# ECOLOGY OF SOME WEEDS OF WINTER CROP FIELDS IN KATHMANDU VALLEY

A THESIS SUBMITTED TO THE

**CENTRAL DEPARTMENT OF BOTANY**

**INSTITUTE OF SCIENCE AND TECHNOLOGY**

**TRIBHUVAN UNIVERSITY**

**NEPAL**

**FOR THE AWARD OF**

**DOCTOR OF PHILOSOPHY**

**IN BOTANY**

BY

**BABY BABITA DAS "MALLIK"**

**August 2021**

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# DECLARATION

Thesis entitled **"Ecology of Some Weeds of Winter Crops in Kathmandu Valley"** which is being submitted to the Central Department of Botany, Institute of Science and Technology (IOST) Tribhuvan University, Nepal for the award of the degree of Doctor of Philosophy (Ph.D), is a research work carried out by me under the supervision of Prof. Dr. Bipana Devi Acharya (Pandey), Department of Botany, Amrit Campus, Tribhuvan University, Nepal and co supervised by Prof. Dr. Mohammad Saquib, Department of Biological sciences, University of Maiduguri, Maiduguri (Borno state), Nigeria (West Africa).

This research is original and has not been submitted earlier in part of full in thesis or any other form to any university or institute here or elsewhere, for the award of any degree.

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# RECOMMENDATION

This is to recommend that **Baby Babita Das "Mallik"** has carried out research entitled "**Ecology of some Weeds of Winter Crops in Kathmandu Valley"** for the award of the degree of Doctor of Philosophy (Ph.D.), in BOTANY under our supervision. To our knowledge, this work has not been submitted for any other degree.

She has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur for the submission of the thesis for the award of Ph.D. degree.

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RECOMMENDATION

**This is to certify that the thesis entitled " ECOLOGY OF SOME WEEDS OF WINTER CROP FIELDS IN KATHMANDU VALLEY'' submitted to Central Department of Botany, Tribhuvan University for the degree of Doctor of Philosophy in Botany, is the outcome of original research work carried out by Baby Babita Das Mallik, under our supervision. This work has not been submitted for a degree of any other University.**


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# LETTER OF APPROVAL

Date: 22nd June, 2021

On the recommendation of supervisor Prof. Dr. Bipana Devi Acharya (Pandey) and Co-supervisor Prof. Dr. Mohammad Saquib, this Ph.D. thesis submitted by Baby Babita Das "Mallik", entitled **"Ecology of Some Weeds of Winter Crops in Kathmandu Valley"** forwarded by Central Department Research Committee (CDRC) to the Dean, Institute of Science and Technology, Tribhuvan University.

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Baby Babita Das "Mallik"

June 2021

# ABSTRACT

In Nepal, weeds cause yield loss up to 45% in the mustard (*Brassica campestris* L.) field and 50% in wheat (*Triticum aestivum* L.), sometimes even more losses when the weed population and density are higher. Usually, weeds are harmful but some may have economic importance as organic compost, food or fodder, medicine, and industrial uses. The use of invasive plants (like *Ageratina adenophora* (Spreng) King & Rob. *and Parthenium hysterophorus* L.) and a native weed (*Artemisia dubia* Wall. Ex. Besser), for preparing biofertilizer and their effect on weed and winter crops have been investigated in the present study. The main objectives of the present study were to understand the weed ecology in winter crop fields. Other important objectives were to investigate the allelopathic effect of *Artemesia dubia*, *Ageratina adenophora* and *Parthenium hysterophorus* to control selected weeds of winter crops by using aqueous extract, compost extract, and their compost. The study was carried out at the wheat and mustard fields of selected sites (Kirtipur, Bhaktapur, Godawari, Chapagaon, Dharamsthali, and Shivapuri) during winter (Oct-March) in the year 2012-2014. Based on the highest IVI value only four common weed species (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cyperus rotundus* L., and *Galinsoga parviflora* Cav.) were selected for a further ecological studies like phenology, soil seed bank, seed morphology, seed germination, and allelopathic effect. Altogether 40 plants of each weed (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) were randomly selected and their phenophase was carefully examined from the germination stage to seed dispersal stage of plants using the phenological index technique. The shape, color, and size (length and breadth) of the four common weed seeds were measured under a compound microscope for weed seed morphology study.

Seed germination experiment was conducted on environmental conditions like moisture (content 3, 6, 9, 12, 15 ml), temperature (5, 10, 15, 20 and 25˚C), pH (value 4, 5, 6, 7, 8 and 9) and light (normal, red, yellow, blue, green and dark color). For the crops, optimum moisture content (9 ml) was required. The experiments on seed germination of moisture indicated that *Cyperus rotundus* and *Galinsoga parviflora* do not require more moisture to germinate and grow. Seed germination of both crops enhanced significantly at 15 to 20˚C treatments but all weed seeds were significantly high at 10 to 15˚C. The percentage of seed germination of both crops *Brassica campestris* and *Triticum aestivum* increased significantly in normal and green light.

Seed germination of *Ageratum conyzoides*, *Cyperus rotundus*, and *Galinsoga parviflora* was significantly different in normal, red, yellow, and green light. Germination of all weed seeds was completely inhibited in blue and dark light. Seed germination and seedling growth were higher in pH 5-7 in most cases. Seed germination was also conducted with different concentrations (control, 1, 2.5, 5, 10%) of chemical fertilizer solutions and different doses of fertilizer amended in soil (control, 10, 20, 40, 50 g/kg soil). Seed germination of both crops and all the weeds were mostly high in control and 1% of both urea and potash solution. The germination of selected weed seeds reduced significantly with increasing concentrations of both urea and potash in soil. The aqueous extracts vegetative parts of *Ageratina adenophora*, *Parthenium hysterophorus*, and *Artemisia dubia*, their compost extract (of the whole plant) of different concentration (control, 1, 2.5, 5, and 10%) and soil amended with composts (of different doses 0, 10, 20, 40, and 50 g compost/kg soil) were used to understand their effects on seed germination, seedling growth of crops (*Triticum aestivum*, *Brassica campestris*) and the common weed. The aqueous and compost extracts of *Ageratina adenophora* and *Parthenium hysterophorus* significantly reduced seed germination and seedling length (shoot and root) with increasing concentrations. The stem and leaf extracts of *Ageratina adenophora* showed a more inhibitory effect on the seed germination of both winter crops and all weeds as compared to root extract. In the soil amended with different amounts of *Ageratina adenophora* and *Parthenium hysterophorus* compost showed more reduction in seed germination among the weeds in comparison to both crop plants. Seed germination of *Cyperus rotundus* was completely inhibited even at 1% *Parthenium* compost extract and soil amended with 10 g/kg *Parthenium* compost. The aqueous extract and compost extracts and compost of the native plant *Artemisia* also significantly reduced seed germination, seedling length of both selected crops and weeds, with increasing concentrations, but were less detrimental than the compost of the other two invasive weeds. From this study, it was found that compost of *Ageratina adenophora* and *Parthenium hystrophorus* at the rate of 20-40 g/kg soil was effective to control the winter weeds. Hence the use of *Ageratina adenophora* and *Parthenium hysterophorus* compost are suggested to use at low concentrations (20-40 g/kg soil) in wheat or mustard fields, especially to control most of the common weeds. This information suggests preparing compost from the invasive weeds which can act as environmentally safe and cost-effective bio-herbicides along with an important strategy for weed management.

# LIST OF ACRONYMS AND ABBREVIATION

| | |
|---|---|
| °C | Degree celsius |
| µm | Micrometer |
| ABA | Abscisic acid |
| Abun. | Abundance |
| ANOVA | Analysis of variance |
| B | Breadth |
| Ca | Calcium |
| cm | Centimeter |
| Freq. | Frequency |
| g/kg | Gram per kilogram |
| GC-MS | Gas chromatography-Mass spectrometry |
| ha | Hactare |
| hrs. | Hours |
| IVI | Importance Value Index |
| K | Potassium |
| L | Length |
| Mg | Magnesium |
| ml | Millileter |
| mm | Milimeter |
| Mt | Metric tonne |
| nm | Nanometer |
| P | Probablity value |
| pH | Potential of hydrogen |
| RL | Root length |
| SG | Seed germination |
| SL | Shoot length |
| sp. | Species |
| spp. | Species |
| t/ha | Tonne per hectare |

# LIST OF TABLES

**Page No.**

# LIST OF FIGURES

**Page No.**

# TABLE OF CONTENTS

# CHAPTER 1

## 1. INTRODUCTION

### 1.1 Background

Agriculture is the most governing economic activity of the Nepalese people. It employs more than 81% of the total labor force of the country. Foodgrains are predominant in the agriculture sector of Nepal. Lowland and upland are two types of land in the Terai. Two to three crops are grown in one year at hills and terai while at high mountains mostly one crop is cultivated. Paddy (*Oryza sativa*) and maize (*Zea mays*) are the main cereal crops grown during summer in Terai and hills. The main crops in winter are wheat (*Triticum aestivum* L.), mustard (*Brassica campestris* L.), potato (*Solanum tuberosum*), peas (*Pisum sativum*), etc. (Tiwari *et al.*, 2005). The most practiced cropping system in Nepal is the Paddy-wheat cropping system. The paddy-wheat cropping system in Nepal covers about 0.5 million ha of land in the country and has a share of 65.8% and 72.1% of total area and total production of cereal crops (Lamsal & Khadka, 2019; Khanal *et al*., 2012). In the paddy-wheat cropping system, paddy is normally grown in water stagnated field whereas following crop wheat requires well-drained soil conditions. Under this system, Nepalese farmers cultivate paddy during June/July whereas wheat is planted in November following the harvest of paddy (Amgain & Timsina, 2005). Similarly, mustard (*Brassica campestris* L. var. toria), commonly called tori in Nepali, is one of the important oilseed crops of Nepal and is grown in uplands after a rainy season (Basnet, 2005; Ghimire *et al.*, 2000). Weed management is a challenging issue in both winter and summer crops and further, it has been aggravated by climate change. To overcome this issue several measures for weed control like physical and chemical are mostly used but now some integrated approach for weed management needs to be explored for improving the crop yield.

### 1.2 Weeds

Weeds are the native and non-native plants growing at unwanted places and are competitive in nature, as they compete for water, soil, nutrients, light, space, etc. so resulting in reduced crop yield and quality in agricultural ecosystems (McErlich &

Boydston, 2013). The crop-weed interaction is multifarious. The weeds compete with the crop plants in different ways; fast-growing weeds compete for light, while slow-growing weeds compete for water & nutrients (Schonbeck, 2013).

Weeds can be defined as plants out of place, but this only considers the human perception of a weed, not the fact that weeds are the plants that are ecologically in place, they grow in an environment provided or managed by the human who meets their needs. Weeds possess special plasticity in growth, which allows adaptation to various conditions and very fast growth rates that give them advantages over the crop (FAO, 1987). Weeds reduce the crop yield either by reducing the amount of harvestable product (grain, Stover, forage) or by reducing the amount of crop harvested (Aldrich, 1984). The energy expended on the weed (ing) of the main crop is sometimes more than for any other single human task (Holm, 1971).

Weeds inhabit and multiply rapidly with fast seedling growth at the sites concerned. It can grow in diverse environmental conditions. Therefore, weeds are found in limitless amounts. Worldwide, there are about 250,000 plant species in which 3%, i.e., 8000 weeds species have harmful chemical substances that adversely affect crop plants (Charles *et al.*, 2018). The frequent and diverse distribution of weeds creates intense pressure on the environment (Akhtar & Hussain, 2007).

Some weeds were documented recently in the detailed lists of the Global Naturalized Alien Flora (GloNAF) database (Inderjit *et al*., 2018). While naturalized species are also listed for some Asian countries such as China (Wu *et al*., 2010; Jiang *et al*., 2011), Singapore and Hong Kong (Corlett, 1992), Sri Lanka (Iqbal & Cheema, 2008, 2009), Nepal (Shrestha *et al*., 2014) and Taiwan (Wu & Wang, 2005), large parts of Asia are still data-deficient (van Kleunen *et al*., 2015; Inderjit *et al*., 2018).

The widely documented impacts of invasive alien species on native biodiversity, ecosystem functioning and economy, as well as human health (Vila *et al.*, 2010, 2015; Kumschick *et al.*, 2015; Rumlerova *et al*., 2016; Inderjit *et al.*, 2018), invasive alien species have long been recognized as a key component of global environmental change (Millenium Ecosystem Assessment, 2005; Kettunen *et al*., 2009).

Weeds generally not only compete for nutrients and space but are troublesome in many ways with crops. It often serves as a host for crop diseases; they may also provide shelter for insects and diseases for hibernation. Weeds remove large quantities of plant nutrients from the soil and deprived the crop plants (Rathore *et al.*, 2011) and also reported that in general the losses of crops caused by weeds (28%) have exceeded the losses from agricultural pests such as insects (23%), diseases (25%), rodents (8%), storage (10%), and others (6%) in India. The total loss has been at Rs 50,000 million, which is about 18% of the gross national agriculture production in India (Manncsa, 2009). While Rao (2000) had reported that the total annual loss of agricultural yield from various pests, weeds account for 45%, insects 30%, diseases 20%, and other pests 5% in India. But the potential crop yield loss due to weed was estimated to be 43%, on a global scale (Oreke, 2006).

## 1.3 Problem of weeds in winter crops in Nepal

Multiple cropping is an agriculture system long adopted by marginalized small landholder farmers, especially in hills and mountains. This practice was meant to enhance farm productivity when the farming area is limited (Amgain & Timsina, 2005). According to the statistical information of Nepalese agriculture (2015-16), the total production of wheat and mustard in Nepal are 1,736,849 and 171,499 (Metric tonne) (Table 1). Similarly, the production of wheat and mustard in Kathmandu, Bhaktapur, and Lalitpur are given in Table 2.

**Table 1.** The production of wheat and mustard in Nepal

| SN | Year | Grain | Area (hectare) | Production (metric tonne) | Yield (kg/hectare) |
|---|---|---|---|---|---|
| 1 | 2015-16 | Wheat | 745,823 | 1,736,849 | 2,329 |
| 2 | 2015-16 | Mustard | 169,769 | 171,499 | 1,010 |

Source: Statistical Information of Nepalese Agriculture B.S. 2072-73 (2015-16), Ministry of Agricultural Development, Monitoring, Evaluation and Statistics Divisions, Agri Statistics section, Kathmandu, Nepal

**Table 2.** The production of wheat and mustard in Kathmandu, Bhaktapur and Lalitpur of Nepal

| SN | Year | Grain | Place | Area (hectare) | Production (metric tonne) | Yield (kg/hectare) |
|---|---|---|---|---|---|---|
| 1 | 2015-16 | Wheat | Kathmandu | 3,900 | 12,480 | 3,200 |
| | 2015-16 | | Bhaktapur | 3000 | 10,500 | 3,500 |
| | | | Lalitpur | 3000 | 7800 | 2600 |
| 2 | 2015-16 | Mustard | Kathmandu | 971 | 1015 | 1045 |
| | 2015-16 | | Bhaktapur | 200 | 350 | 1750 |
| | | | Lalitpur | 2918 | 2773 | 950 |

Source: Statistical Information of Nepalese Agriculture B.S. 2072-73 (2015-16), Ministry of Agricultural Development, Monitoring, Evaluation and Statistics Divisions, Agri Statistics section, Kathmandu, Nepal

In Nepal, there are 370 weeds in the field of *Triticum aestivum* L. in which 69 spp. of weeds belong to the Asteraceae family. The most commonly reported weeds of wheat in Nepal are *Ageratum conyzoides* L., *Bidens pilosa* L., *Cyperus rotundus* L., and *Galinsoga parviflora* Cav. (Dangol, 2013). In Nepal, the wheat yields have also been reported to decrease up to 50% by weeds and decreases are far greater when weed population and density are higher (Ranjit *et al.*, 2009). In the case of the Chitwan area of Nepal, Dangol and Choudhary (1993) have reported 30 weed species from wheat fields. Ranjit (2002) and Shah (2013) have reported the broadleaf weeds as the major problem in the agricultural field. Chaudhary (1979) reported 108 angiospermic weeds of 36 families from six different sites of the Kathmandu valley like Kirtipur, Bhaktapur, Dharamsthali, Thankot, Khumaltar and Indrayani. He observed that the weeds were from Asteraceae followed by Gramineae. Sapkota *et al.* (2010) reported a total of 44 weed species representing 18 families from wheat fields of Khokana whereas a new weed (*Vicia* sp.) was reported along with other dominant weeds like *Chenopodium album*, *Polygonum plebeium,* and *Spergula arvensis*.

Wheat is considered the most important cereal crop after rice in Nepal. Of the total cultivated area in the country that is 2,968,000 ha, rice is cultivated in 1,544,990 ha and wheat in 669,014 ha. Eighty-four percent of the wheat cultivation area falls under the rice-wheat rotational system (Singh, & Paroda, 1994). However, rotational cropping has led to losses in the yield of wheat (Joshi, 1996). Nevertheless, the grassy weeds are also equally blamed for the loss in wheat yield (Aslam *et al*., 1989).

The main crops in winter are wheat, mustard, buckwheat, lentil, and chickpea in the terai and inner-terai regions. The major recorded weeds of families were Asteraceae, Fabaceae, and Poaceae, and dominant weed species were *Gnaphalium luteo-album* L., *Chenopodium album* L., *Cynodon dactylon* (L.) Pers., *Equisetum debile* Roxb. ex Voucher, *Lathyrus aphaca* L., *Anagalis arvensis* L., *Rumex dentatus* L., *Lolium temulentum* L, *Digitaria adscendens* (HBK.) Henr. and *Polygonum plebeium* R. Br (Amgain & Timsina, 2005) in the wheat field of Chitwan, Nepal.

The production of rice and wheat crops in the same year is the predominant cropping pattern in the country. Weeds are the major problem in both crops grown under this system. Many weeds identified in the wheat crop weeds like *Phalaris minor, Chenopodium album, Cyperus rotundus, Convolvulus arvensis, Cnicus arvensis,* *Parthenium, Chromolena adenophora, Ageratum conyzoides,* and *Galinsoga parviflora* have recently become most problematic in the winter crop field. In Nepal, yield loss in wheat ranged from 15% to 70%. The use of 2,4-D and isoproturon to control the broadleaf and grass weeds is common in Nepal's Terai region (Ranjit, 1997).

Mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm oil (*Elaeis guineensis Jacquin*) plants. The global production of mustard and its oil, respectively is around 38–42 and 12–14 mt. Weeds cause an alarming decline in crop production ranging from 15-30% to a total failure in rapeseed-mustard yield (Patel *et al*., 2017; Shekhawat *et al*., 2012). In mustard fields interference of weeds causes yield losses up to 45%. A variety of weeds affect these crops but the extent of damage in terms of yield and resources is location-specific (Singh, *et al*., 2013).

A total of 75 weed species were recorded in the mustard fields of Mahendranagar, Kanchanpur. The dominant weeds were Poaceae (16 species) and Cyperaceae (8 species), Asteraceae (8 species), Scrophulariaceae (6 species each) and Leguminosae, Euphorbiaceae (5 species each). Based on density and IVI, 21 weed species dominated (Bhatt, *et al*., 2009).

### 1.4 Diversity of weeds

Weeds cause major changes in the biodiversity of the invaded areas, inhibiting germination and growth of other plant species (Kilewa & Rashid, 2013; Dogra *et al*., 2011; Inderjit *et al*., 2018). Invasive plants are non-native plants that affect the composition and function of ecosystems and have large economic effects through nutrient loss, degradation of land use, and eradication costs. Despite their negative importance, very little comprehensive information on the abundance, distribution, and impact of non-native invasive plants is available (Gray *et al*., 2011). A total of 190 invasive alien species under 112 genera, belonging to 47 families have been recorded from the Indian Himalayan region (Kumar *et al*., 2016; Sekar, 2012). Kumar *et al*. (2016) have reported the loss of plant diversity in both the crop and forest areas over the last two to three decades due to invasive plants. *Parthenium hysterophorus*, *Eupatorium adenophorum* (*syn. Ageratina adenophora*), *Lantana camara*, *Ageratum conyzoides,* and *Bidens pilosa* degrading the valuable crop and fodder plants (especially herbs and grasses) have been observed during the last 2-3 decades. The leachates of *Eupatorium adenophorum* (Syn. *Ageratina adenophora*) damaged the cell membrane and influenced the concentration of endogenous hormones like abscisic acid, indole 3-acetic acid and zeatin riboside of roots in the upland rice (Zheng *et al.*, 2012).

*Parthenium hysterophorus* is an invasive weed, commonly known as carrot grass, bitter weed, or star weed, and belongs to the family Asteraceae. Due to the rapid growth of this plant, it is now a challenging weed for the biodiversity and ecosystem in the tropical regions. Physiological studies have shown that *Parthenium* weed, with low photorespiratory activity, has the C3 photosynthetic pathway but with positive C4 tendencies (Patil & Hegde, 1983).

In Nepal, *Parthenium hysterophorus* L. has already invaded sugarcane, maize, and mustard fields (Shrestha *et al.*, 2014). It is an erect herbaceous plant that multiplies rapidly and completes its life cycle within 16-18 weeks (Shrestha *et al.*, 2010). The surrounding plants are affected by the parthenin, an allelochemical discharged from different parts of *P. hysterophorus* (Belz *et al.*, 2007). The rapid expansion of this plant, which causes ecological impact and economic loss, has become a big environmental issue of the tropical world (Gnanavel, 2013). Parthenin leaching as root exudate plays a pivotal role in the allelopathic interference with the surrounding plants (Belz *et al*., 2007). Parthenin has also been reported as a germination and radicle growth inhibitor in a variety of dicot and monocot plants (Gunaseelan, 1998; Patel, 2011).

*Ageratina adenophora* (Spreng) King & Rob. is a troublesome, aggressive, noxious perennial weed. The plant is reported to contain the collection of bioactive constituents like monoterpenes, sesquiterpenes, flavonoids, phenylpropanoids, and their derivatives (Proksch & Rodriguez, 1983). Sesquiterpenoids are the major constituents of leaves and flowers (Ding & Ding, 1999). Cadenene sesquiterpenes were also identified in leaves (Lan *et al*., 2008; Rajmohan & Ramaswamy, 2007). This invasive plant is also known for its insect repelling properties (Kundu *et al*., 2012). It came to Nepal through Mexico and is one of the serious weeds in Asia. It quickly spread across the terai, mid-hill, and low mountain areas of Nepal (Bisht *et al*., 2016).

The native weed *Artemisia dubia* Wall. ex Besser is a hardy herbaceous shrub, species between 200 and 400 (Gingade *et al.*, 2014). Most of them are found primarily in Asia, Europe and North America (Mucciarelli & Maffei, 2002). Leaf extract of *Artemisia dubia* caused an inhibitory effect on germination and growth of barnyard grass (Jankju, 2008, 2013; Poudel *et al*., 2005).

Three species of *Artemisi*a widely distributed in Nepal, (i.e, *Artemisi*a *dubia* Wall. ex Besser, *Artemisi*a *indica*, and *Artemisi*a *vulgaris* L.) are also used as medicine (Satyal *et al.*, 2012; Gewali, 2008). The components 1, 8-cineole, α-bergamotene, (E)-caryophyllene, and τ-cadinol and essential oils are reported to be present in *Artemisi*a *dubia* of Nepal (Satyal *et al.*, 2012).

## 1.5 Allelopathy

The study of abundance and distribution of weed species helps to manage weeds in agricultural lands for crop production. Some weeds are harmful but others have economic importance, as they are used for organic compost, food or fodder, medicinal and industrial fields.

DeCandolle (1832) was probably the first person to suggest the possibility that many plants may excrete something from their roots which is injurious to other plants. Molisch (1937) proposed the term "allelopathy" for expressing the harmful effect that one plant species has on another through the formation of chemical retardants escaping into the environment. The concept of allelopathy was further described by different researchers like Bonner (1950), Grummer and Beyer (1960), Evenari (1961), Whittaker (1970), Pitman and Duke (1978), and Fischer *et al*. (1978). Allelochemicals (inhibitors) are produced by plants as end products, by-products and metabolites. They are contained in the stem, leaves, roots, flowers, inflorescence, fruits and seeds of the plant. Of these plant parts, leaves seem to be the most consistent producers of these allelochemicals.

Allelopathy of invasive plants affects the plant community, occurrence, growth, succession, dominance, diversity and plant productivity. Initially, many studies showed the negative impact of allelopathy on other plants, but in the 1980s research was begun to identify the species that exhibit beneficial, neutral, or selective effects on crop plants (Ferguson *et al*., 2003). Aqueous extract of some weeds like

*Parthenium hysterophorus, Ageratum conyzoides, Cynodon dactylon,* and *Solanum nigrum* showed inhibition or stimulation in seed germination as well as seedling growth of crops like soybean (Verma & Rao, 2006).

A study in China found that 25 out of 33 highly noxious weeds had a significant allelopathic impact on the surrounding plants. The release of biochemical, called allelochemicals that are toxic to germination and growth of other plant species, reduces seed germination and seedling growth of the contiguous plants (Ferguson *et al.*, 2013; Tripathi *et al.*, 1981). The plant species belonging to the family Asteraceae produce chemical substances, which reduce seed germination and the emergence of subsequent small grain crops when grown in rotation (Watban & Salma, 2012).

The study of allelopathy can be steadfast only if the present and forthcoming research results are converted into new technologies that can be used for weed management and/or in reducing the dependence on synthetic herbicides. Allelopathy is a mechanism for managing invasive plants by establishing effective monoculture and may contribute to the ability of particular exotic species to become dominants in the invaded plant communities (Hierro & Callaway, 2003; Kanchan and Jaychandra, 1979; Maharjan *et al.*, 2007). Many phytotoxic substances released by weeds help to suppress the seed germination and seedling growth of other plants. Over ten thousand chemicals are estimated to be released by plants to protect themselves against other plants, especially weeds. The study of the allelopathic relation between weeds and crops, and between weeds and weeds may be beneficial to manage the weeds and crop yield (Kadioglu & Yanar, 2004; Camurkoylu & Demirkan, 1993).

The allelochemicals discharged from a plant are due to (i) volatilization; i.e., terpenes are discharged from the leaves of some plant species (ii) leaching; the living or dead leaves of many plants contain growth inhibitors (iii) exudation; roots of several crop and non-crop species release large quantities of organic compounds that inhibit the growth of other plants, and (iv) decomposition; allelochemicals are released from plant residue (Gill *et al.*, 1993). Considerable research work has been conducted on the allelopathic effect of weeds on natural plant communities, in abandoned or old fields (Wahab *et al.*, 1967; Neil & Rice, 1971).

Kumar and Vishwakarma (2005) reported that the composition of nutrients parameter was high in the pre-flowering phase of *Parthenium hysterophorus* L. in comparison to the post-flowering one. Krishnamurthy *et al*. (2005) also reported that the highest grain yield was obtained after the application of *Chromolaena odorata* compost at 7.5t/ ha, whereas the lowest yield in the control.

Many plants are reported to have allelopathic properties but the information about their effective uses with field crops, an effective active ingredient, extraction, and composting technology is lacking (Patil, 2007; Grundy, 1999). Recent research conducted at the Rodel Institute has proved that the use of compost extract with different dilutions, chemical and biological properties leads to a reduction in weed germination without affecting the crop plants (Zinati *et al*., 2015). The utilization of invasive and native weed plants in research on weeds may help in increasing the yield crop on one hand, and in the management of invasive species on the other.

Mineral nutrient (N, P and K) contents in the seeds depended on the nutrient contents in soils and on factors controlling their availability to plants. So that phenotype-based variation in seed size may arise from variations in soil fertility or a combination of environmental and maternal effects (Kołodziejek & Patykowski, 2015).

This is accepted that seedling size is also related to its food reserves or micronutrients present on the seeds. The position of a seed or fruit on a plant can affect morphology, germination, and dormancy characteristics (Kołodziejek & Patykowski, 2015).

### 1.6 Justification of the study

The work of enumeration of winter weeds has been carried out by many workers (Chaudhary & Shrestha, 1981; Manandhar, 1978; Ranjit *et al*., 2009) in Nepal but due to excessive urbanization and changes in land use pattern in Kathmandu valley, mostly at the cost of agricultural lands (Ishtiaque, 2017), weeds composition and diversity might have changed. The rising temperature is also expected as the main factor in determining the distribution of different plant species (Subedi *et al*., 2015). At present, it is not known which weeds have a high IVI value and are most abundant in winter crop fields. Besides that, researches on soil seed banks of common weeds in winter crop fields have not been conducted. It is apparent from many publications that the weed survey works were mostly done in the Kathmandu valley but conducting systematic and ecological surveys of the weed community in the soil seed bank and IVI of the weed community in the wheat and mustard fields to understand vegetation and prioritize the weed management researches are lacking.

To control weed, the use of synthetic herbicides is quite common but it is hazardous for human health. To overcome this problem, it is important to find some alternatives to the biological origin that may be biodegradable and harmless to human health. It is also known that some of the native weeds like *Artemisia dubia* Wall. Ex. Besser is found from the eastern to western zone of Nepal (Sharma & Devkota, 2018; Press *et al*., 2000). It spreads vigorously highly competitively with other plant communities and produces different flavonoids, phenolics, terpenoids with a higher concentration in vegetative parts (Satyal *et al*., 2012; Sharma & Devkota, 2018; Press *et al.*, 2000). The invasive weeds like *Ageratina denophora* (Subba & Kandel, 2012; Lallianrawna *et al*., 2013) and *Parthenium hysterophorus* (Ahmed *et al*., 2018) possess allelopathic effect due to the presence of different allelochemicals (Rai & Tripathi, 1984; Kumar & Gautam, 2008). It is not known if the plant extract and compost extract from these weeds will suppress the seed germination of winter crops and/or winter weed. Therefore, it is important to investigate the effect of aqueous extract, compost extract, and compost of invasive weeds like (*Ageratina adenophora* and *Parthenium hysterophorus*) and the native weed (*Artemisia dubia*) on seed germination and seedling growth of both winter crops and weeds. This research aims to use the effectiveness of compost prepared from invasive plants (*Ageratina adenophora, Parthenium hysterophorous*) and native weed (*Artemisia dubia*) especially to control other winter weeds.

## 1.7 Research questions

a. Which are the most dominant weeds in the winter crops in Kathmandu valley?

b. What are the effects of aqueous extract, compost extract, and the compost of native weed *Artemisia dubia* and invasive weeds (*Ageratina adenophora* and *Parthenium hysterophorus*) on seed germination and seedling growth of wheat, mustard, and associated weeds?

## 1.8 Objectives

The general aim of the present work is to understand the weed ecology of most common weeds of winter crops for making their control possible. To achieve this bigger target, the following specific objectives have been set for the study.

1) To analyze the weed community structure of the winter crop weed community in Kathmandu valley.

2) To study the phenology of some dominant weeds.

3) To study the morphology of selected weed seeds and their soil seed bank.

4) To study seed germination of some weeds and two winter crops under different environmental conditions *viz*. moisture, light, temperature, pH, and chemical conditions.

5) To investigate allelopathic effects of some weeds on seed germination of other crops as selected within weeds.

# CHAPTER 2

## 2. LITERATURE REVIEW

Weeds can inhabit and multiply rapidly in diverse environmental conditions that give them advantages over the crop (FAO, 1987; Charles *et al.*, 2018), so they are found in a limitless amount. Worldwide, there are about 250,000 plant species in which approximately 3% or 8000 weed species have harmful chemical substances that adversely affect crop plants (Charles *et al.*, 2018). The frequent and diverse distribution of weeds creates intense pressure on the environment as noted by Akhtar and Hussain (2007).

Many works on weed ecology have been conducted in Nepal (Joshi, 1982; Khatiwada, 1986; Manandhar, 2004; Acharya, 2005; Joshi, 2005; Koju, 2005; Dangol, 2013). Some ecophysiological works on the weeds like *Ageratum conyzoides, Ageratum houstonianum, Chenopodium album, Cirsium argyracanthus, Oenothera rosea, Vicia hirsuta, Vicia sativa, Trifolium repens, Eupatorium adenophorum, Artemesia* and *Cannabis sativa* have also been conducted (Ranabhatt, 1978; Yadav, 1985; Chettri, 1986; Raut, 1986; Bhandari, 1999; Pokharel, 2004; Parajuli, 2005). Weed enumeration and taxonomic work have been done by Chaudhary (1978). Extensive work on some grasses and forbs of Morang districts was studied by Jha (2003, 2005) and weed competition study in paddy field and their control measures was conducted by Thapa (2005).

Biogeographically, more than one-third (35%) of the alien flora in India has found its native in South America, followed by Asia (21%), Africa (20%), Europe (11%), Australia (8%), North America (4%); and cryptogenic (1%) (Khuroo *et al*., 2012). The documentation on the impact of invasive alien species on native biodiversity, ecosystem functioning economy and human health has long been recognized. It is well known that some species introduced by humans, maintain populations and become naturalized and only a subset of naturalized species spread rapidly (i.e., become invasive), and even fewer have strong negative ecological and economic impacts (Blackburn *et al.*, 2014; Inderjit *et al*., 2018).

