 4.2: One way analysis of variance (ANOVA) of selected agricultural crops under the influence of different concentrations of *Ageratum conyzoides* at CTRL, 2%,4%,6%,8%,10%.

Parameters	Source of variation CTRL×2%×4%×6%×8%×10%	F-value	p-value
A(B)	-do-	25.294	0.000*
A(O)	-do-	18.107	0.000*
A(Z)	-do-	170.118	0.000*

* Values are significant at p □0.05

5.4.10 Correlation

5.4.11 Germination% w.r.t *Ageratum conyzoides*

Correlation between 2% as well as 4% of *A. conyzoides*(*B. campestris*) and control of *A. conyzoides*(*O. sativa*) shows positively significant relationship (Table 4.3). Similarly, there is also a positive significant relationship between 6%, 8% and 10% of *A. conyzoides*(*B. campestris*) with 4% *A. conyzoides*(*O. sativa*). A positive significant relationship was also found between 8% *A. conyzoides*(*B. campestris*) and 6% *A. conyzoides*(*O. sativa*).

Correlation between 4%, 6%, 8%, 10% of *A. conyzoides*(*B. campestris*) and control of *A. conyzoides*(*Z. mays*) shows positively significant relationships (Table 4.4). Similarly, there is a positive significant relationship between 6%, 8%, 10% of *A. conyzoides*(*B. campestris*) with 2%, 4%, 6%, 8% of *A. conyzoides*(*Z. mays*).

There is a positive significant relationship between 2%, 4%, 8%, 10% of *A. conyzoides*(*O. sativa*) and control of *A. conyzoides*(*Z. mays*). Correlation between 4%, 6%, 8%, 10% of *A. conyzoides*(*O. sativa*) and 2%, 4%, 6%, 8% of *A. conyzoides*(*Z. mays*) shows positively significant relationships (Table 4.5).

Table 4.3: Correlation coefficient (r) values among the different concentrations of *Ageratum conyzoides*(*Brassica campestris*) and *Ageratum conyzoides*(*Oryza sativa*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.815 0.048*	0.000* 1.000	0.224 0.670	0.194 0.713	-0.437 0.386
2%		-0.454 0.366	-0.146 0.736	-0.231 0.659	-0.698 0.123
4%			0.935 0.006*	0.893 0.017*	0.843 0.035*
6%				0.866 0.026*	0.703 0.119
8%					0.778 0.068

*correlation is significant at the 0.05 level (2-tailed)

Table 4.4: Correlation coefficient (r) values among the different concentrations of *Ageratum conyzoides*(*Brassica campestris*) and *Ageratum conyzoides*(*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.552 0.256	0.865 0.026*	0.796 0.058*	0.831 0.040*	0.749 0.087*
2%		0.588 0.220	0.804 0.054*	0.612 0.197	0.549 0.259
4%			0.923 0.009*	0.995 0.000*	0.951 0.004*
6%				0.924 0.008*	0.879 0.021*
8%					0.972 0.001*

*correlation is significant at the 0.05 level (2-tailed)

Table 4.5: Correlation coefficient (r) values among the different concentrations of *Ageratum conyzoides*(*Oryza sativa*) and *Ageratum conyzoides*(*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.944 0.005*	0.876 0.022*	0.777 0.069	0.949 0.004*	0.914 0.011*
2%		0.909 0.012*	0.927 0.008*	0.959 0.002*	0.896 0.016*
4%			0.886 0.019*	0.959 0.002*	0.952 0.003*
6%				0.0850 0.032*	0.844 0.035*
8%					0.919 0.009*

*correlation is significant at the 0.05 level (2-tailed)

5.4.12 Seedling length w.r.t *Ageratum conyzoides*

There is a positively significant relationship between all the different concentrations (control, 2%, 4%, 6%, 8%, 10%) of *A. conyzoides*(*B. campestris*) and *A. conyzoides*(*O. sativa*). Similar relationships are shown between *A. conyzoides*(*B. campestris*) and *A. conyzoides*(*Z. mays*) as well as between *A. conyzoides*(*O. sativa*) and *A. conyzoides*(*Z. mays*) as shown in Table 4.6 to 4.8.

Table 4.6: Correlation coefficient (r) values among the different concentrations of *Ageratum conyzoides*(*Brassica campestris*) and *Ageratum conyzoides*(*Oryza sativa*).

Parameters	2%	4%	6%	8%	10%
CTRL	1.000 0.000*	0.996 0.000*	0.978 0.001*	1.000 0.000*	0.999 0.000*
2%		0.997 0.000*	0.973 0.001*	1.000 0.000*	0.999 0.000*
4%			0.966 0.002*	0.995 0.000*	0.993 0.000*
6%				0.979 0.001*	0.980 0.001*
8%					1.000 0.000*

*correlation is significant at the 0.01 level (2-tailed)

Table 4.7: Correlation coefficient (r) values among the different concentrations of *Ageratum conyzoides*(*Brassica campestris*) and *Ageratum conyzoides*(*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	1.000 0.000*	0.999 0.000*	0.999 0.000*	0.998 0.000*	0.997 0.000*
2%		0.999 0.000*	0.999 0.000*	0.999 0.000*	0.998 0.000*
4%			1.000 0.000*	1.000 0.000*	0.999 0.000*
6%				1.000 0.000*	0.999 0.000*
8%					1.000 0.000*

*correlation is significant at the 0.01 level (2-tailed)

Table 4.8: Correlation coefficient (r) values among the different concentrations of *Ageratum conyzoides*(*Oryza sativa*) and *Ageratum conyzoides*(*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.996 0.000*	0.991 0.000*	0.995 0.000*	0.995 0.000*	0.993 0.000*
2%		0.999 0.000*	0.996 0.000*	0.995 0.000*	0.993 0.000*
4%			0.996 0.000*	0.996 0.000*	0.994 0.000*
6%				0.998 0.000*	0.997 0.000*
8%					1.000 0.000*

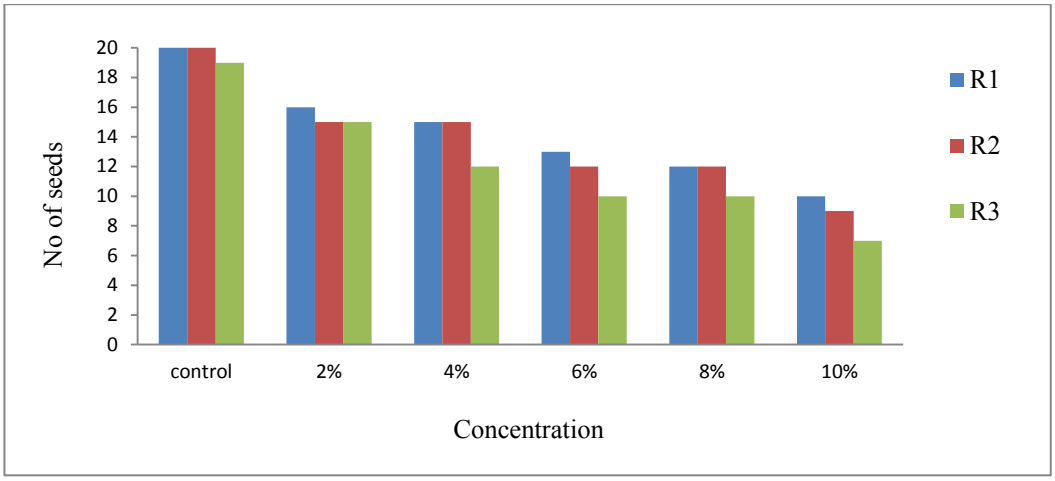
*correlation is significant at the 0.01 level (2-tailed)

5.5.1 Alleopathic effect of *Chromolaena odorata* on the germination % of *Brassica campestris.*

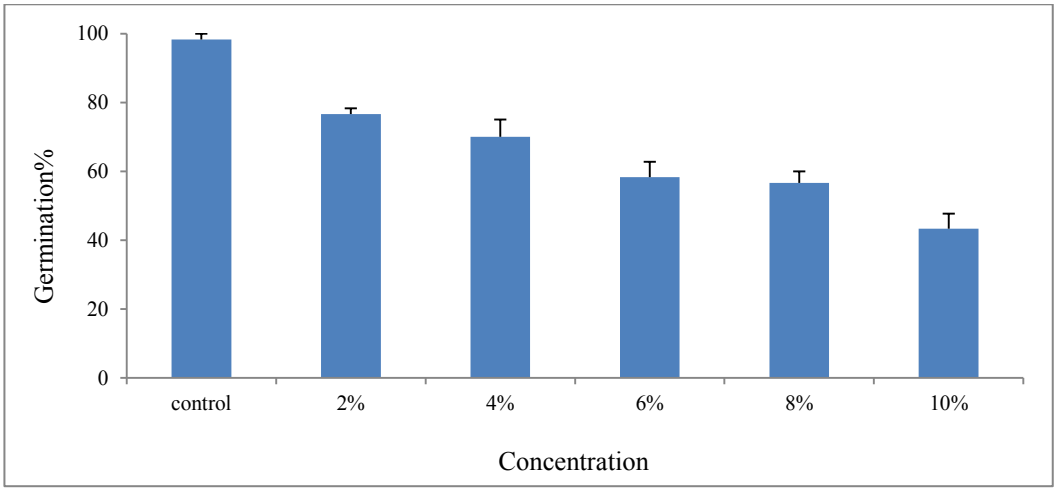
When *Brassica* was treated with aqueous leaf extract of *C. odorata*, there was a gradual decrease in seed germination percentage. It can be seen that though the seeds may germinate even in the presence of different leaf extract, the competition between the weeds and the seeds for survival is high and this leads to the death of the germinated seedlings. At control, 98.3% of the seeds germinated while 43.3% of the seeds germinated at 10% concentration (Table 5.1).

Table 5.1: Germination% of *Brassica campestris* on different concentrations of *Chromolaena odorata.*

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	20	19	98.3%
2%	20	16	15	15	76%
4%	20	15	15	12	70%
6%	20	13	12	10	58.3%
8%	20	12	12	10	56.6%
10%	20	10	9	7	43.3%



Graph 3.1: No. of *Brassica campestris* seeds germinated when treated with *Chromolaena odorata.*



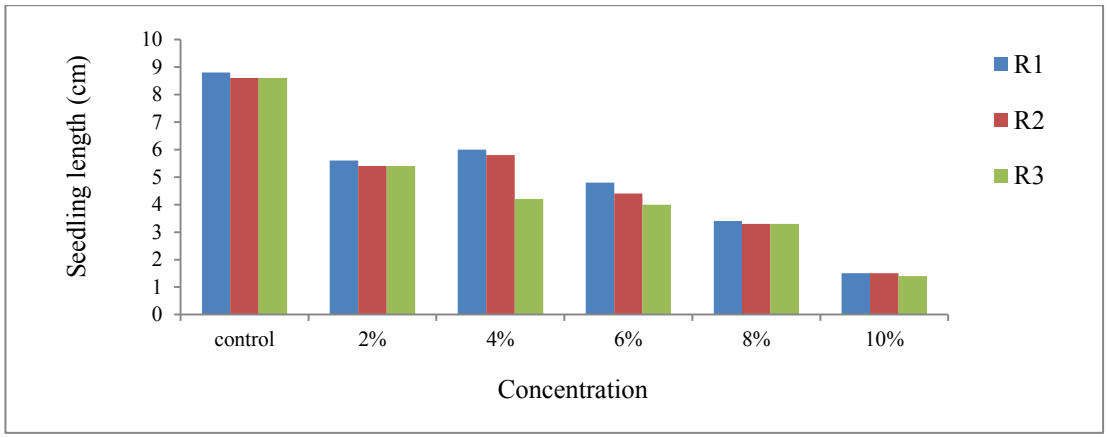
Graph 3.2: Germination% of *Brassica campestris* when treated with *Chromolaena odorata.*

5.5.2 Alleopathic effect of *Chromolaena odorata* on the seedling growth of *Brassica campestris.*

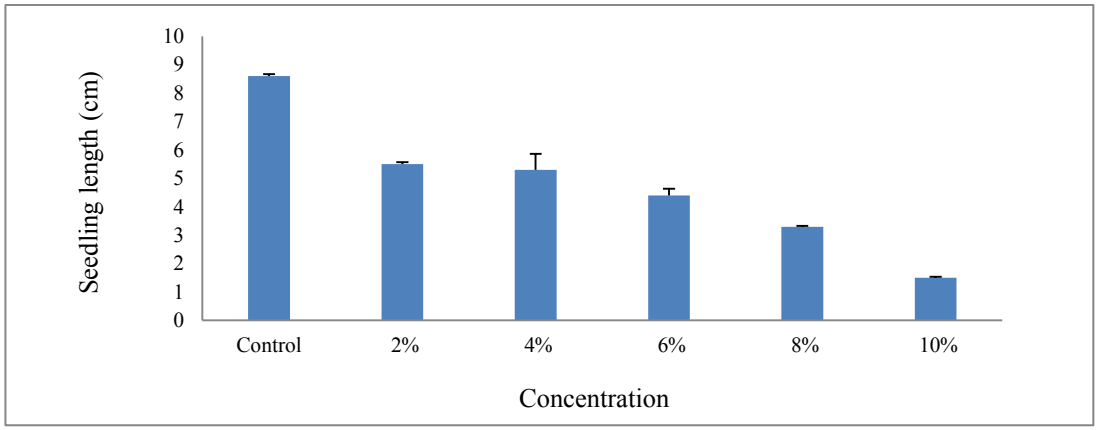
There is a decrease in seedling length from control to the highest concentration of leaf extract. The seedling length at control is as long as 8.6 cm while it is only 1.5cm long at 10% concentration (Table 5.2).