## 2.1 Weed community structure of winter crops

Dangol (2001) reported weeds like *Chenopodium album, Polygonum plebeium, Oxalis corniculata, Anagallis arvensis, Digitaria sanguinalis, Vicia hirsuta*, and *Vicia angustifolia* in the wheat field of Rampur, Chitwan and also reported weeds like *Chenopodium album*, *Oxalis corniculata*, *Cynodon dactylon*, *Ageratum houstonianum*, and *Digitaria sanguinalis* in maize fields during winter in Chitwan. Later on, 34 papers were reviewed on the most common weeds of wheat (*T. aestivum* L.) field of Nepal and listed 370 weed species of 210 genera in 54 families (Dangol, 2013). He reported Asteraceae (69 spp.) as the dominant family followed by Poaceae (52 spp.), Leguminosae (25 spp.), Polygonaceae (19 spp.), Caryophyllaceae (18 spp.), Scrophulariaceae (17 spp.), Euphorbiaceae and Lamiaceae (14 spp. each), Brassicaceae and Cyperaceae (13 spp.), and Solanaceae (11 spp.), which accounted for 71.35% of the total weeds in the wheat fields. In the mustard fields of Mahendranagar- Kanchanpur, 75 dominant weed species of different families like Poaceae (16 species), Cyperaceae (8 species), Asteraceae (8 species), Scrophulariaceae (6 species each) and Leguminosae, Euphorbiaceae (5 species each) were recorded based on density and IVI (Bhatt *et al.,* 2017). Ranjit *et al.* (2009) studied the effect of mulching on weed management strategies in wheat fields at Khumaltar (during the winter season of 2000-2002). In wheat fields, *Alopecuros sp*., *Cannabis sativa*, *Chenopodium album*, *Phalaris minor*, *Polygonum hydropiper*, *Rumex crispus*, *Soliva anthemifolia*, and *Stellaria media*, were dominant species. Among them, *Alopecuros aqualis*, *C. album*, *P. minor,* and were the more dominant species. Compared to that without mulching the effect of mulching showed suppressed the weeds about fifty percent. Wheat yields together with yield attributing were also higher in the treatments with straw mulch. Subedi (2013) surveyed rice and wheat fields to understand local knowledge on weed intensity diversity and weed management practices, under the rice-maize-wheat cropping system located at Chitwan. The weeds like *Chenopodium album*, *Vicia sativa, Vicia hirsutum, Anagalis arvensis*, *Oxalis corniculata* were reported to be the major weed based on density and frequency whereas *Polypogon fudax, Polygonum plebijum, Chenopodium album, Solanum nigrum*, *Gnaphalium affine, Anagalis arvensis* were reported as a major weed in a wheat field based on the frequency of weed population and density. Total weed population reported were 332.4%, 350%, 165.3% higher in lowland, upland,

and zero tillage than herbicides applied fields, respectively. *Cyperus rotundus* L. is also a troublesome weed, which is economically harmful and is widely spreaded in the tropical and subtropical regions of the world (Peerzada, 2017; Jha & Sen, 1985a). It has also been reported to cause 20–90% yield losses in various agronomic and horticultural crops across the world (Peerzada, 2017). Jha and Sen (1985b) studied the survival strategies of *Cyperus rotundus* L. and reported that the critical moisture level of the tubers, perennating organ is 43% even at minimum soil moisture of about 0.4%. Weeds like *Cyperus rotundus*, *Chenopodium album*, *Cyanodon dactylon, Phalaris minor, Echinocloa colonum*, *Convolvulus arvensis*, *Ageratum conyzoides*, *Angallis arvensis, Solanum nigrum,* and *Parthenium hyserophorus* were found in mustard fields of Uttar Pradesh, India (Singh, *et al*., 2013). Roger *et al*. (2015) estimated the distribution and population of weeds and reported that the knowledge of the weed population's abundance and distribution is important to determine how the population changes occur during a long time due to selective pressure by different agronomic practices. Accuracy of estimation of these two variables of weed is very helpful and important for the management of the agricultural field in terms of both productivity and biodiversity.

## 2.2 Phenology of some dominant weeds

*Ageratum conyzoides* were found as a common weed germinated in agricultural fields in tropical and subtropical regions (Feng *et al*., 2007; GISD, 2016). The ideal temperature for the germination of *Ageratum conyzoides* L. and *Ageratum houstonianum* ranges from 20 to 25˚C. The species are highly adaptable to different ecological conditions due to large morphological variations. Feng *et al*. (2007) and Holm *et al.* (1977) also reported *Ageratum conyzoides* and *Ageratum houstonianum* to be among the commonest weeds in warmer regions of the world as an important weed in all crops in the tropics and subtropics. They also reported it as a weed in China, as it flowers all year-round (where soil moisture is adequate) and produces large quantities of seed, which allows for a heavy infestation of crop fields.

Huang *et al.* (2012) investigated the floral biology of *Bidens pilosa* L. var. radiata, a member of Asteraceae. They defined six floral stages according to another tube and style morphology to observe the process of pollen presentation to assess pollen viability and stigma receptivity. They observed significant differences in the number of disk florets per capitulum and the number of pollen grains in each floret among individuals. The secondary pollen grains that come out from the anther tube occur due to activities like brushing and pumping of growing style was observed. Shivakumar *et al*. (2014) investigated the biology of *Bidens pilosa* L. seed production under the canopy of crop plants. They reported good growth from July to September along with a wide variation in plant height, number of branches, biomass, and seed production potential. They reported the time interval between seed initiation and rain episodes varied from 4 to 15 days and took nearly 37 to 73 days to complete the entire seed rain episode in the population. Positive significant correlations between the growth parameters and the seed yield have also been reported.

Baloch, *et al*. (2015) considered *Cyperus rotundus* as the world's top 10 noxious weeds of agricultural fields of different economically important crops. *Cyperus rotundus* is distributed all over the world in tropical, subtropical, and temperate regions. This plant appears from the ground in all seasons wherever there is even slight moisture. During the rainy and winter seasons, the population of *Cyperus rotundus* is very dense and causes heavy damage to crop production (Holzner & Numata, 2013). The roots and rhizome of *Cyperus rotundus* usually penetrate up to 20 cm into the soil but over 90% of their phytomass is restricted to the upper 10 cm. In a dense population, the underground parts form an enmeshed mass of root and rhizome ranging from 3 mm-1.25 cm. The tuber fails to sprout below 13$^{\circ}$C and with lower moisture content (less than 13 %) was reported by Ambasth (1964). The control of weed *Cyperus rotundus* is very difficult due to its rapid growth capacity and well developed underground rhizome/tuber system. Although this weed also produces seeds it mostly spreads by tubers. The tuber formation depends upon the seasons in temperate latitudes, which begins in late summer as photoperiods become shorter (Molero & Stoller, 1978). Schonbeck (2015) reported that *Cyperus rotundus* usually flower about 7–8 weeks after emergence, although flowering can occur as early as 3 weeks. The formation of a new tuber starts at the time of flowering & most tubers are set in the top 8 inches of the soil profile, with a few forming at greater depths. After flowering, the tubers continue to form for several weeks after shoot growth ceases because *Cyperus rotundus* undergoes a marked shift from above ground to below ground development.

## 2.3 Soil weed seed bank estimation

The important component of many plant ecology studies and weed dynamics is the study of the viable seeds in the soil. The soil seed banks refer to the all viable seed reservoir present in the soil or mixed to soil debris (Simpson *et al*., 1989). Benvenuti, (2003) performed experiments in the laboratory to investigate if the physical characteristics of the soils were involved in both buried-seed ecology and emergence dynamics. He buried seeds of weed (*Datura stramonium* L.) in 10 different soil types (with or without the control of soil external gas environment) with pronounced sandy or clay texture to study seed germination and emergence characteristics. Germination obstruction was reported to be due to burial depth and was also to be directly proportional to clay content and inversely proportional to sand content. He suggested that the inhibition in seed germination with depth was not so much due to hypoxia but was mainly due to the presence of fermenting metabolites that could not readily be removed due to decreased respiratory activity. Based on the experiment he also suggested that the increased time required for the emergence of buried seeds in clay soils was primarily due to increased mean germination time not due to difficulty in penetration of seedling to come out through the soil before emergence. His experiments demonstrated that soil physical properties have a strong effect on buried-seed ecology and soil seed-bank dynamics in the agro-ecosystem. Mesagaran *et al*. (2007) estimated seed bank by three extraction methods (sieving, cloth bag, and flotation) using different types of seeds of *Datura stramonium, Amaranthus retroflexus, Portulaca oleracea* and *Plantago major*. The total seed recoveries from the flotation, sieving and cloth bag methods were 61%, 67%, and 75%, respectively, and were insignificantly different. The estimation of seed density and species composition of soil seed banks in the soil of natural grassland in Patagonia was analyzed by Gonzalez and Ghormendi (2012). They found four-time higher seed density in the grassland soil with the extraction method than that from the seedling emergence method. From this study, they concluded that differences in seed bank estimation in both methods may be associated with seed size, seed mass, seed dormancy and specific requirements for germination.

There is no standardized method for seed bank evaluation techniques **(**Espeland *et al.,* 2010). They compared the emergence of the seed from soil and petri plate germination experiments of *Bromus tectorum* (L.), *Vulpia bromoides* (L.S.F. Gray), *Amaranthus retroflexus* (L.), *Kochia scoparia* (L. Schrad.), *Chenopodium album* (L.), and *Lepidium campestre* (L. R. Br.). They reported less seed bank estimations from the emergence method than that from the petri plate germination and concluded that the soil is an important post-germination barrier to seedling emergence. The weed seed bank study in rice fields showed that the amount of the weed seed bank is highly variable which depends on various factors like climate, relief position, soil moisture content, depth of sampling, history of the areas and management practices by farmers **(**Mesquita, 2017). Most common weeds produce a huge number of seeds and vegetative propagules with physical and physiological dormancy mechanisms, as a survival strategy. After seed rain, a large proportion of weed seed banks remained on or close to the soil surface. Determination of the weed seed-bank can be made by seed direct extraction and germination methods. He suggested the germination method to be more accurate concerning record viable seeds in the soil.

## 2.4 Seed germination

### 2.4.1 Under different environmental conditions

Dormancy of a seed is defined as the inability of seeds to germinate under favorable conditions. Unfortunately, it is not the only way to identify whether the seed is dormant or non-dormant. A non-dormant seed will germinate under the right set of conditions whereas the dormant seed will exhibit a more strict set of conditions before it germinates (Madrid, 2012). It was also stated that during maturation, seeds may enter a state of dormancy that requires another set of conditions to break it.

The light response and seed mass coevolved as an adaptive feature to ensure germination of small-seeded species only when close to the soil surface (Milberg *et al.*, 2000). Temperature is a major factor for modifying seed responses to light; a seed may require light to germinate at a given temperature but not at other temperatures. In some species, temperature fluctuations can fully or partially substitute for the light requirement. The soil temperature fluctuation is highest close to the soil surface without vegetation or with vegetation gaps (Milberg *et al.*, 2000). Phytochrome is another factor that mediates light-promoted germination and is also known to increase the number of bioactive gibberellins in seeds. According to Cann (2014), seed responses to the timing of germination in the field are controlled by light and also affect seedling survival, growth and fitness. Seeds that require light for germination are usually small in size. The effect of light on germination in 131 taxa of the Campanulaceae family, from all five continents, was investigated by Koutsovoulou *et al*. (2014). They found seed germination higher in light than in darkness for every temperature tested and also reported that the light requirement for germination decreased significantly with increasing seed mass. It was suggested that smaller seeded taxa might germinate only on the soil surface or at shallow depths, while larger seeded species might germinate even when buried in the soil. The effects of temperature, light, sodium chloride (NaCl), hydrogen ion concentration (pH), potassium nitrate ($KNO_3$), and polyethylene glycol 6000 on seed germination of *Rumex confertus* was studied by Kołodziejek and Patykowski (2015) and found significantly higher germination percentage in light than in darkness. From these experiments, they conclude that in the vegetation gaps or disturbed sites the weed *R. confertus* possibly established through the germination of seeds that originated from a long-lived seed bank in the upper surface of the soil. Experiments on the adaptation to temperature and water stress in three species *Ageratum conyzoides, Crassocephalum crepidioides,* and *Conyza canadensis* was conducted by Yuan and Wen (2018) and found that these three species have wide array of temperature ranges to allow seed germination. High germination and seedling growth were achieved between 15˚C and 30˚C, but germination was drastically inhibited at 35˚C; and *Ageratum conyzoides* favored warmer temperatures. The light was a vital germination prerequisite for *C. crepidioides* and *Ageratum conyzoides*, whereas most *C. canadensis* seeds germinated in dark condition. Although all three species have a good adaptation to bare ground habitat characterized by high temperatures and water stress, including their tolerance to soil surface temperatures of 70˚C in air-dried seeds. *Ageratum conyzoides* seeds showed high tolerance to both high-temperature treatment of 40˚C, and water constraint (e.g., ca. 65% seeds germinated to -0.8 MPa created by NaCl), which were reliable with their field conditions in China. This study suggests that seed high-temperature tolerance contributes to weed becoming invasive.

### 2.4.2 On chemical fertilizers (urea and potash)

The adverse effect of urea fertilizer on seed germination of wheat (*Triticum aestivum* L.), rye (*Secale cereale* L.), barley (*Hordeum vulgare* L.), and corn (*Zea mays* L.) in soil was investigated by Bremner and Krogmeier (1989). They compared the effect on seed germination in the soil of purified urea, urea fertilizers, urea fertilizer impurities, and compounds formed by enzymatic and microbial transformations of urea in soil. Their result showed that ammonia volatilized from soils treated with urea completely inhibited germination of seeds close to, but not in contact with, these soils. Their experiments also showed that the adverse effect of urea fertilizer on seed germination in soil was eliminated when the soil was autoclaved to destroy urease or was treated with phenyl phosphorodiamidate (before treatment with urea fertilizer) to hinder soil urease activity. Hence they recommended integrating organic manure with inorganic chemical fertilizer for effective agriculture and sustainability of the environment. Similarly, the impact of high evaluation of artificial fertilizer and mitotic index was studied by Tabur and Oney (2009) in root tips of *Vicia hybrida* L. and reported that high concentrations of artificial fertilizers decreases mitotic index and increases various chromosomal abnormalities. Urea has high N content (45 to 46%), and rapid converts to plant-available N (Weiss *et al*., 2009). They mentioned that if urea is surface applied and not incorporated (either by rain or tillage), N losses to the air (as ammonia) can approach up to 40%. It is also mentioned that a rapid pH increase after application caused by hydrolysis of urea can result in ammonia release and that can damage seedlings if the urea is applied near the seed. Conversion of ammonium to nitrate resulted in the formation of hydrogen ions ($H^+$). So, like most N fertilizers, repeated applications of urea will reduce soil pH over time. The effect of various concentrations of ammonium sulfate and potassium sulfate was investigated by a series of experiments on direct-seeded upland rice (Singh, *et al.*, 2010). From the studies, they reported that productivity of rainfed upland rice can be increased by the integration of seed invigoration techniques combining hormone priming by GA3 and thermal hardening that improved the crop competitive ability. They reported suppression of weeds substantially with intercropping of pigeon pea and cowpea with rice at 4:1 and 4:2 row ratios, respectively. They manipulated fertilizer scheduling using controlled-release urea and basal application of N and integration with an optimal dose of herbicide to reduce weed infestation, nutrient uptake by weeds, enhance agronomic nitrogen use efficiency, and to improve upland rice productivity.

The impact of organic manure and compost on the productivity of wheat (*Triticum aestivum* L. cv. Inqlab-91) growing in sandy clay loam soil was conducted by Ibrahim, *et al*. (2008). They have reported mainly to optimize the amounts of various organic manures to supplement the inorganic fertilizers for crop yield. They reported an increase in the wheat yield by 11.13 (105 %) to 13.53 (128 %) g in the pot than in control with the organic manure application. The wheat plant height, number of tillers, spike length, straw yield, grain yield, and 1000 grain weight all were reported to be statistically different from that of control. Their findings suggested that crop productivity may be improved significantly by the application of various organic manures instead of using inorganic chemical fertilizer alone. The effect of various organic fertilizers (farmyard manure, vermicompost and composted coir pith) and inorganic fertilizers (nitrogen, phosphorus, and potassium) on germination of green gram (*Vigna radiata* L.) was studied by Vaitiyanathan and Sundarmoorthy (2016). They analyzed various parameters (like germination percentage, seedling length, fresh weight, dry weight, and photosynthetic pigments such as chlorophyll a, chlorophyll b, total chlorophyll, and carotenoid) and found that all studied parameters increased in plants with vermicompost applied soil, than in soil with other organic and inorganic fertilizers. They concluded that vermicompost is very useful for crop production. The experiments with compost extract were conducted by Zinati *et al.* (2015) and they found that the tested compost extract dilutions did negatively impact the germination percentage of pepper but not on tomato, cucumber or basil. However, their results showed that compost extract at 1:4 dilution, produced from designed compost 2 (i.e higher percentage of brown or C: N) with lower NO3-N levels and a higher number of nematodes, has the potential to reduce lambsquarter seed germination percentage by 32% without affecting the germination of the tested seed crop species. Experiments on weed control using chemically- and microbial-designed compost extracts (CMD-CE) were conducted by Zinati (2017) and their results indicated that the application of compost extracts can be effective in managing weeds and also in producing comparable crop yields to the standard grower's method.

## 2.5 Allelopathic effect of two invasive plants (*Ageratina adenophora* and *Parthenium hysterophorus*) and one native weed (*Artemisia dubia*)

Phytochemical investigation of aerial part of plant *Eupatorium adenophorum* Spreng. [or *Ageratina adenophora* (Spreng.) King & Robinson] (Compositae) for its allelochemicals conducted by Zhao *et al.* (2009) and identified eleven terpenes (2 monoterpenes and 9 sesquiterpenes) from *Ageratina adenophora* and also reported that it has caused a great economic loss in China, especially the southwestern region, as it is gravely threatening the native biodiversity. They also recorded the potential allelopathic effects of these compounds on the *Arabidopsis* seeds germination. Out of 11 compounds isolated, only 2 compounds retarded the *Arabidopsis* seeds germination, while other compounds showed no obvious inhibitory effects. Further**,** Zhu *et al*. (2011) tested the allelopathic effect of phytotoxicity of *Eupatorium adenophorum* (crofton weed) to a native plant species *Brassica rapa,* both in the sand and in native soil. They concluded that natural soils from different invaded habitats eliminated the efficacy of potential allelochemicals in comparison to sand cultures. They also found that when that soil is sterilized, the allelopathic effects return. This made them suggest that soil biota were responsible for the reduced phytotoxicity in natural soils. Two allelopathic compounds (9-Oxo-10,11-dehydroageraphorone and 9b-Hydroxyageraphorone) which are present in the *E. adenophorum* are absent in the natural soils infested by the invader, but when they added those compounds to the soils as leachates, they showed significant degradation occurred after 24 hours in natural soils but not in the sand. From this finding, it has been concluded that soil biota can reduce the allelopathic effects of invaders and also play an important role in reducing community invasibility. Altogether 45 volatile compounds are identified from essential oil extracted from *Ageratina adenophora* (Subba & Kandel, 2012). It is expected that in future, the rapid expansion of *Ageratina adenophora* will be essential to initiate effective management measures to prevent further negative impacts of this invasive plant (Poudel *et al*., 2020).

Among them, torreyol (16.8%) was the major component in oil. Their result also showed a higher fraction of sesquiterpene than the monoterpene in the essential oil. Their results also showed the antibacterial activity extracted essential against both gram-positive (*Klebsiella pneumoniae* and *Staphylococcus aureus*) and gram-negative (*Escherichia coli* and *Proteus vulgaris*) bacteria. Allelopathic effects of fresh and composted *Ageratina adenophora* on the physiology of three solanaceae vegetables (*Capsicum annum*, *Solanum lycopersicum*, and *Solanum melongena*) and yield quality was studied by Jiao *et al*. (2016) of pepper. They reported that *Ageratina adenophora* composed with microbial inoculum eliminated the physiological inhibition of seed germination and seedling growth and the compost amended with chemical fertilizer increased pepper yield as well as improved the quality. The allelopathic effects of *Ageratina adenophora* were also studied by Qian and Huang (2018) and explained that the fresh plants contained allelopathic toxins which inhibited the hydrolysis of macromolecular inclusions in seed endosperm, and decreased seed germination rate, nutrient absorption by seedlings, including nitrogen, phosphorus, and potassium, and inhibited seedling growth. He reported that organic fertilizer made from *Ageratina* *adenophora* which was added with microbial inoculum stimulated wheat seed germination, and increased the yield and seed quality.

Phytotoxic effects of *Parthenium hysterophorus* (whole plant, leaves, and roots) residues on three *Brassica* species (*Brassica campestris*, *B. oleraceae*, and *B. rapa*) was studied by Singh, *et al*. (2005) in the laboratory. The aqueous extract of this plant severely reduced the seedling growth of *Brassica* species. The phenolic constituent of *Parthenium hysterophorus* residues extracts increased with increasing residues concentration. The allelopathic effects of *Ageratum conyzoides*, *Cynodon dactylon*, *Parthenium hysterophorus*, and *Solanum nigrum* L. were also examined by Verma and Rao (2006) on seed germination, seedling growth, total protein content, and protein profile on Ankur, Bhatt, Bragg, PK -416, PS-1042 and Shilajeet varieties of soybean (Glycine max (L) Merill). They reported both inhibitory and stimulatory effects of aqueous extracts of weed (10% w/v) on seed germination and seedling growth in different varieties of soybean. Among weed extracts, *Solanum nigrum* and *Parthenium hysterophorus* were reported to have more detrimental effects as compared to others. Allelopathic effect of aqueous extract of *Parthenium hysterophorus* was studied by Maharjan *et al.* (2007) on seedling emergence and seedling growth of three cereal crops (*Oryza sativa* L., *Zea mays* L., and *Triticum aestivum* L.), three crucifers (*Raphanus sativa*, *Brassica campestris* L. and *Brassica oleraceae* L.) and two families of Asteraceae (*Artemisia dubia* Wall ex. Besser and *Ageratina adenophora* (Spreng King and H.E. Robins). Kishor *et al*. (2010) suggested that composting of uprooted *Parthenium* or use as a green manure *Parthenium* extract helps to reduce its spreading and inhibit the weed seedling growth. They documented that the nutrient composition of *Parthenium* compost is higher than farmyard manure and suggested its use in agriculture. The biomass of *Parthenium hysterophorus* and *Chromolaena odorata* can be used for composting **(**Krishnamurthy *et al*., 2010). They recorded more organic carbon and nitrogen in *Chromolaena* compost than in *Parthenium* compost. Further higher P content in composts was recorded due to the enrichment of *Parthenium* and *Chromolaena* with rock phosphate, but K, Ca, Mg, and S contents did not show much difference in both the composts. Netsere and Mendesil (2011) investigated the effects of aqueous extracts of vegetative parts of *Parthenium hysterophorus* L. (shoot, leaf, flower, and root) on seeds of the soybean (*Glycine max* L.) and haricot bean (*Phaseolus vulgaris* L.). Their results showed 100% seed inhibition of both crops with all concentrations of aqueous extracts of flower, 10 and

15% of leaf extract and 15% concentration of shoot extract. They also reported that the roots of the crops to be more sensitive to allelopathic effect than shoots. To avoid weed, poor germination and seedling growth of soybean and haricot beans and to ensure sustainable production of the crops they recommended designing an integrated weed management strategy. Afridi and Khan (2015) conducted the laboratory and pot experiment to investigate the allelopathic aqueous extract of (*Parthenium hysterophorus*, *Datura alba*, *Phragmites australis*, and *Oryza Sativa*) against *Triticum aestivum* and associated weeds (*Avena fatua*, *Rumex crispus*), *Parthenium hysterophorus,* and *D*atura *alba* showed a significant effect on associated weeds of *Triticum aestivum* L. Their study showed the degree of toxicity of different treatment following the order of inhibition *P. hysterophorus* >*D. alba* >*P. australis* >*O. Sativa*. Phytochemical constituents and ethnobotanical uses of invasive weed *Parthenium hysterophorus* L. were reviewed by Khan *et al.* (2015).

The allelopathic effect of fresh *Parthenium hysterophorus*, *Parthenium hysterophorus* compost, and *Parthenium hysterophorus* composted with other plant materials was investigated by Wakjira *et al.* (2009) on the emergence and growth of lettuce plant. Their results clearly showed that composting greatly reduced allelopathic effects of *Parthenium hysterophorus* L. compared to fresh *Parthenium hysterophorus* L. Furthermore, composting *Parthenium hysterophorus* L. with other plants resulted in lower inhibition of emergence radicle and plumule lengths compared to composting *Parthenium hysterophorus* alone. Therefore, they suggested *Parthenium hysterophorus* composting with locally available plant materials as a measure to reduce its allelopathic inhibitory effect. Roy and Shaik (2013) worked on toxicology, phytochemistry, bioactive compounds, and pharmacology of *Parthenium hysterophorus.* They suggested that *P. hysterophorus* is a rich source of terpenoids, volatile oils, sugar, and phenolic derivatives. The effect of compost of *Parthenium hysterophorus* weed on germination and growth of wheat (*Triticum aestivum*) was also studied by Ameta *et al*. (2016). They studied the productivity of wheat under three conditions- (i) with *Parthenium* compost as an external nutrient source, (ii) with an inorganic fertilizer as an external nutrient source, and (iii) without fertilizer and reported that the compost of *Parthenium hysterophorus* weed gave good results in a yield of wheat. Khalid *et al*. (2017) studied the allelopathic effect of root, stem, and leaves of aqueous extract of *Parthenium hysterophorus* on mung beans at laboratory along with control. All treatments (i.e different concentrations of aqueous extract of root, stem, and leaf of *P. hysterophorus*) severely decreased the germination percentage, stem, and root length of mung in comparison to control.

Singh, *et al.* (2008) conducted the work on phytotoxicity of the three major monoterpenes constituents of the essential oil from leaves of *Artemisia scoparia* Waldst. & kit (redstem wormwood). They described that the essential oil and the three monoterpenes exhibited phytotoxicity and reduced seed germination, shoot and root length, chlorophyll content of *Avena sativa* and *Triticum aestivum*. *Artemisia scoparia* oil and β-myrcene can be explored for phytotoxicity against weeds was suggested by them. Gholami *et al*. (2011) reported the allelopathic effect of aqueous extract of aerial parts of *Artemisia kopetdaghensis* and *Satureja hortensison* on the growth of *Portulaca oleraceae* and *Chenopodium album*. Significant inhibitory effect on the growth of the root, stem, leaf, root/shoot, and germination rate and germination percentage of weed seeds were shown by aqueous extract of concentrations of 75% and 100%. They suggested using it as a non-chemical weedicide in organic farming systems. Satyal *et al*. (2012) extracted essential oil from the leaves of *Artemisia dubia, Artemisia indica* and *Artemisia vulgaris* found wild in Nepal. They reported the major constituents of *Artemisia dubia* oil were chrysanthenone (29.0%), caumarine (18.3%), and camphor (16.4%). These essential oils against *Lactuca sativa* (lettuce) and *Lolium perenne* (perennial ryegrass) using both seed germination and seedling growth and all three *Artemisia* oils displayed a remarkable allelopathic activity.

From the above, it is evident that invasive plants like *Ageratina adenophora* (Krishnamurthy *et al*., 2010) and *Parthenium hysterophorous* have been used for preparing the compost (Krishnamurthy *et al*., 2010; Wakjira *et al*., 2009; Ameta *et al*., 2016) and have also been reported to enrich soil nutrients like organic carbon, phosphorus and nitrogen (Krishnamurthy *et al.*, 2010). Both these invasive species also have allelopathic effects (Verma & Rao, 2006; Maharjan *et al*., 2007), but the research on the seed germination of crops, other weeds, and seedling growth with their compost and compost extract have not been investigated so far. Besides that, the aqueous extract of aerial parts of native weed *Artemisia dubia* also have an allelopathic effect on seed germination and seedling growth (Satyal *et al*., 2012), but the studies of its compost on seed germination and seedling growth have also not been conducted so far.

# CHAPTER 3

## MATERIALS AND METHODS

### 3.1 Weed community analysis

#### 3.1.1 Study site

To ascertain common weed in winter crops, the adjoining areas like Kirtipur, Bhaktapur, Godawari, Chapagaon, Dharamsthali, and Shivapurin Kathmandu valley, where winter cultivation is common were selected. Among these study areas Kirtipur, Dharamsthali, and Shivapuri falls in Kathmandu district; Godawari and Chapagaon in Lalitpur district and Bhaktapur in Bhaktapur district. For other objectives like phenology, seed morphology, seed bank estimation, and others, the weed seeds and soil were collected from Kirtipur and Bhaktapur. Sites of Kirtipur (27˚40'43.39" N 85˚16'39.00" E) were Machhegaon, Chobhar, fields near Tribhuvan University, Dhalpa and Chhugaon and that of Bhaktapur (27˚40'22.7" N 85˚25'48.2"E) sites were Manoharakhola (Lokanthali), Gatthaghar, Sano Thimi, Balkot, and Thimi. The cropping pattern in the studied fields is summarized in Table 3.

**Table 3.** Cropping pattern of Kirtipur and Bhaktapur (studied fields)

| Kirtipur | Cropping pattern | Bhaktapur | Cropping pattern |
|---|---|---|---|
| Machhegaon | Wheat-Rice-Tomato | Manoharakhola (Lokanthali) | Wheat, Maize |
| Chobhar | Wheat-Rice | Gatthaghar | Wheat, Legumes |
| Fields near Tribhuvan University | Wheat, Maize | Sano Thimi | Wheat-Mustard |
| Dhalpa | Mustard-Legumes-Tomato | Balkot | Mustard, Rice |
| Chhugaon | Mustard-Legumes | Thimi | Wheat-Rice |


**Figure 1a:** Location of study sites in Kathmandu, Bhaktapur and Lalitpur district

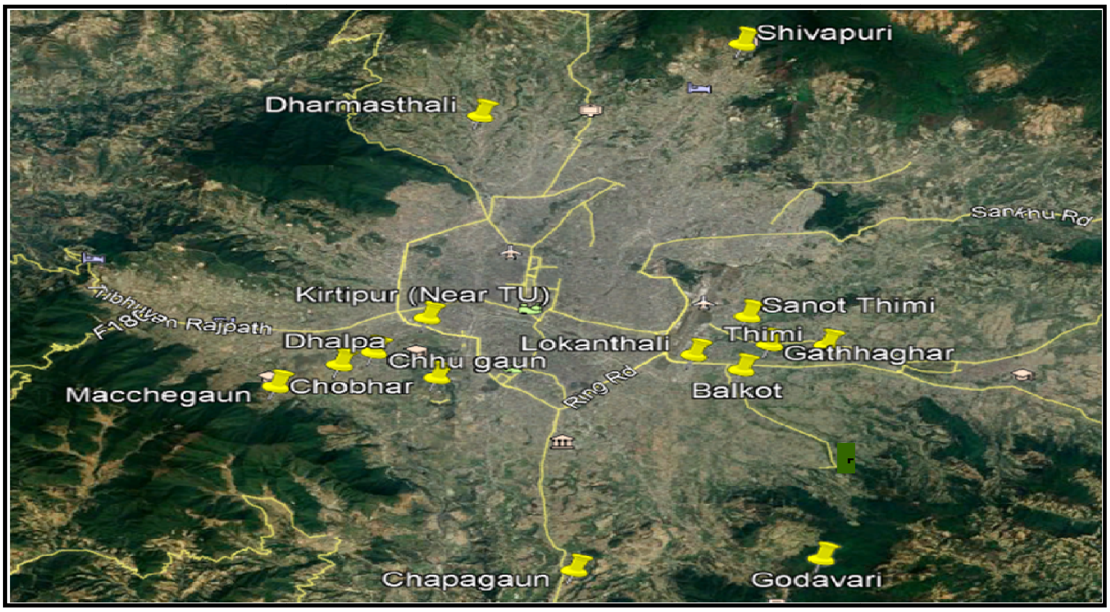
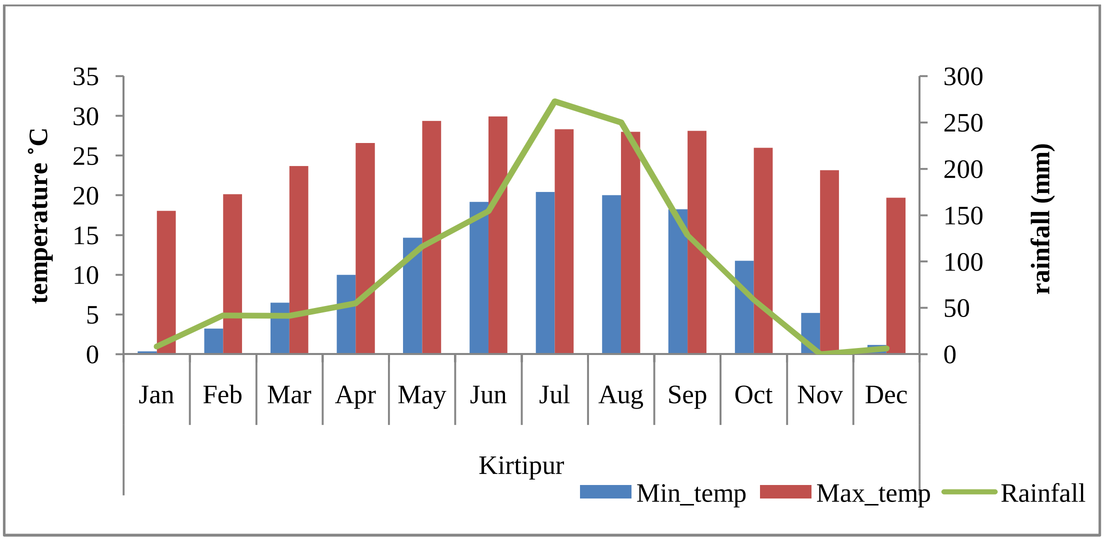


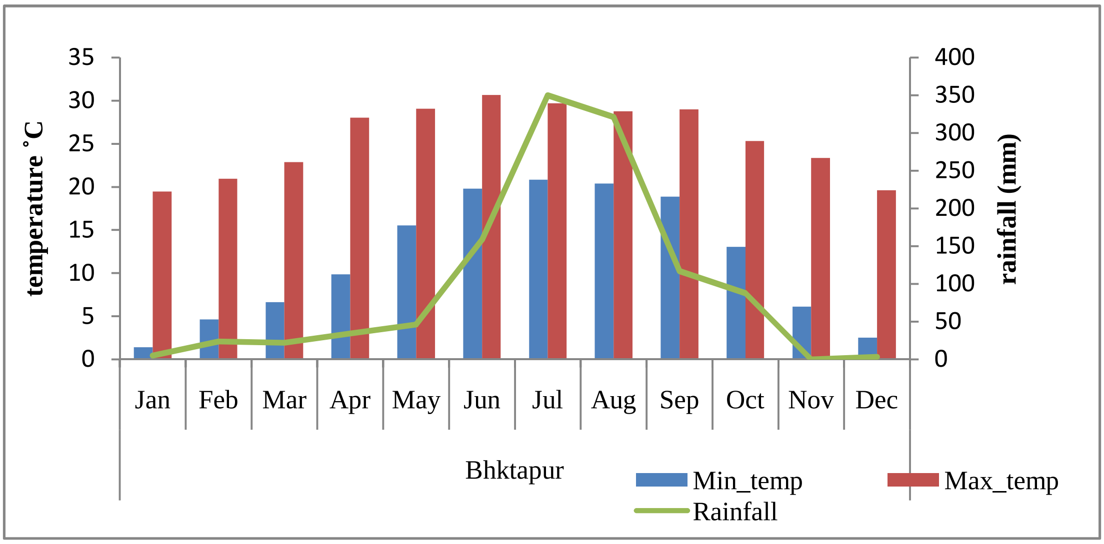

**Figure 1b:** Sample collections sites in google map

### 3.1.2 Climatic data

The climatic data of three years (2012-2015) shows that the rainfall and temperature were maximum in the month of July and minimum in the month of December in both Kirtipur and Bhaktapur (Figures 2a, b). The maximum rainfall in Kirtipur was 272.65 ml and in Bhaktapur, it was 350.0 ml in July. Mean minimum temperature in Kirtipur and Bhaktapur was in January (0.38 and 1.40˚C, respectively) and maximum in July (20.40 and 20.85˚C, respectively). The mean maximum temperature in Kirtipur and Bhaktapur was in June (29.9 and 30.7˚C, respectively) and the mean maximum in Jan (18.1 and 19.5˚C, respectively) (Tables 2a, b).




(a) Kirtipur




(b) Bhaktapur

**Figure 2:** Rainfall, maximum and minimum temperature in between the year 2012-2015 at (a) Kirtipur and (b) Bhaktapur

Source: Department of Hydrology and Meterology, Ministry of Energy, Water Resources and Irrigation, Babarmahal, Kathmandu, Nepal

### 3.1.3 Frequency, density, and abundance of weeds

**Field visit-** A survey was conducted during the winter season (Oct-March) in these three years 2012-2014 (repeated sampling) to study weeds in the fields of wheat and mustard crops at selected sites. These two crops were selected for the present study because they are mostly grown by farmers in the winter season in Kathmandu valley.

**Quadrat method-** To understand the dominant weed, altogether six sites (Kirtipur, Bhaktapur, Godawari, Chapagaon, Dharamsthali, and Shivapuri) was selected. At each site, five areas were selected and two plots were identified at each area. At each plot, 5 quadrats of (1 m × 1 m) were studied, so in total 50 quadrats were laid in each site. Weeds were present in each quadrat and their numbers were recorded. For quantitative analysis of weed, parameters like frequency, density, abundance, and their relative values for IVI were calculated using the following formulae according to Mishra (1968) and Curtis and Mcintosh (1951).

$$\text{Frequency (F)} = \frac{\text{Number of quadrate in which the species occurred}}{\text{Total number of quadrate studied}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of species}}{\text{Total frequency of all the species}} \times 100$$

$$\text{Density (D)} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrate studied}} \times 100$$

$$\text{Relative Density (RD)} = \frac{\text{Density of an individual species}}{\text{Total density of all the species}} \times 100$$

$$\text{Abundance (A)} = \frac{\text{Total number of the individual of the species in all quadrates}}{\text{Number of quadrate in which species occurred}} \times 100$$

$$\text{Relative Abundance (RA)} = \frac{\text{Abundance of an individual species}}{\text{Total aabundance of all species}} \times 100$$

### 3.1.4 Importance value index

The IVI is commonly used in ecology to show the ecological importance of a species in a given ecosystem. According to Curtis and McIntosh (1950) and Tauseef *et al.* (2012), Importance Value Index (IVI) is to assess the overall significance of a species since it takes into account several properties of the species in the vegetation.

Importance Value Index (IVI) = Relative frequency (RF) + Relative density (RD) + Relative abundance (RA) (Mishra, 1968; Rao & Vijayalakshmi, 2017; Bhadra, & Pattnayak, 2016).

Based on the highest IVI value only four common weed species (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cyperus rotundus* L. and *Galinsoga parviflora* Cav.) were selected for another study like phenology, seed estimation, seed characteristics, seed germination and allelopathic effect. For IVI of uncommon weeds, only mean and standard deviation were calculated.

### 3.1.5 Diversity indices

To measure weed species diversity in winter crop fields, two diversity indices were applied namely: A) Simpson's Diversity Index and B) Shannon Wiener index (Hussain *et al.* 2017).

**A) Simpson's diversity index**: Simpson's index (D) was calculated by using the formula:

$$D = \Sigma \text{ pi2}$$

$$D = \sum \frac{n\,(n-1)}{N\,(N-1)}$$

Where, n = the total number of a particular species

N = the total number of all the species

Value of D ranges between 0 and 1, with this index, 0 represents infinite diversity and 1, no diversity (i.e greater the value of D, the lower is the diversity), which is quite unscientific and hence D is often subtracted from 1 to give Simpson's index of diversity (Simpson's Index of Diversity= 1-D).

**B) Shannon Wiener diversity index**

$$H = -\sum[(pi) * 1n(pi)]$$

$$D = \frac{H}{H_{max}}$$

Σ = Summation, $p_i$ = proportion of the individuals of species/total number of samples

H = Number of species, H max = ln (N)

$H_{max}$ = Maximum diversity possible, E = Evenness

### 3.2 Phenology of selected weeds

For phenological study soil from wheat and mustard fields from Kirtipur and Bhaktapur were collected and placed in five plots bordered with bricks, separately in the garden. Different stages of a plant's life cycle like germination, vegetative growth, flowering, fruiting, senescence of fruits, and seed dispersal was noted monthly and phenophases are given in phenograms. The plants were observed from the month of October- March in the year 2014 and 2015. Altogether 40 plants of each common weed (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) were studied. 40 plants of each of the selected weed species were randomly selected and their phenophase was carefully examined (monthly) from the germination stage to the seed dispersal stage of plants using the phenological index technique (Hegazy & Eesa, 1991).

1–Germination, 2–Vegetative, 3–Flowering, 4–Fruiting, 5–Senescence of fruits, 6–Dispersal of seeds

### 3.3 Weed seed characteristics

The matured (Senescence of fruits) weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) were collected from wheat and mustard fields of selected sites at Kirtipur and Bhaktapur. The 50 seeds of each species were observed under a stereomicroscope. The size (length and breadth) of the seeds were measured using ocular divisions (micrometer) after standardization with stage divisions. The color of the weed seeds and their shape was noted.

### 3.4 Soil properties

The soils were collected from the wheat and mustard field of Kirtipur and Bhaktapur in the month of august before the cultivation of winter crops. Soil samples were collected by a composite sampling method from four corners and a center of each 1 m x1 m quadrat, from the 10x10 cm soil surface to 15 cm depth using an auger. The soil samples thus collected were mixed thoroughly, and ultimately half kg of samples was obtained. Altogether 50 soil samples were collected from five fields of each site. The collected soil samples were dried under shade conditions.

**a)** **Soil texture-** The soil samples were collected from study sites of Kirtipur and Bhaktapur wheat and mustard fields and were dried. Soil texture was determined using the sieve of different mesh sizes (size 5, 10, 60, 120, and 230) (Ho *et al.* 2019; Pandey *et al.*, 2019).

**b)** **Soil pH test-** 10 g of soil samples were taken from the selected sites and diluted with 20 ml of distilled water in a 100 ml beaker. The beaker was covered and left for 30 minutes and measured with the pH meter that was standardized using the buffer solution of pH 4 and 7 (Reed, 1987).

**c)** **Soil humus test**- The crucible with lid was weighed. 10 g of soil from selected sites were taken. 10 g of soil was kept in the crucible with a lid and again weighed. It was heated in an oven at 80˚C for 30 minutes and weighed again. 5 ml Hydrogen peroxide was added to the soil and heated again, and the weight was taken. Humus content (%) was calculated according to Zobel *et al*. (1987).

**d)** **Soil NPK test-** NPK of soil was tested at the Department of Forest Research and Survey, Ministry of Forest and soil Science, Nepal. The nitrogen test was done by the Kjeldahl method (1883). Phosphorus test was done by Hanway & Heidel (1952) and potassium by Flame Photometer.

### 3.5 Nutrient analysis of selected crops and weed seeds

Seeds of two crops (mustard and wheat) and weeds (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cyperus rotundus* L., and *Galinsoga parviflora* Cav.) were collected, cleaned, and dried. The nutrients like protein (test method-AOAC 19$^{th}$ Edition, 2012, 950, 920.87), carbohydrate, crude fibre and fat per gram seeds (test method-CFL Manual) were analyzed at the Department of Food Technology and Quality Control, Central Food Laboratory, Babarmahal, Kathmandu**.**

### 3.6 Soil weed seed bank estimation

The seed bank estimation was done by (A) Differential floatation technique (Khatri, 1997) and (B) Germination method (Robert, 1981).

#### 3.6.1 Differential flotation technique

**Standardization**- The weed seeds of *Ageratum conyzoides*, *Bidens pilosa, Galinsoga parviflora* and *Cyperus rotundus* (100 seeds each) were kept separately in 100 g soil of four types i.e sandy soil, sandy loam soil, silt and clay in beaker. Weed seeds and soil were moistened with about 150 ml water and left overnight for 24 hours. After 24 hrs, the soil samples were sieved with full force shower through sieving mesh of 279 micron. Seeds and other debris were kept undisturbed in 80 ml floatation solution

(30% calcium chloride solution) for half an hour. This process separated the organic matter and seeds from mineral soil fraction. The floating materials were carefully removed and collected on a small sieve of 100 micron. Then it was washed thoroughly and the contents were transferred to lined muslin cloth (with 25 lines drawn at the spacing of 1 cm and the lines were numbered from 1 to 25). The content was distributed evenly on the cloth spread over a glass plate with the help of a needle and the seeds were counted under the stereo microscope. There were 5 replications for each soil type. The total number of the seeds in the soil sample was calculated with a correction factor based on the percentage of seed recovered (Lopez-Granados & Garcia-Torres, 2008).

Seed bank estimation of four weeds was carried out in soil samples (5 replications for each soil sample) collected from fields of Kirtipur and Bhaktapur. The number of weed seeds per 100 g soil was calculated.

$$\text{Actual number of weed} = \frac{\text{Number of recovered seeds per 100 g of soil}}{\text{Weed seed standardization index*}} \times 100$$

*Mean value of weed seed recovered in 4 different types of soil

### 3.6.2 Germination method

For seed estimation by germination method, the soil samples (topsoil-about 15 cm) were collected from five different sites of the Kirtipur and Bhaktapur area, separately. The soil bulk density of Kirtipur and Bhaktapur were 1.04 and 1.03 g/cm3. About 500 g soil samples were placed in a polybag (15 cm depth and 7 cm radius) and were kept in the orchid house of Amrit Campus for germination during October-November (maximum temperature 26˚C and minimum 10˚C). There were five replications for each site. From time to time the soil in the polybags was moistened with tap water. Regular observations every 7 days were done and the total number of seedlings emerged of each species selected for the present study was recorded based on morphological characters (Thompson & Grime, 1979).

## 3.7 Seed germination

Two crop seeds (*Brassica campestris* L. var. toria and *Triticum aestivum* L. variety RR 21) were bought from an agro shop in Kathmandu, Nepal. Matured weed seeds of

*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora* were collected from wheat and mustard fields of different areas of Kirtipur and Bhaktapur in the month of March and April 2014.

Weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora* Cav.) and the crop seeds of *Brassica campestris* and *Triticum aestivum* were treated with 2% Sodium hypochlorite for 2 minutes separately for surface sterilization. The seeds were then washed with distilled water thoroughly. The sterilized petridishes were lined with single Whatman No. 1 filter paper and moistened with 5 ml distilled water. The crops (*B. campestris*, *T. aestivum*) and weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus*, and *G. parviflora*) seeds of uniform size were selected and ten seeds of each species were kept in five sterilized petridishes separately. Seed germination percentage, shoot, and root lengths are also noted.

$$\text{Germination percentage (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds used}} \times 100$$

### 3.7.1 Environmental conditions

**a)** **Moisture–** Five replications of petridishes containing 10 sterilized seeds of selected crops and weed seeds were grown in filter paper soaked with 3, 6, 9,12 and 15 ml distilled water for 10 days according to Costa *et al.* (2019).

**b)** **Temperature–** Five replications of petridishes containing 10 sterilized seeds of selected crops and weed seeds were kept in an incubator maintaining different temperature levels (5, 10, 15, 20, 25˚C) separately for 10 days following to Ghaderi (2010).

**c)** **Light–** According to Devkota and Jha (2010), the petridishes containing 10 sterilized seeds of crops and weeds were covered by cellophane papers of different colors like red, yellow, blue, green, and black polyethylene (for dark condition). For control, the petridishes containing crop and weed seeds were grown in filter paper soaked with 5 ml distilled water in normal light. All these experiments were conducted under normal room temperature (20˚C) with five replications.

**d)** **pH–** To study the effect of pH on seed germination of two winter crops (*Brassica campestris* and *Triticum aestivum*) and some weeds (*Ageratum conyzoides, Bidens pilosa, Cyperus rotundus,* and *Galinsoga parviflora*), the solutions with different pH values of 5, 6, 7, 8 and 9 were prepared using 0.1 HCl and 0.1 KOH. 10 seeds of crops and weeds were kept in each petriplate lined with single layer of Whatmen No. 1 paper, moistened with 5 ml of solutions of different pH. The petriplates were kept at room temperature (20˚C) in the month of November.

### 3.7.2 Chemical fertilizer

To study the effect of different concentrations of common chemical fertilizers (urea and potash) on seed germination and seedling growth of crop and weed seeds following experiments were conducted.

**Seed germination**

a) Chemical fertilizer solutions of urea and potash separately

b) Fertilizers urea and potash g/kg amended with soil separately

#### 3.7.2.1 Chemical fertilizer solutions of urea and potash separately

To prepare a 10% aqueous fertilizer solution, 2 g of urea and potash were soaked in 20 ml distilled water for 24 hours, separately. The solution was filtered using Whatman No.1 filter paper and thus 10% stock solution was prepared. From this stock solution, 5, 2.5, and 1.0% concentration was prepared by diluting it with distilled water. Ten seeds of each species were kept in sterilized petridishes in different concentrations of urea and potash solution (control, 1, 2.5, 5, and 10%) for 10 days. For control, seeds were grown in filter paper soaked with distilled water. All these experiments were conducted under normal room temperature with five replications.

#### 3.7.2.2 Fertilizers urea and potash g/kg amended with soil separately

The seed germination experiment was also conducted in a poly bag (35.56 cm × 17.78 cm) by using different concentrations (10, 20, 40, and 50 g/kg soil) of chemicals urea and potash in the month of November 2015. There were five replications of each treatment (10 selected seeds of weed and crops were sown). After 30 days seed germination and seedling growth were recorded.

## 3.8 Allelopathic effect on seed germination

### Collection of two invasive plants and one native plant

The two invasive plants *Parthenium hysterophorus*, *Ageratina adenophora* and one native plant *Artemisia dubia* were collected from different places of Kirtipur and Bhaktapur.

### Seed germination experiment

The dominant weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus,* and *Galinsoga parviflora*) and the crop seeds of *Brassica campestris* and *Triticum aestivum* were soaked in 2% Sodium hypochlorite for 2 minutes separately. The seeds were then washed with distilled water thoroughly. The sterilized petridishes were lined with single Whatman No. 1 filter paper.

### 3.8.1 Weed aqueous extract

For the preparation of the aqueous extracts of the stem, root, and leaf of selected two invasive and one native plant were collected, air-dried, and then a leaf, stem, and roots were separated. To prepare the aqueous extract, 2 g of ground air-dried leaves, stem, and root were soaked in 20 ml distilled water for 24 hrs. separately (Hassan *et al.*, 2013). The extracts were filtered using Whatman No.1 filter paper and thus 10% stock solution was prepared. From this stock solution, 5%, 2.5%, and 1.0% concentration was prepared by diluting with distilled water. The sterilized crop seeds and weed seeds are kept in sterilized petridishes for 10 days. For control, seeds were grown in filter paper soaked with 5 ml. distilled water. All these experiments were conducted under normal room temperature with five replications (10, 5, 2.5, and 1.0% concentration). The moisture level in the petridish was maintained by adding distilled water as required.

### 3.8.2 Weed compost extract and compost

**Preparation of compost extract and compost** - A pit of 3x3x3 feet was prepared at a shady place and was filled with 4 layers of *Parthenium hysterophorus, Ageratina adenophora,* and *Artemisia dubia* plant parts and 3 layers of soil alternately altering with soil separately. Each layer of plant parts was about 5-7” thick and that of excavated soil about 2”. It was left for seven months (from March to September) and decomposed compost was ready. From this compost, the experiment on compost extract at the laboratory was conducted.

To prepare compost extract, at first compost was air-dried and then 2 g of compost was soaked in 20 ml distilled water for 24 hours. The compost extract was filtered using Whatman No.1 filter paper and thus 10% stock solution was prepared. From this stock solution, 5, 2.5and 1.0% concentration was prepared. The crops (*Brassica campestris*, *Triticum aestivum*) and weeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) seeds of uniform size were selected and ten seeds of each species were kept in sterilized petridishes containing 5 ml of (distilled water) control, 1, 2.5, 5 and 10% concentrations of compost extracts for 10 days.

The seed germination experiment was also conducted in a poly bag (35.56 × 17.78 cm) by using different concentrations of *Parthenium hysterophorus*, *Ageratina adenophora*, and *Artemisia dubia* (10, 20, 40, and 50 g/kg soil) in the month of November 2015. There were five replications for each treatment (10 selected seeds of weed and crops were sown). After 30 days seed germination and seedling growth were recorded. The soil without compost was taken as control (Kishor *et al.*, 2010).

### 3.9 Data analysis

The data for IVI at each site for each weed species; weed seed estimation in soil from the flotation and germination technique; seed germination of crops and weeds under different environmental conditions and chemical fertilizers; seed germination and seedling growth of crops and weeds from the allelopathic effects experiments using aqueous extract, compost extract, and compost; were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple RangeTest (DMRT) at P=0.05 level of significance.

The data of weed seed estimation (Floatation and germination method), seed germination in chemical and environmental conditions, and allelopathic effect of invasive plants and one native weed were also analyzed by statistically using SPSS statistics version 20. The data obtained were analyzed by Analysis of Variance (ANOVA) followed by Duncan's Multiple RangeTest (DMRT) at the P=0.05 level of significance.

# CHAPTER 4

## 4. RESULTS AND DISCUSSION

## 4.1 Results

### 4.1.1 Weed community analysis

#### 4.1.1.1 Frequency, density, and abundance of weeds

In the present study, frequency (%), density (number/m2), and abundance of the most common weeds in winter crop fields were recorded on all the study sites (Tables 4a, b). Some of the weeds which were not common in all sites were grouped as 'others'. The highest frequency of *Ageratum conyzoides* L. was observed at Kirtipur and Dharmasthali, whereas the highest frequency of *Oxalis corniculata* L., *Cyperus rotundus*, and *Ageratum houstonianum* Mill. was observed at Bhaktapur, Godawari, Chapagoan, and Shivapuri, respectively. The highest density and abundance of *Ageratum conyzoides* was observed at Chapagoan, Dharmasthali, Shivapuri, and Godawari; and that of *Bidens pilosa* L. at Bhaktapur. Kirtipur showed the highest density and abundance of *Galinsoga parviflora.*

**Table 4a:** Frequency (%), density (number/$m^2$) and abundance of weeds found in winter crop fields (wheat and mustard)

| | | Kirtipur | | | Bhaktapur | | | Godawari | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SN** | **Species** | **Freq.** | **Den** | **Abun** | **Freq.** | **Den** | **Abun.** | **Freq.** | **Den.** | **Abun.** |
| 1 | *Ageratum conyzoides* L. | 96±8.9 | 9.3±0.8 | 9.7±0.6 | 90±10 | 6.4±1.8 | 7.1±2.2 | 90±10 | 12.0±0.9 | 13.0±2.5 |
| 2 | *Ageratum houstonianum* Mill. | 64±11.4 | 1.7±1.3 | 2.7±2.2 | 70±15.8 | 1.7±0.7 | 2.4±0.8 | 82 ±11 | 7.1±0.9 | 8.3±1.4 |
| 3 | *Amaranthus spinosus L.* | 62±16.4 | 1.0±0.5 | 1.7±0.3 | 68±13.0 | 1.5±0.6 | 2.1±0.5 | 68 ±11.0 | 1.9±0.6 | 2.7±0.3 |
| 4 | *Bidens pilosa* (L.) | 72±21.7 | 6.5±1.1 | 9.4±1.6 | 76±15.2 | 7.1±2.2 | 9.9±4.2 | 78±13 | 9.0±2.0 | 10.9±0.9 |
| 5 | *Capsella bursapastoris* (L.) Medik. | 80±10 | 2.2±0.7 | 2.8±0.7 | 76 ±8.9 | 3.9 ±0.9 | 5.1±1.0 | 72 ±4.5 | 19±0.2 | 2.5±0.3 |
| 6 | *Centella asiatica* (L.) Urban | 56±18.2 | 2.8±1.7 | 4.9±1.9 | 50±12.2 | 0.7 ±0.2 | 1.5±0.3 | 70 ±7.1 | 2.4±0.6 | 3.3±0.6 |
| 7 | *Chenopodium album* (L.) | 70±17.3 | 1.2±0.2 | 1.8±0.4 | 78 ±8.4 | 1.9 ±0.4 | 2.4±0.3 | 68 ±14.8 | 2.0±0.8 | 2.8±0.3 |
| 8 | *Cynodon dactylon* (L.) | 52±14.8 | 0.7±0.2 | 1.4±0.1 | 92 ±8.4 | 4.1 ±0.9 | 4.6±1.3 | 84 ±23.0 | 4.3±2.1 | 4.6±1.8 |
| 9 | *Cyperusrotundus* (L.) Bayer | 76±8.9 | 7.7±1.3 | 10.4±2.7 | 90 ±7.1 | 5.8 ±0.9 | 6.6±1.5 | 92 ±4.5 | 9.7±1.9 | 10.1±2.3 |
| 10 | *Drymaria cordata* (L.) Whitesnow | 46±11.4 | 0.9±0.2 | 2.1±0.6 | 82±11.0 | 4.9± 2.1 | 6.0±2.6 | 74 ±11.4 | 5.0±1.8 | 6.3±2.2 |
| 11 | *Eclipt alba* L. ex B.D. Jacks | 74±20.7 | 3.8±1.7 | 5.7±3.3 | 80±10.0 | 2.1± 0.4 | 2.7±0.4 | 76 ±8.9 | 1.6±0.2 | 2.1±0.3 |
| 12 | *Galinsoga parviflora* Cav. | 90±10 | 14.2±1.6 | 16±2.4 | 86±21.9 | 6.2± 1.4 | 7.8±3.0 | 86 ±8.9 | 13.7±2.3 | 15.3±2.2 |
| 13 | *Gnaphalium affine* D. Don | 82±14.8 | 3.9±2.2 | 4.8±2.4 | 86±16.7 | 1.8 ±0.3 | 2.2±0.3 | 70 ±17.3 | 2.7±2.1 | 4.2±3.8 |
| 14 | *Oxalis corniculata* L. | 68±8.4 | 3.3±2.1 | 5.1±3.3 | 96 ±5.5 | 4.6 ±0.5 | 4.8±0.5 | 88 ±13.0 | 6.6±2.9 | 6.9±2.7 |
| 15 | *Rannunculus repens* L. | 70±14.1 | 1.1±0.4 | 1.6±0.2 | 74 ±5.5 | 2.3 ±0.9 | 3.1±1.3 | 64 ±13.4 | 2.3±2.4 | 3.4±3.4 |
| 16 | *Sonchus arvensis* (L.) | 72±17.9 | 3.3±1.4 | 5.1±2.7 | 64 ±8.9 | 1.7± 1.0 | 2.6±1.3 | 74 ±15.2 | 2.8±1.7 | 3.6±1.4 |
| 17 | *Stellaria media* (L.) Vill. | 74±18.2 | 3.4±2.4 | 4.4±2.5 | 86 ±5.5 | 3.9± 0.5 | 4.6±0.8 | 70 ±18.7 | 3.6±4.1 | 4.4±3.7 |
| 18 | Others | 82±13.0 | 2.0±0.9 | 2.4±0.8 | 72± 8.4 | 1.9± 0.4 | 2.6±0.9 | 94 ±13.4 | 6.0±2.4 | 5.9±1.9 |

**Table 4b:** Frequency (%), density (number/m$^2$) and abundance of weeds found in winter crop fields (wheat and mustard)

| | | Chapagaon | | | Dharamsthali | | | Shivapuri | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SN** | **Species** | **Freq.** | **Den.** | **Abun.** | **Freq.** | **Den.** | **Abun.** | **Freq.** | **Densi** | **Abun.** |
| 1 | *Ageratum conyzoides* L. | 92±8.4 | 9.0±1.1 | 9.9±1.8 | 82 ±8.4 | 10.3±0.5 | 12.7±1.3 | 84±5.5 | 9.3±1.4 | 12.7±1.3 |
| 2 | *Ageratum houstonianum* Mill. | 84 ±15.2 | 3.9±1.8 | 4.5±1.9 | 78 ±8.4 | 5.3±0.9 | 6.9±1.5 | 90±17.3 | 4.1±0.0 | 6.9±1.5 |
| 3 | *Amaranthus spinosus* L. | 64 ±15.2 | 1.4±1.2 | 2.2±1.5 | 64 ±13.4 | 1.8±0.9 | 2.9±1.8 | 66±19.5 | 1.2±0.5 | 2.9±1.8 |
| 4 | *Bidens pilosa* L. | 86 ±15.2 | 6.3±1.0 | 7.6±2.3 | 74 ±5.5 | 8.6±0.7 | 11.7±1.4 | 78±11 | 7.7±1.2 | 11.7±1.4 |
| 5 | *Capsella bursapastoris* L. Medik. | 72 ±11.0 | 4.7±0.9 | 6.5±0.8 | 58 ±16.4 | 1.0±0.3 | 1.7±0.3 | 70±20 | 1.1±0.3 | 1.7±0.3 |
| 6 | *Centella asiatica* L. Urban | 66 ±8.9 | 1.9±0.3 | 2.9±0.1 | 66 ±15.2 | 2.8±1.9 | 4.1±2.5 | 78±13 | 2.0±0.4 | 4.1±2.5 |
| 7 | *Chenopodium album* L. | 78 ±8.4 | 2.1±0.4 | 2.7±0.4 | 78 ±16.4 | 2.1±0.7 | 2.7±0.6 | 80±28.3 | 2.2±0.5 | 2.7±0.6 |
| 8 | *Cynodon dactylon* L. | 90 ±14.1 | 4.7±0.8 | 5.2±0.5 | 80 ±12.2 | 3.1±1.2 | 3.9±1.7 | 80±17.3 | 3.7±0.7 | 3.9±1.7 |
| 9 | *Cyperus rotundus* L. Bayer | 94 ±8.9 | 7.8±0.7 | 8.4±1.0 | 78 ±4.5 | 7.0±0.9 | 9.1±1.6 | 88±4.5 | 6.3±1.4 | 9.1±1.6 |
| 10 | *Drymaria cordata* L. Whitesnow | 82 ±8.4 | 2.0±0.3 | 2.4±0.2 | 76 ±8.9 | 5.2±2.1 | 6.7±2.1 | 76±13.4 | 3.5±0.9 | 6.7±2.1 |
| 11 | *Eclipta alba* L. ex B.D.Jacks | 74 ±16.7 | 1.4±0.3 | 1.9±0.2 | 68 ±19.2 | 2.3±0.8 | 3.5±0.9 | 80±18.7 | 2.0±0.9 | 3.5±0.9 |
| 12 | *Galinsoga parviflora* Cav. | 82 ±8.4 | 9.5±0.6 | 11.7±1.0 | 80 ±12.2 | 8.7±0.6 | 11.0±1.4 | 78±8.4 | 8.5±0.5 | 11.0±1.4 |
| 13 | *Gnaphalium affine* D.Don | 80 ±10.0 | 3.6±0.9 | 4.7±1.6 | 60 ±7.1 | 2.5±1.3 | 4.3±2.2 | 64±11.4 | 1.8±0.2 | 4.3±2.2 |
| 14 | *Oxalis corniculata* L. | 82 ±13.0 | 4.1±0.8 | 5.2±1.6 | 68 ±4.5 | 4.9±2.2 | 7.1±3.0 | 68±4.5 | 4.0±0.3 | 7.1±3.0 |
| 15 | *Rannunculus repens* L. | 74 ±8.9 | 1.6±0.4 | 2.2±0.6 | 76 ±5.5 | 1.9±0.9 | 2.4±1.2 | 88±16.4 | 2.1±0.5 | 2.4±1.2 |
| 16 | *Sonchus arvensis* L. | 70 ±18.7 | 2.6±2.4 | 3.3±2.1 | 78 ±8.4 | 2.9±1.6 | 3.8±2.1 | 80±14.1 | 1.9±0.4 | 3.8±2.1 |
| 17 | *Stellaria media* L. Vill. | 66 ±8.9 | 2.4±1.5 | 3.6±2.1 | 78 ±4.5 | 5.6±1.8 | 7.2±2.3 | 82±11 | 2.5±0.6 | 7.2±2.3 |
| 18 | Others | 86 ±5.5 | 2.4±1.1 | 2.8±1.1 | 94 ±5.5 | 3.7±0.6 | 4.0±0.7 | 96±5.5 | 3.5±0.3 | 4.0±0.7 |

#### 4.1.1.2 Importance Value Index (IVI)

The importance value index (IVI) of each species is given in Table 5. *Galinsoga parviflora* Cav. and *Ageratum conyzoides* L. were significantly dominant (P=0.05) in the fields of winter crops, with the highest IVI value at Kirtipur, Bhaktapur, Godawari, Chapagoan, Dharmasthali, and Shivapuri areas. Similarly, high IVI values were also recorded for *Bidens pilosa* L. and *Cyperus rotundus* L. on all these sites. Species like *Amaranthus spinosus* L. and *Chenopodium album* L. were recorded mostly with less IVI on the study sites (Table 5a).

IVI of *Ageratum conyzoides* L. was significantly lower in Bhaktapur than on other study sites. Similarly, IVI of *Galinsoga* parviflora Cav. was significantly low at Bhaktapur and Dharmasthali. The lowest IVI of *Bidens pilosa* L. was observed in Chapagoan and that of *Cyperus rotundus* L. in Shivapuri (Table 5a).

The uncommon weed species in agricultural fields like *Cannabis sativa* L., *Rumex nepalensis* Spreng., *Euphorbia hirta* Linn., *Anagallis arvensis*, *Phalaris minor, Artemesia dubia* Wall Ex. Besser, *Ageratina adenophora* (Spreng) King, and Rob., *Parthenium hysterophorus* L. were recorded in Kirtipur. Similarly, in the Bhaktapur area, the other uncommon species recorded were *Polygonum plebeium* R. Br., *Echinochloa colona* L. Honda, *Malva parviflora* L., *Trifolium repens* L. *and*, *Ageratina adenophora* (Spreng) King and Rob. The other uncommon weed species present on Godawari were *Galinsoga ciliata* (Raf.) Blake., *Polygonum hydropiperoides* Michx., *Cannabis sativa* L., *Trifolium repens* L., *Amaranthus virdis* L. and *Euphorbia hirta* Linn. The other uncommon species recorded in winter crop fields at Chapagoan included *Angallis arvensis* L., *Polygonum plebeium* R. Br., *Spergula arvensis*, and *Commelina benghalensis*. At Dharamsthali, *Fumaria indica*, *Poa annua*, and at Shivapuri *Amaranthus virdis*, *Poa annua*, and *Galinsoga ciliata* were recorded uncommon species (Table 5b).