Table 5.2: Average seedling length of *Brassica campestris* on different concentrations of *Chromolaena odorata.*

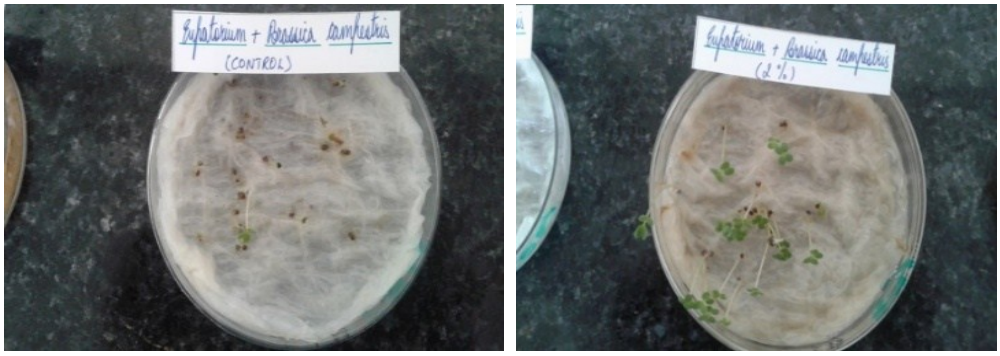
Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	8.8	8.6	8.6	8.6
2%	5.6	5.4	5.4	5.5
4%	6.0	5.8	4.2	5.3
6%	4.8	4.4	4.0	4.4
8%	3.4	3.3	3.3	3.3
10%	1.5	1.5	1.4	1.5



Graph 3.3: Avg. seedling length of *Brassica campestris* when treated with *Chromolaena odorata.*

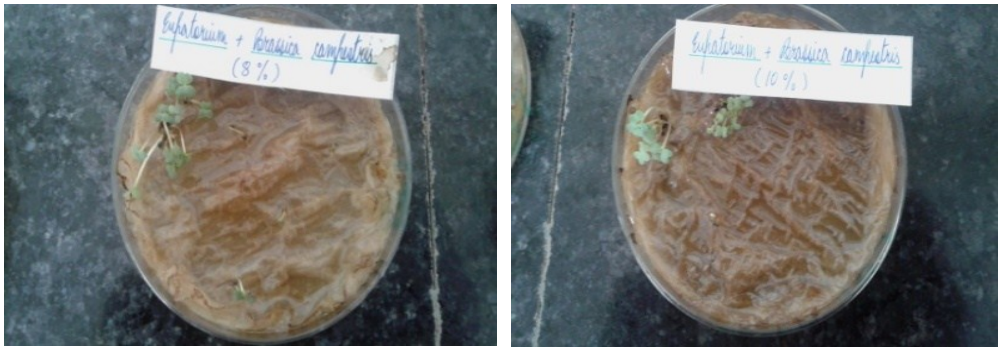


Graph 3.4: Seedling growth of *Brassica campestris* when treated with *Chromolaena odorata.*



A. B.

C. D.



E. F.

Photoplate 4: Germination of *Brassica campestris* seeds at different concentrations of *Chromolaena odorata.*

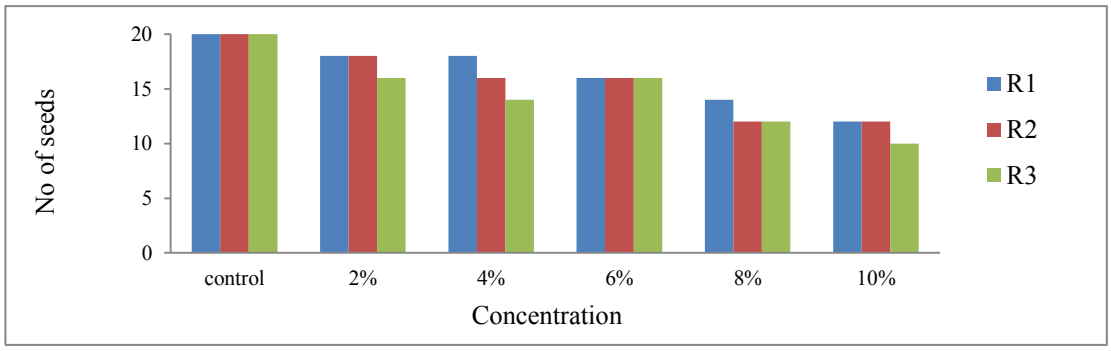
A. *B. campestris* seeds at control.
B. *B. campestris* seeds at 2% concentration.
C. *B. campestris* seeds at 4% concentration.
D. *B. campestris* seeds at 6% concentration.
E. *B. campestris* seeds at 8% concentration.
F. *B. campestris* seeds at 10% concentration.

5.5.3 Alleopathic effect of *Chromolaena odorata* on the germination % of *Oryza sativa.*

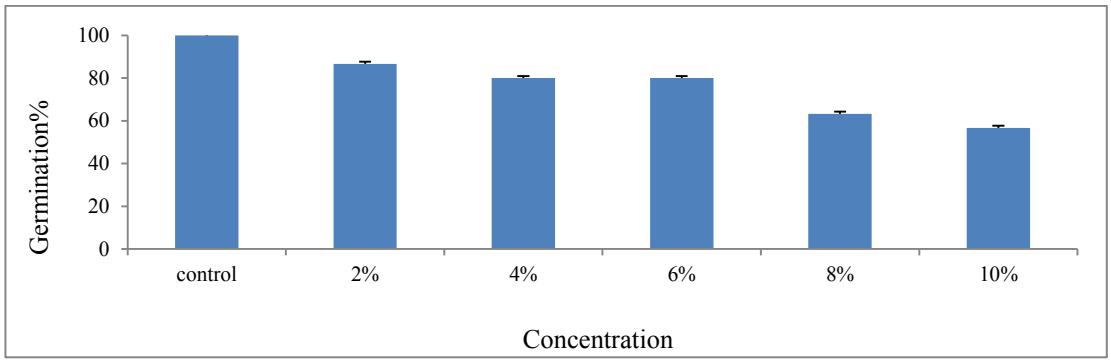
Similarly, treatment with aqueous leaf extract of *C. odorata* too shows decrease in germination rate. All the seeds germinated at control. More than 50% of the seeds germinated even at the highest concentration (Table 5.3).

Table 5.3: Germination% of *Oryza sativa* on different concentrations of *Chromolaena odorata.*

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	20	20	100%
2%	20	18	18	16	86.6%
4%	20	18	16	14	80%
6%	20	16	16	16	80%
8%	20	14	12	12	63.3%
10%	20	12	12	10	56.6%



Graph 3.5: No. of *Oryza sativa* seeds germinated when treated with *Chromolaena odorata.*



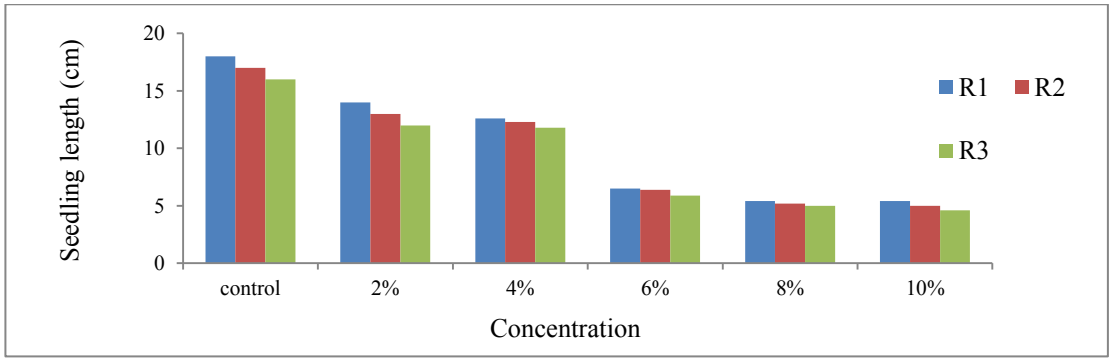
Graph 3.6: Germination% of *Oryza sativa* when treated with *Chromolaena odorata.*

5.5.4 Alleopathic effect of *Chromolaena odorata* on the seedling growth of *Oryza sativa.*

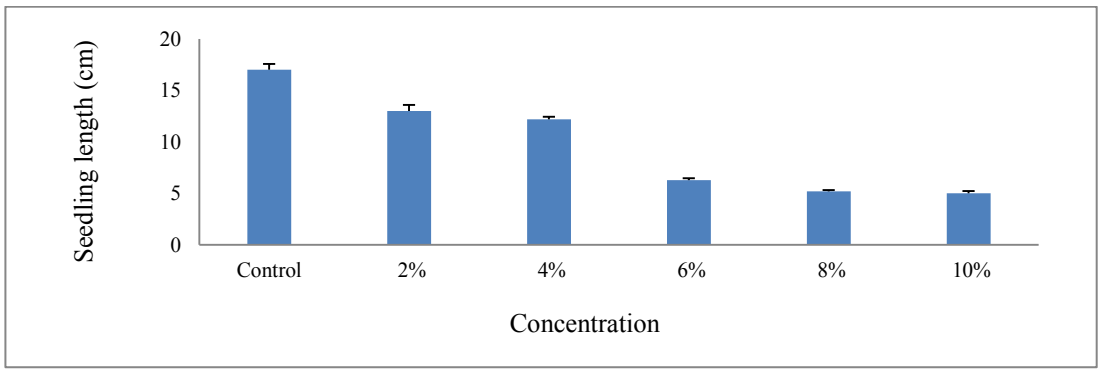
The weed suppressed the seedling length of *O. sativa* gradually as the dilutions increases. The averaged seedling length ranges from 5cm to 17cm as shown in Table 5.4.

Table 5.4: Averaged seedling length of *Oryza sativa* on different concentrations of *Chromolaena odorata.*

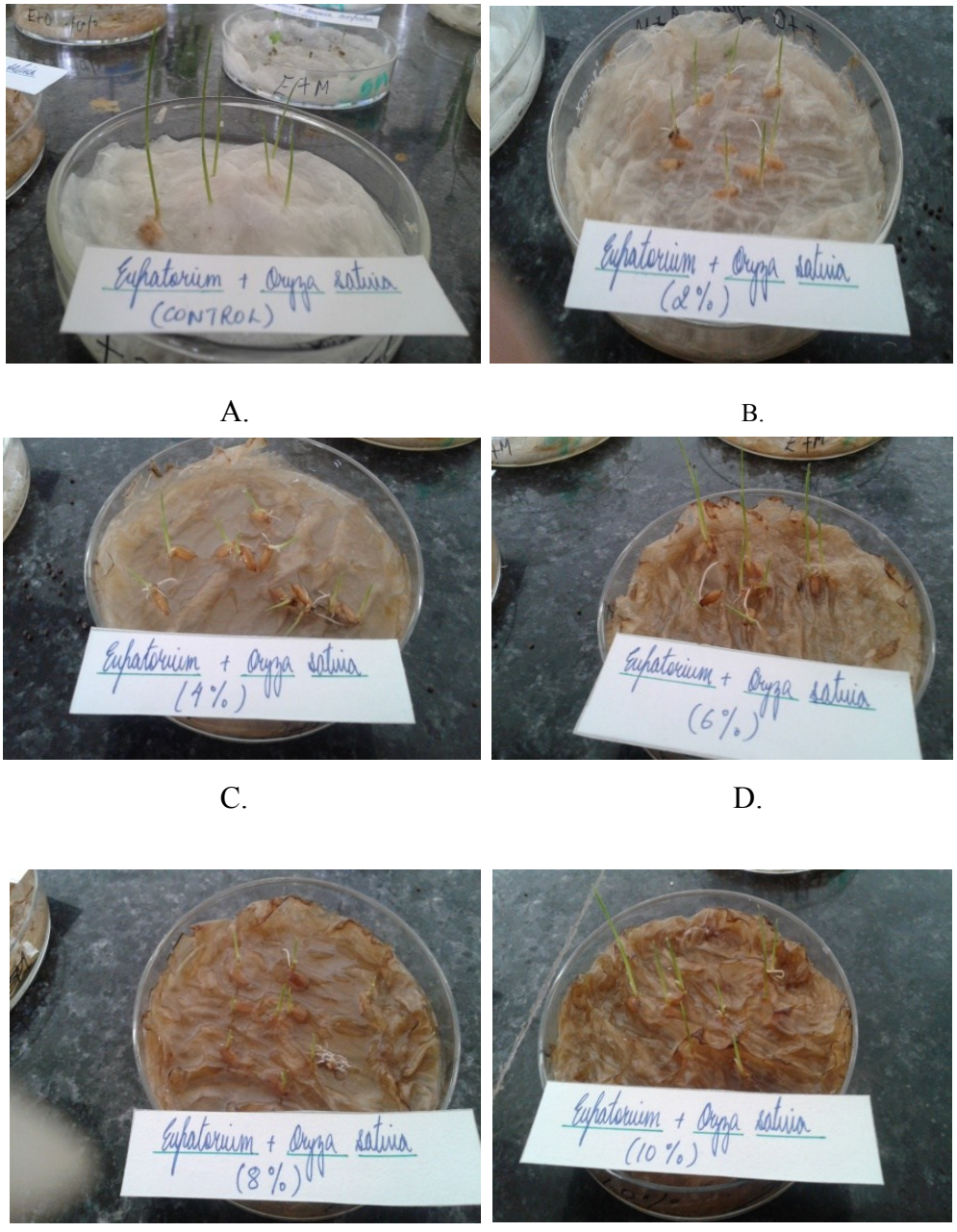
Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	16	17	18	17
2%	14	13	12	13
4%	12.6	12.3	11.8	12.2
6%	6.5	6.4	5.9	6.3
8%	5.4	5.2	5.0	5.2
10%	5.4	5	4.6	5.0



Graph 3.7: Avg. seedling length of *Oryza sativa* when treated with *Chromolaena odorata.*



Graph 3.8: Seedling growth *of Oryza sativa* when treated with *Chromolaena odorata.*



A. B.

C. D.

E. F.

Photoplate 5: Germination of *Oryza sativa* seeds at different concentrations of *Chromolaena odorata.*

A. *O. sativa* seeds at control.
B. *O. sativa* seeds at 2% concentration.
C. *O. sativa* seeds at 4% concentration.
D. *O. sativa* seeds at 6% concentration.
E. *O. sativa* seeds at 8% concentration.
F. *O. sativa* seeds at 10% concentration.

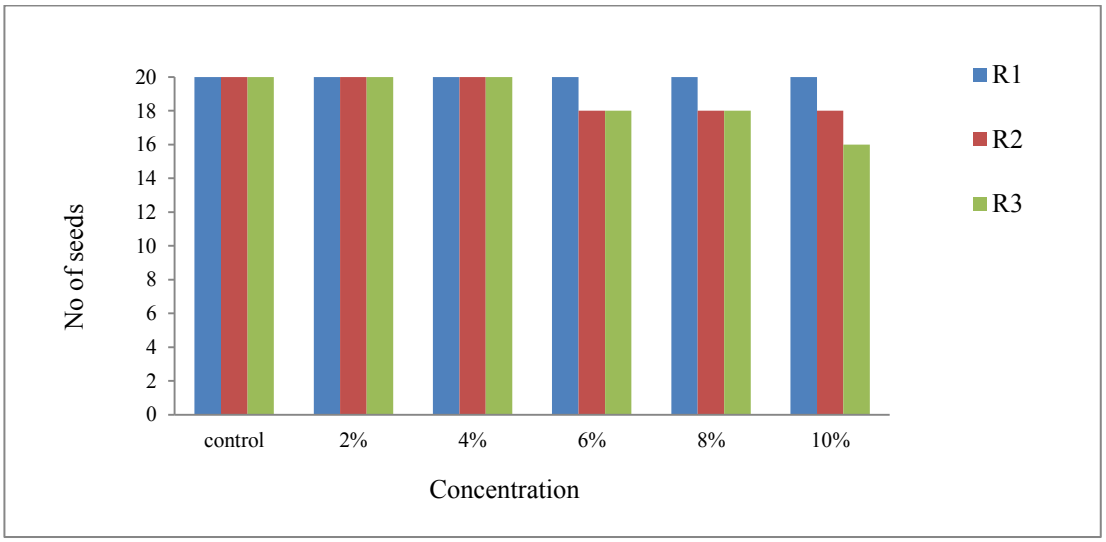
5.5.5 Alleopathic effect of *Chromolaena odorata* the germination % of *Zea mays.*

When treated with *C. odorata,* it shows a decrease in germination percentage, but not so much as compared to the other two weeds. There are more chances of 100% germination of the seeds, which shows that though *C. odorata* have some effect over *Z. mays,* its effect is not lethal enough to inhibit seed germination. Even at 10% concentration, 90% of the seeds germinated (Table 5.5).