**Table 5a:** IVI of common weeds on the winter crop fields (*Brassica campestris* and *Triticum aestivum*) at different sites of Kathmandu valley

| SN | Species | Kirtipur | Bhaktapur | Godawari | Chapagaon | Dharamsthali | Shivapuri |
|---|---|---|---|---|---|---|---|
| 1 | *Ageratum conyzoides* L. | 31.71±2.47 G b | 25.89±4.11 EF a | 30.83±1.5 I b | 30.42±2.17 DE b | 31.78±4.19 I b | 30.10±6.45 F a |
| 2 | *Ageratum houstonianum* Mill. | 10.54±3.43 ABC a | 10.84±2.39 B a | 20.86±1.33 FG c | 16.44±4.83 B b | 19.19±0.92 F bc | 16.82±1.6 D b |
| 3 | *Amaranthus spinosus* L. | 8.20 ±1.98 AB a | 12.34±3.86 B b | 9.36±1.43 A ab | 9.13±3.33 A a | 9.55±1.49 AB ab | 7.92±1.66 A a |
| 4 | *Bidens pilosa* (L.) | 25.79±1.92 F ab | 29.37±5.19 F b | 29.94±2.63 GH ab | 23.66±3.35 C a | 27.90±3.35 H ab | 27.23±5.94 F ab |
| 5 | *Capsella bursapastoris* (L.) Medik. | 12.60±2.05 BCD b | 18.43±2.30 C c | 9.35±0.41 A a | 18.96±2.03 B c | 7.31± 1.40 A a | 8.17±1.66 A a |
| 6 | *Centella asiatica* (L.) Urban | 13.61±4.21 CDF b | 6.69±1.32 A a | 10.66±1.21 AB b | 10.60±0.81 A b | 11.94±3.35 AB b | 10.89±0.90 A b |
| 7 | *Chenopodium album* (L.) | 9.13±1.39 AB a | 11.72±1.18 B c | 9.51±1.91 A ab | 11.45±0.98 A bc | 11.10±1.60 A abc | 11.08±2.07 A abc |
| 8 | *Cynodon dactylon* (L.) | 6.54±1.05 A a | 19.41±3.32 C d | 14.73±4.67 BCD b | 18.75±1.63 B cd | 13.37±2.08 CD b | 15.53±2.32 CD bc |
| 9 | *Cyperu srotundus* (L.) Bayer | 28.40±3.81 FG b | 24.49±2.35 D ab | 25.86±2.33 H ab | 27.14±1.82 D ab | 23.49±2.28 G ab | 23.24±5.52 E a |
| 10 | *Drymaria cordata* (L.) Whitesnow | 7.36±0.77 A a | 21.27±5.06 CD d | 16.15±3.31 CDE c | 11.26±1.15 A b | 18.31±2.34 EF cd | 15.17±2.77 BCD c |
| 11 | *Eclipta alba* L.ex B.D. Jacks | 17.58±4.36 E c | 12.79±1.53 B b | 9.05±10.87 A a | 9.25±1.18 A a | 11.71±2.58 AB ab | 10.60±3.38 A ab |
| 12 | *Galinsoga parviflora* Cav. | 45.01±3.80 H d | 26.29±3.39 EF a | 34.44±2.77 I c | 32.44±1.88 E bc | 27.95±2.84 H a | 28.74±5.11 F ab |
| 13 | *Gnaphalium affine* D. Don | 17.15±5.07 E b | 11.98±1.24 B a | 11.65±4.76 ABC a | 16.07±2.07 B b | 11.58±2.58 AB a | 9.91±1.09 A a |
| 14 | *Oxalis corniculata* L. | 15.64±5.55 DE a | 20.67±1.78 C b | 19.53±5.36 EF ab | 17.30±1.68 B ab | 17.55±2.88 EF ab | 16.51±2.05 D ab |
| 15 | *Rannunculus repens* L. | 8.88±1.59 AB a | 13.48±2.90 B b | 11.55±3.87 ABC ab | 9.87±1.12 A a | 10.16±1.41 ABC a | 11.22±1.93 AB ab |
| 16 | *Sonchus arvensis* (L.) | 15.85±3.38 DE b | 10.61±3.03 B ab | 10.12±5.44 AB a | 12.50±6.78 A ab | 12.79±2.21 ABC ab | 10.57±1.72 A ab |
| 17 | *Stellaria media* (L.) Vill. | 15.58±6.41 DE abc | 18.67±1.73 C bc | 12.92±8.08 ABC ab | 12.04±3.98 A a | 19.82±4.20 F c | 11.93±1.22 ABC a |

Value (mean ±SD) bearing the same small letter (IVI of individual species in selected sites) in the same rows and capital letter (IVI of all species in selected sites) in same column after mean±SD do not differ significantly according to ANOVA followed by the Duncan's Multiple Range Test at P=0.05

**Table 5b:** IVI of uncommon weeds on the winter crop fields (*Brassica campestris* and *Triticum aestivum*) at different sites of Kathmandu valley

| Species | Kirtipur | Bhaktapur | Godawari | Chapagaon | Dharamsthali | Shivapuri |
|---|---|---|---|---|---|---|
| *Cannabis sativa* | 7.91±2.65 | - | 10.31±3.48 | - | - | - |
| *Rumex nepalensis* | 7.08±2.36 | - | - | - | - | - |
| *Euphorbia hirta* | 7.95±2.68 | - | - | - | - | - |
| *Angallis arvensis* | 7.39±2.47 | - | - | 16.77±5.60 | - | - |
| *Phalaris minor* | 7.71±2.57 | - | - | - | - | - |
| *Artemisia dubia* | 6.78±2.26 | - | - | - | - | - |
| *Ageratina adenophora* | 8.68±2.93 | 10.81±3.60 | - | - | - | - |
| *Parthenium hysterophorus* | 8.65±2.89 | - | - | - | - | - |
| *Polygonum plebium* | - | 12.52±4.48 | - | 10.27±3.43 | - | - |
| *Echinochloa crus-galli* | - | 10.39±3.52 | - | - | - | - |
| *Malva parviflora* | - | 12.02±4.01 | - | - | - | - |
| *Trifolium repens* | - | 13.83±4.66 | 10.31±3.48 | - | - | - |
| *Galinsoga ciliata* | - | 10.81±3.60 | 10.22±3.44 | - | - | 11.68±3.94 |
| *Polygonum hydropiperoides* | - | - | 9.06±3.06 | - | - | - |
| *Amaranthus virdis* | - | - | 9.79±3.26 | - | 15.24±5.11 | - |
| *Spergula arvensis* | - | - | - | 13.05±4.46 | - | - |
| *Commelina benghalensis* | - | - | - | 15.79±5.26 | - | - |
| *Fumaria indica* | - | - | - | - | 14.61±4.91 | |
| *Poa annua* | - | - | - | - | 19.28±6.66 | 15.41±5.19 |

IVI of uncommom species (Mean ±SD)

From the above ecological study, the four most common weed species having high IVI values were selected for further study; Relative Frequency, Relative Density, and Relative Abundance of those species are given below (Figure 3).

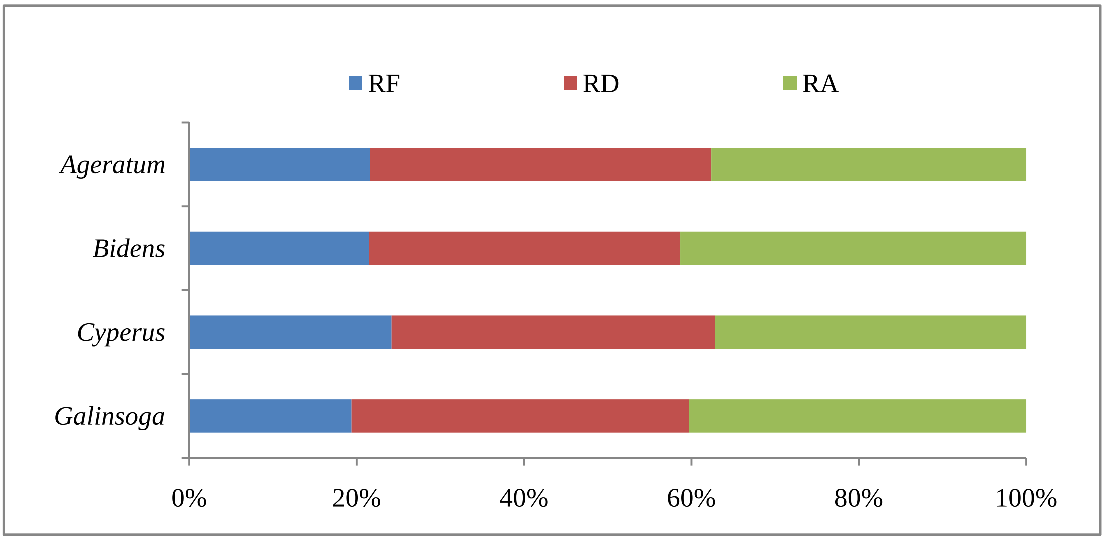



**Figure 3:** The relative frequency (RF-mean %), relative density (RD-mean %) and relative abundance (RA-mean %) of four common weeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora*)

#### 4.1.1.3 Diversity indices

Altogether 36 weeds were recorded from the winter crop fields of 6 sites of Kathmandu valley. The number of weed species was 25 in Kirtipur, 22 in Bhaktapur, 23 in Godawari, 21 in Chapagoan, 20 in Shivapuri, and 19 in Dharmasthali. Among these, the richness of weedy species was the highest in Kirtipur. Among the weeds recorded, nine species were from the family Asteraceae, followed by 6 species of Poaceae, 4 of Caryophyllaceae, 3 of Polygonaceae, 2 of Amaranthaceae, and 1 each of Malvaceae, Fabaceae, Euphorbiaceae, Cannabinaceae, Umbelliferae, Commelinaceae, Primulaceae, Ranunculaceae, Chenopodiaceae, Oxalidaceae, Cyperaceae, and Brassicaceae. Simpson's reciprocal index was the highest in Bhaktapur and the lowest in Kirtipur. Similarly, the Shannon wiener index (H) was the highest at Shivpuri with evenness 0.916 and the lowest at Kirtipur with evenness 0.814 (Table 6).

**Table 6:** Simpson's index of diversity and Shannon Wiener diversity index (H) and eveness of weed species recorded in winter crop fields

| SN | Places | Simpson's index of diversity (1-D) | H | Eveness |
|---|---|---|---|---|
| 1 | Kirtipur | 0.914 | 2.623 | 0.814 |
| 2 | Bhaktapur | 0.943 | 2.784 | 0.900 |
| 3 | Godawari | 0.932 | 2.775 | 0.885 |
| 4 | Chapagaon | 0.935 | 2.738 | 0.899 |
| 5 | Dharamsthali | 0.938 | 2.767 | 0.882 |
| 6 | Shivapuri | 0.935 | 2.745 | 0.916 |

### 4.1.2 Phenology of selected weeds

All the weeds, namely *Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora,* emerged in the first week of October, while the vegetative growth and flowering occurred in all the species around the end of November (Table 7). Among these four weeds, flowering and fruiting of *Ageratum conyzoides* and *Bidens pilosa* occurred during the last week of November and continued during December and January. Senescence of fruits was observed in all studied, except *Cyperus rotundus*, toward the last week of January. Fruiting of *Cyperus rotundus* was observed towards the mid of February. Senescence of fruits and dispersal of seeds were observed during February and March. In *Galinsoga parviflora* fruiting was also observed during February and March.

**Table 7.** Phenograms of selected weeds (*Ageratum conyzoides* L., *Bidens pilosa* L., *Cyperus rotundus* L. and *Galinsoga parviflora* Cav.) from October to March

| SN | Species | October | November | December | January | February | March |
|---|---|---|---|---|---|---|---|
| 1 | *Ageratum conyzoides* L. | 1, 2 | 1, 2, 3, 4 | 3, 4, 5 | 3, 4, 5 | 3, 4, 5 | 4, 5, 6 |
| 2 | *Bidens pilosa* L. | 1, 2, 3 | 1, 2, 3, 4 | 1, 2, 3, 4 | 3, 4, 5 | 3, 4, 5 | 4, 5, 6 |
| 3 | *Cyperus rotundus* L. | 1 | 1, 2 | 2, 3, 4 | 3, 4 | 3, 4, 5 | 5, 6 |
| 4 | *Galinsoga parviflora* Cav. | 1 | 1, 2, 3 | 2, 3, 4 | 3, 4, 5 | 4, 5 | 4, 5, 6 |

1–Germination, 2–Vegetative, 3–Flowering, 4–Fruiting, 5–senescence of Fruits, 6–Dispersal of seeds

In the present study, the biological processes like vegetative growth, and flowering were seen simultaneously very early in October in *Ageratum conyzoides and Bidens pilosa* and their fruiting continued till February. In these two weed plants, the fruiting and senescence period is also quite long extending from January to March. In *Galinsoga parviflora* the fruit was initiated late in December and lasted till March. The long duration of fruiting in these three weeds might have contributed to more number of their seeds in the seed bank. In *Cyperus rotundus* the fruiting stage continues only for three months.

### 4.1.3 Weed seed characteristics

Seed morphology varied among the weeds studied. Seeds of *Ageratum conyzoides* were dark black, non-endospermic, and with scaly pappus and bracts at the base. Achenes of *Ageratum conyzoides* were pointed at the base. Seeds of *Bidens pilosa* were longer than of *Ageratum conyzoides*, black in color, flattened and lined with a row of two pointed scales. Seeds of *Galinsoga parviflora* were black in color with many short white bristles bearing pappus. Seeds of *Cyperus rotundus* were slightly elongated, oval, and with brownish-black seed coats (Figure 4). Among the four weeds, the length and breadth of *Bidens pilosa* were found larger than the other selected weed seeds.


***A. conyzoides***
L – 15.46±0.58 mm, B – 3.91±0.33 mm


***B. pilosa***
L – 17.65±0.70 mm, B – 6.16 ±0.39 mm


***C. rotundus***
L – 13.33±0.67 mm, B – 4.76±0.38 mm


***G. parviflora***
L – 13.53 ±0.39 mm, B – 3.61±0.32 mm

**Figure 4:** Size of common weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora*)

L – Length of weeds seeds, B – Breadth of weed seeds, mm – milimeter

### 4.1.4 Soil properties

The Kirtipur and Bhaktapur's soil samples exhibited sandy loam and loam types, respectively (Table 8). The pH value of the selected areas of both these regions was recorded to be 6.10-6.44 (pH<7). The humus content near Tribhuvan University was more than at other selected sites of Kirtipur and Bhaktapur regions. The nitrogen content of the soil was more in the Kirtipur region than in the Bhaktapur region. The range of phosphorus was very low in Kirtipur's sites as compared to the Bhaktapur's sites. The range of potassium was in the medium range (Table 8).

**Table 8:** Soil properties of (*Brassica campestris* and *Triticum aestivum*) field's of Kirtipur and Bhaktapur

| Site | SN | Site | Humus (%) | pH | N (%) | P (%) | K (%) | Types of soil |
|---|---|---|---|---|---|---|---|---|
| Kirtipur | 1 | Machhegaon | 0.70 | 6.13 | 0.15 | 0.003 | 0.02 | Sandy loam, Acidic |
| | 2 | Dhalpa | 0.84 | 6.24 | 0.15 | 0.004 | 0.03 | Loamy, Acidic |
| | 3 | Chobhar | 0.90 | 6.18 | 0.12 | 0.003 | 0.02 | Loamy, Acidic |
| | 4 | Near TU | 1.04 | 6.10 | 0.14 | 0.002 | 0.01 | Sandy loam, Acidic |
| | 5 | Chhugaon | 0.95 | 6.44 | 0.14 | 0.002 | 0.01 | Loamy, Acidic |
| Bhaktapur | 1 | Lokanthali | 0.90 | 6.41 | 0.11 | 0.006 | 0.03 | Loamy, Acidic |
| | 2 | Gatthaghar | 0.86 | 6.16 | 0.11 | 0.005 | 0.03 | Sandy loam, Acidic |
| | 3 | Sano thimi | 0.94 | 6.42 | 0.09 | 0.005 | 0.02 | Loamy, Acidic |
| | 4 | Balkot | 0.96 | 6.20 | 0.04 | 0.007 | 0.02 | Loamy, Acidic |
| | 5 | Thimi | 0.80 | 6.18 | 0.05 | 0.006 | 0.02 | Sandy loam, Acidic |

### 4.1.5 Nutrient analysis of selected crops and weed seeds

The crop *Triticum aestivum* L. showed higher contents of moisture, crude fiber, and carbohydrate than *Brassica campestris* (Table 9) and also the weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*). Fat content was more in *Brassica campestris* (39.7%) than in *Triticum aestivum* (3.0%) and weed seeds. The crude fiber was the highest in *Triticum aestivum* L. and the lowest in *Brassica campestris* L. Among the weeds, protein content ranged from 9.6 to 18.2 %, fat from 0.9 to 8.2% and carbohydrate from 21.3 to 51.6% (Table 9).

**Table 9:** Nutrient analysis of per gram seeds of two winter crops and four common weeds

| Test Parameter (%) | *Triticum* (bran) | *Brassica campstris* | *Bidens pilosa* | *Ageratum conyzoides* | *Galinsoga parviflora* | *Cyperus rotundus* |
|---|---|---|---|---|---|---|
| Moisture | 11.9 | 8.5 | 7.4 | 8.5 | 9.2 | 11.2 |
| Protein | 14.6 | 20 | 18.2 | 18.1 | 17.0 | 9.6 |
| Fat | 3.0 | 39.7 | 8.2 | 3.3 | 7.3 | 0.9 |
| Total Ash | - | - | 6.6 | 7.4 | 8.4 | 5.4 |
| Crude fibre | 6.8 | 1.8 | 38.3 | 25.9 | 29.9 | 21.3 |
| Carbohydrate | 66 | 23.8 | 21.3 | 36.8 | 28.2 | 51.6 |

Source: Department of Food Technology and Quality control, Central food laboratory, Babarmahal, Kathmandu, Ministry of Agricultural Development, Government of Nepal

### 4.1.6 Soil weed seeds bank estimation

#### 4.1.6.1 Differential floatation technique

**Standardization-** The soil texture plays an important role in seed bank recovery. Large seeds of *Ageratum conyzoides* recovered more in clay soil (80 %) and loamy soil (67%) while that of *B. pilosa* recovered by 98 % in loamy soil and by 98 % in clay soil (Figures 5a, b). The recovery of *C. rotundus,* which had small seeds, was 96, 91, and 84 % in clay, sandy loam, and sandy soil, respectively. Similarly, in *G. parviflora* also with small seeds, seed recovery was 93.0, 86.8, and 80% in clay, sandy loam, and sandy soil, respectively (Figures 5c, d).

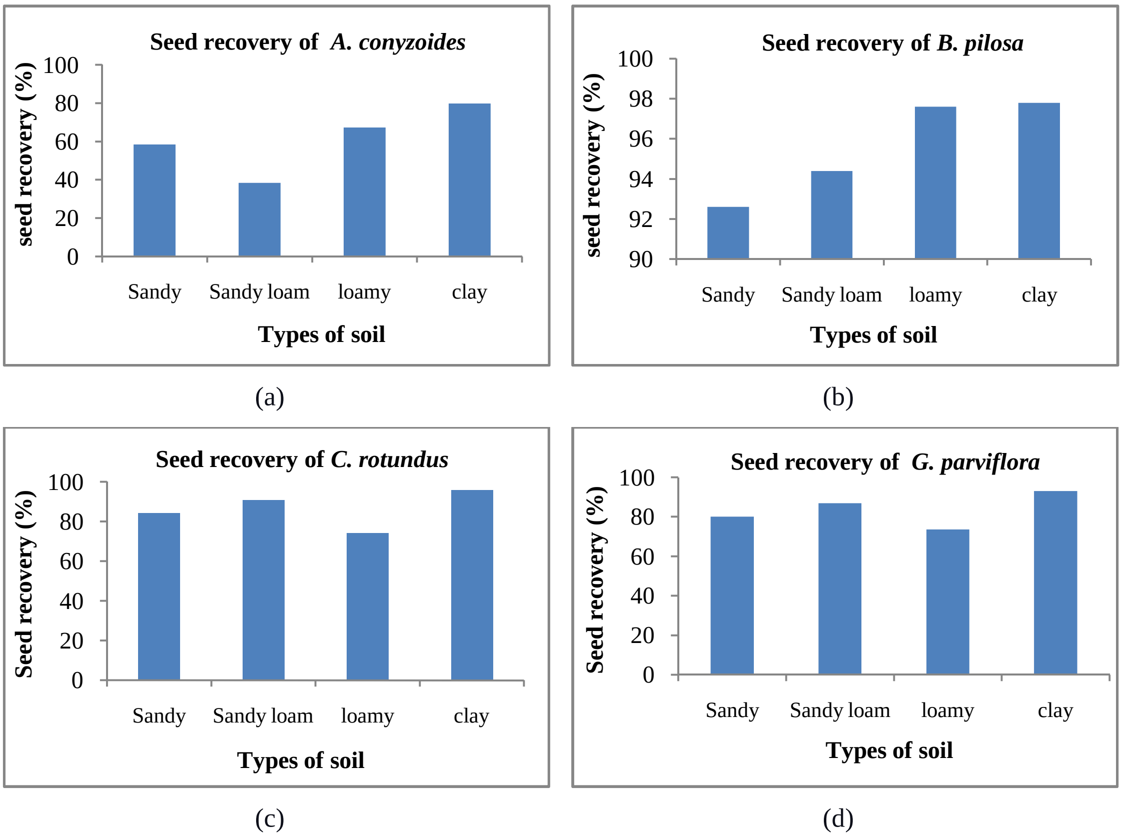



**Figure 5:** Weed seed recovery (%) of common weeds (a) *Ageratum conyzoides,* (b) *Bidens pilosa,* (c) *Cyperus rotundus*, and (d) *Galinsoga parviflora*

The mean value and Standard Deviation of each weed seed recovered in four different types of soil (sandy, sandy loam, loam and clay) was considered to determine the weed seed standardized index for each species (Figure 6). As the recovery of *Bidens pilosa* seeds was maximum in all types of soil, which was followed by *Galinsoga parviflora*, *Cyperus rotundus* and *Ageratum conyzoides,* the weed seed standardization index of *Bidens pilosa* was the maximum (96), followed by *Cyperus rotundus* (86), *Galinsoga parviflora* (86), and *Ageratum conyzoides* (61) (Figure 6).

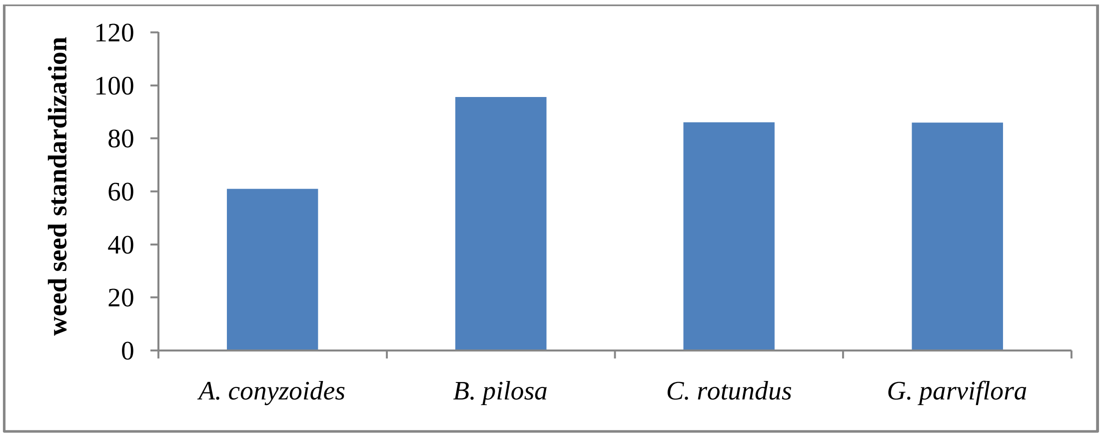



**Figure 6:** Weed seed standardization index of four common weeds

The actual number of weed seeds per 100 g of soil was recorded by the differential flotation method. The number of *Ageratum conyzoides* seeds per 100 g soil was more at the Chobhar, Chhugaon, and TU fields in comparison to the fields of Bhaktapur (Table 10).

The number of seeds of *Bidens pilosa* and *Cyperus rotundus* was more or less the same at all the selected sites of Kirtipur. Seeds of *Galinsoga parviflora* were significantly (P=0.05) more in Chobhar than in *Bidens pilosa* and *Cyperus rotundus*. At Lokanthali, the soil seed bank of *Bidens pilosa* was significantly higher (P=0.05) than of the other species. At Thimi and Sanothimi, the seed number obtained per 100 gm soil of all the weeds observed was more or less the same. At Balkot, the seeds of *Bidens pilosa* and *Galinsoga parviflora* were not recorded by this method (Table 10).

**Table 10.** Number of seeds/100 g soil, the number of four weeds seed (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora*) of winter crop fields (*Brassica campestris* and *Triticum aestivum*)

| SN | Site | *Ageratum conyzoides* | *Bidens pilosa* | *Cyperus rotundus* | *Galinsoga parviflora* |
|---|---|---|---|---|---|
| 1 | Machhegaon | 2.11±0.84 a | 1.31±0.52 a | 2.01±1.10a | 2.46±1.42 a |
| 2 | Chobhar | 5.06±1.69 c | 1.36±0.46 a | 2.30±0.81a | 3.19±1.64 b |
| 3 | Dhalpa | 2.53±0.69ab | 1.83±1.57 ab | 2.30±0.94a | 1.53±0.61 a |
| 4 | Chhugaon | 4.38±2.55bc | 1.88±0.87 ab | 2.53±0.96a | 2.44±0.87ab |
| 5 | TU field | 4.38±1.51bc | 1.40±0.60 ab | 2.48±0.90a | 2.42±1.50ab |
| 6 | Lokanthali | 2.55±0.87ab | 2.71±0.93 b | 1.66±0.61a | 1.40±0.52 a |
| 7 | Thimi | 1.99±0.79 a | 2.35±0.52 ab | 1.75±0.66a | 1.49±0.56 a |
| 8 | Sano Thimi | 2.23±0.87 a | 1.46±0.57 ab | 1.23±0.14a | 1.64±1.05ab |
| 9 | Gatthaghar | 1.99±0.79 a | 1.99±0.13 ab | 1.75±0.66a | 1.15±0.05 a |
| 10 | Balkot | 1.53±0.11 a | 0 | 1.23±0.09a | 0 |
| | Mean | 2.875 | 1.629 | 1.924 | 1.772 |

Values (mean±SD) bearing the same letters in the same rows do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at P=0.05

#### 4.1.6.2 Soil seed bank estimation-germination method

In the germination method, several weed seeds/500 g soil, the number of weeds seedling emerged in soil collected from all the sites of Kirtipur and Bhaktapur were insignificantly different. Along with the weeds studied, some other weeds, like *Oxalis, sonchus, Trifolium, Cyanodon,* etc. also emerged in the soils collected from different places of Kirtipur and Bhaktapur (Table 11).

**Table 11.** Germination method for soil weed seed bank estimation-emergence number of weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora*/500 g soil

| SN | Site | *Ageratum conyzoides* | *Bidens pilosa* | *Cyperus rotundus* | *Galinsoga parviflora* |
|---|---|---|---|---|---|
| 1 | Machhegaon | 2.25±1.25 a | 1.50±1.00 a | 2.00±0.81 a | 2.50±1.00 a |
| 2 | Chobhar | 1.60±0.54 a | 1.20±0.44 a | 1.60±0.54 a | 2.60±0.89 a |
| 3 | Dhalpa | 1.75±0.50 a | 1.10±0.15 a | 1.75±0.50 a | 2.25±0.50 a |
| 4 | Chhugaon | 2.01±0.70 a | 1.40±0.54 a | 1.60±0.54 a | 2.60±1.14 a |
| 5 | TU field | 2.01±0.70 a | 1.25±0.52 a | 1.60±0.54 a | 2.60±0.54 a |
| 6 | Lokanthali | 1.40±0.54 a | 1.20±0.44 a | 1.60±0.54 a | 1.80±0.83 a |
| 7 | Thimi | 1.75±0.50 a | 1.50±0.57 a | 1.75±0.95 a | 2.25±0.95 a |
| 8 | Sano Thimi | 1.80±0.44 a | 1.40±0.54 a | 1.80±0.44 a | 2.40±0.88 a |
| 9 | Gatthaghar | 1.75±0.58 a | 1.14±0.10 a | 1.75±0.50 a | 2.25±0.50 a |
| 10 | Balkot | 1.66±0.57 a | 1.33±0.57 a | 2.00±1.00 a | 2.33±0.57 a |
| | Mean | 1.798 | 1.302 | 1.745 | 2.358 |

Values (mean±SD) bearing the same letters in the same rows do not differ significantly according to ANOVAfollowed by Duncan‛s Multiple Range Test at P=0.05

### 4.1.7 Seed germination

#### 4.1.7.1 Under environmental conditions

#### i) Moisture (water level)

The effects of different amounts of moisture on seed germination (SG) and shoot length (SL) and root length (RL) are given in Table 12. Seed germination of winter crops *Brassica campestris* and *Triticum aestivum* was reduced maximally at 6 ml and 9 ml treatments, and the reduction was significant at 15 ml treatment. SG of weed seeds like *Ageratum conyzoides* and *Bidens pilosa* was mostly high at 3 ml and 6 ml treatments. SG of *Cyperus rotundus* and *Galinsoga parviflora* was insignificantly different in all the treatments. No Seed germination was observed at 15 ml treatment in both weeds (Table 12).

The SL and RL of both germinated crop seeds were significantly high at 6 ml treatment. Similarly, SL and RL of germinated seeds of *Ageratum conyzoides* and *Bidens Pilosa* were significantly high at 6 ml treatment but in the case of *Cyperus rotundus* and *Galinsoga parviflora*, it was significantly high at 3 ml treatment. This concluded that *Cyperus rotundus* and *Galinsoga parviflora* do not require added moisture to germinate and grow (Table 12).

**Table 12:** Effect of moisture on seed germination SG (%±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weeds

| SN | Species | | 3 ml (control) | 6 ml | 9 ml | 12 ml | 15 ml |
|---|---|---|---|---|---|---|---|
| 1 | *Brassica campestris* | SG | 77.5±9.57bc | 82.5±5.00 c | 75± 10.00bc | 65 ±10.00b | 52.5 ± 5.00a |
| | | SL | 2.99±1.66bc | 5.43 ±2.55 d | 3.43 ±2.04 c | 2.40±1.81b | 1.05 ±1.03 a |
| | | RL | 2.80±1.56bc | 5.39 ±2.54 d | 3.23 ±1.91c | 2.27±1.71b | 0.93±0.92 a |
| 2 | *Triticum aestivum* | SG | 80 ± 8.16 b | 87.5±17.07b | 77.5±9.57ab | 65±17.32ab | 55 ± 5.77 a |
| | | SL | 3.30±1.69 b | 5.2 ±3.66 c | 4.56 ±2.52 c | 2.74±2.05b | 1.13±1.09 a |
| | | RL | 3.11 ±1.60b | 5.11 ±3.60 c | 4.43 ±2.44c | 2.59±1.93 b | 0.98±0.97 a |
| 3 | *Ageratum conyzoides* | SG | 57.5±12.58c | 57.5 ±5.00 a | 55 ±5.77 a | 55 ±5.77 a | 45±5.77 a |
| | | SL | 1.81±1.58 c | 1.96 ±1.73 b | 1.50±1.42 b | 1.16±1.12 a | 1.37±0.09 a |
| | | RL | 1.68 ±1.48ab | 1.83 ±1.61 b | 1.37±1.31 a | 1.03±1.02 a | 1.18±0.09 a |
| 4 | *Bidens pilosa* | SG | 80 ±8.16 c | 67.5±5.00ab | 70±11.54 ab | 65 ±12.90ab | 57.5 ±9.57 a |
| | | SL | 3.41±1.73 b | 3.61 ±2.55 b | 2.91±1.96 b | 2.61±1.88 b | 0.93± 0.87 a |
| | | RL | 3.27 ±1.65 b | 3.29±2.36 b | 2.60 ±1.76 b | 2.52± 1.76 b | 0.74 ±0.73 a |
| 5 | *Cyperus rotundus* | SG | 45 ±5.77 a | 47.5 ±5.00 a | 45 ±12.90 a | 42.5 ±9.57 a | NG |
| | | SL | 1.13 ±1.08 b | 0.85±0.80ab | 0.83±0.79ab | 0.71 ±0.70 a | NG |
| | | RL | 0.99 ±0.96 b | 0.72±0.69ab | 0.71±0.69ab | 0.57±0.54 a | NG |
| 6 | *Galinsoga parviflora* | SG | 57.5 ±5.0 b | 55 ±10.00ab | 57.5±15.00b | 42.5 ± 5.00a | NG |
| | | SL | 1.35 ±1.19 b | 0.96±0.92ab | 0.95±0.90ab | 0.79±0.78 a | NG |
| | | RL | 1.21±1.06 b | 0.82 ±0.80 a | 0.97 ±0.89 a | 0.65±0.63a | NG |

Values (mean±SD) bearing the same letters in the same rows do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at P=0.05, NG-No Germination

### ii) Temperature

Data on seed germination of crops (*Brassica campestris* and *Triticum aestivum*) and selected weeds at different temperatures are given in Table 13. SG of both crops enhanced insignificantly at 15 to 20°C treatments. Seed germination of weeds was insignificantly high at 10 to 15°C (Table 13).

Shoot length and root length in both the crops were significantly high at 15 to 20°C. SL and RL in weeds seeds also increased significantly high at 15 to 20°C, except in *Bidens pilosa*, where it increased at 10 to 15°C. This indicated that low temperature enhances the growth of *Bidens pilosa* more in comparison to other weeds (Table 13).

**Table 13:** Effect of temperature on seed germination SG (%±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weed

| SN | Species | | 5°C | 10°C | 15°C | 20°C | 25°C |
|---|---|---|---|---|---|---|---|
| 1 | *Brassica campestris* | SG | 65±19.14a | 75±17.2a | 82.5±5.00a | 85±5.77 a | 72.5±5.00a |
| | | SL | 4.49±1.0b | 6.82±0.52c | 10.85±0.4d | 11.12±0.73 d | 3.32±1.09a |
| | | RL | 3.69±0.88b | 6.17±0.61c | 10.18±0.60d | 10.79±0.70 e | 2.72±0.93a |
| 2 | *Triticum aestivum* | SG | 57.5±15.0a | 80±11.54 b | 87.5±5.00 b | 82.5±9.57 b | 52.5±5.00a |
| | | SL | 4.05±0.52b | 9.59±0.61c | 12.02±0.56d | 12.66±0.91 d | 2.86±0.45a |
| | | RL | 3.66±0.54b | 8.94±0.62c | 11.64±0.57d | 12.16±0.64 d | 2.60±0.43a |
| 3 | *Ageratum conyzoides* | SG | 62.5±5.00b | 55±12.90 b | 65±10.00 b | 52.5±9.57 ab | 40±8.16 a |
| | | SL | 1.75±0.23a | 2.21±0.84b | 2.42±0.31 b | 2.32±0.18 b | 2.28±0.16a |
| | | RL | 1.52±0.12a | 2.04±0.78b | 1.76±0.42ab | 1.93±0.35 b | 1.56±0.10a |
| 4 | *Bidens pilosa* | SG | 57.5±9.57ab | 72.5±5.00a | 70±8.16 a | 62.5±9.57 a | 65±25.16 a |
| | | SL | 2.69±0.31 b | 6.04±0.64d | 6.57±0.15 d | 2.98±0.46 c | 1.44±0.70a |
| | | RL | 2.12±0.38 b | 6.27±0.70d | 6.13±0.31 d | 2.72±0.39 c | 1.05±0.38a |
| 5 | *Cyperus rotundus* | SG | 45±10.00 ab | 50±16.32 b | 47.5±5.00 ab | 42.5±9.57 a | 40.5±5.00a |
| | | SL | 1.31±0.30 a | 2.36±0.12c | 3.1±0.34 d | 1.49±0.15 b | 1.52±0.21b |
| | | RL | 1.08±0.26 a | 2.01±0.36d | 1.60±0.15 e | 1.33±0.13 b | 1.28±0.19b |
| 6 | *Galinsoga parviflora* | SG | 55±10.00 ab | 57.5±9.57b | 65±5.77 c | 60±8.16 ab | 60±8.16 a |
| | | SL | 1.68±0.17 a | 2.33±0.30c | 3.67±0.18 e | 3.01±0.34 d | 2.00±0.57b |
| | | RL | 1.41±0.20 a | 1.83±0.36a | 3.47±0.18 c | 2.77±0.33bc | 1.67±0.46a |

Values (mean±SD) bearing the same letters in the same rows do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at P=0.05

### iii) Light

The percentage of seed germination of both crops *Brassica campestris* and *Triticum aestivum* increased significantly (P=0.05) in normal white and green light. SG of *Ageratum conyzoides*, *Cyperus rotundus*, and *Galinsoga parviflora* was insignificantly different in normal, red, yellow, and green light. In *Bidens pilosa*, it increased slightly at normal white light than in all colored lights (Table 14). The SL and RL of both the crops *Brassica campestris* and *Triticum aestivum* were increased significantly (P=0.05) at normal light.

The Shoot and root length of weed *Ageratum conyzoides* were significantly large (P=0.05) in yellow light treatment, but in *Bidens pilosa*, it was so under red and green lights. Similarly in *Cyperus rotundus*, SL and RL were large in normal white light but in *Galinsoga parviflora* it was so in green light treatment (Table 14).

**Table 14:** Effect of different colors of light on seed germination SG (% ±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weed seeds

| SN | Species | | Normal | Red | Yellow | Blue | Green | Dark |
|---|---|---|---|---|---|---|---|---|
| 1 | *Brassica campestris* | SG | 65±5.77 b | 52.5±5.00a | 52.5±5.00 a | 55±5.77 a | 57.5±5.00ab | NG |
| | | SL | 6.80±0.33d | 4.68±0.49c | 4.35±0.15 b | 3.44±0.32a | 4.58±0.52 c | NG |
| | | RL | 6.37±0.37d | 4.44±0.44c | 4.14±0.15b | 3.15±0.33a | 4.27±0.53bc | NG |
| 2 | *Triticum aestivum* | SG | 65±5.77 b | 55±5.77 ab | 42.5±12.58a | 55±10.00ab | 57.5±9.57b | NG |
| | | SL | 8.07±0.53d | 5.94±0.44c | 5.63±0.31 b | 3.96±0.50 a | 6.11±0.45c | NG |
| | | RL | 7.82±0.46d | 5.70±0.35c | 5.29±0.39 b | 3.69±0.48 a | 5.78±0.53c | NG |
| 3 | *Ageratum conyzoides* | SG | 57.5±9.57a | 55±5.77 a | 62.5±12.58a | NG | 60.5±12.56a | NG |
| | | SL | 0.56±0.19 a | 0.49±0.12a | 0.94±0.18 b | NG | 0.53±0.16 a | NG |
| | | RL | 0.34±0.18ab | 0.26±0.10a | 0.73±0.16 c | NG | 0.36±0.10 b | NG |
| 4 | *Bidens pilosa* | SG | 65±10.00 b | 55±10.00 b | 55±5.77 ab | NG | 50±8.16 a | NG |
| | | SL | 3.87±0.63 a | 5.27±0.87c | 3.83±0.37 a | NG | 4.84±0.48 b | NG |
| | | RL | 3.49±0.65 a | 4.99±0.84b | 3.45±0.38a | NG | 4.70±0.36 b | NG |
| 5 | *Cyperus rotundus* | SG | 47.5±9.57 b | 47.5±5.00b | 42.5±5.00 a | NG | 42.5±5.00 a | NG |
| | | SL | 1.19±0.30 d | 0.26±0.06a | 0.40±0.09 b | NG | 0.57±0.21 c | NG |
| | | RL | 0.95±0.29 c | 0.15±0.05a | 0.24±0.07 a | NG | 0.37±0.21 b | NG |
| 6 | *Galinsoga parviflora* | SG | 62.5±5.00 a | 55±5.77 a | 57.5±5.00 a | NG | 62±9.57 a | NG |
| | | SL | 2.47±0.60 c | 0.36±0.11a | 0.76±0.18 b | NG | 2.67±0.60 c | NG |
| | | RL | 2.08±0.71 c | 0.18±0.07a | 0.55±0.18 b | NG | 2.42±0.54 d | NG |

Values (mean ±SD) bearing the same letters in the same rows do not differ significantly according to ANOVAfollowed by Duncan‘s Multiple Range Test at P=0.05, NG-No Germination

### iv) pH

Seed germination of both crops (*Brassica campestris* and *Triticum aestivum*) and in two weeds (*Ageratum conyzoides* and *Bidens pilosa*) was highly significant at pH7. Germination of *Cyperus rotundus* seeds was insignificantly high, but in *Galinsoga parviflora*, it was significantly high at pH 6 treatments (Table 15). Seeds of *Ageratum conyzoides* and *Bidens pilosa* could not germinate in a low acidic and alkaline condition of pH 5 and pH 9, respectively. Similarly, seeds of *Cyperus rotundus* could not germinate in alkaline conditions of pH 8 and 9 (Table 15). An increase in the SL and RL of the crop *Brasica campestris* was found to be significantly high in acidic conditions at pH 5, but in *Triticum aestivum*, it was so in alkaline condition of pH 8. The SL and RL of most of the weed seeds (*Ageratum conyzoides*, *Cyperus rotundus* and *Galinsoga parviflora*) were significantly large in slightly acidic conditions pH 6 except for *B. pilosa* where it was so in alkaline condition of pH 8 (Table 15).

**Table 15:** Effect of pH value (acidic and alkaline medium) on seed germination SG (% ±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weed seeds

| | | | Range of pH | | | | |
|---|---|---|---|---|---|---|---|
| **SN** | **Species** | | **5** | **6** | **7** | **8** | **9** |
| 1 | *Brassica campestris* | SG | 87.5±12.58bc | 87.5±18.92bc | 95±5.77 c | 65±10.00 a | 72.5±9.57 ab |
| | | SL | 4.61±0.45 d | 4.39±0.27 c | 4.37±0.34c | 3.66±0.35b | 3.05±0.42 a |
| | | RL | 4.91±0.35 d | 4.38±0.17 c | 4.53±0.27c | 3.01±0.39 b | 3.21±0.43 a |
| 2 | *Triticum aestivum* | SG | 77.5±17.07 a | 77.5±5.00 a | 85±5.77 a | 82.5±5.00 a | 77.5±5.00 a |
| | | SL | 3.15±0.19 a | 4.36±0.82 b | 5.79±0.39c | 7.87±0.47d | 4.54±0.15 b |
| | | RL | 3.46±0.21 a | 4.36±0.82 b | 5.72±0.37c | 7.76±0.40d | 4.53±0.22 b |
| 3 | *Ageratum conyzoides* | SG | NG | 52.5±5.00 a | 65±10.00b | 55±5.77 ab | NG |
| | | SL | NG | 1.44±0.35 c | 1.31±0.27ab | 1.17±0.11 a | NG |
| | | RL | NG | 1.21±0.29 b | 1.20±0.25 b | 0.99±0.11 a | NG |
| 4 | *Bidens pilosa* | SG | NG | 57.5±15.0 a | 62.5±5.00 a | 552.5±12.58a | NG |
| | | SL | NG | 1.24±0.38 a | 1.35± 0.48 a | 1.60±0.41 b | NG |
| | | RL | NG | 1.21±0.26 a | 1.22±0.43 a | 1.45±0.35 b | NG |
| 5 | *Cyperus rotundus* | SG | 55± 10.00 a | 55.5±9.57 a | 52.5±9.57 a | NG | NG |
| | | SL | 1.44±0.33 b | 1.38±0.13 b | 0.67±0.09 a | NG | NG |
| | | RL | 1.29±0.31 b | 1.26±0.19 b | 0.46±0.06 a | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 65±5.77 ab | 75±5.77 b | 65±10.00 ab | 65±5.77 ab | 57.5±9.57 a |
| | | SL | 1.45±0.29 b | 1.81±0.33 a | 1.36±0.32 a | 1.34±0.09 a | 1.30±0.09 a |
| | | RL | 1.30±0.26 b | 1.70±0.32 a | 1.33±0.26 a | 1.22±6.10 a | 1.20±0.10 a |

Value (mean ±SD) bearing the same letters in the same rows do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at P=0.05 NG-No Germination

#### 4.1.7.2 Chemical fertilizers (urea and potash)

##### 4.1.7.2.1 Chemical fertilizer solutions of urea and potash separately

Seed germination of both the crops and all the weeds were mostly high in the control and 1% of both urea and potash solutions. SG of both crops and weeds was reduced significantly (P=0.05) with an increase in concentrations of urea and potash. SG of both the crops and selected weeds was not observed at a 10% concentration. Seeds of *Cyperus rotundus* and *Galinsoga parviflora* could not germinate at 5% urea and potash solutions (Table 16). SL and RL of *Brassica campestris* and *Triticum aestivum* were enhanced significantly (P=0.05) in a 1% solution treatment of urea and potash. In the case of weeds, these parameters are enhanced significantly in control conditions than in all the treatments of both urea and potash solutions (Table 16).

**Table 16:** Seed germination SG (% ±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weed seeds, grows on chemical fertilizer solution of urea and potash

| SN | Species | | 0 | 1 | 2.5 | 5 | 10 |
|---|---|---|---|---|---|---|---|
| | | | Urea solution concentration (%) | | | | |
| 1 | *Brassica campestris* | SG | 75± 5.77 b | 67.5±5.00ab | 65±5.77 ab | 60±8.16 a | NG |
| | | SL | 6.57±0.38c | 7.03±1.29 d | 4.42±0.41b | 3.20±0.40a | NG |
| | | RL | 5.80±1.22c | 6.65±1.32 d | 4.18±0.38b | 2.80±0.42a | NG |
| 2 | *Triticum aestivum* | SG | 80±8.16 b | 75±5.77 ab | 67.5±9.57a | 65±5.77 a | NG |
| | | SL | 12.02±1.95b | 14.95±0.51c | 9.22±2.38a | 8.8±1.38 a | NG |
| | | RL | 11.59±1.93b | 14.20±0.52c | 9.00±2.39a | 8.60±1.38a | NG |
| 3 | *Ageratum conyzoides* | SG | 72.5±5.00 b | 67.5±5.00 b | 65±5.77 ab | 57.5±5.00a | NG |
| | | SL | 3.50±0.40 d | 2.36±0.14 c | 1.37±0.13b | 1.00±0.32a | NG |
| | | RL | 3.21±0.42 d | 2.11±0.80 c | 1.11±0.09b | 0.78±0.28a | NG |
| 4 | *Bidens pilosa* | SG | 75±5.77 b | 65±5.77 a | 62.5±5.00a | 55±5.00 a | NG |
| | | SL | 5.53±0.15 d | 4.64±0.38 c | 3.30±0.20b | 2.47±0.10a | NG |
| | | RL | 5.25±0.12 d | 4.30±0.47 c | 3.06±0.18b | 2.20±0.09a | NG |
| 5 | *Cyperus rotundus* | SG | 45±5.77 a | 47.5±9.57a | 45±12.90 a | NG | NG |
| | | SL | 3.24±0.19 c | 2.25±0.24 b | 0.56±0.14a | NG | NG |
| | | RL | 2.85±0.37 c | 1.85±0.48 b | 0.38±0.13a | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 57.5±9.57 a | 47.5±9.57 a | 45±5.77 a | NG | NG |
| | | SL | 4.21±0.20 c | 3.38±0.31 b | 1.82±0.80a | NG | NG |
| | | RL | 4.01±0.31 c | 3.05±0.26 b | 1.58±0.76a | NG | NG |
| | | | Potash solution concentration (%) | | | | |
| 1 | *Brassica campestris* | SG | 70±14.14 b | 67.5±9.52 b | 62.5±5.00ab | 47.5±9.57a | NG |
| | | SL | 7.66±0.38 c | 8.61±0.45cd | 6.08±1.32 b | 4.78±0.49a | NG |
| | | RL | 7.22±0.52 c | 8.26±0.43 d | 5.81±1.32 b | 4.49±0.44a | NG |
| 2 | *Triticum aestivum* | SG | 75±5.77 b | 67.5±5.00ab | 65±10.00 ab | 57.5±9.57a | NG |
| | | SL | 11.80±8.16c | 13.72±0.99d | 10.29±0.99b | 8.67±0.61 a | NG |
| | | RL | 11.37±1.14c | 13.19±1.19d | 9.97±0.92ab | 8.41±10.54a | NG |
| 3 | *Ageratum conyzoides* | SG | 55±12.90 b | 52.5±12.58b | 45±12.90 b | 32.5±5.00 a | NG |
| | | SL | 4.74±0.35 d | 2.21±0.54 c | 1.40±0.31 b | 0.71±0.30 a | NG |
| | | RL | 3.85±0.40 d | 2.01±0.48 c | 1.18±0.29 b | 0.55±0.19 a | NG |
| 4 | *Bidens pilosa* | SG | 75±5.77 c | 72.5±9.57 c | 47.5±15.00ab | 32.5±5.00 a | NG |
| | | SL | 8.79±0.46 c | 5.52±0.15 b | 5.27±0.55 b | 2.91±0.78 a | NG |
| | | RL | 8.45±0.45 d | 5.23±0.14 c | 4.81±0.43 b | 2.65±0.70 a | NG |
| 5 | *Cyperus rotundus* | SG | 45±12.90 a | 42.5±15.00a | 44.5±9.57 a | NG | NG |
| | | SL | 3.18±0.15 c | 2.47±0.36 b | 1.45±0.16 a | NG | NG |
| | | RL | 3.20±0.10 c | 2.21±0.29 b | 1.17±0.13 a | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 57.5±12.58a | 52.5±15.00a | 45±10.00 a | NG | NG |
| | | SL | 3.45±0.15 c | 2.37±0.12 b | 1.28±0.12 a | NG | NG |
| | | RL | 3.77±1.39 c | 3.12±0.08 b | 1.08±0.10 a | NG | NG |

Values (mean ±SD) same letters in the same rows do not differ significantly according to ANOVA followed by Duncan‛s Multiple Range Test at P=0.05, NG-No Germination

#### 4.1.7.2.2 Chemical fertilizers urea & potash g/kg amended with soil separately

Seed germination of both the crops was highly significant in the control and the 10 g urea and potash/kg soil treatment separately. The germination of selected weed seeds reduced significantly in all soils amended with different concentrations of both urea and potash. No germination occurred in seeds of any crop weed with 50 g/kg soil of urea or potash (Table 17).

The growth of SL and RL in *Brassica campestris* and *Triticum aestivum* was significantly high in the soil treated with potash 10 g/kg soil. Similarly, SL and RL growth of *Brassica campestris* were significantly high in 10 g urea/kg soil, but in *Triticum aestivum* it was significantly not different in the 10 g urea/kg soil treatment. In all the weeds, the SL and RL growth was significantly (P=0.05) higher in control than in other treatments (Table 17).

**Table 17:** Seed germination SG (% ±SD), shoot length SL and root length RL (cm ±SD) of crops and weed seeds, grows on chemical fertilizer urea g/kg and potash g/kg amended with soil

| SN | Species | | 0 | 10 | 20 | 40 | 50 |
|---|---|---|---|---|---|---|---|
| | | | | Urea fertilizer g/kg soil | | | |
| 1 | *Brassica campestris* | SG | 70±14.14 b | 62.5±5.00 b | 57.5±5.00 ab | 47.5±9.57 a | NG |
| | | SL | 18.55±0.91 d | 22.80±0.30 c | 16.55±0.95 b | 8.53±0.70 a | NG |
| | | RL | 18.01±0.94 c | 22.49±0.46 d | 15.92±1.21 bc | 8.12±0.60 a | NG |
| 2 | *Triticum aestivum* | SG | 75±10.00 b | 70±8.16 b | 60±8.16 b | 50±11.54 a | NG |
| | | SL | 21.86±1.27 d | 23±0.97 c | 18.19±1.08 b | 10.99±1.92 a | NG |
| | | RL | 21.39±1.35 c | 22.75±1.10 c | 17.68±0.96 b | 10.70±1.98 a | NG |
| 3 | *Ageratum conyzoides* | SG | 70±8.16 b | 55±5.77 a | 52.5±9.57 a | 47.5±9.57 a | NG |
| | | SL | 7.83±0.93 d | 4.50±0.41 c | 3.58±0.40 b | 2.62±0.38 a | NG |
| | | RL | 3.21±0.42 d | 2.11±0.09 c | 1.11±0.92 b | 0.78±0.28 a | NG |
| 4 | *Bidens pilosa* | SG | 67.5±5.00 b | 55±5.77 ab | 52.5±15.00 a | 47.5±5.00 a | NG |
| | | SL | 14.04±1.07 d | 10.92±0.80 c | 6.82±0.47 b | 5.11±0.28 a | NG |
| | | RL | 13.61±1.11 d | 10.53±0.82 c | 6.50±0.49 b | 4.78±0.28 a | NG |
| 5 | *Cyperus rotundus* | SG | 45±8.16 b | 55±5.77 ab | 47.5±5.00 a | NG | NG |
| | | SL | 5.54±0.66 c | 2.91±0.44 b | 1.80±0.38 a | NG | NG |
| | | RL | 3.70±1.54 c | 2.60±0.39 bc | 0.43±0.33 a | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 67.5±9.57 a | 62.5±9.57 a | 52.5±9.57 a | NG | NG |
| | | SL | 10.37±0.73 c | 9.21±1.96 b | 5.70±0.54 a | NG | NG |
| | | RL | 9.63±1.92 b | 8.82±1.90 b | 5.33±0.63 a | NG | NG |

| | | | Potash fertilizer g/kg soil | | | | |
|---|---|---|---|---|---|---|---|
| 1 | *Brassica campesrtis* | SG | 70±8.16 c | 65±5.77 bc | 57.5±9.57 ab | 52.5±5.00 a | NG |
| | | SL | 18.68±0.92 c | 22.24±0.75 d | 16.86±0.80 b | 8.30±1.91 a | NG |
| | | RL | 18.28±0.80 c | 21.42±0.75 d | 16.17±0.84 b | 7.92±1.81 a | NG |
| 2 | *Triticum aestivum* | SG | 72.5±5.00 c | 65±12.90 ab | 60±8.16 ab | 52.5±5.00 a | NG |
| | | SL | 22.11±0.84 c | 23.32±0.87 d | 18.36±0.96 b | 10.10±1.52 a | NG |
| | | RL | 21.50±0.96 c | 22.85±0.89 d | 18.01±0.97 b | 9.74±1.47a | NG |
| 3 | *Ageratum conyzoides* | SG | 62.5±9.57 a | 60±11.54 a | 55±10.00 a | 50±14.14 a | NG |
| | | SL | 8.01±0.68 d | 4.80±0.41 c | 3.65±0.27 b | 2.62±0.38 a | NG |
| | | RL | 7.72±0.61 d | 4.45±0.49 c | 3.25±0.26 b | 2.25±0.25 a | NG |
| 4 | *Bidens pilosa* | SG | 57.5±5.00 a | 52.5±9.57 a | 50±14.14 a | 47.5±5.00 a | NG |
| | | SL | 14.00±1.05 d | 10.16±2.40 c | 6.95±0.75 b | 5.21±0.34 a | NG |
| | | RL | 13.61±1.10 d | 9.79±2.33 c | 6.57±0.79 b | 4.92±0.20 a | NG |
| 5 | *Cyperus rotundus* | SG | 42.5±9.57 a | 40±5.77 a | 41.0±11.54 a | NG | NG |
| | | SL | 3.37±0.72 ab | 3.49±1.39 ab | 2.03±0.34 a | NG | NG |
| | | RL | 3.83±13.48 b | 2.10±1.29 ab | 1.31±0.46 a | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 62.5±5.00 a | 60±8.16 ab | 50±8.16 a | NG | NG |
| | | SL | 10.18±0.70 c | 9.59±0.66 b | 5.00±1.63a | NG | NG |
| | | RL | 9.81±0.69 b | 9.20±0.68 b | 5.00±0.66 a | NG | NG |

Values (mean ±SD) same letters in the same rows do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at p=0.05, NG-No Germination

### 4.1.8 Allelopathic effect

The allelopathic effect of the aqueous extract of two invasive plants (*Ageratina adenophora* (Spreng) R.M. King and H. Rob. and *Parthenium hysterophorus* L.) and one native plant (*Artemisia dubia Wall. ex Besser*), compost extract and compost were studied on seed germination of two winter crops (*Brassica campestris* and *Triticum aestivum*) and four common weeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) (Figure 7).

*Artemisia dubia* Wall Ex. Besser — *Ageratina adenophora* (Spreng) King & Rob. — *Parthenium hysterophorus* L.

**Figure 7:** Invasive plants (*A. adenophora* and *P. hysterophorus*) and one native plant (*A. dubia*)

#### 4.1.8.1 *Ageratina adenophora* (Spreng) King & Rob.

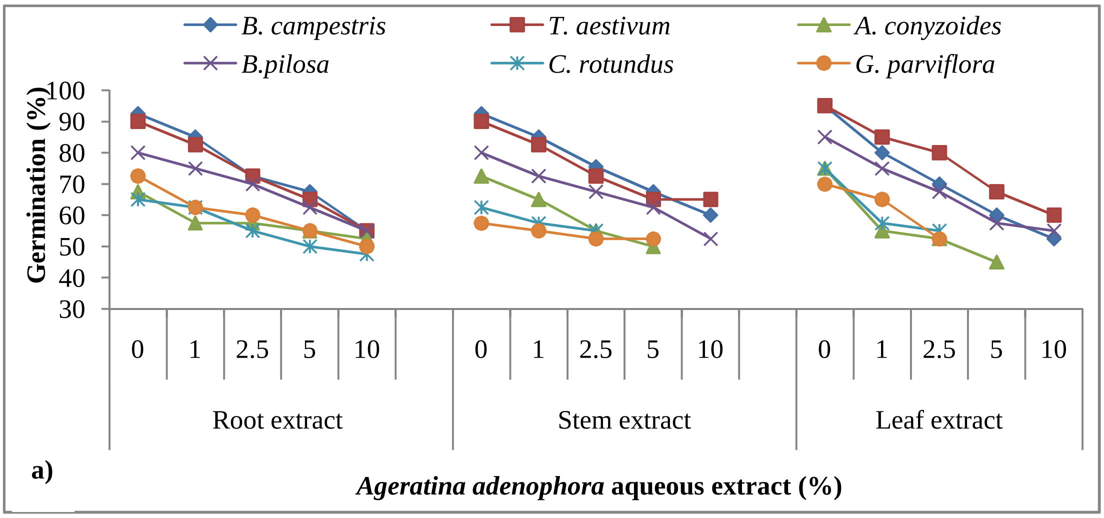
##### 4.1.8.1.1 Aqueous extract

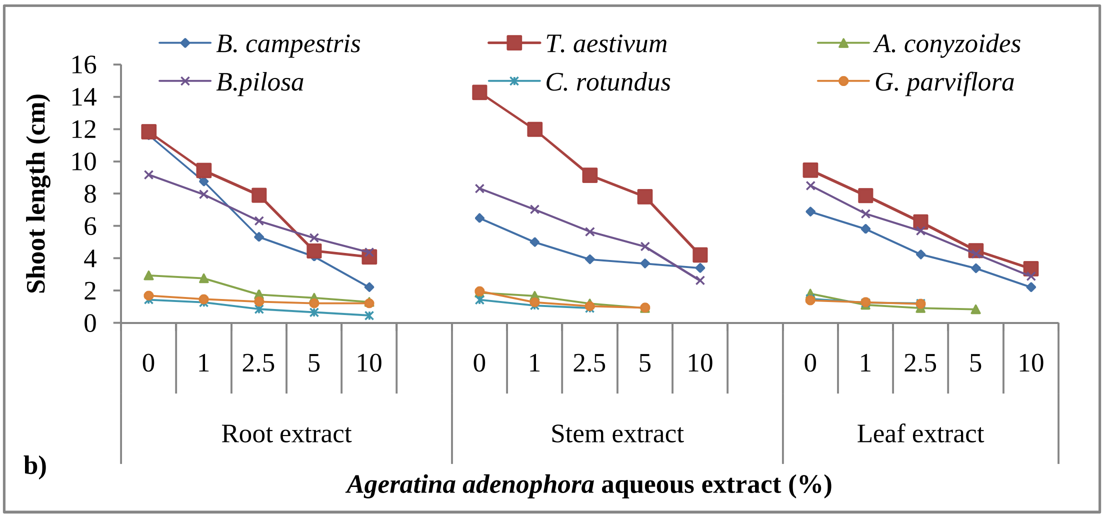
Seed germination of *Brassica campestris* was statistically insignificant with 2.5 and 5% of *Ageratina adenophora* root and stem extracts and with 5 and 10% of the leaf extract (Figure 8a). The percentage of SG of *Brassica campestris* seed was higher in stem extract than in root and leaf extract. The SL and RL in the seedlings of *B Brassica campestris* were reduced significantly in all treatments in comparison to the control. Mostly, an insignificant reduction in SL and RL was observed with 5 and 10% root and stem extracts. In the case of leaf extract, the root length of *Brassica campestris* decreased significantly in all the treatments except with 1 and 2.5% concentrations (Figures 8b, c).

Reduction in percentage germination of *Triticum aestivum* seeds was more in root extract than in stem and leaf extract treatments. A significant decrease in SG was observed at 5 and 10% concentrations of the root and leaf extracts (Figure 8a). The SL and RL of *Triticum aestivum,* seedlings reduced significantly in all the treatments. The root length was reduced significantly in all treatments of *Ageratina adenophora* plant parts (Figure 8c).

The impact of the aqueous extract of *Ageratina adenophora* was more or less similar in all the weeds studied. Compared to the control, seed germination of *Ageratum conyzoides* decreased significantly with all treatments in root extracts but significantly (p=0.05) with higher concentrations of the stem and leaf extracts, showing a complete inhibition at 10% of both these extracts. Seed germination was less in leaf extract than in root or stem extract at 1% concentration, but it was reduced insignificantly (p=0.05) at 2.5 and 5% concentrations of stem extract. The shoot length of seedlings decreased significantly with the root, stem, and leaf extracts (Table 16). Seed germination of weed *Bidens pilosa* was decreased insignificantly in 1 and 2.5% of all the three extracts of *Ageratina adenophora*. There was a significant decline in the percentage of germination in all the treatments up to 2.5% of root, stem, and leaf extract of *Ageratina adenophora*. The shoot and root length of the seedlings decreased significantly (p=0.05) with all these treatments showing a greater effect with an increase in concentration (Figures 8b, c).

Application of the extract of *Ageratina adenophora* plant parts severely affected seed germination and seedling growth of the weed *Cyperus rotundus.* Seed germination was reduced as the concentration increased, but the reduction was insignificant in all treatments of stem extract. Total inhibition was observed at 5 and 10% treatment in stem and leaf extracts. The growth of *Cyperus rotundus* seedling was inhibited at high concentrations of aqueous extract (Figures 8b, c). The germination percentage of *Galinsoga parviflora* seeds decreased with an increase in the concentration of root, stem, and leaf extract of *Ageratna adenophora*. Seed germination in the root extract was more than in the stem and leaf extracts. Leaf extract showed a greater allelopathic effect than the root or stem extract. Total inhibition was observed at 5% concentration of stem extract and at 5 and 10 % of leaf extract. SL and RL exhibited insignificant reduction with 1, 2.5, 5, and 10% root extracts in comparison to the control. Leaf extract caused a significant reduction both in SL and RL (Figures 8b, c).



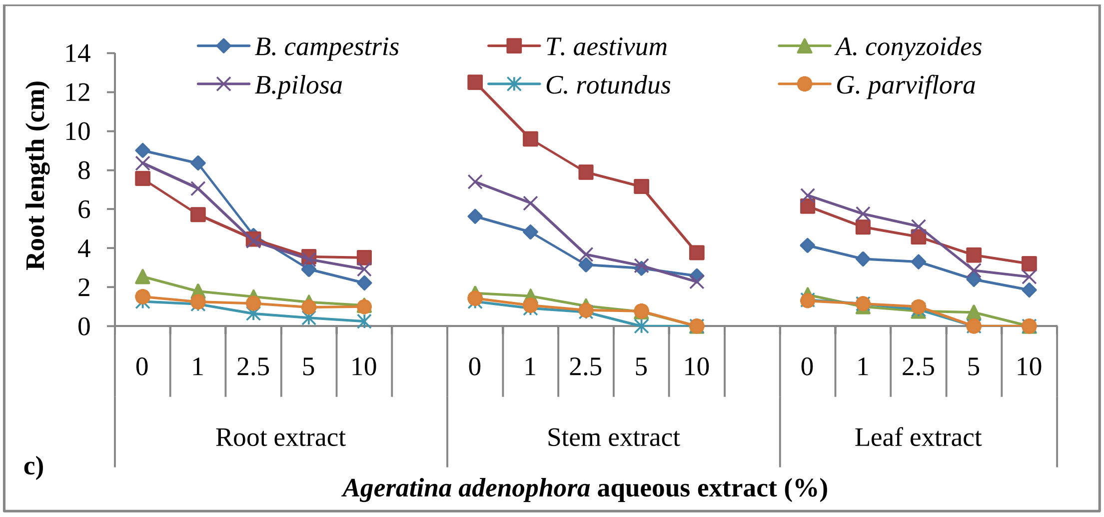


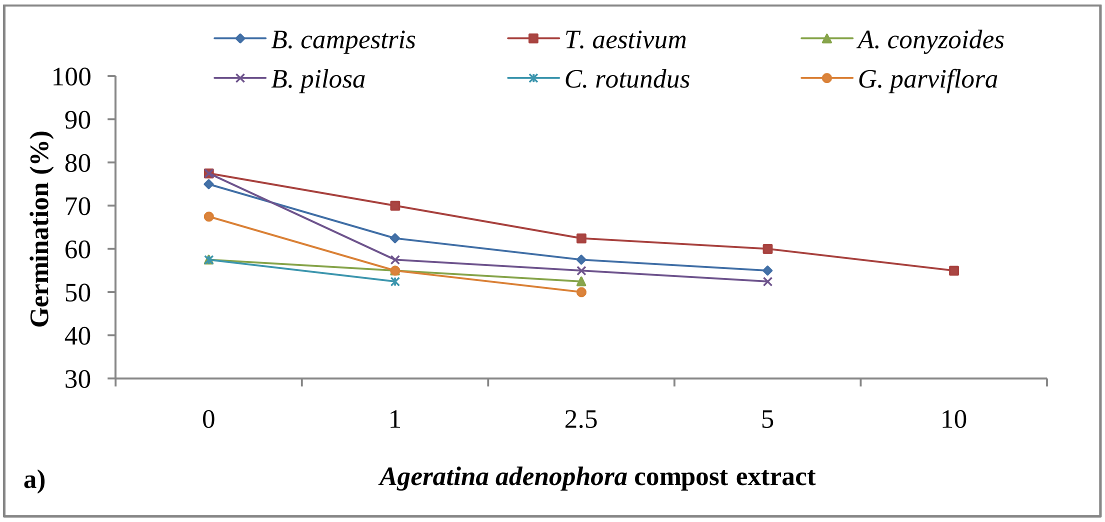

**Figure 8:** (a) Seed germination (% ±SD), (b) Shoot length (cm ±SD) and (c) Root length (cm ±SD) of crops and weed seeds on aqueous extract (root, stem and leaves) of *Ageratina adenophora*

### 4.1.8.1.2 Compost extract

Seed germination and seedling growth analyzed under laboratory conditions with different concentrations of compost aqueous extract (ranging from 1 to 10%) showed different responses. SG, SL, and RL decrease more in the weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) than in crops *Brassica campestris* and *Triticum aestivum* with the increase in the concentration of *Ageratina adenophora* compost extract (Figure 9).

Seed germination of the crop *Brassica campestris* showed with 1, 2.5, and 5% of *Ageratina adenophora* compost extract was not reduced significantly in comparison to the control, but it was completely inhibited in 10% concentration. Seed germination of *Triticum aestivum* reduced significantly (p=0.05) at 1% but at higher concentrations (2.5, 5, and 10%) the reduction was insignificant. The SG of weeds *Ageratum conyzoides* and *Galinsoga parviflora* reduced insignificantly up to 2.5 %. The seeds of *Bidens pilosa* showed statistically insignificance with 1, 2.5, and 5% concentrations. Total inhibition of SG of *Bidens pilosa* weed was observed at 10%. The SG of *Cyperus rotundus* was reduced significantly at a 1% concentration of *Ageratina adenophora* compost extract in comparison to control (Figure 9a).

The SL of *Brassica campestris* was reduced significantly but RL had a significant reduction with 1 and 2.5% concentrations. In *Triticum aestivum*, the shoot and root length got reduced significantly at all concentrations (1, 2.5, 5, and 10%). In all studied weed, shoot, and root lengths were significantly reduced with an increase in concentrations of compost extracts. In *Bidens pilosa*, SG and SL were reduced significantly but RL reduced significantly at 2.5 and 5% concentrations, compared with the control (Figure 9b).



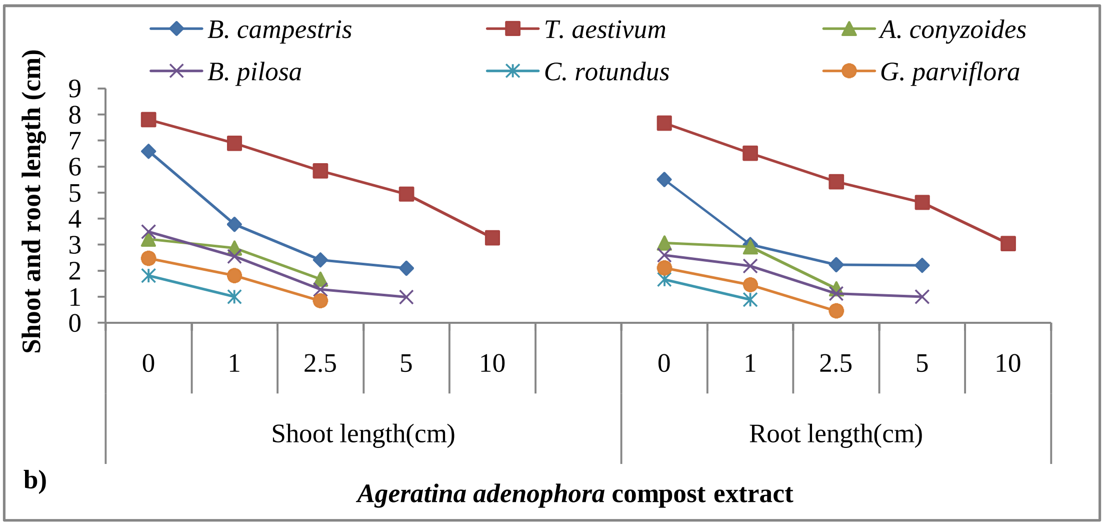




**Figure 9:** (a) Seed germination (% ±SD), (b) Shoot length (SL±SD) and root length RL (cm ±SD) of crops and weed seeds on compost extract of *Ageratina adenophora*

#### 4.1.8.1.3 Compost g/kg amended with soil

The Seed germination of *Brassica campestris* and *Triticum aestivum* reduced insignificantly with 10, 20, and 40 g compost/kg soil. SG of *B. campestris* was completely inhibited at 50 g/kg soil (Table 18).