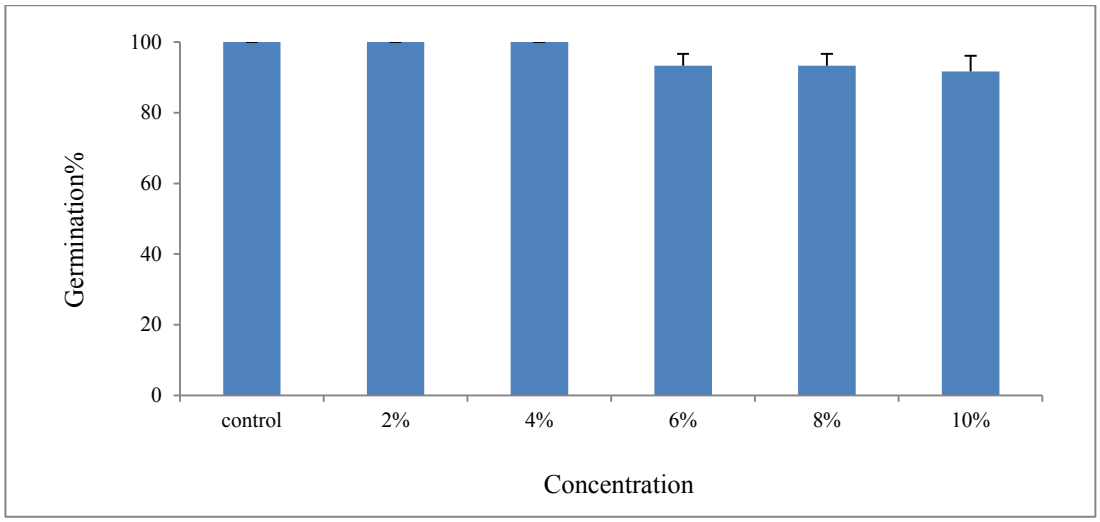
Table 5.5: Germination% of *Zea mays* on different concentrations of *Chromolaena odorata.*

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	20	20	100%
2%	20	20	20	20	100%
4%	20	20	20	20	100%
6%	20	20	18	18	93.3%
8%	20	20	18	18	93.3%
10%	20	20	18	16	90%

uuu



Graph 3.9: No. of *Zea mays* seeds germinated when treated with *Chromolaena odorata.*



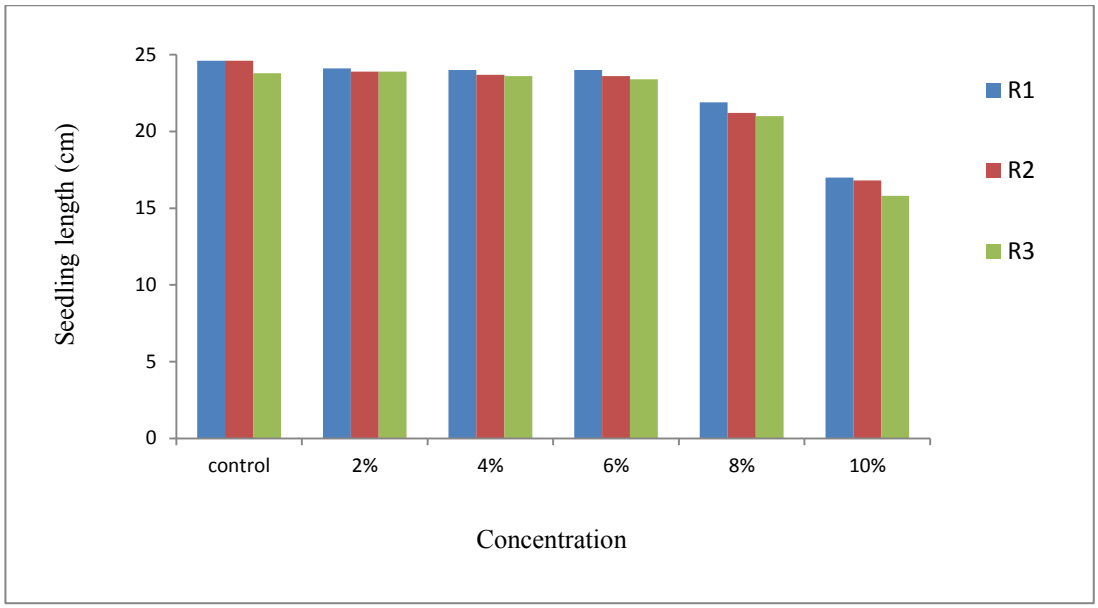
Graph 3.10: Germination% of *Zea mays* when treated with *Chromolaena odorata*.

5.5.6 Alleopathic effect of *Chromolaena odorata* on seedling growth of *Zea mays.*

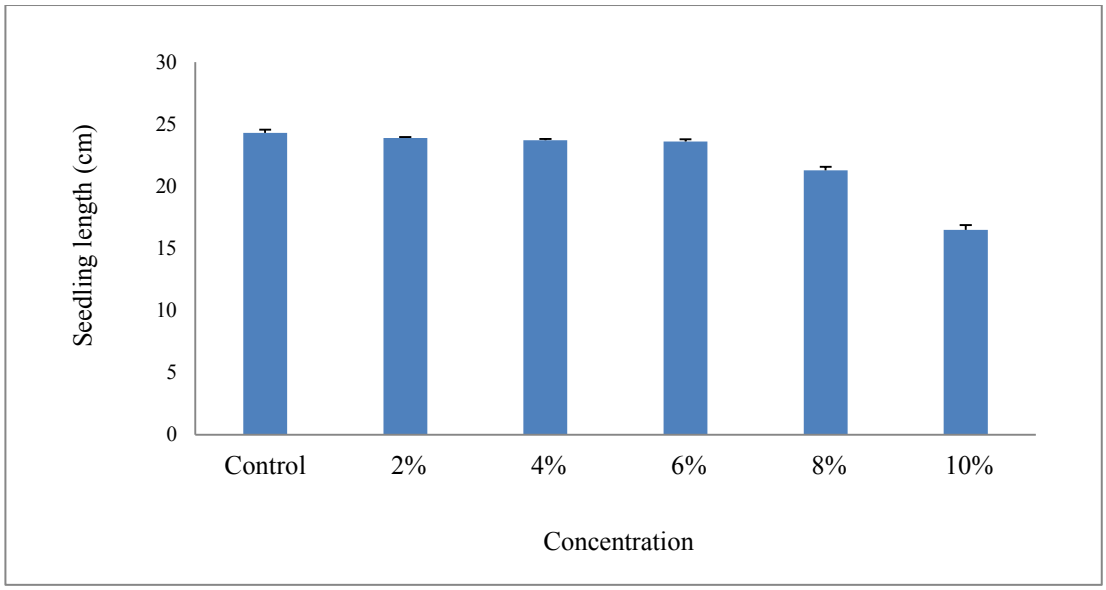
The seedling length of *Z. mays* at control was approximately 24cm in length which shows the best growth as compared to the other treatment. At 10% concentration, the seedling length is measured at 16.5cm. *Z. mays* was able to grow abundantly even in presence of *C. odorata* (Table 5.6).

Table 5.6: Averaged seedling length of *Zea mays* on different concentrations of *Chromolaena odorata.*

Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	24.6	24.6	23.8	24.3
2%	24.1	23.9	23.9	23.9
4%	24	23.7	23.6	23.7
6%	24	23.6	23.4	23.6
8%	21.9	21.2	21	21.3
10%	17	16.8	15.8	16.5



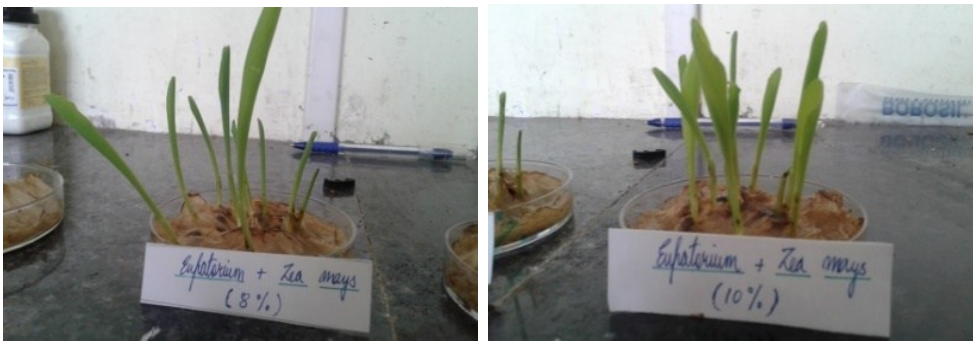
Graph 3.11: Avg. seedling length of *Zea mays* when treated with *Chromolaena odorata.*



Graph 3.12: Seedling growth of *Zea mays* when treated with *Chromolaena odorata.*

A. B.

C. D.



E. F.

Photoplate 6: Germination of *Zea mays* seeds at different concentrations of *Chromolaena odorata.*

A. *Z. mays* seeds at control.
B. *Z. mays* seeds at 2% concentration.
C. *Z. mays* seeds at 4% concentration.
D. *Z. mays* seeds at 6% concentration.
E. *Z. mays* seeds at 8% concentration.
F. *Z. mays* seeds at 10% concentration.

5.5.7 Statistical Analysis

5.5.8 Germination%

The ANOVA table for the influence of different concentrations of *C. odorata* on the three agricultural crops are given in Table 6.1. The study revealed that the effects of the selected weed on the germination% of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p □0.05).

Table 6.1: One way analysis of variance (ANOVA) of selected agricultural crops under the influence of different concentrations of *Chromolaena odorata* at CTRL, 2%,4%,6%,8%,10%. [C(B)=*Chromolaena odorata(Brassica campestris* C(O)=*Chromolaena odorata*(*Oryza sativa*) C(Z)=*Chromolaena odorata*(*Zea mays*)].

Parameters	Source of variation CTRL×2%×4%×6%×8%×10%	F-value	p-value
C(B)	-do-	27.200	0.000*
C(O)	-do-	22.267	0.000*
C(Z)	-do-	2.307	0.109

*Values are significant at p □0.05

5.5.9 Seedling growth

The ANOVA table for the influence of different concentrations of *C. odorata* on the three agricultural crops are given in Table 6.2. The study revealed that the effects of the selected weed on the seedling growth of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p □0.05).

Table 6.2: One way analysis of variance (ANOVA) of selected agricultural crops under the influence of different concentrations of *Chromolaena odorata* at CTRL, 2%,4%,6%,8%,10%.

Parameters	Source of variation CTRL×2%×4%×6%×8%×10%	F-value	p-value
C(B)	**-do-**	**89.498**	**0.000***
C(O)	**-do-**	**181.971**	**0.000***
C(Z)	**-do-**	**162.187**	**0.000***

* Values are significant at p □0.05

5.5.10 Correlation

5.5.11 Germination% w.r.t *Chromolaena odorata*

There is a positive significant relationship between 4%, 6%, 10% of *C. odorata* (*B. campestris*) and 2% of *C. odorata* (*O. sativa*). Similarly, 8% and 10% of *C. odorata*(*B. campestris*) shows positive significant relationship with 4% of *C. odorata* (*O. sativa*) as well as 10% of *C. odorata* (*B. campestris*) with 6%, 10% of *C. odorata* (*O. sativa*) as shown in Table 6.3.

4%, 6%, 8%, 10% of *C. odorata* (*B. campestris*) shows positively significant relationship with 2% of *C. odorata* (*Z. mays*). There is also a positive significant relationship between 6%, 8%, 10% and 4%, 6%, 8% of *C. odorata* (*Z. mays*) as shown in Table 6.4.

A positively significant relationship was shown between 4%, 6%, 8%, 10% of *C. odorata* (*O. sativa*) with 2% of *C. odorata* (*Z. mays*). Similarly, 8%, 10% of *Ch. odorata* (*O. sativa*) shows positively significant relationship with 4%, 6%, 8% of *C. odorata* (*Z. mays*) as shown in Table 6.5.

Table 6.3: Correlation coefficient (r) values among the different concentrations of *Chromolaena odorata* (*Brassica campestris*) and *Chromolaena odorata* (*Oryza sativa*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.478 0.338	0.735 0.096	0.733 0.098	0.775 0.070	0.775 0.070
2%		0.805 0.053*	0.819 0.046*	0.694 0.126	0.926 0.008*
4%			0.702 0.120	0.949 0.004*	0.896 0.016*
6%				0.740 0.092	0.905 0.013*
8%					0.833 0.039*

*correlation is significant at the 0.05 level (2-tailed)

Table 6.4: Correlation coefficient (r) values among the different concentrations of *Chromolaena odorata* (*Brassica campestis*) and *Chromolaena odorata* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.506 0.306	0.707 0.116	0.630 0.180	0.591 0.217	0.582 0.225
2%		0.962 0.002*	0.970 0.001*	0.971 0.001*	0.977 0.001*
4%			0.976 0.001*	0.974 0.001*	0.971 0.001*
6%				0.995 0.000*	0.996 0.000*
8%					0.997 0.000*

*correlation is significant at the 0.05 level (2-tailed)

Table 6.5: Correlation coefficient (r) values among the different concentrations of *Chromolaena odorata*(*Oryza sativa*) and *Chromolaena odorata*(*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	a	a	a	a	a
2%		0.968 0.001*	0.800 0.056*	0.901 0.014*	0.924 0.006*
4%			0.775 0.070	0.918 0.010*	0.904 0.013*
6%				0.948 0.004*	0.954 0.003*
8%					0.977 0.001*

a cannot be computed because atleast one of the variables is constant.

*correlation is significant at the 0.05 level (2-tailed)

5.5.12 Seedling length w.r.t *Chromolaena odorata*

All the different concentrations (control, 2%, 4%, 6%, 8%, 10%) of *C. odorata* (*B. campestris*) and *C. odorata* (*O. sativa*) show positively significant relationships. Similar case was shown between *C. odorata* (*B. campestris*) and *C. odorata* (*Z. mays*) as well as between *C. odorata* (*O. sativa*) and *C. odorata* (*Z. mays*) as shown in Table 6.6 to 6.8.