The Seed germination of weeds *Bidens pilosa* and *Galinsoga parviflora* was reduced significantly at 10 and 20 g compost/kg soil. SG of *Ageratum conyzoides* and *Cyperus rotundus* was completely inhibited at higher concentrations of compost (20, 40, and 50 g/kg soil) in the Kirtipur and Bhaktapur soil (Table 18).

The SL and RL of *Brassica campestris* significantly increased with 10 g compost/kg soil concentration of Kirtipur and Bhaktapur but declined significantly at high concentrations (20 g compost/kg and above). The SL and RL of *Triticum aestivum* showed not much difference with the compost 10 g/kg soil in both crops. The SL and RL of weeds *Ageratum conyzoides*, and *Cyperus rotundus* showed a significant reduction at 10 g compost/kg soil concentration but in the case of *B. pilosa*, SL and RL significantly were reduced with 10, 20, and 40 g compost/kg soil concentration in comparison to control. In *Galinsoga parviflora* significant reduction was observed in 10 and 20 g compost/kg soil concentration in comparison to control but the insignificant reduction was recorded with 10 and 20 g compost/kg soil concentration (Table 18).

**Table 18.** Seed germination SG (% ±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weed seeds, grows on *Ageratina* compost g/kg amended with soil

| | | | Concentration (g/kg soil) | | | | |
|---|---|---|---|---|---|---|---|
| **SN** | **Species** | | **0** | **10** | **20** | **40** | **50** |
| (A) Kirtipur | | | | | | | |
| 1 | *Brassica campestris* | SG | 60±8.16 a | 55±10.00 a | 52.5±5.00 a | 50±0.00 a | NG |
| | | SL | 16.58±1.96 c | 17.25±1.09 c | 12.71±1.36 b | 4.41±1.49 a | NG |
| | | RL | 14.40±2.11 c | 15.10±1.34 c | 11.53±1.16 b | 3.46±0.91 a | NG |
| 2 | *Triticum aestivum* | SG | 62.5±9.57 a | 57.5±5.00 a | 55±12.90 a | 52.5±5.00 a | 50±11.54 a |
| | | SL | 17.99±0.50 c | 17.59±0.91 c | 13.20±4.37 b | 5.60±1.54 a | 4.44±0.19 a |
| | | RL | 17.41±0.56 c | 17.10±0.73 c | 12.68±4.23 b | 5.27±1.49 a | 4.25 ±0.19 a |
| 3 | *Ageratum conyzoides* | SG | 55±12.90 a | 52.5±5.00 a | NG | NG | NG |
| | | SL | 3.15±0.24 b | 2.14±0.10 a | NG | NG | NG |
| | | RL | 2.92±0.25 b | 1.75±0.41 a | NG | NG | NG |
| 4 | *Bidens pilosa* | SG | 57.5±5.00 b | 55±5.77 ab | 52.5±5.00 ab | 50±0.00 a | NG |
| | | SL | 13.19±0.79 d | 8.94±0.79 c | 3.62±0.98 b | 2.30±0.19 a | NG |
| | | RL | 12.37±0.55 d | 8.74±0.91 c | 3.21±0.93 b | 2.02±0.21 a | NG |
| 5 | *Cyperus rotundus* | SG | 55±10.00 a | 52.5±5.00 a | NG | NG | NG |
| | | SL | 3.86±0.44 b | 3.01±0.27 a | NG | NG | NG |
| | | RL | 3.55±0.45 b | 2.97±0.53 a | NG | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 65±5.77 b | 55±5.77 ab | 39±23.41 a | NG | NG |
| | | SL | 4.64±0.70 b | 3.01±0.27 a | 2.81±0.07 a | NG | NG |
| | | RL | 4.32±0.71 b | 2.77±0.29 a | 2.51±0.16 a | NG | NG |
| (B) Bhaktapur | | | | | | | |
| 1. | *Brassica campestris* | SG | 70±8.16 b | 62.5±5.00 ab | 57.5± 5.00 a | 55±10.00 a | NG |
| | | SL | 12.09±8.08 c | 10.68±8.41 c | 7.08±6.23 b | 2.62±2.57 a | NG |
| | | RL | 10.58±7.11 c | 9.77±7.75 c | 6.71±5.90 b | 2.21±2.15 a | NG |
| 2. | *Triticum aestivum* | SG | 67.5±5.00 b | 62.5±5.00 ab | 57.5±9.57 ab | 57.5±9.57 ab | 52.5±9.57 a |
| | | SL | 12.24±8.61 c | 10.52±8.72 bc | 7.90±7.30 b | 3.41 ±3.02 a | 2.41±2.33 a |
| | | RL | 10.88±8.54 c | 9.83±8.58 bc | 7.61±7.08 b | 3.03±2.87 a | 2.23±2.15 a |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3. | *Ageratum conyzoides* | SG | 55 ± 10.00 a | 52.5±5.00a | NG | NG | NG |
| | | SL | 1.73±1.60 b | 1.17±1.13 a | NG | NG | NG |
| | | RL | 1.61±1.48 b | 1.03±1.00 a | NG | NG | NG |
| 4. | *Bidens pilosa* | SG | 60±8.16a | 57.5±5.60 a | 52.5±12.58 a | 52.5±5.00 a | NG |
| | | SL | 7.58±6.30 d | 5.13±4.58c | 2.14±2.08 b | 1.21±1.17 a | NG |
| | | RL | 7.31±6.07d | 5.01±4.45 c | 1.97±1.92 b | 1.07±1.04 a | NG |
| 5. | *Cyperus rotundus* | SG | 57.5±5.00 a | 52.5±9.57 a | NG | NG | NG |
| | | SL | 2.27 ±1.96 b | 1.64±1.51 a | NG | NG | NG |
| | | RL | 2.05±1.82 b | 1.44±1.34 a | NG | NG | NG |
| 6. | *Galinsoga parviflora* | SG | 62.5±5.00 b | 55±5.77 ab | 52.5±5.00 a | NG | NG |
| | | SL | 3.01±2.30 b | 1.62±1.50 a | 1.49±1.32 a | NG | NG |
| | | RL | 2.80±2.15 b | 1.43±1.39 a | 1.22±1.20 a | NG | NG |

Values (mean ±SD) bearing the same letters in the same column do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at P=0.05 NG-No Germination

#### 4.1.8.2 *Parthenium hysterophorus* L.

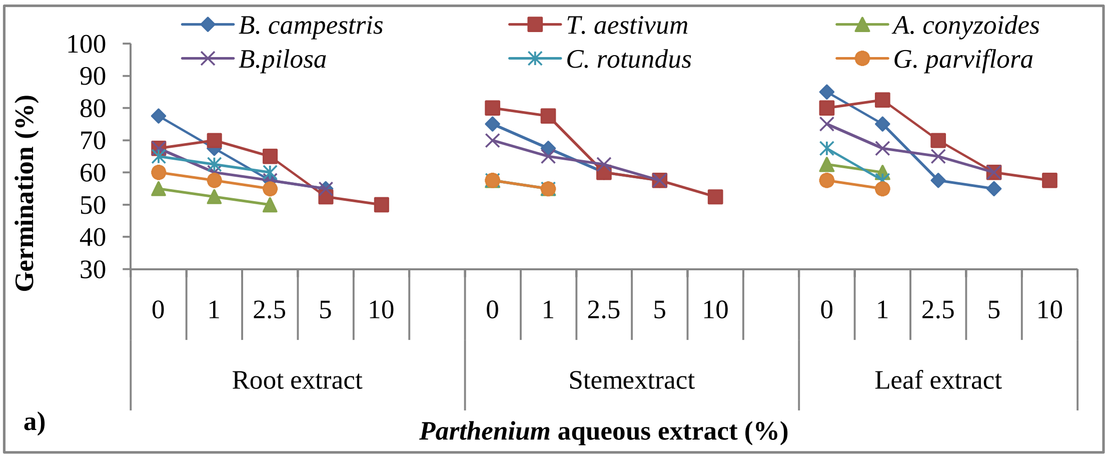
##### 4.1.8.2.1 Aqueous extract

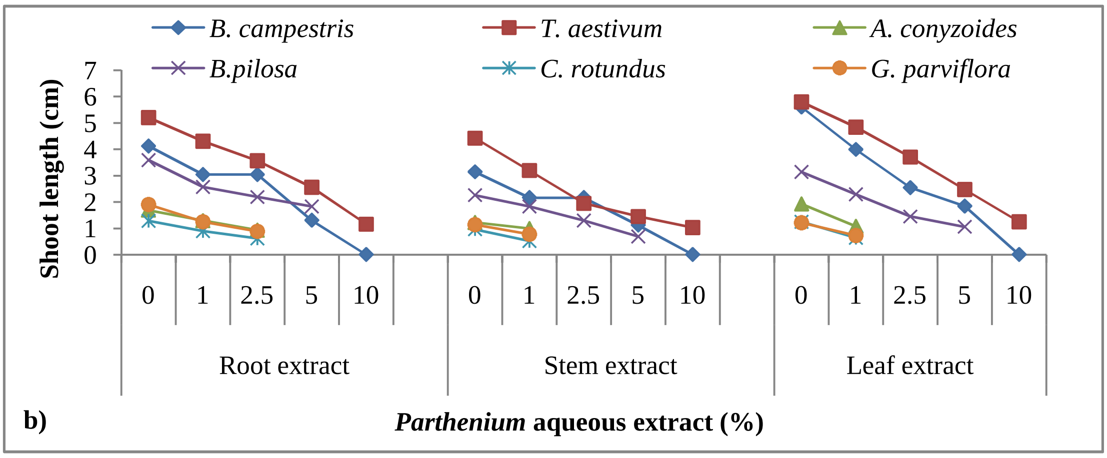
Seed germination percentage and the extent of seedling growth (SL and RL) mostly decreased with an increase in the concentration of *Parthenium hysterophorus* root, stem and leaf aqueous extracts in both crops (*Brassica campestris* and *Triticum aestivum*) and different weeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) (Figure 10a).

Seed germination of *Brassica campestris* showed a significant reduction with 1% root and leaf extracts of *Parthenium hysterophorus*, but it was significant with 2.5 and 5% root, stem, and leaf extracts. SL and RL of *Brassica campestris* seedlings were significantly reduced with all concentrations of root stem and leaf extracts with reference to the control. SG was completely inhibited with 10% treatment (Figure 10a). Seed germination of *Triticum aestivum* showed an insignificant reduction in treatments with 1, 2.5, and 5% root and leaf extract of *Parthenium hysterophorus*, but it reduced significantly with 10% extracts in all cases. Stem extract caused a significant reduction in SG even at 2.5 and 5% concentrations. Shoot length and root length also decreased significantly with increasing concentrations of the root, stem, and leaf extracts (Figure 10a).

The impact of the aqueous extract on weeds was more or less similar in all the weeds**.** SG of *Ageratum conyzoides* got reduced significantly with 1 and 2.5% root extract of

*Parthenium hysterophorus*, but significantly (P=0.05) with 1 and 2.5% of the stem and leaf extracts. The SL and RL were insignificantly reduced with 1% stem extract of *Parthenium hysterophorus*, but the reduction was significant with the root and leaf extracts. Total inhibition of *Ageratum conyzoides* seed germination was observed with 5 and 10% of root extract and with 2.5, 5, and 10% of the stem and leaf extracts of *Parthenium hysterophorus* (Figure 10a). SG of *Bidens pilosa* was reduced significantly in the *Parthenium hysterophorus* root, stem, and leaf extract up to 5%. The SL and RL of the seedlings were reduced significantly (P=0.05) compared to the control with *Parthenium hysterophorus* root extract (1, 2.5, and 5%). Both SL and RL in stem extract of *Parthenium hysterophorus* L. showed an insignificant reduction with a low concentration (1%) but a significant one (P=0.05) with high concentrations (2.5 and 5%). Similarly, high concentrations of leaf extract cause significant reduction in SL and RL both (Figures 10b, c). Seed germination of *Cyperus rotundus* and *Galinsoga parviflora* was reduced insignificantly in the root, stem, and leaf extracts of *Parthenium hysterophorus*. The SL and RL were reduced significantly with all the treatments. SG was inhibited with higher concentrations (Figure 10a).



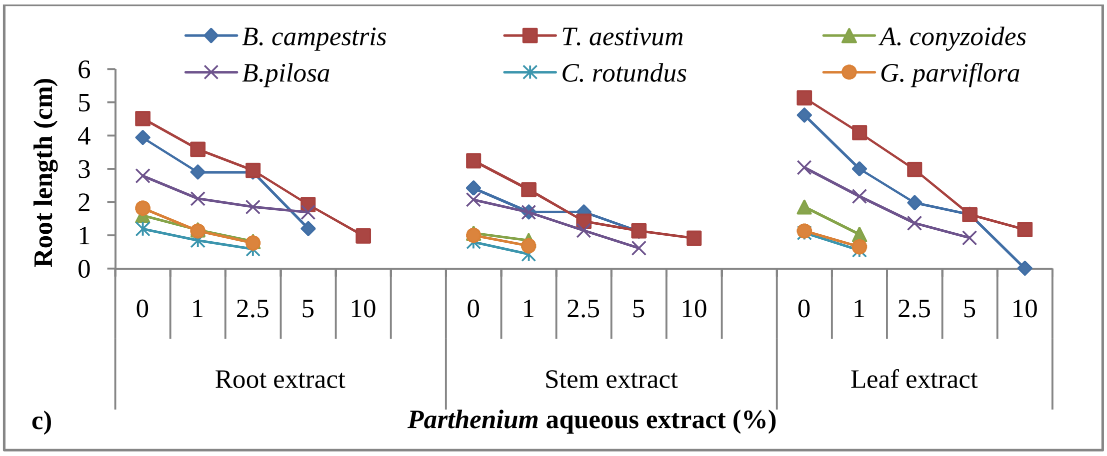



**Figure 10:** (a) Seed germination (% ±SD), (b) Shoot length (cm ±SD) and (c) Root length (cm ±SD) of crops and weed seeds on aqueous extract (root, stem and leaves) of *Parthenium hysterophorus*

#### 4.1.8.2.2 Compost extract

Crop and weed seeds grown on petri plates with different concentrations of compost aqueous extract ranging from 1 to 10% showed some different responses. SG, SL, and RL decreased with an increase in the concentration of *Parthenium hysterophorus* compost extract (in the lab), more in the weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) than in the crops (*Brassica campestris* and *Triticum aestivum*) (Figure 11a).

Seed germination of *Brassica campestris* showed a significant reduction with 1 and 2.5% of *Parthenium hysterophorus* compost extract, but it reduced significantly with 5% and got completely inhibited at 10% *Parthenium hysterophorus* compost extract. SG of *Triticum aestivum* enhanced significantly (P=0.05) at 1 and 2.5% concentration, but declined significantly at higher concentrations (5 and 10%). The SG of *Ageratum conyzoides* and *Galinsoga parviflora* got reduced insignificantly up to 5 %, but it showed a significant reduction with 2.5 and 5% treatments of *Bidens pilosa*. Total inhibition of weed was observed at 10%. No SG of *Cyperus rotundus* was observed even at lower concentrations of the *Parthenium hysterophorus* compost extract (Figure 11a).

The shoot length and root length of *Brassica campestris* were significantly reduced with an increase in the concentration of *Parthenium hysterophorus* compost extract. In *Triticum aestivum*, the SL and RL increased significantly at 1% concentration but reduced significantly at higher concentrations (5 and 10%). In the weed seedlings, the axis growth was significantly reduced with increasing concentrations of compost extracts (Figure 11b).

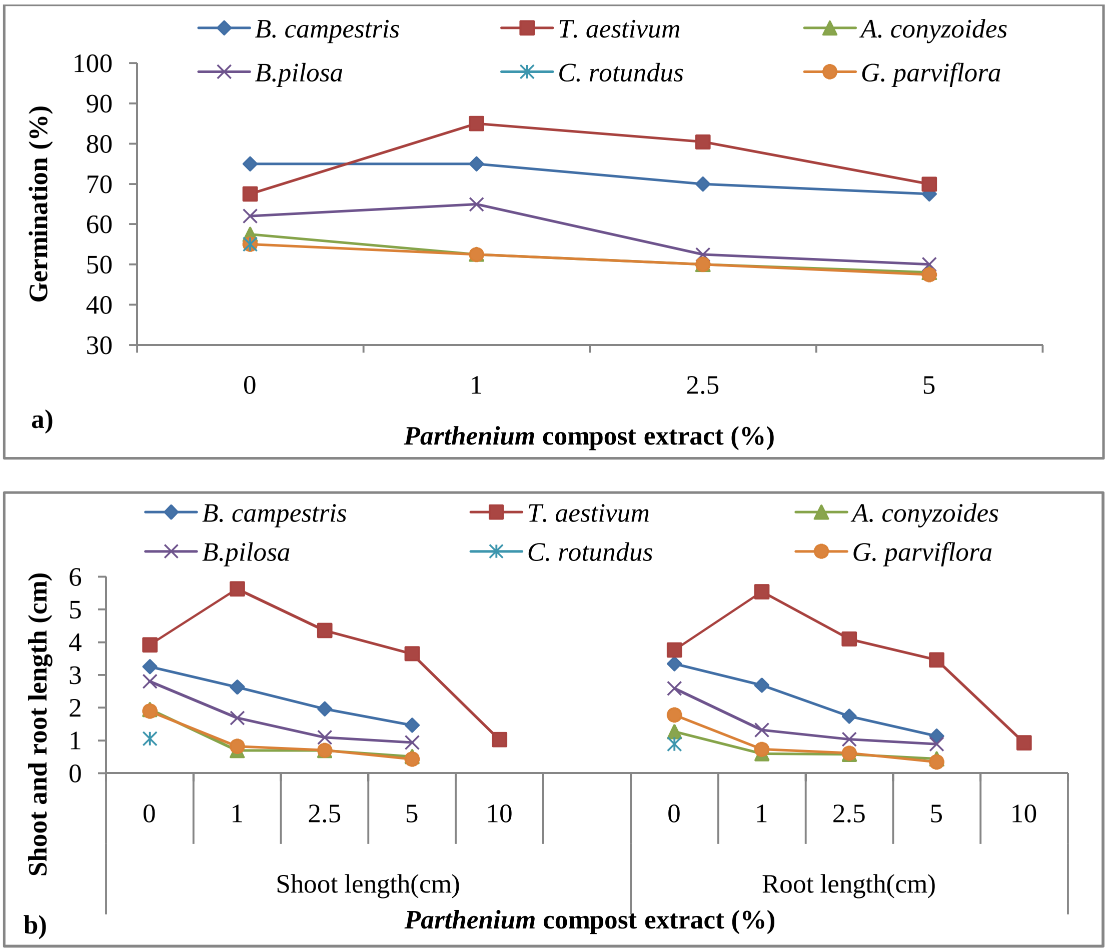



**Figure 11:** (a) Seed germination (% ±SD), (b) Shoot length SL (cm ±SD) and (c) Root length RL (cm ±SD) of crops and weed seeds on compost extract of *Parthenium hysterophorus*

#### 4.1.8.2.3 Compost g/kg amended with soil

The seed germination of crops *Brassica campestris* and *Triticum aestivum* increased insignificantly with 10 and 20 g compost/kg soil treatment, but it was significantly reduced with high concentrations in compost amended with soil. SG of *Brassica campestris* was inhibited at 50 g/kg soil treatment (Table 19) in Kirtipur and Bhaktapur soil. The SG of weeds (*Ageratum conyzoides, Bidens pilosa*, and *Galinsoga parviflora*) was reduced at 10 and 20 g compost/kg soil treatment, while that of *Cyperus rotundus* was completely inhibited at all treatments of *Parthenium hysterophorus* compost g/kg soil (Table 19). The SL and RL of *B. campestris* and *T. aestivum* significantly increased with 10 and 20 g compost/kg soil treatment but decreased significantly with high concentrations (40 gm compost/kg and above) in both the crops. The SL and RL of weed *Ageratum conyzoides* reduced significantly with 10 and 20 g compost/kg soil treatments, but only with 20 g compost/kg soil treatment in the case of *Bidens pilosa* and *Galinsoga parviflora* in Kirtipur and Bhaktapur soil (Table 19).

**Table 19.** Seed germination SG (% ±SD), shoot length SL ( (cm ±SD) and root length RL (cm ±SD) of crops and weed seeds, grows on *Parthenium hysterophorus* compost g/kg amended with soil

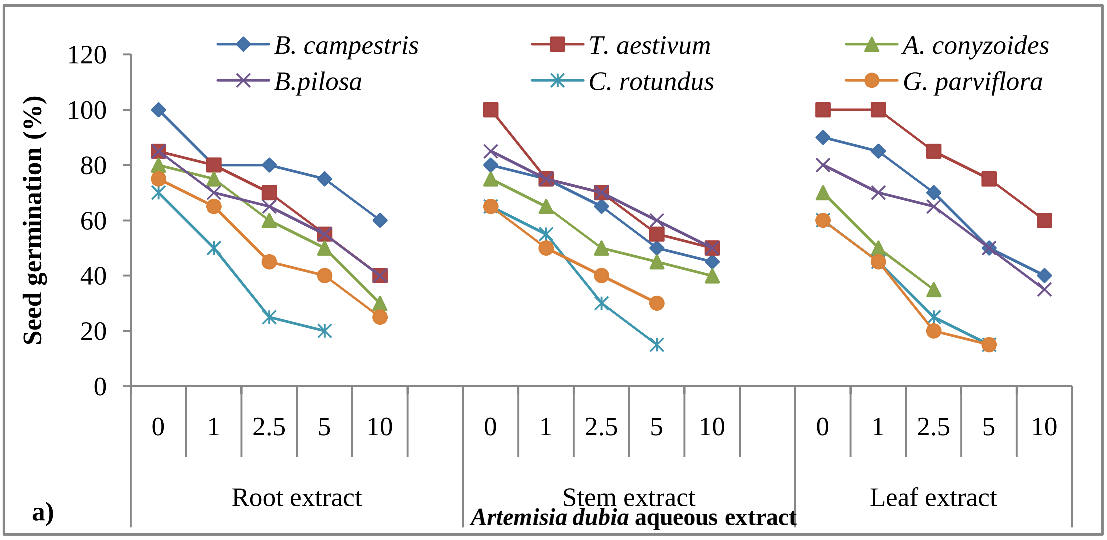
| SN | Species | | 0 | 10 | 20 | 40 | 50 |
|---|---|---|---|---|---|---|---|
| (A) Kirtipur | | | | | | | |
| 1 | *Brassica campestris* | SG | 60±14.14 b | 65±12.50 b | 70±8.16 ab | 60±0.00 a | NG |
| | | SL | 8.16±7.21 b | 12.31±8.84 b | 19.9±10.19b | 6.25±5.10 a | NG |
| | | RL | 6.44±5.92 b | 10.92±7.93 b | 10.33±5.87b | 5.14±4.11 a | NG |
| 2 | *Triticum aestivum* | SG | 57.5±5.00ab | 70±11.54 bc | 68±14.14 bc | 65±5.77 ab | 52.5±12.58a |
| | | SL | 9.26±7.73 b | 14.64±9.83c | 17.23±11.4c | 9.86±7.72 b | 3.68±3.56 a |
| | | RL | 7.66±6.47 b | 11.71±7.83 c | 12.31±9.03c | 8.24±6.42ab | 3.30±3.20 a |
| 3 | *Ageratum conyzoides* | SG | 55±5.77 a | 52.5±5.00 a | 45±5.00 a | NG | NG |
| | | SL | 2.25±2.14 b | 1.05±1.02 a | 0.90±0.86 a | NG | NG |
| | | RL | 1.90±1.76 b | 0.96±0.92 a | 0.82±0.79 a | NG | NG |
| 4 | *Bidens pilosa* | SG | 55±12.90 b | 50±8.16 ab | 47.5±9.57 a | NG | NG |
| | | SL | 2.27±2.19 b | 2.01±1.94 b | 1.26±1.21 a | NG | NG |
| | | RL | 2.00±1.94 b | 1.84±1.79 b | 1.04±1.02 a | NG | NG |
| 5 | *Cyperus rotundus* | SG | 52.5±9.57 a | NG | NG | NG | NG |
| | | SL | 1.21±1.16 a | NG | NG | NG | NG |
| | | RL | 1.09±1.05 a | NG | NG | NG | NG |
| 6 | *Galinsoga parviflora* | SG | 55±5.77 a | 52.5 ±5.00 a | 50±8.16 a | NG | NG |
| | | SL | 1.69±1.62 b | 1.32±1.27 b | 0.71±0.68 a | NG | NG |
| | | RL | 1.63±1.54 b | 1.24±1.19 b | 0.61±0.59 a | NG | NG |
| (B) Bhaktapur | | | | | | | |
| 1. | *Brassica campestris* | SG | 62.5±15.0 b | 67.5±9.57 b | 65.5 ±9.47 b | 60 ±8.16 a | NG |
| | | SL | 8.7 ±7.25 ab | 11.93 ±8.55 b | 16.83 ±11.92 b | 7.41 ±6.06 a | NG |
| | | RL | 7.5 ±6.18 ab | 10.10 ±7.45 b | 9.29 ±6.96 b | 5.57 ±4.54 a | NG |
| 2. | *Triticum aestivum* | SG | 55 ±5.77 a | 70 ±8.16 b | 72.5 ±5.0 b | 55 ±5.77 a | 52.5 ±5.00 a |
| | | SL | 8.22 ±7.73 b | 14.65 ±9.84 c | 17.37 ±10.96 c | 8.47 ±8.00 b | 4.33 ±4.21 a |
| | | RL | 6.86 ±6.39 b | 11.92 ±7.99 c | 13.67 ±8.70 c | 6.87±6.45 b | 3.66 ±3.59 a |
| 3. | *Ageratum conyzoides* | SG | 52.5 ±5.00 b | 50 ±0.00 ab | 47.5 ±5.00 a | NG | NG |
| | | SL | 2.30 ±2.17 c | 1.18 ±1.14 b | 0.65 ±0.63 a | NG | NG |
| | | RL | 2.11 ±1.99 c | 1.04 ±1.00 b | 0.55 ±0.53 a | NG | NG |
| 4. | *Bidens pilosa* | SG | 52.5 ±5.00 a | 50 ±11.54 a | 47.5 ±5.00 a | NG | NG |
| | | SL | 2.32 ±2.24 c | 1.73 ±1.66 b | 1.05 ±1.02 a | NG | NG |
| | | RL | 2.20 ±2.13 c | 1.62 ±1.56 b | 0.95 ±0.92 a | NG | NG |
| 5. | *Cyperus rotundus* | SG | 55 ±12.9 a | NG | NG | NG | NG |
| | | SL | 0.88 ±0.82 a | NG | NG | NG | NG |
| | | RL | 0.76 ±0.71 a | NG | NG | NG | NG |
| 6. | *Galinsoga parviflora* | SG | 55 ±5.77 a | 52.5 ±9.57 a | 50±14.14 a | NG | NG |
| | | SL | 1.72 ±1.65 b | 1.33 ±1.28 b | 0.74 ±0.68 a | NG | NG |
| | | RL | 1.61 ±1.56 b | 1.24 ±1.20 b | 0.64 ±0.59 a | NG | NG |

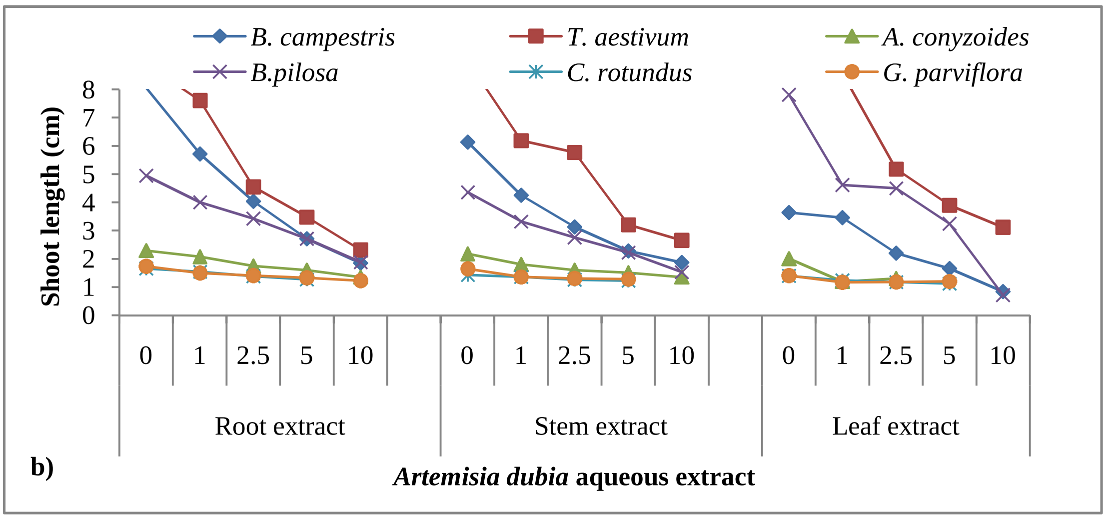
Values (mean ±SD) bearing the same letters in the same column do not differ significantly according to ANOVA followed by Duncan's Multiple Range Test at P=0.05. NG-No Germination

### 4.1.8.3 *Artemisia dubia* Wall Ex. Besser

#### 4.1.8.3.1 Aqueous extract

Seed germination of both crops (*Brassica campestris* and *Triticum aestivum*) was reduced significantly with an increase in the concentration of root, stem, and leaf extracts of *Artemisia dubia* (Figure 12a). A significant decrease in the germination of *Brassica campestris* seeds was observed at 1, 2.5, and 5% root extract but a significant reduction was noticed at 5 and 10% concentrations. Similarly, an insignificant decrease in *Triticum aestivum* seed germination was observed up to 2.5% root and leaf extract treatments. Germination of *Brassica campestris* seeds was found to be higher in root extract than the stem or leaf extract, but in *Triticum aestivum*, the reduction in seed germination was more in root and stem extract treatments than the leaf extract. Inhibitions of seedling growth were the highest with leaf extract in *Brassica campestris*, but the growth was enhanced with root extracts in *Triticum aestivum* (Figures 12b, c).



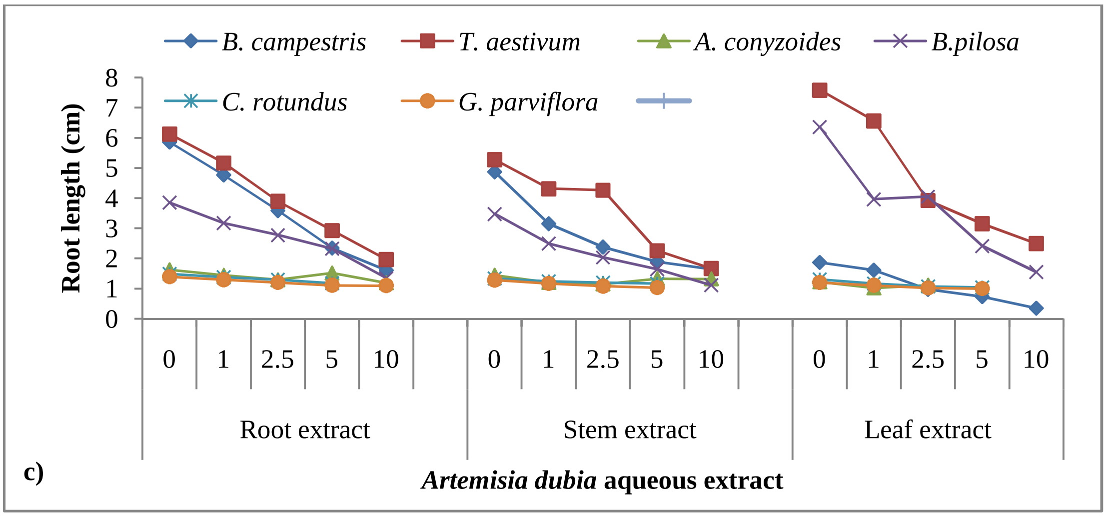
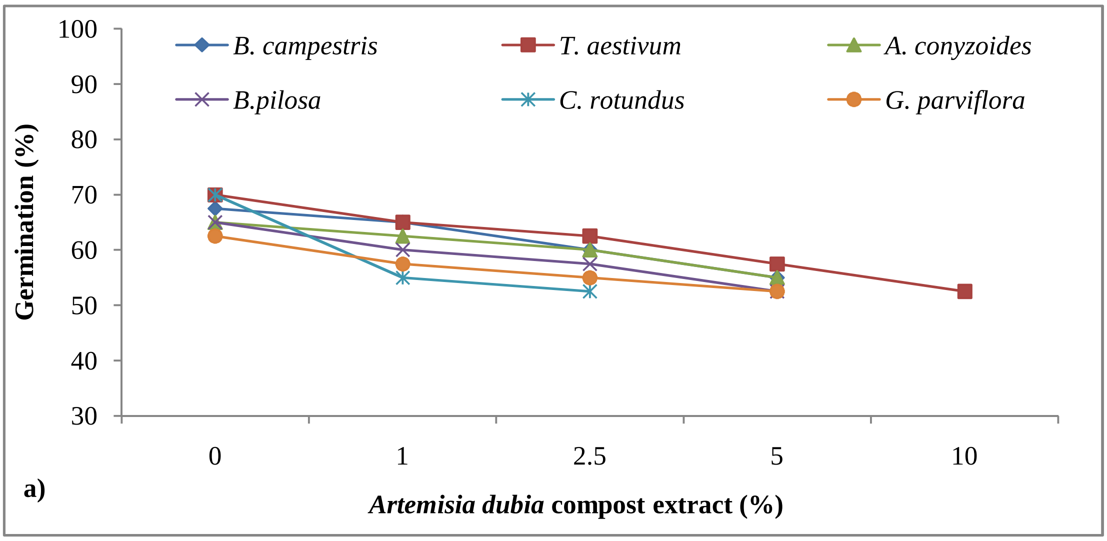



**Figure 12:** (a) Seed germination (% ±SD), (b) Shoot length (cm ±SD) and (c) Root length (cm ±SD) of crops and weed seeds on aqueous extract (root, stem and leaves) of *Artemisia dubia*

An insignificant effect on seed germination was observed up to 2.5% of the root, stem, and leaf extracts in *Bidens pilosa* (Figure 12a) and up to 1% of these extracts in *Ageratum conyzoides* (Figure 12a). In both weeds, seed germination decreased significantly (P=0.05) with higher concentrations of extracts. The SL and RL of seedlings decreased significantly (P=0.05) in all treatments and with an increase in the extract concentration (Figures 12b, c). Leaf extract of 5 and 10% concentration was found to be more detrimental for germination of *Ageratum conyzoides* seeds, and no germination was observed at all. SG of *Galinsoga parviflora* and *Cyperus rotundus* decreased with an increase in the concentration of the root, stem, and leaf extracts of *Artemisia dubia* (Figure 12a). In both weeds, SG was better with the root extract than with the extracts of stem and leaves. The lowest SG percentage was observed with leaf extract treatment, indicating that it had a more profound allelopathic effect in comparison to the root or stem extracts. A significant decrease in SL and RL of seedlings was observed with high concentrations. Germination of *Galinsoga parviflora* seed was completely inhibited with 10% stem and leaf extracts of *A. dubia* (Figure 12a). Similarly, complete inhibition of SG was observed with 10% root stem and leaf extracts in *Cyperus rotundus* (Figure 12a).