Table 6.6: Correlation coefficient (r) values among the different concentrations of *Chromolaena odorata* (*Brassica campestris*) and *Chromolaena odorata* (*Oryza sativa*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.958 0.003*	0.967 0.002*	0.923 0.009*	0.965 0.002*	0.964 0.002*
2%		0.985 0.000*	0.972 0.001*	0.999 0.000*	1.000 0.000*
4%			0.986 0.000*	0.990 0.000*	0.988 0.000*
6%				0.974 0.001*	0.972 0.001*
8%					1.000 0.000*

*correlation is significant at the 0.01 level (2-tailed)

Table 6.7: Correlation coefficient (r) values among the different concentrations of *Chromolaena odorata* (*Brassica campestris*) and *Chromolaena odorata* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	1.000 0.000*	0.998 0.000*	1.000 0.000*	1.000 0.000*	1.000 0.000*
2%		0.998 0.000*	1.000 0.000*	1.000 0.000*	0.999 0.000*
4%			0.999 0.000*	0.998 0.000*	0.998 0.000*
6%				1.000 0.000*	0.999 0.000*
8%					0.999 0.000*

*correlation is significant at the 0.01 level (2-tailed)

Table 6.8: Correlation coefficient (r) values among the different concentrations of *Chromolaena odorata* (*Oryza sativa*) and *Chromolaena odorata* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.964 0.002*	0.979 0.001*	0.983 0.000*	0.984 0.000*	0.981 0.001*
2%		0.998 0.000*	0.996 0.000*	0.996 0.000*	0.996 0.000*
4%			1.000 0.000*	1.000 0.000*	0.999 0.000*
6%				1.000 0.000*	0.999 0.000*
8%					0.999 0.000*

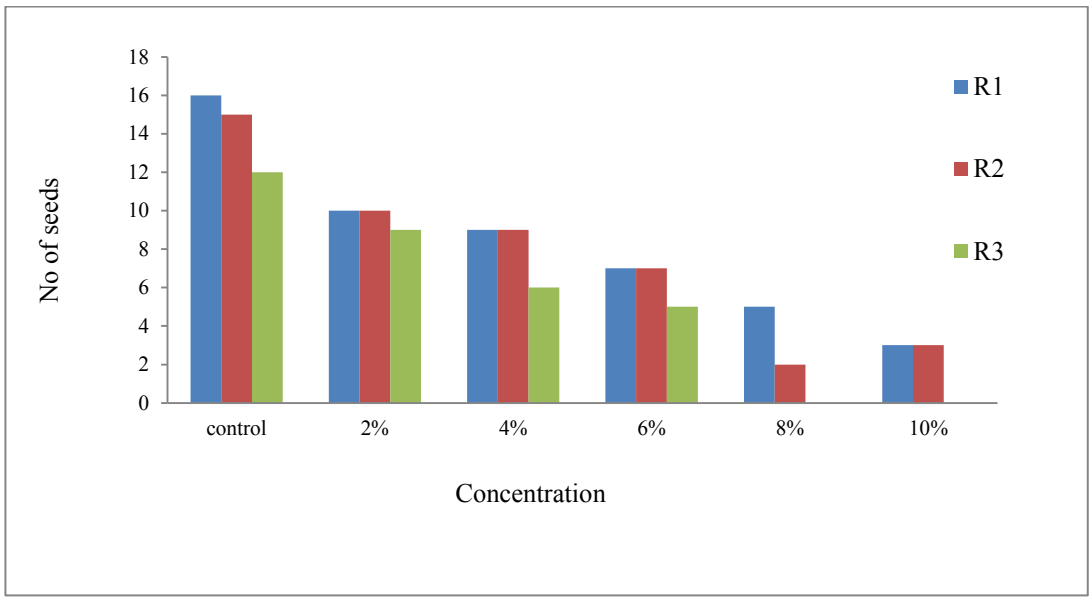
*correlation is significant at the 0.01 level (2-tailed)

5.6.1 Alleopathic effect of *Mikania micrantha* on the germination% of *Brassica campestris.*

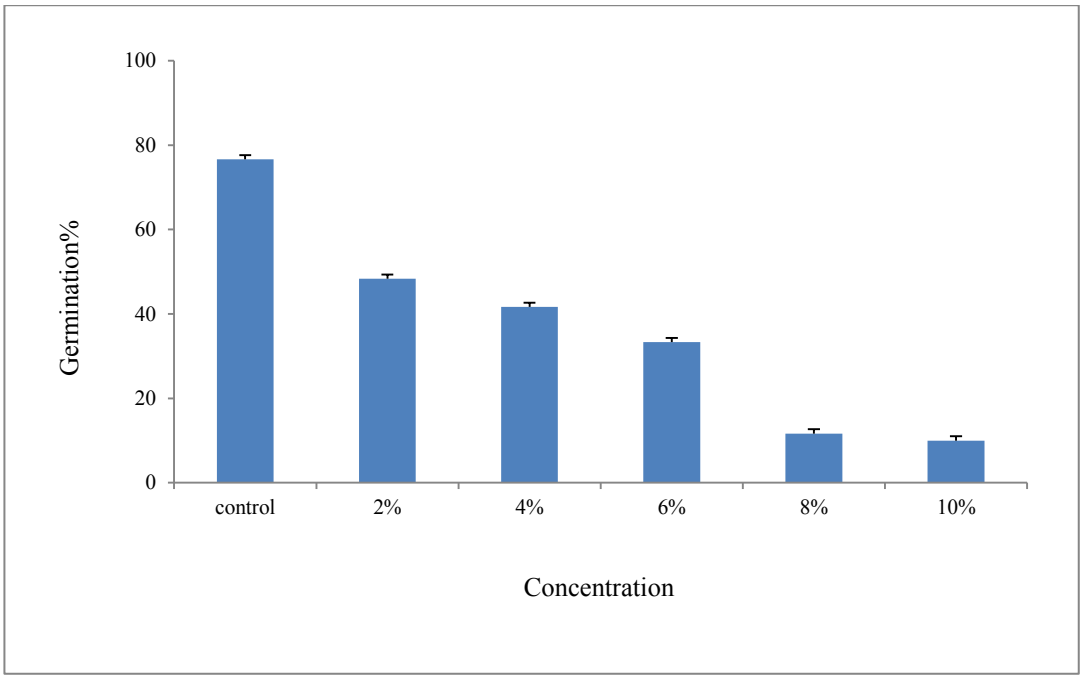
B. campestris when treated with different concentration of leaf extracts of *M. micrantha*, showed that there was a sharp decline in seed germination from control to 2% concentration. As the concentration increases, the germination% decreases gradually. Although the germination% is high at control, at 10% concentration only 10% of the seeds shows germination (Table 7.1).

Table 7.1: Germination% of *Brassica campestris* on different concentrations of *Mikania micrantha*.

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	16	15	15	76.6%
2%	20	10	10	9	48.3%
4%	20	9	9	7	41.6%
6%	20	7	7	6	31.6%
8%	20	5	2	0	11.6%
10%	20	3	3	0	10%



Graph 4.1: No. of *Brassica campestris* seeds germinated when treated with *Mikania micrantha.*



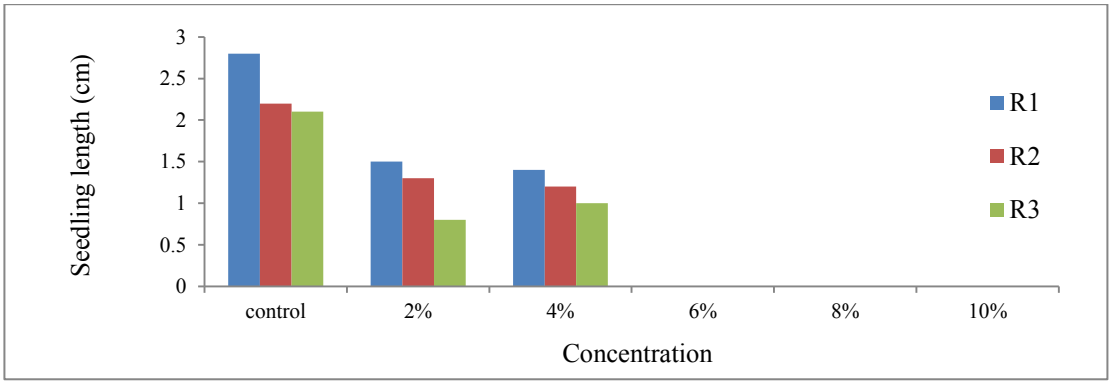
Graph 4.2: Germination% of *Brassica campestris* treated with *Mikania micrantha*.

5.6.2 Alleopathic effect of *Mikania micrantha* on the seedling growth of *Brassica campestris.*

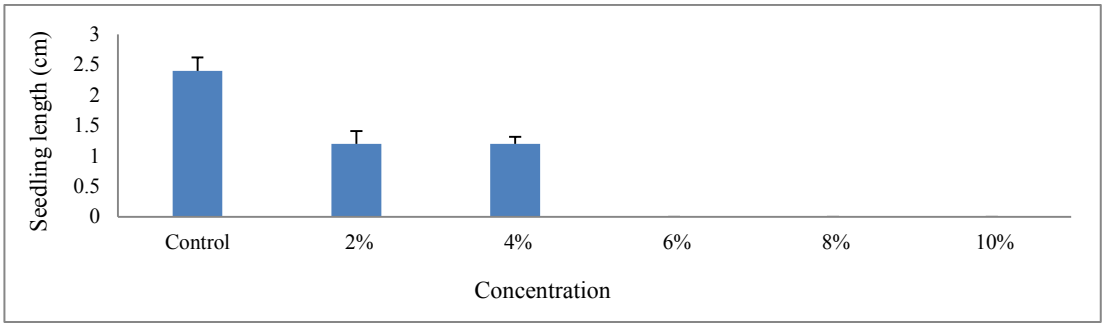
In control, the seedling length is recorded at 2.4 cm. The seedling length can hardly be recorded at higher concentration. It can be concluded that *M. micrantha* greatly influenced the seedling growth of *B. campestris* (Table 7.2).

Table 7.2: Averaged seedling length of *Brassica campestris* on different concentrations of *Mikania micrantha.*

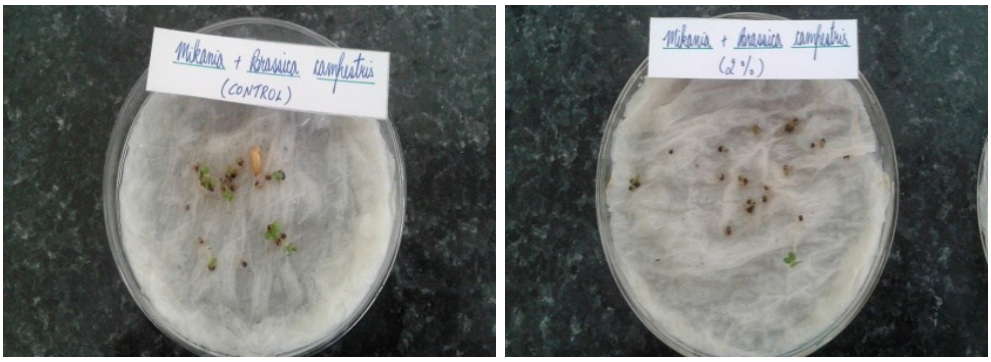
Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	2.8	2.2	2.1	2.4
2%	1.5	1.3	0.8	1.2
4%	1.4	1.2	1.0	1.2
6%	0	0	0	0
8%	0	0	0	0
10%	0	0	0	0



Graph 4.3: Avg. seedling length of *Brassica campestris* when treated with *Mikania micrantha.*



Graph 4.4: Seedling growth of *Brassica campestris* when treated with *Mikania micrantha.*



A. B.

C. D.

E. F.

Photoplate 7: Germination of *Brassica campestris* seeds at different concentrations of *Mikania micrantha.*

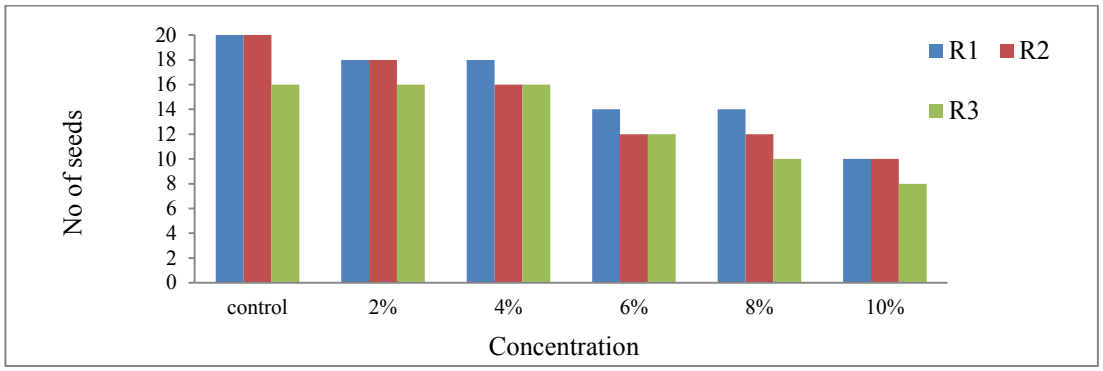
A. *B. campestris* seeds at control.
B. *B. campestris* seeds at 2% concentration.
C. *B. campestris* seeds at 4% concentration.
D. *B. campestris* seeds at 6% concentration.
E. *B. campestris* seeds at 8% concentration.
F. *B. campestris* seeds at 10% concentration.

5.6.3 Alleopathic effect of *Mikania micrantha* on the germination% of *Oryza sativa.*

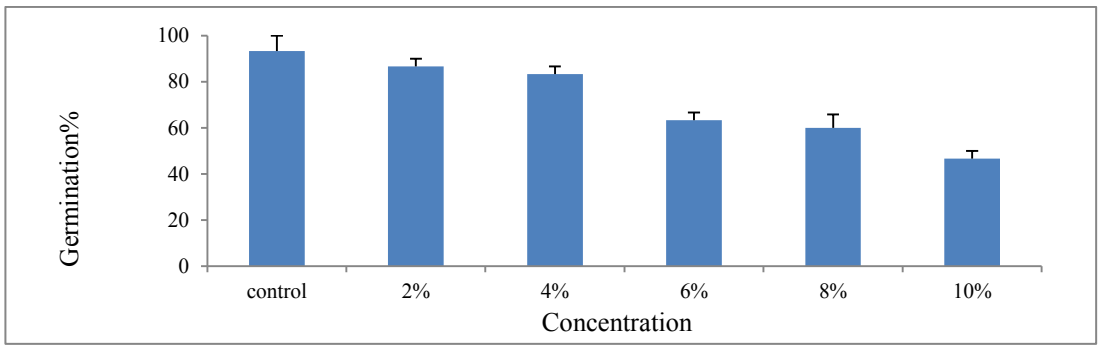
O. sativa when treated with different leaf extracts of *M. micrantha* shows a decrease in the germination rate with increase in concentration. Even in the presence of *M. micrantha,* 93.3% of the seeds germinated at control and at 10% concentration 46.6% of the seeds germinated (Table 7.3).

Table 7.3: Germination% of *Oryza sativa* on different concentrations of *Mikania micrantha.*

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	20	16	93.3%
2%	20	18	18	16	86.6%
4%	20	18	16	16	83.3%
6%	20	14	12	12	63.3%
8%	20	14	12	10	60%
10%	20	10	10	8	46.6%



Graph 4.5: No. of *Oryza sativa* seeds germinated when treated with *Mikania micrantha.*



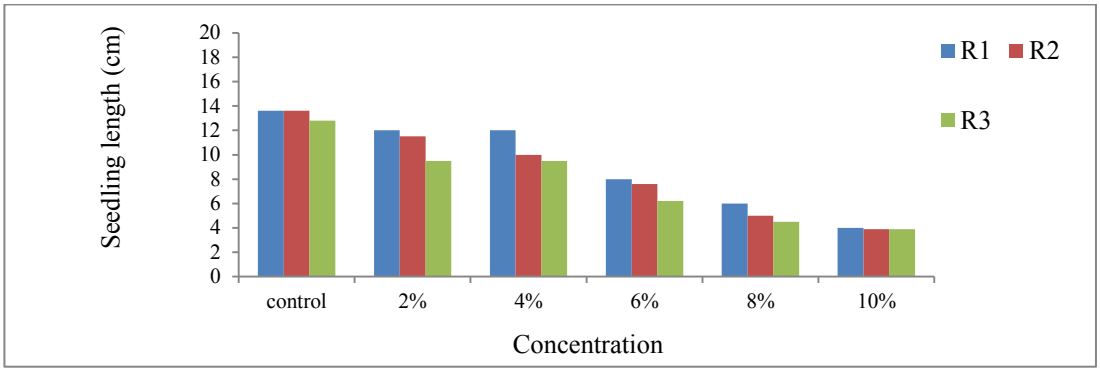
Graph 4.6: Germination% of *Oryza sativa* when treated with *Mikania micrantha*.

5.6.4 Alleopathic effect of *Mikania micrantha* on the seedling growth of *Oryza sativa.*

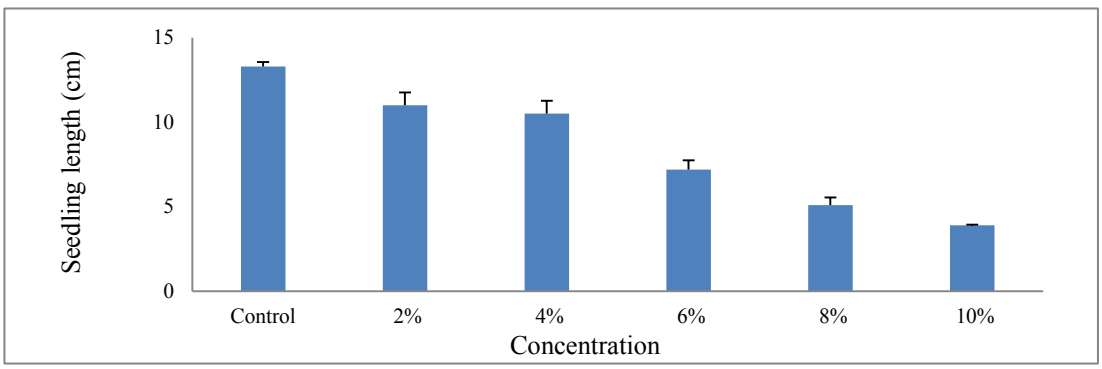
In case of seedling growth of *O. sativa* when treated with *M. micrantha*, it was found that the control has the longest seedling length of 13cm and the highest concentration (10%) of leaf extract has the least seedling length of 3.9cm as shown in Table 7.4.

Table 7.4: Averaged seedling length of *Oryza sativa* on different concentrations of *Mikania micrantha.*

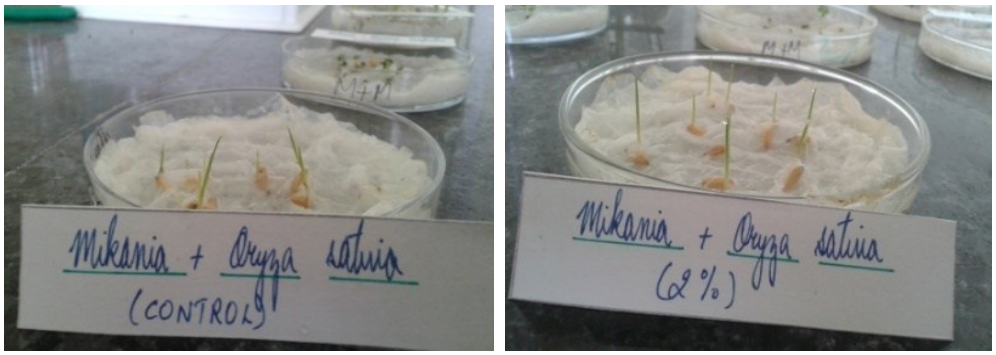
Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	13.6	13.6	12.8	13.3
2%	12	11.5	9.5	11
4%	12	10	9.5	10.5
6%	8	7.6	6.2	7.2
8%	6	5	4.5	5.1
10%	4	3.9	3.9	3.9



Graph 4.7: Avg. seedling length of *Oryza sativa* when treated with *Mikania micrantha*



Graph 4.8: Seedling growth *of Oryza sativa* when treated with *Mikania micrantha.*



A. B.

C. D.

E. F.

Photoplate 8: Germination of *Oryza sativa* seeds at different concentrations of *Mikania micrantha.*

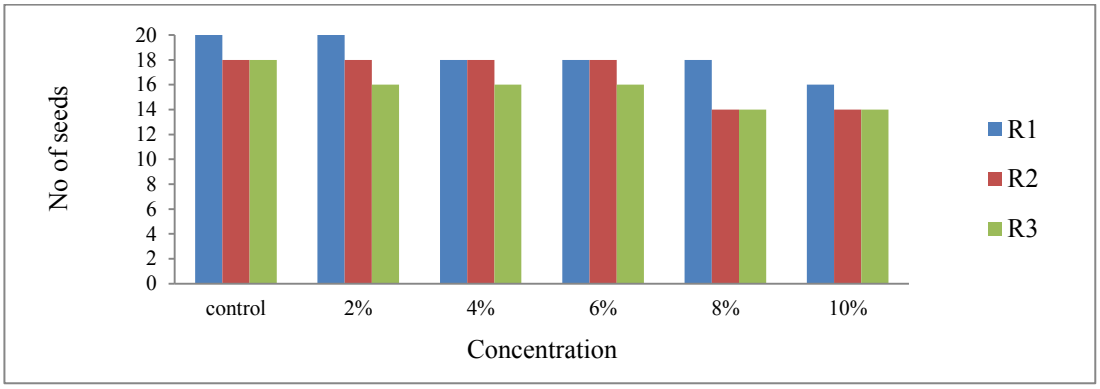
A. *O. sativa* seeds at control.
B. *O. sativa* seeds at 2% concentration.
C. *O. sativa* seeds at 4% concentration.
D. *O. sativa* seeds at 6% concentration.
E. *O. sativa* seeds at 8% concentration.
F. *O. sativa* seeds at 10% concentration.

5.6.5 Alleopathic effect of *Mikania micrantha* on the germination % of *Zea mays.*

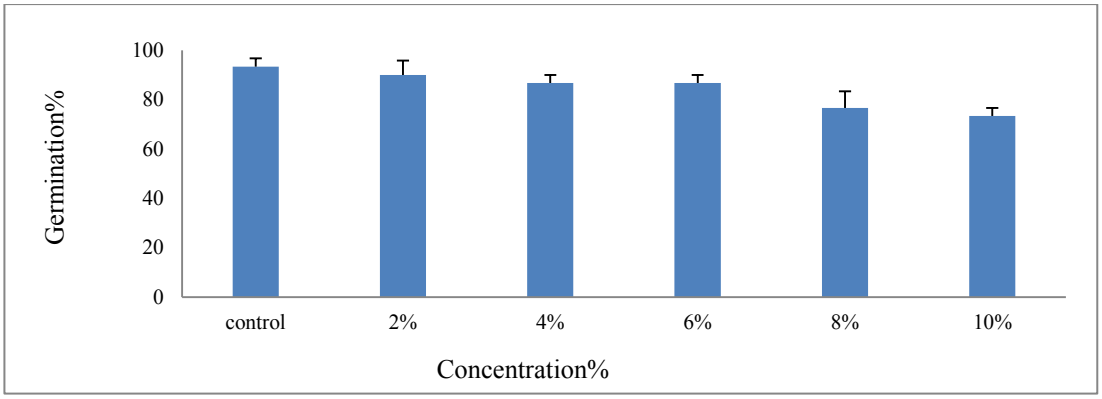
When *Z. mays* was treated with different concentration of aqueous leaf extract of *M. micrantha*, there was a gradual decrease in seed germination but it does not inhibit it's growth. *Z. mays* can germinate well even in presence of *M. micrantha* as shown in Table 7.5.

Table 7.5: Germination% of *Zea mays* on different concentrations of *Mikania micrantha.*

Dilutions	No. of seeds	Germination			Germination percentage
		R1	R2	R3	
Control	20	20	18	18	93.3%
2%	20	20	18	16	90%
4%	20	18	18	16	86.6%
6%	20	18	18	16	86.6%
8%	20	18	14	14	76.6%
10%	20	16	14	14	73.3%



Graph 4.9: No. of *Zea mays* seeds germinated when treated with *Mikania micrantha.*



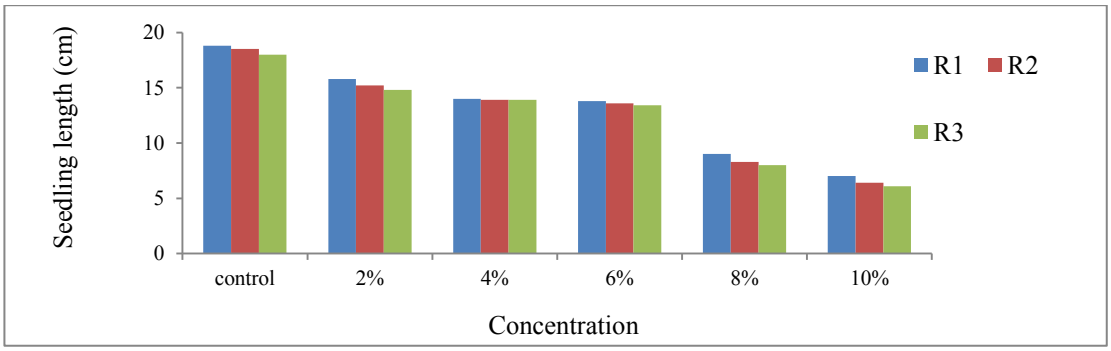
Graph 4.10: Germination% of *Zea mays* when treated with *Mikania micrantha*.

5.6.6 Alleopathic effect of *Mikania micrantha* on the seedling growth of *Zea mays.*

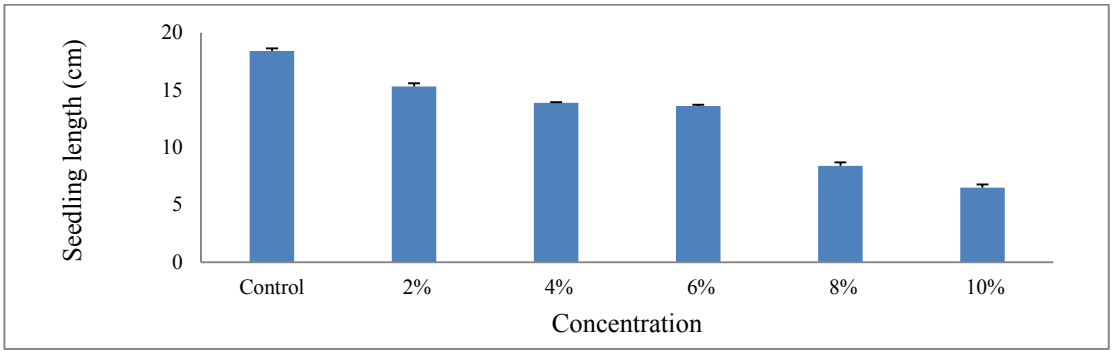
It is apparent that leaf extract of *M. micrantha* influences the growth of *Z. mays*. At control, the seedling length of *Z. mays* is as long as 18cm as shown in Table 7.6. The seedling length decreases with increase in *M. micrantha* concentration.

Table 7.6: Averaged seedling length of *Zea mays* on different concentrations of *Mikania micrantha.*

Dilutions	Seedling length			Avg. seedling length
	R1	R2	R3	
Control	18.8	18.5	18	18.4
2%	15.8	15.2	14.8	15.3
4%	14	13.9	13.9	13.9
6%	13.8	13.6	13.4	13.6
8%	9	8.3	8	8.4
10%	7	6.4	6.1	6.5



Graph 4.11: Avg. seedling length of *Zea mays* when treated with *Mikania micrantha.*



Graph 4.12: Seedling growth of *Zea mays* when treated with *Mikania micrantha.*

A. B.

C. D.

E. F.

Photoplate 9: Germination of *Zea mays* seeds at different concentrations of *Mikania micrantha.*

A. *Z. mays* seeds at control.
B. *Z. mays* seeds at 2% concentration.
C. *Z. mays* seeds at 4% concentration.
D. *Z. mays* seeds at 6% concentration.
E. *Z. mays* seeds at 8% concentration.
F. *Z. mays* seeds at 10% concentration.

5.6.7 Statistical analysis

5.6.8 Germination%

The ANOVA table for the influence of different concentrations of *M. micrantha* on the three agricultural crops are given in Tables 8.1. The study revealed that the effect of the selected weed on the germination% of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p □0.05).

Table 8.1: One way analysis of variance (ANOVA) of selected agricultural crops under the influence of different concentrations of *Mikania micrantha* at CTRL, 2%,4%,6%,8%,10%. [M(B)=*Mikania micrantha*(*Brassica campestris*) M(O)=*Mikania micrantha*(*Oryza sativa*) M(Z)=*Mikania micrantha*(*Zea mays*)].

Parameters	**Source of variation CTRL×2%×4%×6%×8%×10%**	**F-value**	**p-value**
M(B)	-do-	21.411	0.000*
M(O)	-do-	16.291	0.000*
M(Z)	-do-	2.982	0.05*

* Marked effects are significant at p □0.05

5.6.9 Seedling growth

The ANOVA table for the influence of different concentrations of *M. micrantha* on the three agricultural crops are given in Table 8.2. The study revealed that the effect of the selected weed on the seedling growth of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p □0.05).

Table 8.2: One way analysis of variance (ANOVA) of selected agricultural crops under the influence of different concentrations of *Mikania micrantha* at CTRL, 2%,4%,6%,8%,10%.

Parameters	**Source of variation CTRL×2%×4%×6%×8%×10%**	**F-value**	**p-value**
M(B)	-do-	53.934	0.000*
M(O)	-do-	46.507	0.000*
M(Z)	-do-	379.675	0.000*

* Marked effects are significant at p □0.05.

5.6.10 Correlation

5.6.11 Germination% w.r.t *Mikania micrantha*

All the different concentrations (control, 2%, 4%, 6%, 8%, 10%) of *M. micrantha* (*B. campestris*) and *M. micrantha* (*O. sativa*) show a positive significant relationships (Table 8.3). Similar case is shown by the different concentrations (control, 2%, 4%, 6%, 8%, 10%) of *M. micrantha* (*B. campestris*) and *M. micrantha* (*Z. mays*) as shown in Table 8.4. There is a positive significant relationship between 8%, 10% of *M. micrantha* (*O. sativa*) with 6%, 8% of *M. micrantha* (*Z. mays*) as shown in Table 8.5.

Table 8.3: Correlation coefficient (r) values among the different concentrations of *Mikania micrantha* (*Brassica campestris*) and *Mikania micrantha* (*Oryza sativa*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.872 0.023*	0.869 0.024*	0.870 0.024*	0.921 0.009*	0.921 0.009*
2%		0.978 0.001*	0.975 0.001*	0.969 0.001*	0.984 0.000*
4%			0.998 0.000*	0.978 0.001*	0.986 0.000*
6%				0.979 0.001*	0.980 0.001*
8%					0.979 0.001*

*correlation is significant at the 0.05 level (2-tailed)

Table 8.4: Correlation coefficient (r) values among the different concentrations of *Mikania micrantha* (*Brassica campestris*) and *Mikania micrantha* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.906 0.013*	0.930 0.007*	0.902 0.014*	0.952 0.003*	0.927 0.008*
2%		0.987 0.001*	0.984 0.000*	0.978 0.001*	0.980 0.001*
4%			o.996 0.000*	0.976 0.001*	0.991 0.000*
6%				0.975 0.001*	0.993 0.000*
8%					0.987 0.000*

*correlation is significant at the 0.05 level (2-tailed)

Table 8.5: Correlation coefficient (r) values among the different concentrations of *Mikania micrantha* (*Oryza sativa*) and *Mikania micrantha* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.759 0.081	0.447 0.374	0.178 0.736	0.614 0.194	0.316 0.541
2%		0.728 0.101	0.482 0.333	0.766 0.076	0.514 0.296
4%			0.662 0.152	0.687 0.132	0.471 0.345
6%				0.819 0.046*	0.937 0.006*
8%					0.874 0.023*

*correlation is significant at the 0.05 level (2-tailed)

5.6.12 Seedling length w.r.t *Mikania micrantha*

All the different concentrations (control, 2%, 4%, 6%, 8%, 10%) of *M. micrantha* (*B. campestris*) and *M. micrantha* (*O. sativa*) shows a positively significant relationships. Similar case was also shown between *M. micrantha* (*B. campestris*) and *M. micrantha* (*Z. mays*) as well as between *M. micrantha* (*O. sativa*) and *M. micrantha* (*Z. mays*) as shown in Table 8.6 to 8.8.