#### 4.1.8.3.2 Compost extract

Seed germination of *Brassica campestris* showed an insignificant reduction with 2.5 and 5% of the *A. dubia* compost extract and was completely inhibited at 10% concentration. SG of *T. aestivum* at 1 and 2.5% compost extract treatment were the same, but at higher concentrations (5 and 10%) it reduced significantly. The SG of weeds *Ageratum conyzoides* and *Galinsoga parviflora* reduced significantly up to 5 %, but *Bidens pilosa* showed a significant reduction with 1 and 2.5% treatments. Total inhibition of germination was observed at 10%. SG of *Cyperus rotundus* exhibited significant reduction with 1 and 2.5% of *Artemesia dubia* compost extract in comparison to control (Figure 13a). The shoot and root length of *Brassica campestris* was reduced significantly with the increase in the concentration of *Artemesia dubia* compost extract. In *Triticum aestivum*, the SL and RL displayed insignificant same variation at 2.5 and 5% concentration but decreased significantly at higher concentrations (5 and 10%). The seedling growth of *Bidens pilosa* was insignificantly reduced at 1-5%. SL and RL of weed seedlings reduced significantly with increasing concentrations of the compost extracts (Figure 13b).



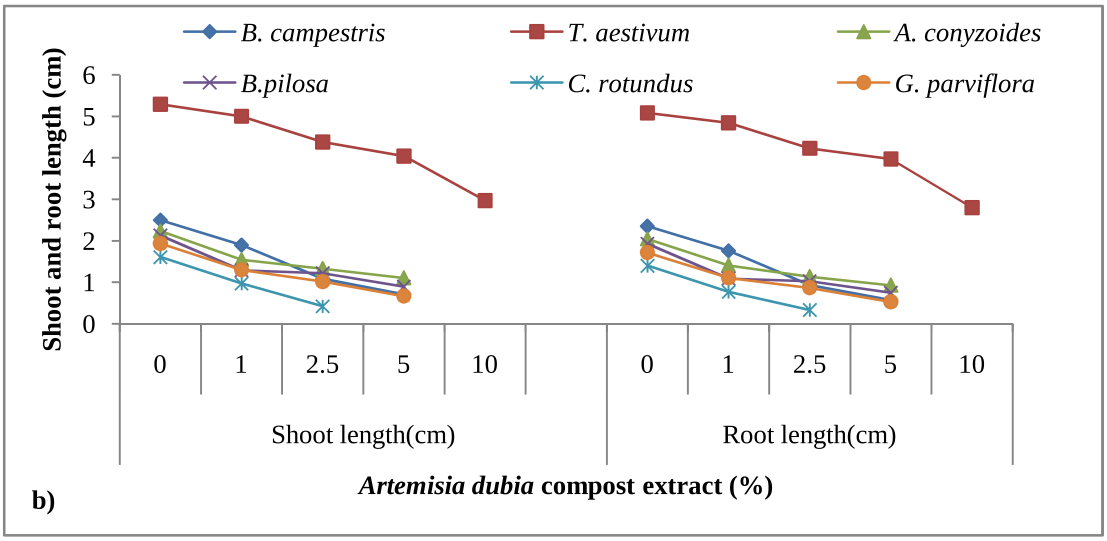




**Figure 13:** (a) Seed germination (% ±SD), (b) Shoot length SL (cm ±SD) and (c) Root length RL (cm ±SD) of crops and weed seed on compost extract of *Artemisia dubia*

#### 4.1.8.3.3 Compost g/kg

The seed germination of crops (*Brassica campestris* and *Triticum aestivum*) varied insignificantly with 10-40 g compost/kg soil treatment, but it was reduced significantly with high concentrations of compost amended with the soil. SG of *Brassica campestris* was totally inhibited at 50 gm/kg soil treatment in Kirtipur and Bhaktapur soil (Table 20). The SG of weeds (*Ageratum conyzoides, Bidens Pilosa, Cyperus rotundus*, and *Galinsoga parviflora*) showed insignificant reduction at 10, 20, and 40 g compost/kg soil treatments (Table 20). The shoot and root length of *Brassica campestris* significantly decreased with 20 and 40 compost g/kg soil treatment whereas in *Triticum aestivum* seedling growth was insignificantly reduced at higher concentration. The SL and RL of all the weeds got reduced significantly with 10, 20, and 40 g compost/kg soil treatment (Table 20).

**Table 20:** Seed germination SG (% ±SD), shoot length SL (cm ±SD) and root length RL (cm ±SD) of crops and weed seeds, grows on *Artemisia dubia* compost g/kg amended with soil

| | | | **Concentration (gm/kg soil)** | | | | |
|---|---|---|---|---|---|---|---|
| **SN** | **Species** | | **0** | **10** | **20** | **40** | **50** |
| (A) Kirtipur | | | | | | | |
| 1 | *Brassica campestris* | SG | 62.5± 8.00a | 60±8.16a | 57.5 ± 5.00a | 55±5.77a | NG |
| | | SL | 14.38±11.33c | 8.21±7.45b | 6.11±5.06ab | 4.93±4.53a | NG |
| | | RL | 14.07±11.15c | 7.81 ±7.11b | 5.84±4.83ab | 4.57±4.20a | NG |
| 2 | *Triticum aestivum* | SG | 65 ±10.00b | 65±5.77b | 62.5 ± 5.00ab | 55±5.77ab | 52.0±9.57a |
| | | SL | 18.84±13.25b | 18.03±13.41b | 16.80±13.19b | 13.71±13.22ab | 10.46±10.14a |
| | | RL | 18.43±12.96b | 17.77±13.22b | 16.49±12.96b | 13.24±2.77ab | 10.14±9.84a |
| 3. | *Ageratum conyzoides* | SG | 62.5±5.00a | 57.5±5.00a | 55±10.00a | 52.5±5.00a | NG |
| | | SL | 5.15±4.23b | 4.29±3.78ab | 3.80±3.51ab | 3.14±3.04a | NG |
| | | RL | 4.81± 3.91b | 3.96±3.48ab | 3.37±3.11ab | 2.78±2.71a | NG |
| 4. | *Bidens pilosa* | SG | 65.2±9.57a | 57.5±5.00a | 55±10.00a | 52.5±9.57a | NG |
| | | SL | 8.07±6.68b | 7.18±5.97b | 4.93±4.75a | 4.57±4.45a | NG |
| | | RL | 7.81±6.41b | 6.94±5.83b | 4.74±4.58a | 4.42±4.31a | NG |
| 5. | *Cyperus rotundus* | SG | 60±14.14a | 57.5±9.57a | 52.5±17.05a | NG | NG |
| | | SL | 4.47±3.74b | 3.45±3.17b | 2.39±2.19a | NG | NG |
| | | RL | 4.26±3.57b | 3.29±3.02b | 2.20±2.02a | NG | NG |
| 6. | *Galinsoga parviflora* | SG | 65±5.77a | 60±8,16a | 55±12.90a | NG | NG |
| | | SL | 7.95±5.95b | 6.00±5.03b | 3.36±3.09a | NG | NG |
| | | RL | 7.77±5.78b | 5.77±4.84b | 3.15±2.92a | NG | NG |
| (B) Bhaktapur | | | | | | | |
| 1. | *Brassica campestris* | SG | 62.5±9.57a | 57.5±5.00a | 55±5.77a | 52.5±9.57a | |
| | | SL | 13.01±10.22c | 10.32±9.00bc | 7.55±6.59ab | 4.81±4.65a | |
| | | RL | 12.60±9.91c | 10.09±8.79bc | 7.36±6.42ab | 4.66±4.50a | |
| 2. | *Triticum aestivum* | SG | 67.5±9.57c | 60±8.16bc | 60±8.16b | 57.5±9.57a | 55±5.77a |
| | | SL | 18.22±12.81c | 14.52±11.39bc | 11.81±9.85ab | 9.78±8.52a | 7.31±6.70a |
| | | RL | 17.85±12.62d | 14.45±11.37cd | 11.81±9.85ab | 9.78±8.52a | 7.31±6.70a |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3. | *Ageratum conyzoides* | SG | 62.5±5.00b | 57.5±5.00ab | 55±5.77ab | 52.5±5.00a | NG |
| | | SL | 5.34±4.50c | 4.31±3.97bc | 3.58±3.14ab | 2.34±2.27a | NG |
| | | RL | 5.12±4.25c | 4.08±3.75bc | 3.37±2.96ab | 2.13±2.05a | NG |
| 4. | *Bidens pilosa* | SG | 60±14.14a | 60±8.16a | 57.5±5.00a | 52.5 ±9.57a | NG |
| | | SL | 8.11±6.71c | 7.24±6.01b | 6.06±5.32ab | 4.42±4.31a | NG |
| | | RL | 7.81±6.46b | 6.99±5.83b | 4.74±4.58a | 4.42±4.31a | NG |
| 5. | *Cyperus rotundus* | SG | 57.5±5.00a | 55±10.00a | 52.5±9.57a | NG | NG |
| | | SL | 4.50±3.97c | 2.86±2.63b | 1.78±1.72a | NG | NG |
| | | RL | 4.21±3.70c | 2.64±2.44b | 1.64±1.58a | NG | NG |
| 6. | *Galinsoga parviflora* | SG | 62.5±5.00a | 57.5±5.00a | 55±5.77a | NG | NG |
| | | SL | 6.56±5.16b | 5.20±4.56b | 3.36±3.21a | NG | NG |
| | | RL | 6.33±4.98a | 4.75±4.40b | 3.05±2.92a | NG | NG |

Values (mean ±SD) bearing the same letters in the same column do not differ significantly according to ANOVA followed by Duncan‘s Multiple Range Test at P=0.05 NG-No Germination

## 4.2 Discussion

### 4.2.1 Weed community analysis

The present work showed the frequency, density and IVI of those *Ageratum conyzoides* and *Cyperus rotundus* L. as the dominant weeds on the selected winter crop fields. The work conducted by Manandhar *et al.* (2007) also demonstrated that the *Cyperus rotundus* and *Ageratum conyzoides* were present as the dominant weeds on the paddy field of Kirtipur based on IVI followed by other 52 weeds.

The present work showed the higher IVI value among the weeds from the family Asteraceae (*Ageratum conyzoides*, *Bidens pilosa*, *Galinsoga parviflora*) and Cyperaceae (*Cyperus rotundus*) in the winter crop (wheat and mustard) fields. Dangol (2013) also reported a high number of weeds from Asteraceae in the wheat crop fields of Nepal. The frequency and density of weeds like *Galinsoga parviflora* and *Ageratum conyzoides* were found to be high in the fields of wheat, mustard in winter. Neogi and Rao (1980) also reported that the frequency and density of weeds like *Galinsoga parviflora* and *Ageratum conyzoides* in agricultural fields of Khasi hills, Meghalaya, India, were higher in winter than in summer and spring seasons.

*Ageratum conyzoides* have a capitulum inflorescence which produces an enormous number of more than 40,000 seeds from a single plant and dispersed into a wide area making it invasive (Dogra *et al.*, 2009a; Kohli *et al.*, 2006). The invasion of *Ageratum conyzoides* increases the soil's physical and chemical properties (organic carbon and inorganic matter, NPK, Calcium, Magnesium, and chloride) except the pH in comparison to other parameters (Dogra *et al.*, 2009b). The allelochemicals like phenolics may contribute to the ability of particular alien species to become dominant in the native plant communities (Dogra *et al.*, 2009b; Ridenour & Callaway, 2001). *Ageratum conyzoides* have a strong competitive ability and fast propagation (Kaur *et al*., 2012).

The high importance value index (IVI) value of *Galinsoga parviflora* in the winter crop fields is possibly due to its several features, lack of special requirements for germination, rapid seedling development, the ability to generate roots and establish new plants from the cut stem, the ability to flower after a short period of vegetative growth and production of flowers and fruits throughout the growing seasons, self-compatibility and the production of a large number of viable seeds under a wide range of environmental conditions (Warwick & Sweet, 1983). All these features must have helped in the soil seed bank and establish as a common weed in winter crops.

*Bidens pilosa* was also found as a dominant weed species in the winter crop fields with high IVI values. This may be due to a large number of flower heads (80 heads per plant), with high seed production potential (3000 seeds/ year produced by a single plant) (Mvere, 2004) and capacity to form dense stands (Weber, 2003). Due to high seed production, seed dormancy, seed longevity it possesses higher possibilities of germination and grows into a new plant. These facts probably must have contributed to increasing the IVI of this species.

*Cyperus rotundus* was also quite common and had a high IVI (23.24 to 28.40) in our present study. *Cyperus rotundus* is a noxious weed of the tropical and subtropical regions of the world and is reported in 52 different crops in 92 countries (Rao, 2000). The reasons to obtain a high IVI value of *Cyperus rotundus* may be due to its ability to propagate by the underground modified parts like rhizome, tuber, and corms (Brosnan & DeFrank, 2008; Lati *et al*., 2011).

*Cyperus rotundus* is distributed all over the tropical, subtropical, and temperate regions of the world. The plants are found in all the seasons but its populations are more in the rainy and winter period, damaging the crop and reducing crop production (Ambastha, 1982).

*Cyperus rotundus* is a perennial plant that rarely reproduces through seeds (Riemens *et al*., 2008). Seed germination mostly depends on the seed size, the larger the seed, the higher the chances of germination (Thullen & Keeley, 1979; Riemens *et al*., 2008). *Cyperus rotundus* plant spreads through its profuse production of the rhizome, basal bulbs, and tubers. These tubers undergo a period of dormancy after separating from a mother plant. The irregular germination of a new plant of *Cyperus rotundus* from dormant tubers in varying degrees makes it a weed plant (Omezine and Skhiri, 2009). The present study showed the dominant weed was *Cyperus rotundus* on winter crops' field. Similar results were also found by Marques *et al*. (2017), the two dominant weeds *C. rotundus* and *Portulaca oleraceae* with the highest density and IVI in the field of eggplant. Different types of weeds present in the agricultural fields interfere directly or indirectly depending on the geographic region, crop types, crop production, and cultivars in the crop production system.

### 4.2.2 Phenology of selected weed

The above-mentioned weeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*) are also quite common in summer crops. Several studies showed that the differences of morphological and phenological behavior among plants are manifested at different stages of life (El Keblawy, 2003; Clavijo, 2001) and are dependent on environmental factors (Kadmon & Shmida, 1990; Hegazy *et al.*, 2005). A study conducted by Kanwar and Kharwara (1988) demonstrated that at the maize field (summer crop) of Himachal Pradesh in India, *Ageratum conyzoides* starts appearing at the tassel stage of maize, produces flowers, and sets seeds by the time the crop is harvested. Reddi *et al*. (1977) also reported that *Ageratum conyzoides* is a major weed in the sugarcane crop field. Rao (2000) and Iqbal and Cheema (2009) also noted the weed *Cyperus rotundus* in the summer crop fields like cotton, rice, sugarcane, and maize in the Indus valley. In *Cyperus rotundus* the fruiting stage continues only for three months (Dec, Jan and feb) so this may be due to its lower seed density of *Cyperus* seeds in the soil and also its low seed production than in other species (Brosnan & DeFrank, 2008; Lati *et al*., 2011). After seeding of *Cyperus rotundus*, the growth in early stages is slow but in later stages, it grows very fast (within 30 to 45 days) (Juraimi & Begum, 2009). Molero and Stoller (1978) explained that the *Cyperus rotundus* germinates in the mid or late spring season and after four weeks of the initial plant development. The cycle repeats and new shoots develop during July in the central US and the process continues.

In favorable condition, *Galinsoga parviflora* produces several generations at its vegetation stage, because this plant needs 4 to 6 weeks for full growth (Rutgers

Cooperation Extention, 1999). In tropical areas, *Galinsoga parviflora* can germinate at any time of the year (Toit & Court, 1991).

*Bidens pilosa* can be found in all seasons in tropical areas, but it grows in the summer and wetter part of the season (Holm *et al*., 1977). Kirszenzaft and Felippe (1978) described that *Bidens pilosa* is a short-day plant, taking short time (10-14 short days) for inducing flowers.

*Ageratum conyzoides* seeds are small, black in color, and light in weight along with pappus, which helps them to disperse up to thousands of miles (Bansal, & Singh, 1986). Seeds of *G. parviflora* are also black in color and are with pappus, which helps them to disperse easily. It is reported that smaller seeds germinate faster than larger ones because the smaller seeds are colonized in micro places in advance of larger seeds (Norden *et al*., 2009; Liu *et al*., 2014).

#### 4.2.3 Weed seed characteristics

The size and shape of seeds have also been studied concerning seed banks in the soil. A small size of seeds was observed among *Cyperus rotundus* and *Galinsoga parviflora*. The size of the seed is a key character in determining seed fate, as small seeds are both less attractive to animals and more easily buried in soil than large ones. Data from all four published studies (Thompson *et al*., 1993; Leishman *et al.*, 1998; Funes *et al*., 1999; Moles *et al*., 2000) showed that long-term persistent species tend to have spherical seeds, while short term persistent species have more flattened and/or elongate seeds. In the present study, *Cyperus rotundus* has small oval shaped seeds; *Ageratum conyzoides* and *Galinsoga parviflora* have small conical seeds, and *Bidens pilosa* has long flattened seeds. The seed bank of *Ageratum* and *Galinsoga parviflora* is mostly higher than *Bidens* pilosa in the present study, which may be due to differences in size and shape. The size of the seedling is usually directly related to food reserves or secondary metabolites and mineral content or energy of seeds.

#### 4.2.4 Soil properties

The soil texture of Kirtipur and Bhaktapur was found in sandy loam. Bhattrai (2010) also found the soil texture of Kirtipur is silty loam and the mean pH of the soil was found 6.4 to 6.8. Similarly, the mean value of total nitrogen Bhattrai (2010) and Gautam and Bhattrai (2013) was found 0.16- 0.14%, phosphorus was 0.01% and the potassium content was low in the soil.

Mbong *et al.* (2020) suggested that the distribution of species of Cyperaceae depends on soil properties like soil pH, moisture content, organic matter, exchangeable Ca, and phosphorus. He has conducted the experiments to assess the abundance and distribution of species in relation to soil properties with the three families of Cypereaceae (*Cyperus rotundus*, *Cyperus iria*, and *Cyperus difformis* and other associated species were *Sida acuta*, *Scoparia dulcis*, *Chromolaena odorata*, *Eleusine indica*, *Ludwigia decurens*, etc. The *Cyperus rotundus* showed a strong preference in acidic soil.

High soil nutrients influenced invaders in the invaded range (Maron & Marler, 2007; Tyler *et al.*, 2007). Soil biota and soil nutrients impact invasives of plants like *Bidens pilosa and Saussurea deltoidea* (Cui & He, 2009).

*Ageratum* was found in more silt and clay of the soil, highest soil moisture, possessing highest acidic soil pH of agricultural fields at Bhadaure Tamagi VDC, Kaski, Nepal, (Kunwar & Acharya, 2013). *Galinsoga parviflora* and *Galinsoga quadriradiata* species grow in high levels of N, P, and K (Ivany, 1971). He also stated that flowering was inhibited in absence of N and in the absence of P or K reduction takes place in flowering and root weight was increased in plants of *G. parviflora* with reduced levels of N and K.

#### 4.2.5 Nutrient analysis of selected crops and weed seeds

The seed reserve content (nutrients) is correlated with germination percentages (Soriano *et al*., 2014). During germination, the mobilization of seed reserves varies with the amount of reserve content (like Carbohydrate, protein, lipid) and the species. For various species different seed reserves may have different roles during germination. Zhao *et al.* (2018) found that different patterns of seeds reserve mobilization in six species (*Chloris virgata, Kochia scoparia, Lespedeza hedysaroides, Astragalus adsurgens, Leonurus artemisia, and Dracocephalum moldavica*) during seed germination- Starch and soluble protein was mainly used during seed imbibition stage to the highest germination stage. There was no change in the fat content and it remained relatively constant for all species during germination. These results provide a new outlook into the role of seed reserves as energy resources in the step of germination.

### 4.2.6 Soil weed seed bank

Generally, the difference in the number of weed seedlings density can be explained by several factors like climate, the position of the sampling plots, soil moisture content, and depth of soil sampling, history of the area, and management practices used by the farmers (Mesquita, 2017). In the present study though all the soil samples from Kirtipur and Bhaktapur were collected for this study were from surface to 15 cm depth but insignificant differences in a number of weed species seedlings emergence were observed, which may be due to similar climate, soil moisture, and same history and management practices.

The seed bank of *Cyperus rotundus* was found to be significantly less than the seed bank of other studied weeds in all sites from the flotation technique, which may be due to low seed production in *Cyperus* (Brosnan & DeFrank, 2008; Lati *et al*., 2011) and a high number of seed production among other members of Asteraceae. The weed seed standardization showed the weed seed recovery was higher in clayey soil.

In the present study, the seed bank estimation results are not the same from the floatation and germination techniques. Gonzalez and Ghermandi (2012) also observed similar results on seed bank estimation from floatation and germination method. Both of these methods have certain merits and demerits. The weakness of the floatation method is that there are chances of overestimation of active seed banks as both viable and nonviable seeds are counted in this method. In the case of the germination method, only the seeds that get the opportunity and adequate environmental conditions undergo germination. The weakness of this method of seed bank estimation is that it does not take into account dormant viable seeds (Mesagaran *et al*., 2007).

The seed bank obtained from the floatation technique in this study is mostly higher than the germination technique. This must be due to the presence of dormant seeds in the soil seed bank and a similar result was also noted by Goto and Tsuyuzaki (2004).

### 4.2.7 Seed germination

#### 4.2.7.1 Different environmental conditions

Seed germination in both the crops (*B. campestris* and *T. aestivum*) was the highest in 6 ml and 9 ml treatments and got reduced significantly in 15 ml treatment. Similar results were also obtained for *Phaseolus vulgaris*, *Spinacea oleracea* (Orphanos & Heydecker, 1968), and *Beta vulgaris* (Heydecker *et al*., 1971). Similarly, seed germination of *Cyperus* and *Galinsoga* got completely inhibited with 15 ml treatment. This may be possible due to the formation of a water film over the seed's surface (Ely, 1979), as the seeds were completely immersed in water with 15 ml treatment. The water film might have acted as a barrier to osmotic diffusion (Ely, 1979).

Germination of seeds and seedling growth were dependent on favorable environmental conditions. Temperature is one of the most significant environmental conditions for seed germination and seedling growth (Fenner & Thompson, 2005). Germination of two winter crops (*B. campestris* and *T. aestivum*) was higher at 15-20˚C in the present study and lower at 25˚C, indicating that the high temperature is not favorable for germination. All weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus*, and *G. parviflora*) could germinate at all the treatments of temperature, indicating their tolerance to a wide range of temperature. These weeds are quite common in summer crops as well. High-temperature availability will increase the atmospheric water demand which could lead to additional water stress from increased water pressure deficits (Thapa, 2001; Zhao *et al*., 2016; Assang, 2011). A Study done by Malla (2009) on $CO_2$ enrichment technology at Khumaltar concluded that the yield of rice and wheat increased by 17.1% and 8.6% due to an increase in temperature, respectively. A crop simulation model (DSSAT) was also studied by Malla the effects of $CO_2$, temperature, and rain in NARC showed a positive effect on the yield of rice and wheat.

Light is one of the most significant factors for seed germination and seedling growth. The seeds of both crops germinated in all light conditions (even in blue light), but weed seeds could not germinate in blue light. Seeds that require light for germination are usually small (Cann, 2014). Milberg *et al*. (2000) suggested that the light response and seed mass must have coevolved as an adaptive feature to ensure seed germination of small-seeded species only when close to the soil surface. On the other hand, a phylogenetic component of light promoted germination regardless of the seed size has also been suggested as phytochromes are well known to mediate the light promoted germination. Phytochromes are also known to increase the number of bioactive gibberellins in seeds (Cann, 2014) and this might have initiated the germination process.

In the present study, both the crops and weed could not germinate in the dark. This show that light is required for seed germination and seedling growths Phytochrome plays a significant role in determining the time of germination (Kołodziejek & Patykowski, 2015). A seed germination experiment conducted an experiment in 131 taxa of Campanulaceae by Koutsovoulou *et al*. (2014) and found that germination was higher in light than in darkness.

The wheat and mustard seeds germinated in blue light, more or less similar as in red, yellow, or green light. In wheat (Xu *et al*., 2009) and *Brassica napus* (Chatterjee *et al.*, 2006) Cryptochromes, the blue/ultraviolet-A light-sensing photoreceptors have also been reported to interplay. In wheat, two cryptochrome genes, TaCRY1 and TaCRY2, have been identified, which might be involved in the ABA signaling pathway in addition to their role in primary blue light signal transduction (Xu *et al.*, 2009). Possibly in *Brassica campestries* also the cryptochromes act as the photoreceptor to initiate seed germination in blue light.

Mostly seed germination was high in red light and low or nil in blue light, which is consistent with the general observation that red light promotes germination while blue light inhibits it. All the selected weeds could not germinate in blue light. Blue light is usually referred to as radiation with a wavelength between 400 and 500 nm. Different phytochromes activate at different wavelengths of light. Under wavelength 700 nm both phytochromes A and B are active. However, phytochrome A functions optimally around 600 to 690 nm whereas at wavelength larger than 700 nm it becomes in-activate although phytochrome B remains active (Kami *et al*., 2010). As blue light ranges from 400-500 nm, both these phytochromes might remain inactive and this might have not initiated germination in the selected weeds.

Besides this, the seed germination in wheat and mustard might be due to the higher concentration of endogenous gibberellins than the abscisic acid (Srivastava, 2002; Zhong *et al.*, 2013). The gibberellin synthesis occurs when seeds absorb moisture, this hormone diffuses across the endosperm to the aleurone layer (in the case of wheat), which then produces and releases the hydrolytic enzyme required to digest the stored food of endosperm. The stored starch was broken down by enzymes to its smaller unit glucose, protein to an amino acid, etc. which is then translocated to the embryo. The embryo used them for the growth of radical and plumule during germination (Bhattarai, 2007).

Both crops and some weeds could germinate from pH 5 to 9 (Mallik *et al*., 2020). Similar results were also reported by Mathews *et al.* (2012). Hannaway and Larson (2004) reported that Mustard can adapt in sandy to clay soil and also germinate in the range of pH 4.8 to 8.5. *Triticum aestivum* have comparatively large seeds with storage of reserve food materials. It appears that both the winter crops have high membrane integrity and could resist a high range of pH (Chatterjee & Nagarajan, 2006; Bagchi, & Srivastava, 2003). Weeds like *Ageratum conyzoides*, *Bidens pilosa*, and *Cyperus rotundus* might have low membrane integrity and therefore could not germinate at high pH (McCauley *et al*., 2017).

#### 4.2.7.2 Chemical fertilizers

Seed formation depends on the nutrients present from the seed coat to the endosperm (Martínez-Ballesta *et al.,* 2020). The macronutrients like nitrogen, change the endosperm structure, influencing seed moisture and in subsequent germination stages (Wen *et al.,* 2017). Seed germination of both crops and weeds was reduced significantly with high concentrations of fertilizer solutions. A number of studies have demonstrated that the potential use of compost and fertilizer solution helps to enhance seed germination and seedling growth and improves soil physical properties (Zinati, 2017). In the present study, shoot and root length mostly decreased with solutions having 2.5% concentrations of urea and potash. In higher concentrations, the cells might be in stress due to exosmosis. Bam, *et al.* (2006) suggested that the high concentration of the nutrient solutions may have damaged membranes and changed enzyme relations, leading to reduced germination.

The soil amended with both chemical fertilizers - urea and potash, showed reduced germination with an increase in the concentrations. The root and shoot lengths increased up to 10 gm/kg soil treatment but decreased with higher doses. In the case of the soil amended with urea, the soil bacteria must have played an important role. The soil bacteria possess enzyme urease which catalyzes urea to ammonia or ammonium and bicarbonate ions. The ammonia volatilized from the soil completely inhibits the germination of seeds (Bremner & Krogmeier, 1988, 1989). This might be the reason for the reduction in seed germination.

Potassium, an important osmotic agent, is also involved in more specific metabolic roles like protein and starch syntheses and enzyme activation (Al-Karaki, 2001).

Cases of K+ toxicity have been reported in glycophytes (Rathert, 1982; El-Haddad & O'Leary, 1994). Generally, a high concentration of K causes N deficiency and this may affect the uptake of other nutrients (Crouse, 2018), which possibly reduces percentage germination, and the shoot and root lengths.

### 4.2.8 Allelopathic effect

#### 4.2.8.1 *Ageratina adenophora* (Spreng) King & Rob.

The alkaloids are more in leaves than in the stem and root of the same plant species (Achakzai *et al*., 2009). There are forty-five volatile compounds found in *Ageratina adenophora* plants. The compounds identified from the stem and leaves of this species are octacosanoic acid, hydroxycinnamic acid, ferulic acid, cafeicacid, etc. (Subba & Kandel, 2012). The presence of flavonoid glycosides in the leaves was also reported by Nair *et al.* (1995). Seed germination in *T. aestivum* was higher with the stem than with the root and leaf extracts of *A. adenophora*. Seed germination was observed in the stem and leaf extracts even at higher concentrations (2.5-10%), in comparison to the root extract. Seed germination was reduced significantly in comparison to control, but the germination of both crops was observed even at higher concentrations. The shoot and root lengths of both crops were significantly reduced in the aqueous extract of *A. adenophora* plant's part (root, stem, and root).

The weeds *A. conyzoides* and *C. rotundus* were fully inhibited at a higher concentration of leaf extract. In a 1% aqueous concentration, the seed germination of *A. conyzoides* was higher in the stem extract. In *B. pilosa* seed germination was reduced significantly, as the concentration increased but was not completely inhibited even at higher concentration, unlike in the other weeds. This may be due to the size of the seed. Katoch (2012) also reported that the large-sized seeds were least sensitive to germinate and grow. The *C. rotundus* and *G. parviflora* were completely inhibited at 10% aqueous stem and leaf extracts of *A. adenophora.* A number of researchers reported that a large number of allelochemicals released from leaves inhibit the growth (Zhao *et al.*, 2009; Das *et al.* 2018). The antioxidant activities of methanol, extracts from leaves of *Ageratina* also inhibited the seed germination and seedling growth of other species (Ralte & Sameul, 2014).

The compost extract of *A. adenophora* showed detrimental effects more in selected weeds than in winter crops. Seed germination of *B. campestris* was inhibited at higher concentration but that of *Triticum* was unaffected. *Ageratum* and *Galinsoga* significantly reduced at lower concentration but completely inhibited at higher concentration. In *B. pilosa,* seed germination was inhibited at a higher concentration. Only at a lower concentration of *Ageratina* compost extract the seed germination of *C. rotundus* was observed. Similar results found by Zhang (2008), showed that the aqueous leachates of stems and leaves of *A. adenophora* inhibited seed germination and seedling growth of *Neocheiropteris palmatopedata.* The inhibitory effects increased with increasing leachate concentrations.

The reduction in the seed germination and seedling growth of *B. campestris* and *T. aestivum* increases with an increase in the concentration of the soil amended with a compost of *A. adenophora*. It might be due to the allelochemicals released by *Ageratina* plant residues into the soil. It affects the germination and seedling growth processes by reducing the cell division or the auxin-induced growth of roots (Katoch, 2012; Mc Calla & Haskins, 1964). At higher concentration (50 g compost/kg soil), seed germination of *B. campestris* was fully inhibited but *Triticum* germinated. In comparison to *Brassica* and weed seeds, nutrient content (carbohydrate and protein) and seed weight per seed were higher in *T. aestivum* (Table 9). The presence of defensins and high nutrient content of seeds possibly overcome the adverse impact of phenolic compounds on seed germination of *T. aestivum*. The seed germination, and the shoot and root growth of *A. conyzoides* and *C. rotundus* took place at lower concentration (10 g compost/kg) only. Besides, *B. pilosa* and *G. parviflora* totally were inhibited at higher concentrations (5 and 10 g compost/kg soil). It might be possible due to the additive and synergistic effects of allelochemicals which under field conditions become significant even at lower concentrations (Einhelling & Rasmussen, 1978). In *G. parviflora* germination was higher in sandy and loamy soils and it could germinate in 4-10 mm depth (Cauwer *et al.*, 2013). *Eupatorium adenophorum* plant was rich in a phenolic compound like 2-hydroxycoumaric acid which inhibited seed germination and seedling growth of the crop and its surrounding plants (Zheng *et al*., 2012).