Table 8.6: Correlation coefficient (r) values among the different concentrations of *Mikania micrantha* (*Brassica campestris*) and *Mikania micrantha* (*Oryza sativa*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.994 0.000*	0.991 0.000*	0.994 0.000*	0.990 0.000*	0.998 0.000*
2%		0.994 0.000*	0.999 0.000*	0.996 0.000*	0.989 0.000*
4%			0.995 0.000*	0.999 0.000*	0.989 0.000*
6%				0.997 0.000*	0.990 0.000*
8%					0.988 0.000*

*correlation is significant at the 0.01 level (2-tailed)

Table 8.7: Correlation coefficient (r) values among the different concentrations of *Mikania micrantha* (*Brassica campestris*) and *Mikania micrantha* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	1.000 0.000*	1.000 0.000*	1.000 0.000*	0.999 0.000*	0.998 0.000*
2%		0.999 0.000*	0.999 0.000*	0.999 0.000*	0.999 0.000*
4%			1.000 0.000*	0.998 0.000*	0.997 0.000*
6%				0.999 0.000*	0.998 0.000*
8%					1.000 0.000*

*correlation is significant at the 0.01 level (2-tailed)

Table 8.8: Correlation coefficient (r) values among the different concentrations of *Mikania micrantha* (*Oryza sativa*) and *Mikania micrantha* (*Zea mays*).

Parameters	2%	4%	6%	8%	10%
CTRL	0.970 0.001*	0.934 0.006*	0.996 0.000*	0.977 0.001*	0.988 0.000*
2%		0.962 0.002*	0.981 0.001*	0.984 0.000*	0.945 0.004*
4%			0.955 0.003*	0.975 0.001*	0.908 0.012*
6%				0.981 0.001*	0.974 0.001*
8%					0.972 0.001*

*correlation is significant at the 0.05 level (2-tailed)

5.7 Phytochemical content of selected weeds

5.7.1 Phytochemical screening of selected weeds

The phytochemical screening of selected weeds showed that the leaves were rich in phytochemical constituents. It showed the presence of Phenols, Flavanoids, Alkaloids, Quinones, Cardiac glycosides, Terpenoids and Tannins in all the weeds. However, Saponins and Anthraquinones were found to be absent in all the weeds (Table 9.1).

Table 9.1: Phytochemical screening of the extracts of leaves of selected weeds.

Part used	Phenols	Flavonoids	Alkaloids	Saponins	Quinones	Cardiac glycosides	Terpenoids	Tannins	Anthraquinones
C	+	+	+	-	+	+	+	+	-
M	+	+	+	-	+	+	+	+	-
A	+	+	+	-	+	+	+	+	-

C*=*Chromolaena odorata* M*=*Mikania micrantha* A* =*Ageratum conyzoides*

5.7.2 Total Phenolic Content:

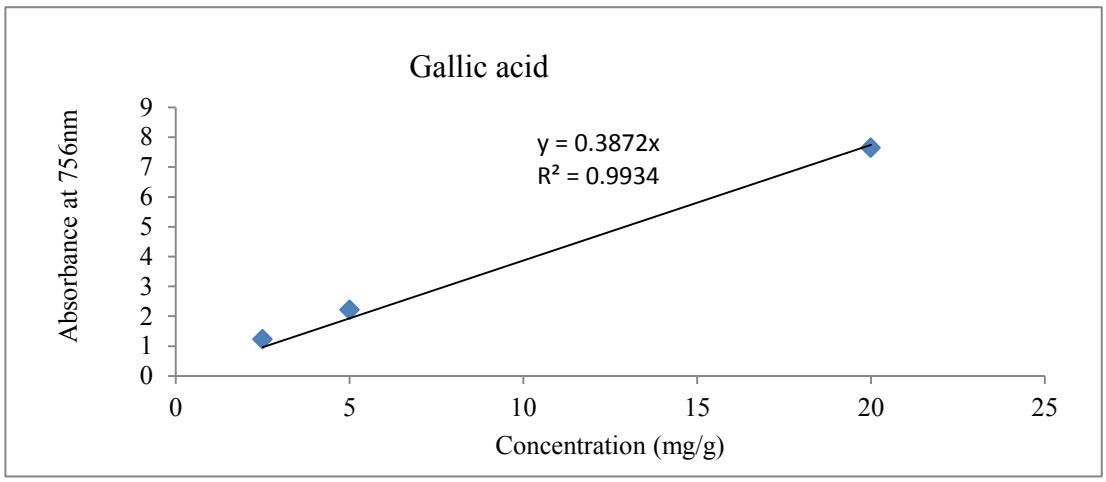
The Phenolic content was estimated to understand their antioxidative properties content. The selected plants are expressed in terms of dry weight basis as mg/g. The amount of total phenol contents differ in each plants and ranged from 8.6 mg/g to 10.2 mg/g with maximum value in *M. micrantha* (10.2±1.086 mg/g) and minimum in *A. conyzoides* (8.6±0.446 mg/g).

Table 9.2: Total Phenolic Content of selected weeds.

Name of species	Total phenolic content (mg/g)
Ageratum conyzoides	8.6±0.446
Chromolaena odorata	9.6±1.909
Mikania micrantha	10.2±1.086

Table 9.3: Standard concentration at 756nm Absorbance.

Gallic acid (Concentration)	Absorbance
2.5	1.229
5	2.217
20	7.641



Graph 5.1: Standard curve for Total phenolic content.

5.7.3 Total Flavonoid content

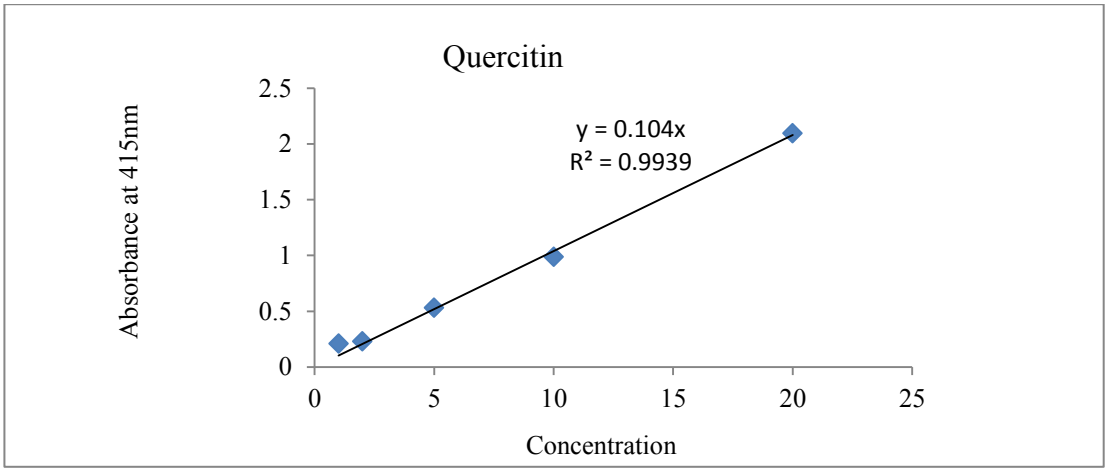
All the weeds contain almost the same amount of Flavonoid. *M. micrantha* contain the highest amount of flavonoid (27.9±0.473 mg/g) and *C. odorata* (27.6±0.687 mg/g) contain the least amount although their differences are almost negligible.

Table 9.4: Total Flavonoid content of selected weeds.

Name of species	**Total Flavonoid content (mg/g)**
Ageratum conyzoides	27.8±0.685
Chromolaena odorata	27.6±0.740
Mikania micrantha	27.9±0.473

` Table 9.5: Standard concentration at 415nm Absorbance.

Quercitin (Concentration)	**Absorbance**
1	0.211
2	0.229
5	0.531
10	0.987
20	2.096



Graph 5.2: Standard curve for Total Flavonoid content.

5.7.4 Total Alkaloid content

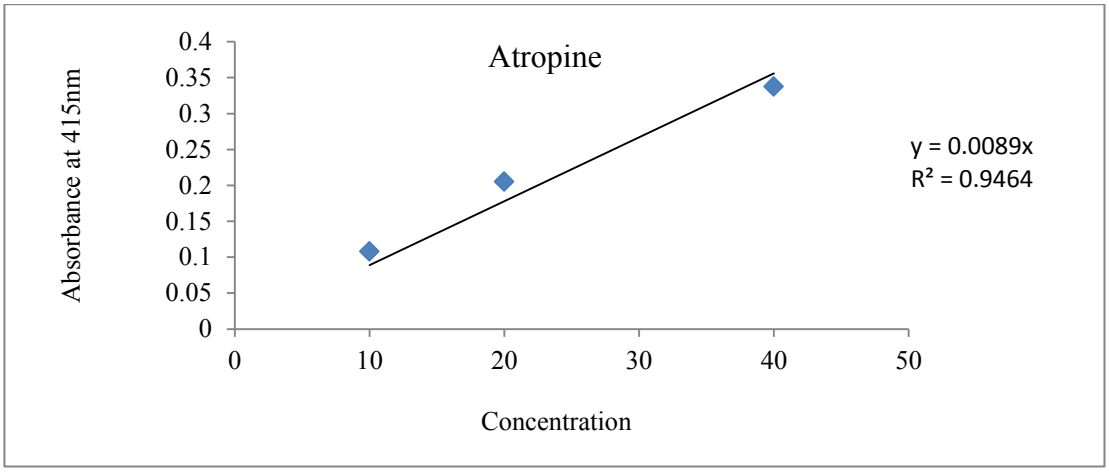
The total alkaloid content ranges from 1.347 mg/g to 2.067mg/g. The highest alkaloid content was found in *A. conyzoides* (2.067±1.581 mg/g) and the least amount of alkaloid was found in *C. odorata* (1.347±3.381 mg/g).

Table 9.6: Total Alkaloid content of selected weeds.

Name of species	**Total Alkaloid content (mg/g)**
Ageratum conyzoides	2.067±1.581
Chromolaena odorata	1.347±3.381
Mikania micrantha	1.554±1.258

Table 9.7: Standard concentration at 415nm absorbance.

Atropine (concentration)	**Absorbance**
10	0.108
20	0.205
40	0.338



Graph 5.3: Standard curve for Total Alkaloid content.

5.8 Discussion

Most of the weed species found in abundant during summer where rainfall, air temperature and relative humidity were high. The increasing density and frequency of weeds corresponds to increasing environmental factors. The climatic factors along with the growth and vigour of the weed species greatly influence the density and frequency of these weeds. During peak summer (June-August), density of weeds like *A. conyzoides, S. media, I. cylindrica* and *A. oleracea* are found to be maximum, and these are widely distributed and found to be available throughout the year in the study site. However, as the rainfall, humidity and temperature decreases, the density as well as the frequency of the weed species have decreased. The density and frequency of many species like *A. tiliaefolia* (Benth.) Muell, *C. argentea* and *M. pudica* sharply declined when the rainfall, humidity and temperature decreases. Significant seasonal variation in the weed flora was observed not only in the number of weed species in different months, but also in the density and IVI of the individual species (Neogi and Rao, 1979). It has been observed that the number of weed species increases with increase in temperature from February onwards. January being the coldest month of the year supports very few weed species. The growth and vigour of crop plants coupled with the seasonal climatic factors play an important role in the distribution and spread of these weeds. The study of the phenological pattern helps in understanding seed production and seed dispersal. Weeding before weed maturation will help in controlling weed population. The rapid growth of these weeds is largely due to the soil seed bank. It is an important part of weed life cycle. It allows annual

weeds to withstand harsh environmental conditions of winter. Further investment in managing the soil seed bank will provide reduction in future weed control costs.

The chemicals exudates from allelopathic plants were proposed to play an important role in the allelopathic mode of action. The allelopathic effect of these chemicals causes inhibition of seed germination (Gupta and Mittal, 2012). From the above data collected, it can be concluded that all target species demonstrated a significant degree of suppression and a negative response to the increasing concentration of different weed extracts. There was a significant difference between the test treatments and control. During the course of experiment the germination percentage and seedling length of *Z. mays* against the different weeds remain the highest and it is least suppressed by the weeds as compared to *B. campestris* and *O. sativa*. This shows that the presence of weeds did not bother the growth and that it can still grow abundantly even in presence of weeds. The crop that gets affected and suppressed the most by the different weeds is *B. campestris*. The allelopathic effects of *A. conyzoides, C. odorata* and *M. micrantha* greatly influenced the growth and yield of *B. campestris*. Therefore weed control in areas where *B. campestris* is highly important in order to prevent damage and loss of yield and improve weed management. Weeding at regular intervals is recommended in areas where crops are suppressed by presence of weeds. Suppressive effect was increased with an increase in extract concentration indicating that the effect of weeds depends very much on their extract concentration. These findings showed weed-crop competition where the weeds and agricultural crops compete for space and nutrients. Similar findings were also shown by the work done by Gupta and Mittal (2012) who reported the effect of allelopathic leaf extract of five selected weeds on *T. aestivum* L. The five selected weeds *P. minor* L., *C. murale* L., *S. oleraceus* L., *C. dactylon* L. and *C. arvensis* L. shows a certain degree of suppression and a negative response to the increase in concentration of their extracts when treated on *T. aestivum* L. Similar observation was also found by Ballester *et al*., (1982).

The present findings suggested that *M. micrantha* was the most toxic weed and *B. campestris* was the most suppressed agricultural test crop. Similar findings were observed by Kumar *et al*., (2007) where two dominant weeds (*A. conyzoides* and *C. odorata*) were tested for their allelopathic influences on agricultural crops (*O. sativa, B. campestris and G. max*) in Mizoram. Effects of leaf extracts of various

weeds on germination and radical extension of field crops have also been reported by Sugha (1980) and Singh *et al* (1989). Singh *et al*., (1989) studied allelopathic effects of aqueous extracts of *I. cylindrica, A. conyzoides* and *C. benghalensis* on germination and vigour of soybean and maize. Sugha (1980) studied aqueous extracts of seeds, leaf and root of *A. conyzoides* reduced the germination of wheat in order of inhibition leaf>root>stem. Its aqueous extracts delayed the germination and decreased the root and shoot elongation and number of leaves in chickpea (Angiras *et al*., 1988). *C. odorata* and *C. adenophorum* showed allelopathic effects in wheat, mustard, chickpea and white clover (Datta and Bandopadhya, 1981; Tripathi *et al*., 1981; Angiras *et al*., 1988). Leaf extracts of *C. odorata* reduced the growth of wheat and mustard seedlings (Datta and Bandopadhya, 1981).

Evidence shows that higher plants release a diversity of allelochemicals such as phenolics, alkaloids, terpenoids and flavonoids into the environment (Rice 1984). Many alkaloids are toxic to other organisms. They often have pharmacological effects and are used as medications and as drugs (Manske, 1965). The antifungal and antibacterial properties of saponins are important in cosmetic applications in addition to their emollient effects (Cheeke, 1998). They help to prevent cancer and increase the efficiency of vaccines. Terpenoids have a large and diverse role in antibacterial activity. They defend many species of plants, animals and microorganisms against predators, pathogens and competitors (Gershenzon and Dudareva, 2007). Tannins are polyphenolic compounds and are widely distributed in many species of plants, where they play a role in protection from predation, and perhaps also as pesticides, and in plant growth regulation (Ferrell and Thorington, 2006). Anthraquinone is an organic compound which acts as an effective repellent. Flavonoids extent antimicrobial activity in the healing of wounds and in the treatment of skin diseases (Barnabas and Nagarajan, 1988). They also play significant role as hypoglycaemic, antioxidant, anti-inflammatory and anti-carcinogenic activity (Anila and Vijayalekshmi, 2002). Phenols have biological properties such as anti-apoptosis, anti-aging, anti-carcinogen, anti-inflammation, anti-atherosclerosis, cardiovascular protection and improvement of endothelial function, as well as inhibition of angiogenesis and cell proliferation activities (Chavan *et al*., 2013).

The phytochemical screening of *A. conyzoides, C. odorata* and *M. micrantha* showed that they were rich in phytochemical constituents. *A. conyzoides* shows the presence of phenols, flavonoids, alkaloids, quinones, cardiac glycosides, terpenoids and tannins except saponins & anthraquinones. *C. odorata* and *M. micrantha* also shows the presence of the same phytochemical constituents as in *A. conyzoides.* The results were supported by the findings of Borkataky *et al*., (2013) who reported that the phytochemical analysis of *A. conyzoides, C. odorata and M. micrantha* revealed the presence of alkaloids, flavonoids, phenolics and tannins, steroids and glycosides. Alkaloids, phenolics and tannins, steroids and glycosides were present in all the three plants whereas saponins were present only in *C. odorata*. Also, flavonoids were present in *A.conyzoides* and in *C. odorata* and absent in *M. micrantha.* The above results are also in accordance with the findings of Selvakumar *et al*., (2012) who stated the presence of phytochemical active compounds such as tannins and cardiac glycosides in the leaf and stem extraction of *E. hirta*. Work done by Sharma *et al* (2020) also showed that phytochemicals in the aqueous extract of 10 locally available plants inhibited the growth of *P. sativum* seeds. The results obtained in the present study show the presence of phytochemicals which take part in defense mechanism of the plant. Hence, a complete study conducted with the purpose of finding these chemicals in weeds is significant. Thus the preliminary screening tests may be useful in understanding the bioactive principles and the role of phytochemicals in the development of plants. This is only a preliminary study of the occurrence of certain phytochemicals in selected weeds, further study is required to understand more about the functions of phytochemicals mentioned above.

5.9 Conclusion

In the present study, 37 weed species were found in the study site at jhumland field of Tachhip, Mizoram. The most abundant weed species were *A. conyzoides, C. odorata* and *M. micrantha*. The allelopathic effect of these weed species were studied on three agricultural crops *B. campestris, Z. mays* and *O. sativa.* The results shows a gradual decline in the germination rate as well as seedling growth of the agrilcultural crops with increase in the weed extract concentration.

Among the most common weeds, the phenology of the 10 most abundant weed species was studied. For effective control and preventive measures of these unwanted plants, it is essential to have knowledge of their floristic composition, their seasonal variation and phenology. Most of the plants were annual plants. They were mostly found abundantly throughout the year. Because of this reason, periodical weeding is required to control their rapid growth so that the agricultural crops grown in the jhumland can grow without any inhibitory effect from them.

The allelopathic plants releases chemicals that influences the growth of these crops. *A. conyzoides, C. odorata* and *M. micrantha* shows the presence of phenols, flavonoids, alkaloids, quinones, cardiac glycosides, terpenoids and tannins. The results led to the conclusion that the plants extract possess medicinal as well as antioxidant properties. The presence of these phytochemicals is important for survival of weed plants, which in turn, effects the growth and productivity of agricultural crops. Further studies are essential for quantification, isolation and characterization of the phytochemicals which will help us in better understanding of weeds-crops interaction under different agroecosystems.

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PUBLICATIONS

1. F. Lalnunmawia, J.C. Angel Lalrindiki and R. Lalfakzuala, 2016. Floristic composition, seasonal variation and phenology of weeds of agriculture lands in Mizoram, North-East India. Proceedings of the Mizoram Science Congress 2016. ISBN 978-93-85926-49-5.
2. J.C. Angel Lalrindiki and F. Lalnunmawia, 2017. Allelopathic effects of selected weeds on the germination and seedling growth of *Brassica campestris*. Proceedings of the National Seminar on Biodiversity, Conservation and Utilization of Natural Resources with reference to Northeast India 2017. ISBN 978-818653578-0.
3. J.C. Angel Lalrindiki and F. Lalnunmawia, 2020. Allelopathic effects of *Mikania micrantha* on agricultural crops in Mizoram, North-East India. International Journal of Life Sciences Research. ISSN 2348-3148. Vol 8(4): 10-13.
4. J.C. Angel Lalrindiki, Alex Zohmachhuana and F. Lalnunmawia, 2020. Phytochemical screening and allelopathic effects of *Ageratum conyzoides L.* Science and Technology Journal. ISSN 2321-3388. Vol 8(2).

PAPERS PRESENTED

1. "Floristic composition, seasonal variation and phenology of weeds of agriculture lands in Mizoram, North-East India". Mizoram Science Congress held at Mizoram University during 13th-14th October 2016. ISBN 978-93-85926-49-5.
2. "Allelopathic effects of selected weeds on the germination and seedling growth of *Brassica campestris*". National Seminar on Biodiversity, Conservation and Utilization of Natural Resources with reference to Northeast India (BCUNRNEI) organized by the Department of Botany, Mizoram University, Aizawl during 30th-31th March 2017. ISBN 978-818653578-0.

SEMINAR AND WORKSHOP ATTENDED

1. Advocacy workshop on Oil and Natural Gas Exploration in Mizoram organized by Mizo Academy of Sciences supported by Directorate of Geology and Mineral Resources, Government of Mizoram held on 18th July, 2014 at Conference hall, Directorate of Information and Public Relations, Aizawl.
2. One day workshop on Capacity Development for Forests Management and Personnel Training having theme of Training Improvement Plan organized by Consultants State Project Management Unit, E&F Department Government of Mizoram, under the Japan International Cooperation Agency (JICA) Assisted Project, held on 5th March, 2015 at ARCBR, Aizawl.
3. Mizoram Science Congress held at Mizoram University during 13th-14th October, 2016 organized by MISTIC, MSS, MAS, STAM, MMS, GSM and BIOCONE.
4. National Seminar on Biodiversity, Conservation and Utilization of Natural Resources with reference to Northeast India (BCUNRNEI) organized by the Department of Botany, Mizoram University, Aizawl during 30th-31th March 2017.
5. One Day National Workshop on "IPR and Plant Protection with special reference to NE India" held on 18th December, 2019. Jointly organized by Department of Botany and Department of Horticulture, Government of Mizoram.

ABSTRACT

ECOLOGY OF COMMON WEEDS AND THEIR ALLELOPATHIC EFFECT ON JHUMLAND CROPS IN MIZORAM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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DEPARTMENT OF BOTANY

SCHOOL OF LIFE SCIENCES

FEBRUARY, 2021

ABSTRACT

Ecology of common weeds and their allelopathic effect on Jhumland crops in Mizoram

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Submitted

In partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Botany of Mizoram University, Aizawl.

The present study entitled "Ecology of common weeds and their allelopathic effect on Jhumland crops in Mizoram" has been carried out to explain the effect of common weeds on agricultural crops found in Jhumland of Mizoram as well as study of the phenological events that influences the growth of both weeds and crops. A detailed survey of the weed flora in Jhumland fields was also studied. *Ageratum conyzoides, Chromolaena odorata* and *Mikania micrantha* were selected to test their effects on the seeds of *Brassica campestris, Zea mays* and *Oryza sativa.* The preliminary screening tests were carried out to determine the presence of phytochemicals and their role in the development of plants. Quantitative analysis of the weeds was also carried out.

Weeds are generally plants that are out of place, that adversely affect crop growth, and that for a variety of reasons are difficult to control. Since both weeds and crops are plants, they have basically the same requirements for normal growth and development. They require and compete for an adequate supply of the same nutrients, moisture, light, heat energy (temperature), carbon dioxide and growing space. Weeds compete successfully with crop plants by (i) being more aggressive in growth habits; (ii) obtaining and utilising the essentials of growth at the expense of the crop plants and (iii) in some cases, secreting chemicals that adversely affect the growth and development of the crop plants. The reduction in yield due to weed-crop competition mainly depends on weed species and their densities as well as crop species. As the distribution and infestation intensity of each weed is different, so the extent of crop yield reduction will mainly depend on the number and kind of weeds found in the field. Competition and the presence of vegetative and reproductive parts of weeds at or near to harvest have the greatest adverse effect on crop quality. About 60% of the population in Mizoram is believed to depend on shifting cultivation for their livelihood. Shifting cultivation in Mizoram is characterized by steep slopes; about half of the total land area has slopes of 40% to 100%. It therefore stands out from the other northeast Indian states in the need to perform the many activities of shifting cultivation, like slashing, burning, sowing, weeding and harvesting, on these steep slopes. Shifting cultivation has a deep impact on the socio-economic culture of the Mizo society. Many traditional festivals are named and observed on the basis of various stages of shifting cultivation.

Phenology is the study of the seasonal timing of life cycle events. The timing of emergence, growth and sexual reproduction is highly important for the success of invasive weeds.Temperature and light are probably the major factors regulating plant phenological response; thus, most responses focus on thermal time accumulation, day length and vernalization. Plants may exhibit inhibitory or rarely stimulatory effects on germination and growth of other plants in the immediate vicinity. Plants may compete with one another by biochemical interactions which may occur as a result of one species of plant secreting a growth inhibitory or stimulatory substance into its environment which is absorbed by another. Such interaction results in the inhibition of crop seed germination, formation of abnormal crop seedlings, prevention or reduction of root elongation, and cellular disorganization in roots, among other adverse effects.As the phytotoxic studies of weeds on agricultural crops have not been documented in a vast scale from this part of the world, an attempt has been made to study the phytotoxic influences of some dominant weeds on growth of some agricultural crops. Plants produce a large variety of secondary metabolites like phenols, tannins, terpenoids, alkaloids, polyacetylenes, fatty acids and steroids, which have an allelopathic effect on the growth and development of the same plant or neighbouring plants.For effective control and preventive measures of these unwanted plants, it is essential to have knowledge of their floristic composition, their seasonal variation and phenology. In North-east India, where majority of the population still relies on shifting agriculture as a main source of income, weeds play an important role in the economy of the region. It is more so in North-east states like Mizoram where 'Jhumming' or shifting cultivation is still prevalent and half a population of the population still relies on Jhum cultivation for their livelihood.

A number of studies were made on different aspects of weeds and its management. However, critical review of literatures suggests that there is a limited study on diversity, ecology of weed, their allelopathic effects on agricultural crops as well as phytochemical properties with reference to jhumland of Mizoram. Since, the presence of weed is a nuisance for agricultural crops as they compete for nutrition as well as growing space, thus, understanding the weed's diversity and ecology is essential for weed management as well as for developing crop management models. Thus, it is proposed to study diversity, phenology, allelopathic effects and

phytochemical properties of weeds on crop production with reference to jhumland of Mizoram.

The objectives of the present study include the study of diversity, density, dominance, phenology of weed, allelopathic effect of aqueous extracts of weeds on the seed germination and seedling growth of selected crops, analysing the phytochemical content of the three selected weeds and study of meteorological parameters and soil physico-chemical properties of the experimental site.

The present research was conducted at Tachhip (Aibawk RD Block) which is about 20 km from Aizawl. It enjoys a moderate and pleasant climate. The mean temperature varies from 9°C to 24°C in winter, and in summer from 24°C to 32°C. The entire state comes under the direct influence of the southwest monsoon, receiving an annual average rainfall between 1926mm and 2479mm. Tachhip falls under sub-tropical climate with hot and wet summer and moderately cold and dry winter. It enjoys a pleasant weather almost throughout the year. Highest temperature was recorded at 32°C at the month of April during the study. The surface soils of the hilly region of Mizoram are dark, leached and poor in bases, rich in iron and mostly acidic and pH ranges between 4.5 to 6.0. The soils are well drained, rich in carbon, potassium and low in available phosphorus content. The soil surface is loam to clay loam with clay content increasing with depth. The percentage of clay, silt and sand within 50cm of the surface in most cases are 25%-45% respectively. The pH and organic carbon decreases and clay increases with depth. Agriculture is the mainstay for about 60% of the population of Mizoram. Of the total area 21% is under paddy/seasonal crops. As high as 63% of the total crop area is under shifting cultivation. Paddy occupies almost 50% of the total crop area and more than 88% of the total crop area is occupied by food grains. The practice of shifting cultivation is still prevalent in Tachhip and the majority of population are subsistent farmers. Traditional shifting cultivation in the hilly slopes is the main livelihood of the people. The crop productivity per unit area is low due to technical know-how.

The investigations reported in this study were carried out in the year 2014 and 2015. Density, Frequency, Abundance and IVI of weed species were calculated according to Odum (1971). The IVI was calculated as per Curtis and McIntosh (1950). Among the weeds collected from the quadrats, a total of 10 most dominant

weeds were selected to study their phenology and seasonal variations. The phenological events like germination, vegetative, flowering, fruiting, seeding and death were noted. For phenological study, information from fields as well as from herbarium was gathered. Though considerable variation in the phenological pattern existed, a generalised picture is presented.

Among the dominant weeds found in the plots, *Ageratum conyzoides, Chromolaena odorata* and *Mikania micrantha* were randomly selected to study the germination and seedling growth of the selected agricultural crops *Brassica campestris, Oryza sativa* and *Zea mays.* The leaves were collected and washed to remove soil particles, cut into pieces and air dried and the dried leaves were made into powder by grinding with mortar and pestle and passed through 2mm mesh sieve, and then stored in air tight glass bottles. 10 gm of air dried weed plant material was taken in 100 ml of distilled water and kept for 24 hours at room temperature. It was then filtered through Whatman filter paper no.1 and the volume of the filtrate was made to 1000ml. Different dilutions such as 2%, 4%, 6%, 8% and 10% of the extract were prepared from the stock solution. The seeds of *B. campestris, O. sativa* and *Z. mays* were soaked separately in a petri plates in distilled water overnight. The next day, the seeds were surface sterilized with 0.1% of mercuric chloride solution for two minutes and washed twice with distilled water and kept for germination. Each paper towel was moistened with approximately 10ml. of respective extracts. The soaked seeds were then placed in the petri dishes with the respective concentration and the number of seeds placed were counted. After placing the seeds they were then covered with a layer of moistened paper towel. In each set of treatment two replicates were kept containing the same number of seeds. Observation of germination percentage and seedling length was done after an interval of one week. In each petri-dish, 20 seeds are placed randomly. After a week of incubation, the seeds that showed germination are recorded and their seedling length is measured. Using a ruler, the length of the radicle is measured and expressed in cm.The number of seeds that shows germination is counted and the percentage is calculated.

The soil nutrient status of the study site (pH, OC, N, P and K) was recorded. The estimation of Organic Carbon was done using the method by Walkley and Black,1934. The estimation of Available Nitrogen content was carried out by following Kjeldahl method,1883. The estimation of Available Phosphorus was

carried out by method carried out by Olsen *et al*.,1954. The estimation of Available Potassium was done using the method by Ghosh *et al*.,1983.The phytochemical content of Total Phenol Content (TPC), Total Flavonoid Content (TFC) and Alkaloids was estimated by the method carried out by Ainsworth *et al*.,(2007), Kaufman *et al*.,(1999) and Luyang Li *et al*.,(2014) respectively. The phytochemical screening of the samples was carried out as described by Krishnaiah *et al*.,(2009) and Sofowora (1982) with slight modification. The samples were screened for tannins, saponins, flavonoids, alkaloids,quinones,cardiac glycosides,terpenoids, phenols and anthraquinones. Lastly, the experimental data pertaining to each parameters were analyzed statistically using SPSS16 with the help of ANOVA and Correlation coefficient (r). Statistical significance at p □ 0.05 was considered.

The total averaged rainfall in the study site during the first year of study (2014) was found to be 89.47 mm and in the second year (2015) it was 79mm. The maximum air temperature during the first year of study (2014) was recorded in April (32.1^{o}C) and minimum air temperature in December (10.1^{o}C). During the second year of study (2015), the maximum air temperature was recorded in the month of March (29.22^{o}C) and the minimum air temperature was recorded in December (8.05^{o}C). The mean Relative Humidity (%) of the experimental site during the first year of study (2014) ranged from 26.5 to 91.9%. It was highest during the month of September (91.9%). During the second year of study (2015), the Relative Humidity was highest in the month of November (96.6%) and lowest in the month of March (30.8%).

The soil nutrient status of the study site (pH, OC, N, P and K) was recorded in the year 2014 and 2015. The pH value ranges between 5.8 to 6.2 shows that the soil is acidic to neutral. This shows that the soil is rich in nutrients and both agricultural crops as well as weeds can thrive well in the experimental site. The experimental result of the analysis of soil during the First and Second year showed that the organic carbon content is quite low as well as available Phosphorus found in the experimental site. Available Nitrogen and Potassium was found in moderate amount during both years. The nutrient condition of the soil is because of leaching during heavy rain, water runoff, denitrification etc.

A detailed survey of the weed flora in Jhumland fields yields 37 weed species belonging to 24 families were found in the study site. *A. conyzoides* (187.7 individuals/m²) has the highest density. The other species having high density were *S. media* (Linn.) Villars (59.9 individuals/m²) and *I. cylindrical* (Linn) Raeuschel (30.3 individuals/m²). The number of individuals was found to be highest during summer due to high temperature and abundant moisture with moderate rainfall. *A. conyzoides* was found to be the most dominant species with highest IVI (166) in all the seasons followed by *S. media* (Linn.) Villars. (IVI=107.7). The other dominant species were *C. odorata* (IVI=86.7), *I. cylindrica* (Linn) Raeuschel. (IVI=68.3), *O. corniculata* (IVI=66.6) and *A. oleracea* (IVI=64). Weed species like *A. conyzoides* are an invasive weed. They grow abundantly in presence of rainfall and moisture. They are found throughout the year. The density and frequency of many species like *A. tiliaefolia* (Benth.) Muell, *C. argentea* and *M. pudica* sharply declined when the rainfall, humidity and temperature decreases. Significant seasonal variation in the weed flora was observed not only in the number of weed species in different months, but also in the density and IVI of the individual species (Neogi and Rao, 1979). It has been observed that the number of weed species increases with increase in temperature from February onwards. January being the coldest month of the year supports very few weed species. The growth and vigour of crop plants coupled with the seasonal climatic factors play an important role in the distribution and spread of these weeds.

There is a distinct phenological pattern seen in different weeds. The phenological events of 10 most dominant weeds were shown. Most of the weeds germinate during the month of March-May such as *A. conyzoides, A. lunulatum* and *C. accresens*. Flowering and fruiting usually occurs during June to December. Otherwise the seeds of weeds produced would be disseminated and buried in the soil. As winter approaches, the weeds population decreases.Most of the weeds were found to have died after completing their life cycle during winter and the weed population diminished. They are mostly found throughout the year.Most of the density of weeds like *A. lunulatum, A. conyzoides, C. accrescens, C. odorata, I. cylindrica, A. oleracea* and *S. media* increases from winter to summer. Whereas *M. micrantha* and *O. corniculata* increases from summer to winter. The density of *B. pilosa* is negligible during winter. It was observed that most of the weed species were found in

abundant during summer where rainfall, air temperature and relative humidity were high. The increasing density and frequency of weeds corresponds to increasing environmental factors. During peak summer (June-August), density of weeds like *A. conyzoides, S. media, I. cylindrica* and *A. oleracea* are found to be maximum, and these are widely distributed and found to be available throughout the year in the study site. However, as the rainfall, humidity and temperature decreases, the density as well as the frequency of the weed species have decreased.The study of the phenological pattern helps in understanding seed production and seed dispersal for an effective weed management. Weeding before weed maturation will help in controlling weed population. The rapid growth of these weeds is largely due to the soil seed bank. It is an important part of weed life cycle. It allows annual weeds to withstand harsh environmental conditions of winter. Further investment in managing the soil seed bank will provide reduction in future weed control costs.

It was observed that there is a gradual decrease of seed germination% in *B. campestris* when treated with *A. conyzoides* extracts. About93% of the seeds germinated at control while only 21% germinated at 10% concentration. It greatly inhibit the seedling growth of *Brassica* as most of the seeds did not germinate. The seedling length of control was found to be only 1cm. About 86.6% germinated at control and 53.5% germinated at 10% concentration when *O. sativa* is treated with *A. conyzoides* extracts. It clearly shows a high percentage of germination in all concentrations. This shows that *O. sativa* can germinate even in presence of *A. conyzoides* extracts. The seedling length of *O. sativa* is highest in control i.e. 14cm while in 10% concentration it shows minimum length of 5.5cm. Although, *A. conyzoides* extracts decreases the growth of *O. sativa,* it does not entirely inhibit the seedling length. When *Z. mays* is treated with *A. conyzoides* extracts, all the seeds in control germinated. This indicates that *A. conyzoides* has little or no effect on *Z. mays.* At 10% concentration, 70% of the seeds germinated. There is a slow but gradual decline in the seedling growth. However, the seedling length when measured ranges from 28cm to 15cm.The study revealed that the effect of *A. conyzoides* on the germination% of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant ($p \square 0.05$) with the help of ANOVA. Similarly, the study also revealed that the effect of *A. conyzoides* on the seedling growth of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant ($p \square 0.05$). The study also revealed that

correlation coefficient among the different concentrations of *A. conyzoides* against the different crops shows a positive significant relationship.

It was observed that 98% of *B. campestris* seeds germinated at control while 43% at 10% concentration of *C. odorata* germinated. The aqueous leaf extract of *C. odorata* has a suppressing activity on seed germination of *B. campestris.* The competition between the weeds and the seeds for survival is high and this leads to the death of the germinated seedlings. The averaged seedling length at control is 8.6cm and it is 1.5cm at 10% concentration. All the *O. sativa* seeds at control germinated. 56% of the seeds germinated at 10% concentration of *C. odorata* extracts. Although the presence of *C. odorata* suppresses the growth of weed, it does not entirely inhibit their growth. The averaged seedling length ranges from 5cm to 17cm. About 90% of *Z. mays* seeds at 10% concentration germinated. The seedling length of *Z. mays* at control was approximately 24cm in length which shows the best growth as compared to the other treatment. At 10% concentration, the seedling length is measured at 16.5cm. The study revealed that the effect of *C. odorata* on the germination% of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p□0.05) with the help of ANOVA. Similarly, the study also revealed that the effect of *C. odorata* on the seedling growth of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p□0.05). The study also revealed that correlation coefficient among the different concentrations of *C. odorata* against the different crops shows a positive significant relationship.

It was observed that although the germination% of *B. campestris* is high at control, at 10% concentration of *M. micrantha* only 10% of the seeds show germination. In control, the seedling length is recorded at 2.4 cm. The seedling length can hardly be recorded at higher concentration. It can be concluded that *M. micrantha* greatly influenced the seedling growth of *B. campestris.O. sativa* when treated with different leaf extracts of *M. micrantha* shows a decrease in the germination rate with increase in concentration. 93% of seeds germinated at control while 46% of seeds germinated at 10% concentration. Even in the presence of *M. micrantha,* the rate of germination of *O. sativa* remains high. In case of seedling growth, it was found that the control has the longest seedling length of 13cm and the highest concentration(10%) of leaf extract has the least seedling length of 3.9cm.

When *Z. mays* was treated with different concentration of aqueous leaf extract of *M. micrantha*, there was a gradual decrease in seed germination but it does not inhibit it's growth. 93% of seeds germinated at control and 73% of seeds germinated at 10% concentration. It is apparent that leaf extract of *M. micrantha* influences the growth of *Z. mays*. At control, the seedling length of *Z. mays* is as long as 18cm and at 10% concentration the length of the seeds are 6.5cm. The study revealed that the effect of *M. micrantha* on the germination% of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p□0.05) with the help of ANOVA. Similarly, the study also revealed that the effect of *M. micrantha* on the seedling growth of *B. campestris, O. sativa* and *Z. mays* was found to be statistically significant (p□0.05). The study also revealed that correlation coefficient among the different concentrations of *M. micrantha* against the different crops shows a positive significant relationship. It can be concluded that all target species demonstrated a significant degree of suppression and a negative response to the increasing concentration of different weed extracts. There was a significant difference between the test treatments and control.During the course of experiment the germination percentage and seedling length of *Z. mays* against the different weeds remain the highest and it is least suppressed by the weeds as compared to *B. campestris* and *O. sativa*. This shows that the presence of weeds did not bother the growth and that it can still grow abundantly even in presence of weeds. The crop that gets affected and suppressed the most by the different weeds is *B. campestris*. The allelopathic effects of *A. conyzoides, C. odorata* and *M. micrantha* greatly influenced the growth and yield of *B. campestris.* Therefore weed control in areas where *B. campestris* is highly important in order to prevent damage and loss of yield and improve weed management. Weeding at regular intervals is recommended in areas where crops are suppressed by presence of weeds. Suppressive effect was increased with an increase in extract concentration indicating that the effect of weeds depends very much on their extract concentration.These findings showed weed-crop competition where the weeds and agricultural crops compete for space and nutrients. Similar findings were also shown by the work done by Gupta and Mittal (2012) who reported the effect of allelopathic leaf extract of five selected weeds on *T. aestivum* L. The five selected weeds *P. minor* L., *C. murale* L., *S. oleraceus* L., *C. dactylon* L. and *C. arvensis* L. shows a certain degree of suppression and a negative response to the increase in

concentration of their extracts when treated on *T. aestivum* L. Similar observation was also found by Ballester *et al*., (1982).

The present findings suggested that *M. micrantha* was the most toxic weed and *B. campestris* was the most suppressed agricultural test crop. Similar findings were observed by Kumar *et al*., (2007) where two dominant weeds (*A. conyzoides* and *C. odorata*) were tested for their allelopathic influences on agricultural crops (*O. sativa, B. campestris and G. max*) in Mizoram. Effects of leaf extracts of various weeds on germination and radical extension of field crops have also been reported by Sugha (1980) and Singh *et al* (1989). Singh *et al*.,(1989) studied allelopathic effects of aqueous extracts of *I. cylindrica, A. conyzoides* and *C. benghalensis* on germination and vigour of soybean and maize. Sugha (1980) studied aqueous extracts of seeds, leaf and root of *A. conyzoides* reduced the germination of wheat in order of inhibition leaf>root>stem. Its aqueous extracts delayed the germination and decreased the root and shoot elongation and number of leaves in chickpea (Angiras *et al*., 1988). *C. odorata* and *C. adenophorum* showed allelopathic effects in wheat, mustard, chickpea and white clover (Datta and Bandopadhya, 1981; Tripathi *et al*.,1981; Angiras *et al*.,1988). Leaf extracts of *C. odorata* reduced the growth of wheat and mustard seedlings (Datta and Bandopadhya, 1981).

The qualitative analysis of selected weeds showed that the leaves were rich in phytochemical constituents. It showed the presence of phenols, flavonoids, alkaloids, quinones, cardiac glycosides, terpenoids and tannins in all the weeds. However, saponins and anthraquinones were found to be absent in all the weeds. The amount of total phenol contents differs in each plant and ranged from 8.6 mg/g to 10.2 mg/g with maximum value in *M. micrantha* (10.2±1.086 mg/g) and minimum in *A. conyzoides* (8.6±0.446 mg/g). All the weeds contain almost the same amount of flavonoid. *M. micrantha* contain the highest amount of flavonoid (27.9±0.473 mg/g) and *C. odorata* (27.6±0.687 mg/g) contain the least amount although their differences are almost negligible. The total alkaloid content ranges from 1.347 mg/g to 2.067mg/g. The highest alkaloid content was found in *A. conyzoides* (2.067±1.581 mg/g) and the least amount of alkaloid was found in *C. odorata* (1.347±3.381 mg/g).

The qualitative screening of phytochemical compounds present in *A. conyzoides, C. odorata* and *M. micrantha* showed that they were rich in

phytochemical constituents. *A. conyzoides* shows the presence of phenols, flavonoids, alkaloids, quinones, cardiac glycosides, terpenoids and tannins except saponins & anthraquinones. Many alkaloids are toxic to other organisms. They often have pharmacological effects and are used as medications and as drugs (Manske, 1965).The antifungal and antibacterial properties of saponins are important in cosmetic applications in addition to their emollient effects (Cheeke, 1998). They help to prevent cancer and increase the efficiency of vaccines. Terpenoids have a large and diverse role in antibacterial activity. They defend many species of plants, animals and microorganisms against predators, pathogens and competitors (Gershenzon and Dudareva, 2007). Tannins are polyphenolic compounds and are widely distributed in many species of plants, where they play a role in protection from predation, and perhaps also as pesticides, and in plant growth regulation (Ferrell and Thorington, 2006). Anthraquinone is an organic compound which acts as an effective repellent. Flavonoids extent antimicrobial activity in the healing of wounds and in the treatment of skin diseases (Barnabas and Nagarajan, 1988). They also play significant role as hypoglycaemic, antioxidant, anti-inflammatory and anti-carcinogenic activity (Anila and Vijayalekshmi, 2002).Phenols have biological properties such as anti-apoptosis, anti-aging, anti-carcinogen, anti-inflammation, anti-atherosclerosis, cardiovascular protection and improvement of endothelial function, as well as inhibition of angiogenesis and cell proliferation activities (Chavan *et al*., 2013).The presence of these chemicals are important for their survival, which in turn, effects the growth and productivity of agricultural crops. These chemicals in turn affect the agricultural crops. Hence, a complete study conducted with the purpose of finding these chemicals in weeds is significant. Thus the preliminary screening tests may be useful in understanding the bioactive principles and the role of phytochemicals in the development of plants. This is only a preliminary study of the occurrence of certain phytochemicals in selected weeds, further study is required to understand more about the functions of phytochemicals mentioned above. Further studies are essential for quantification, isolation and characterization of the phytochemicals which will help us in better understanding of weeds-crops interaction under different agroecosystems.