#### 4.2.8.2 *Parthenium hysterophorus* L.

The seed germination and seedling growth of *B. campestris* were reduced with 2.5 and 5% aqueous extract of vegetative parts of *Parthenium.* Similar results were also observed by Singh, *et al.* (2005) in *Brassica* species (*B. campestries, B. oleracea,* and

*B. rapa*) and by Parthsarthi *et al.* (2012) in two pulse crops (*Vigna radiata* (L.) R. Wilczek) and *Vigna mungo* Hepper) and one oilseed crop (*Arachis hypogea* L.). The reduction in seed germination and seedling growth is possibly due to phenolic compounds. A significant amount of phenolics, the largest group of secondary metabolites, was estimated in the aqueous extract (Singh, *et al.*, 2005). The more detrimental effect was observed with the stem and leaf extracts than with the root extracts. This could be due to more accumulation of secondary metabolites in stem and leaf (Safdar *et al.*, 2014). Altogether about 47 photo components (3 terpenoids, 14 fatty acids, 4 hydrocarbons, 7 alcohols, 5 phytosterols, and 14 other metabolites) are reported in the leaf of *Parthenium* (Ahmed *et al*., 2018).

The detrimental effect of *Parthenium* aqueous extract was less on *T. aestivum* than on *B. campestries*. Afridi and Khan (2015) reported that the effect of allelochemicals was unfavorable on the seed germination of *T. aestivum* and other species. SG of *T. aestivum* was significantly reduced only with 10% extracts of roots. Similarly, stem extract of 2.5, 5, and 10%, and leaf extract of 5 and 10%, caused a significant reduction in the seed germination. SL and RL also decreased significantly with increasing concentrations of the root, stem, and leaf extracts. Only the stem extract of *Parthenium* showed an inhibitory effect at 2.5% in seed germination of *T. aestivum*. Comparatively less detrimental effect on *Triticum* seed germination is observed than in weed seeds with *Parthenium* leaf extracts. Khan *et al.* (2012) had also reported the inhibitory effect of *Parthenium* in four varieties of *T. aestivum* treated with 7.5% aqueous extract, quite high concentrations in comparison to the present study.

The insignificant changes in *Triticum* seed germination, SL and RL with lower concentrations may be due to the presence of secondary metabolites cysteine-rich proteins- defensins in the endosperm of *Triticum* (Freeman & Beattie, 2008). In comparison to *Brassica* and other weed seeds, nutrient content (carbohydrate and protein) and seed weight were greater in *Triticum*. The presence of defensins and larger nutrient content in seeds possibly overcome the adverse impact of phenolic compounds on seed germination of *Triticum*. The selected weed seeds (*A. conyzoides*, *B. pilosa*, *C. rotundus*, and *G. parviflora*) mostly showed a reduction at 2.5% concentrations of the stem and leaf aqueous extracts of *Parthenium*. High germination percentage (62%) of *Cyperus rotundus* at lower concentration of *Parthenium* leaf extracts (1%) may be due to less efficacy of leaf extract at low concentration on one hand, and on the other hand high nutrient (carbohydrate, protein and moisture) contents in each seed of *Cyperus rotundus* (Table 9). Only the stem extract of *Parthenium* (25%) showed an inhibitory effect on seed germination of *Triticum aestivum*. Comparatively, the effect was less detrimental on *Triticum* than on weed seeds with *Parthenium* leaf extracts (Mallik *et al*., 2019). Khan *et al.* (2012) also reported the inhibitory effect of *Parthenium* in four varieties of *T. aestivum* treated with 7.5% aqueous extract.

Seed germination of *Brassica* remained more or less unaffected up to 2.5% compost-extract treatment but was enhanced with 5% in *T. aestivum*. Similarly, the soil amended with *Parthenium* compost caused the insignificant difference in seed germination of *Brassica* up to 20 gm compost/kg soil treatment and in *Triticum* up to 40 gm compost/kg soil treatment. Seed germination of *Triticum* increased slightly at 10 and 20 gm/kg treatments. The presence of plenty of micronutrients such as Fe, Zn, Mn and Cu, and macronutrients including N, P, and K, makes *Parthenium* compost two times richer than the farmyard manure (Krishnamurthy *et al*., 2010), and this possibly might have acted as the promoter for seed germination and seedling growth in low concentrations. But at high concentrations, the allelochemicals found in *Parthenium* might also inhibit cell division; and also the gibberelline and indolacetic acid functions (Tomaszewski & Thimann, 1966).

Besides this, various types of terpenoids (9 in roots, 3 in the stem, and 3 in the leaf) are found in *Parthenium* (Ahmed *et al*., 2018). The noxious behavior of this weed is thought to be due to the sesquiterpene lactone called parthenin, which is synthesized by this plant and plays a role of allelopathic interference with surrounding plants (Belz, 2007). Possibly, these terpenoids interfere with enzymatic activity and reduce seed germination of crops as well as of weeds at higher concentrations.

#### 4.2.8.3 *Artemisia dubia* Wall ex. Besser

In the present study, it was found that SG, SL, and RL decreased with the extracts of vegetative parts (leaf, stem, and root) of *Artemisia* but the effect of leaf extract was more pronounced. Putnam (1988) listed 6 classes of allelochemicals, namely alkaloids, bezaoxaziones, cinnamic acid derivatives, cyanogenic compounds, ethylene, and others. More amount of volatile phytotoxic compounds have been recorded from the green leafy part in *Artemesia californica* (Halligen, 1973) and possibly such phytotoxic chemicals are also present in *A. dubia* and this may be the reason for the more allelopathic effect of a leaf on seed germination. The germination of seeds, and the root and shoot lengths of crop plants (*B. campestris* and *T. aestivum*) were inhibited by the aqueous extract of weed *A. dubia*. Seed germination was reduced with 5% and 10% concentrations of root, stem, and leaf extracts among the different treatments. Similar effects of *Artemisia monosperma* extract were obtained by Watban and Salama (2012) on *Phaseolus vulgaris*. A similar decrease in germination, growth, and chlorophyll contents in *T. aestivum* was reported by Deef and El-Fattah (2008) when grown on the aqueous extract of *Artemesia princeps* var. Orientalis. A study of the allelopathic effects of some selected weeds (*Phalaris minor* L., *Chenopodium murale* L., *Sonchus oleraceus* L., *Cyanodon dactylon* L., and *Convolvulus arvensis* L.) on seed germination and seedling growth of wheat (*Triticum aestivum*) also showed similar inhibitory effects on seed germination, seedling length and seedling dry weight of the crop, which increased progressively on increasing the concentration of extracts of weed plants (Gupta & Mittal, 2012). SG and seedling growth of weeds *B. pilosa*, *A. conyzoides*, *G. parviflora*, and *C. rotundus* grew in the aqueous extract of *A. dubia* also revealed a reduction with increase in concentrations. Katoch *et al.* (2012) have also reported that the inhibition of seed germination and seedling growth was dependent on concentration, and a greater inhibition was observed at higher concentrations. In the present study, significant reduction of the shoot and root length occurred with all concentrations of the leaf extract, as was observed by many earlier workers working on other weeds, thus indicating that leaves have a more powerful inhibitory allelopathic effect than other vegetative parts (Kanchan, 1975; Tefera, 2002; Maharjan *et al*., 2007). Lydon *et al.* (1997) also mentioned that the aqueous extract of *Artemisia annua* reduced the SG, SL, and RL of some crops (*Zea mays, Glycine max*) and (Chen & Leather, 1990) inhibited weeds like *Digitaria sanguinalis, Echinochloa crusgalli,* etc., there was a total inhibition of seed germination of *A. conyzoides*, *G. parviflora* and *C. rotundus* with higher concentrations of leaf extract. The work by Mittal and Kohli (2010) shows that *Artemisia* oil has bio herbicidal properties because it causes phytotoxicity and interferes with the growth and physiological processes of some weed species. Similarly, in the present study, more allelopathic effects were found with leaf extract, followed by stem extract and then root extract in most cases, except in *T. aestivum*. Quartey *et al*. (1997) also revealed that leaves of *Artemisia afra* had an inhibitory effect on seed germination, compared to other plant parts. The aerial parts contain high amounts of inhibitory allelochemicals (Gill *et al*., 1993) which may interfere with the processes of plant growth. These allelochemicals may be reducing the cell division or the auxin-induced growth of roots (Gholami *et al.*, 2011). Comparison of seed germination of *B. campestries* and *T. aestivum* with the weeds studied has revealed that seed germination in crops was less adversely affected than in weeds in compost extract and compost amended in soil (Mallik *et al*., 2014). This might possibly be due to large seed size and more reserve food material present in crop seeds than in weed seeds. Artemesinine, a sesquiterpene lactone extracted from *Artemisia annua* L., is a potent plant growth inhibitor (Javaid & Anjum, 2006). Similar allelochemicals may be present in *Artemisia dubia*, as both of them belong to the same genus.

# CHAPTER 5

## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusions

On the basis of IVI values, it can be concluded that weeds like *Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora* are most dominant in the winter fields of Kathmandu valley. Weed diversity was more in the Bhaktapur areas than other selected areas like Kirtipur, Godawari, Chapagaon, Dharamsthali, and Shivapuri. The diversity (Simpson's index of diversity D) of weeds in winter crop fields was highest in Bhaktapur and lowest in Kirtipur.

From the phenological study of common weeds in winter crop fields, it can be concluded that the first weeding should be conducted when the crops are in the 5-6 leaves stage, as all the weeds were recorded flowering in October-November, i.e., at the very initial phase of winter crop.

Both the flotation technique and germination method indicated that *Ageratum conyzoides* and *Galinsoga parviflora* have the largest seed banks and consequently a high infestation in the agricultural fields. Both these weeds are also common in summer crops; hence possibly they have greater adaptive plasticity and add new seeds in each season.

Based on the seed germination experiments under different climatic conditions it is concluded that SG, SL, and RL of weeds (*Cyperus rotundus* and *Galinsoga parviflora*) suppressed with high moisture in petridish (lab) and crops (*Brassica campestris* and *Triticum aestivum*) also significantly reduced. Seed germination of the weeds suppressed with blue light and dark conditions. Both crops are enhanced in 15 and 200C but weeds are high and 10 and 150C. The SG of *Brassica campestris* was found to be significantly high in acidic conditions but in *T. aestivum* it was significantly high in alkaline conditions. The seedling growth of most of the weed seeds (*Ageratum conyzoides*, *Cyperus rotundus* and *Galinsoga parviflora*) were found to be significantly high in alkaline conditions.

Based on the results obtained on SG and on the SL and RL, under different concentrations of urea and potash fertilizers, it can be concluded that both crops and all tested weeds prefer a low concentration of urea and potash. Under high concentrations detrimental effects appeared due to osmotic potentials of the cell, causing the hyperosmotic effects to increase the salt intake and dehydration of the cell. SG, SL, and RL of *B. campestris* and weeds (*Ageratum conyzoides*, *Cyperus rotundus*, and *Galinsoga parviflora*) are found to be high in acidic conditions but *Triticum aestivum* and *Bidens pilosa* are found in alkaline conditions.

On the basis of studies on the effect of aqueous extract of *Ageratina adenophora* on SG and the SL and RL, it can be concluded that allelochemicals are more in stem and leaves than in the roots of *A. adenophora* in comparison to root. SG, SL, and RL of weeds *Ageratum conyzoides*, *Galinsoga parviflora*, and *Cyperus rotundus* were fully suppressed with increasing from 5% concentrations of the aqueous extracts, but both the crops could germinate and survive. This suggests that the aqueous extract 5% and above of *A. adenophora* can possibly be used for suppressing these weeds.

Further, the treatment with 40 g/kg *A. adenophora* compost suppressed seed germination of all weeds except *Bidens pilosa*, but both the crops survived. This shows that application of the compost of *A. adenophora* at the rate of 20-40 g compost/kg soil can be useful to control weeds in the winter crop fields.

The detrimental effect of increased concentrations of *Parthenium* aqueous extract on the germination of crops and weeds with increasing concentrations is mainly due to the allelopathic effect. In comparison to crops, all weeds seeds (*Ageratum*, *Cyperus, and Galinsoga*) except *Bidens* were more affected with increasing high concentrations of aqueous extract. Seed germination of *C. rotundus* was completely inhibited with *Parthenium* compost and this can be possibly due to its allelopathic effect.

The enhancement of seed germination and seedling growth of *Triticum* (up to 40 g compost/kg soil) and *Brassica* (up to 20 g compost/kg soil) indicates that using the compost there is a possibility of *Parthenium hysterophorus* to reduce the associated weeds in wheat and mustard fields. Thus, *Parthnium* compost (20-40 g compost/kg soil) has the potential to control all these weeds because of its allelopathic effects.

Comparing impacts of three plants, one native and two invasives, brought out that the impact of aqueous extract, compost extract, and the compost on seed germination and seedling growth of crops and weeds is less in comparison to two invasive plants (*Parthenium* and *Ageratina*).

From the present study that the aqueous extract of vegetative parts, particularly leaf contains more growth-inhibiting allelochemicals. According to the study, the shoot and root lengths of weeds (*Bidens pilosa*, *Ageratum conyzoides*, *Galinsoga parviflora*, and *Cyperus rotundus*) and crops (*Brassica campestris* and *Triticum aestivum*) are significantly reduced at a high concentration of *A. dubia* extract. Seed germination percentage was found that the seed germination of crops is less adversely affected than weeds. Thus, there is a possibility of extracting such allelochemicals from *A. dubia* and using them to develop environment-friendly bio-herbicides to control weeds.

Further from all these experiments, it can also be concluded that different weeds have their own threshold concentrations to tolerate the allelopathic effect of invasive plants and beyond which seed germination completely suppresses. Mostly threshold concentrations to tolerate alleopathic effect are less for small sized seeds in comparison to large-sized seeds. From this it can be concluded that simply using a compost of invasive species like *Ageratina adenophora* or *Parthenium hystrophorus* in wheat fields or mustard fields, most of the common weeds can be controlled because of their allelopathic effects.

## 5.2 Recommendations

From this research, it can be recommended that the compost of *Ageratina adenophora* and *Parthenium hystrophorus* at the rate of 30-40 g /kg soil (i.e., equivalent to 4.68 to 6.24 t/ha) is effective to control the most of common winter weeds. In the present study, seed germination and seedling growth of crops were enhanced by using *Parthenium hysterophorus* compost (at the rate of 40 g /kg soil in wheat and 20 g /kg soil in mustard). But the effect of *A. adenophora* and *P. hysterophorus* compost on microbial activity after amendment of compost in soil is not known, hence, it is recommended for its detail study before its implementation.

# CHAPTER 6

## 6. SUMMARY

Invasive plants and weeds compete with crops in agricultural fields. Worldwide there is a challenge to maintain crop productivity and biodiversity in agriculture. All weeds are not harmful to crops, but their allelochemicals may stimulate yield and crop growth. For weed management, the best way is to make use of it and to promote it to a level of wanted plants. The basic approach of allelopathic research of invasive plants and weeds in agroecosystem may help in the crop yield and weed management.

To ascertain the common weeds in winter crop (wheat and mustard) fields at some sites in Kathmandu valley (like Kirtipur, Bhaktapur, Godawari, Chapagaon, Dharamsthali, and Shivapuri) quantitative parameters like frequency, density, abundance, IVI, and diversity indices were calculated. The most common weeds in the winter crop fields were *Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*. This study was conducted during the year 2012-2014. To understand the phenology, morphology, weed seed estimation of these common weeds, their seeds were collected from five sites of Kirtipur and Bhaktapur.

To understand the phenology of four common weeds, the phenophases (i.e., germination, vegetative growth, flowering, fruiting, senescence of fruits, and dispersal of seeds) of *A. conyzoides*, *B. pilosa*, *C. rotundus*, and *G. parviflora* were studied. *A. conyzoides* emerged in the first week of October month; the vegetative growth, flowering, and fruiting occurred in the mid of October and the flowering, fruiting, seed drying process, and seed dispersal occurred in Dec-Jan and continued up to February-March. *B. pilosa* germinated in October and vegetative growth took place in early November; flowering, fruiting and seed maturity occurred in Dec-Jan; and senescence of fruits and seed dispersal continued up to February and March. In the *C. rotundus*, the vegetative growth and flowering occurred in the month of October-November; flowering, fruiting and senescence of fruits occurred during December-January months and continued fruiting, senescence of fruits and seed dispersal up to February-March. Seed germination, vegetative growth, and flowering of *G. parviflora* started in the month of October and November; flowering, fruiting, and senescence of fruits during December-January; and the fruiting, senescence of fruits and seed dispersal were observed during February-March.

The soil samples from five sites of Kirtipur and Bhaktapur were collected and soil parameters like soil texture, soil humus, soil pH, and NPK were tested, and also weed seed banks in these soil samples were estimated. The soil texture of sandy loam and loamy type were recorded for Kirtipur and Bhaktapur, respectively. Slightly acidic soils were found in both the areas of Kirtipur and Bhaktapur. Nitrogen content was higher in Kirtipur than in Bhaktapur. The range of phosphorus is very low in Kirtipur's sites in comparison to Bhaktapur's sites.

Seed characteristics and size of four selected weeds showed that the seed size of *Cyperus* (L=13.33 mm) and *Galinsoga* (L=15.53 mm) was smaller than that of *Bidens* (L=17.65 mm) and *Ageratum* (L=15.46 mm). *Ageratum* and *Galinsoga* have small conical seeds, and *Bidens* has long flattened seeds.

The seed bank in soil was estimated by two methods: floatation and germination method. The recovery of weed seeds of *G. parviflora* and *C. rotundus* was recorded more in clay, sandy loam, and sandy soil. Seeds of *A. conyzoides* recovered more in clayey and loamy soil while seed recovery of *B. pilosa* was more in loamy and clayey soil. The result of both methods was not the same in our experiment.

The influences of environmental conditions (moisture, temperature, light, and pH) were also observed on the seed germination of both crop plants (*B. campestris* and *T. aestivum*) and common weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus*, and *G. parviflora*) for the different volume of distilled water (3, 6, 9, 12, 15 ml). The highest moisture showed adverse effects on the seed germination, shoot and root length of *C. rotundus* and *G. parviflora* and also significantly reduced the seed germination of both crops (*B. campestris* and *T. aestivum*) and weed seeds of *A. conyzoides* and *B. pilosa*. Seed germination of both crops and four common weed seeds under different temperatures (5, 10, 15, 20, and 25°C) showed enhanced seed germination, shoot and root length of both crops at 15 to 20°C treatments but those of weeds were high at 10 to 150C. In the laboratory, seed germination of both crops and four common weed seeds were conducted at different colors of light (normal, red, yellow, blue, green, and dark). The colors of light effect were studied by using colorful cellophane paper and for a dark color, black plastic was used. Seed germination percentage of both crops *B. campestris* and *T. aestivum* increased significantly in normal light and green light. Seed germination of *Ageratum conyzoides*, *Cyperus rotundus*, and *Galinsoga* *parviflora* was insignificantly different in normal, red, yellow, and green light. The seed germination of *Bidens pilosa* increased slightly at normal white light than in all other colored light. The blue color and dark color of light inhibited the seed germination, shoot and root length of both crops and selected weeds. The seeds of *Ageratum conyzoides* and *Bidens pilosa* could not germinate in a low acidic and alkaline condition of pH 5 and pH 9. The seeds of *Cyperus rotundus* could not germinate in alkaline conditions of pH 8 and 9. The seed germination, SL, and RL in crop seed of *Brassica campestris* were found to be significantly high in acidic conditions at pH 5 but in *Triticum aestivum* it was significantly high in an alkaline condition of pH 8. The shoot and root length of most of the weed seeds (*Ageratum conyzoides*, *Cyperus rotundus* and *Galinsoga parviflora*) were found to be significantly high in acidic condition pH 6 except *B. pilosa* where it was significantly high in the alkaline condition of pH 8.

Seed germination on chemical fertilizers was conducted on petriplates of different concentrations of the solution of urea and potash (0, 1, 2.5, 5, and 10%). The result showed both the crops *B. campestris* and *T. aestivum* and all the weed seeds germination were mostly high in control and 1% of urea and potash solution but SG, SL, and RL decreased with increase in concentrations. The fertilizers urea and potash were amended with soil separately for different treatments (control, 10, 20, 40, 50 g/kg soil) in a polybag. This experiment showed total inhibition of seed germination of crops and weed seed at 50 g/kg soil.

The allelopathic effects (aqueous extract, compost extract, and compost (g/kg soil) of two invasive plants (*Ageratina denophora* and *Parthenium hysterophorus*) and one native weed (*Artemisia dubia*) were studied on seed germination of two crops (*B. campestris* and *T. aestivum*) and four common weeds (*Ageratum conyzoides, Bidens pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora*). The SG of *Brassica* seed was observed higher in *Ageratina adenophora* stem extract than in root and leaf extract. The reduction in germination percentage of *Triticum* seeds was more in root extract than in stem and leaf extract concentrations. The seedling growth of *T. aestivum* was reduced significantly in all treatments. The aqueous extract of *A. adenophora's* impact was more or less similar in all weeds.

The seedling growth of germinated *Brassica* seedlings reduced significantly with all concentrations of root stem and leaf extracts. The percentage of seed germination of

*B. campestris* was completely inhibited with 10% aqueous treatment. Seed germination, SL, and RL of *T. aestivum* showed a slight reduction with *Parthenium* 1, 2.5, and 5 % root and leaf extract treatment but it was significantly different with 10% aqueous extracts in all cases. The impacts of aqueous extract of *P. hysterophorus* on weeds were more or less similar in all cases**.**

Seed Germination of both crops *B. campestris* and *T. aestivum* was found to be significantly reduced with the increase in the concentration of root, stem, and leaf extract of *A. dubia*. Inhibition of seedling growth (SL and RL) was highest with *A. dubia* leaf extract in *Brassica* and all weeds (*A. conyzoides*, *C. rotundus* and *G. parviflora*) except *B. Pilosa*.

The seed germination of *B. campestris* was fully inhibited at a higher concentration of *A. adenophora* compost extract but *T. aestivum* was reduced insignificantly. In *T. aestivum*, the SL and RL reduced significantly at all concentrations. Total inhibition of SG of *Bidens* weed was observed at 50 g compost/kg soil treatment but *Ageratum* and *Galinsoga* were inhibited at 20, 40, and 50 g compost/kg soil treatment. In all weeds, shoot and root length reduced significantly with increasing concentrations of compost in the soil.

*Parthenium* compost extract decreased SG, SL, and RL in all the tested weed seeds (*A. conyzoides*, *B. pilosa*, *C. rotundus*, and *G. parviflora*) than in crops (*B. campestris* and *T. aestivum*) with an increase in concentration in petriplates in the laboratory. The SG, SL, and RL of both crops *B. campestris* and *T. aestivum* enhanced with 10 and 20 gm compost/kg soil treatment but it reduced significantly with high concentrations. Seed germination of *B. campestris* was inhibited at 50 gm/kg soil treatment. SG of *C. rotundus* was completely inhibited at all treatments of *P. hysterophorus* compost treatment. The SG of weeds *A. conyzoides, B. Pilosa*, and *G. parviflora* reduced at 10 and 20 gm compost/kg soil treatment. The SL and RL of weed *A. conyzoides*, *B.pilosa* and *G. parviflora* reduced with 20 gm compost/kg soil treatment.

The seed germination, shoot, and root length of *Brassica campestris* and *Triticum aestivum* reduced significantly in all the treatments of *Artemisia dubia* compost extract. *B. campestris* was completely inhibited at 10% treatment. The SG, SL, and RL of *C. rotundus* were inhibited at 5 and 10% whereas all the weeds (*Ageratum conyzoides*, *Bidens pilosa*, and *Galinsoga parviflora*) were inhibited at 10% *A. dubia* compost extract. Seed germination of both crops *Brassica campestris* and *Triticum aestivum* were insignificantly the same with *Artemisia dubia* treatments of 10-40 g compost/kg soil, but it reduced significantly with high concentrations. Seed germination of *B. campestris* was inhibited at 50 g compost /kg soil treatment. The seedling growth of *B. campestris* significantly decreased with an increase in concentration, whereas in *Triticum aestivum* it reduced insignificantly at higher concentration. The SG of weeds *Ageratum conyzoides*, *Bidens Pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora* were also reduced insignificantly at 10, 20, and 40 g compost/kg soil treatment. The SL and RL of weed *Ageratum conyzoides*, *Bidens Pilosa*, *Cyperus rotundus*, and *Galinsoga parviflora* reduced at 10, 20, and 40 gm compost/kg soil treatments.

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# APPENDICES

**Appendix 1a:** Frequency (%), density (number/$m^2$) and abundance of weeds found in winter crop fields (wheat)

| SN | Species | Kirtipur | | | Bhaktapur | | | Godawari | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Freq.** | **Density** | **Abun.** | **Freq.** | **Density** | **Abun.** | **Freq.** | **Density** | **Abun.** |
| 1 | *Ageratum conyzoides* L. | 96± 8 | 9.46± 1.34 | 9.88± 1.31 | 94± 8.0 | 8.92± 1.78 | 9.56± 2.05 | 86± 12 | 9.82± 0.42 | 11.69± 2.03 |
| 2 | *Ageratum haustonianum* Mill | 82± 4 | 4.34± 2.01 | 5.27± 2.44 | 66± 12 | 3.42± 2.15 | 4.82± 2.63 | 80± 10.95 | 5.2± 0.82 | 6.68± 1.57 |
| 3 | *Amaranthus spinosus* L. | 64± 8 | 1.36± 0.58 | 2.07± 0.71 | 68± 11.66 | 1.48± 0.51 | 2.11± 0.49 | 58± 11.66 | 1.54± 0.83 | 2.67± 1.59 |
| 4 | *Bidens pilosa* L. | 72± 13.26 | 7.68± 1.74 | 10.82± 2.28 | 86± 13.56 | 6.76± 1.65 | 8.24± 2.97 | 82± 9.79 | 7.84± 1.39 | 9.82± 2.36 |
| 5 | *Capsella bursapastoris* L. | 74± 4.89 | 3.22± 1.51 | 4.33± 1.90 | 68± 9.79 | 1.6± 0.60 | 2.33± 0.77 | 62± 16 | 1.8± 1.34 | 2.93± 2.21 |
| 6 | *Centella asiatica* L. | 58± 17.2 | 1.74± 0.99 | 2.74± 1.128 | 60± 16.73 | 1.98± 0.82 | 3.42± 1.25 | 64± 13.56 | 2.38± 1.38 | 3.48± 1.22 |
| 7 | *Chenopodium album* | 76± 12 | 2.1± 0.46 | 2.73± 0.31 | 70± 6.32 | 1.98± 0.27 | 2.74± 0.77 | 88± 11.6 | 2.52± 0.49 | 2.78± 0.31 |
| 8 | *Cynodon dactylon* L. | 70± 20.9 | 3.6± 1.78 | 4.14± 1.45 | 66± 8 | 3.38± 1.78 | 3.84± 1.98 | 76± 4.89 | 3.78± 0.67 | 4.84± 0.77 |
| 9 | *Cyperus rotundus* (L.) Bayer | 84± 10.19 | 7.86± 0.58 | 9.12± 1.60 | 86± 4.89 | 6.3± 1.30 | 7.35± 1.53 | 86± 10.19 | 7.16± 1.04 | 8.46± 1.73 |
| 10 | *Drymaria cordata* (L.) Whitesnow | 74± 17.43 | 4.04± 2.22 | 5.19± 2.43 | 62± 17.20 | 2.9± 1.63 | 4.34± 1.69 | 80± 8.94 | 4.5± 1.85 | 5.68± 2.34 |
| 11 | *Eclipta alba* L. ex B.D. Jacks | 72± 7.48 | 1.9± 0.62 | 2.28± 0.44 | 66± 18.54 | 2.4± 1.53 | 3.48± 1.40 | 70± 12.64 | 2.12± 0.89 | 2.66± 0.90 |
| 12 | *Galinsoga parviflora* cav. | 82± 4 | 10.9± 2.13 | 13.31± 2.68 | 90± 8.94 | 9.86± 3.94 | 11.14± 4.61 | 82± 11.66 | 9.46± 0.98 | 11.67± 1.32 |
| 13 | *Gnaphalium affine* D. Don | 68± 7.48 | 2.48± 1.06 | 3.40± 1.46 | 60± 6.32 | 1.9± 0.27 | 3.16± 0.27 | 62± 7.48 | 2.32± 1.05 | 3.69± 1.39 |
| 14 | *Oxalis corniculata* L. | 70± 6.32 | 5.02± 1.44 | 5.84± 1.70 | 76± 8 | 4± 1.74 | 5.17± 2.05 | 74± 13.56 | 5.52± 1.55 | 7.48± 1.88 |
| 15 | *Rannunculus repens* L. | 76± 4.89 | 1.66± 0.48 | 1.99± 0.32 | 72± 7.48 | 1.98± 0.89 | 2.79± 1.30 | 78± 7.48 | 2.04± 0.75 | 2.62± 0.95 |
| 16 | *Sonchus arvensis* (L.) | 66± 8 | 1.7± 0.76 | 2.53± 0.99 | 72± 11.66 | 1.82± 0.33 | 2.56± 0.48 | 74± 14.96 | 2± 1.06 | 2.72± 1.49 |
| 17 | *Stellaria Media* | 66± 8 | 1.46± 0.34 | 2.43± 0.68 | 72± 4 | 4.24± 1.62 | 5.32± 1.49 | 76± 4.89 | 3.68± 1.97 | 4.81± 2.49 |
| 18 | Others | 90± 8.9 | 3.48± 1.96 | 3.84± 1.85 | 76± 8 | 2.98± 1.66 | 3.25± 1.64 | 92± 4 | 4.14± 0.86 | 4.47± 0.73 |

**Appendix 1b:** Frequency (%), density (number/$m^2$) and abundance of weeds found in winter crop fields (wheat)

| SN | Species | Chapagaon | | | Dharamsthali | | | Shivapuri | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Freq.** | **Density** | **Abun.** | **Freq.** | **Density** | **Abun.** | **Freq.** | **Density** | **Abun.** |
| 1 | *Ageratum conyzoides* L. | 88± 4 | 10.3± 0.84 | 11.82± 1.36 | 86± 12 | 9.52± 2.61 | 10.31± 2.79 | 92± 7.48 | 8.56± 2.05 | 9.22± 1.96 |
| 2 | *Ageratum haustonianum* Mill | 72± 11.66 | 5.2± 0.85 | 6.24± 1.57 | 80± 10.95 | 4.08± 2.72 | 4.88± 2.75 | 74± 16.24 | 3.88± 1.72 | 5.09± 2.08 |
| 3 | *Amaranthus spinosus* L. | 56± 16.24 | 1.58± 0.39 | 2.16± 0.63 | 58± 11.66 | 1.3± 0.33 | 2.09± 0.41 | 58± 9.79 | 1.3± 0.48 | 2.18± 0.48 |
| 4 | *Bidens pilosa* L. | 68± 4 | 7.64± 1.16 | 10.28± 1.13 | 82± 9.79 | 6.6± 0.77 | 9.30± 2.16 | 72± 11.66 | 7.78± 0.75 | 11.07± 1.96 |
| 5 | *Capsella bursapastoris* L. | 70± 8.94 | 2.16± 1.52 | 3.01± 1.73 | 62± 16 | 3.02± 1.03 | 4.32± 1.82 | 88± 11.66 | 2.2± 0.88 | 2.66± 1.46 |
| 6 | *Centella asiatica* L. | 64± 8 | 2.06± 0.64 | 3.04± 0.81 | 64± 13.56 | 2.14± 0.83 | 3.22± 1.24 | 72± 9.79 | 2.32± 1.37 | 3.19± 1.71 |
| 7 | *Chenopodium album* | 66± 14.96 | 2.22± 0.23 | 2.67± 0.32 | 74± 13.56 | 1.74± 0.30 | 2.56± 0.37 | 62± 20.39 | 1.6± 0.56 | 2.70± 0.78 |
| 8 | *Cynodon dactylon* L. | 64± 8 | 4.24± 0.76 | 4.79± 0.28 | 78± 4 | 3.04± 1.94 | 3.58± 1.87 | 60± 8.94 | 3.12± 1.19 | 5.06± 2.64 |
| 9 | *Cyperus rotundus* (L.)Bayer | 84± 8 | 7.64± 0.73 | 8.31± 0.54 | 86± 10.19 | 7.6± 1.29 | 9.02± 2.31 | 84± 10.19 | 7.62± 1.16 | 9.25± 1.98 |
| 10 | *Drymaria cordata* (L.) Whitesnow | 70± 4 | 3.96± 1.35 | 4.94± 1.68 | 80± 8.94 | 3.12± 1.61 | 4.17± 1.77 | 72± 13.26 | 4.08± 1.51 | 5.49± 1.86 |
| 11 | *Eclipta alba* L. ex B.D. Jacks | 66± 4.89 | 1.84± 0.89 | 2.48± 0.98 | 70± 12.64 | 1.66± 0.33 | 2.17± 0.22 | 76± 17.43 | 2.96± 1.31 | 4.3± 2.94 |
| 12 | *Galinsoga parviflora* cav. | 82± 7.48 | 10.52± 2.06 | 13.46± 2.15 | 82± 11.66 | 11.3± 2.96 | 13.35± 3.50 | 88± 7.48 | 10.04± 2.30 | 11.49± 2.65 |
| 13 | *Gnaphalium affine* D.Don | 72± 7.48 | 1.98± 0.41 | 3.07± 0.36 | 62± 7.48 | 4.38± 2.22 | 6.10± 3.17 | 78± 9.79 | 2.4± 1.50 | 3.08± 1.84 |
| 14 | *Oxalis corniculata* L. | 74± 4.89 | 5.24± 1.25 | 6.65± 0.90 | 66± 4.89 | 4.6± 1.78 | 6.09± 2.46 | 70± 6.32 | 3.7± 1.88 | 4.41± 1.82 |
| 15 | *Rannunculus repens* L. | 76± 10.19 | 1.58± 0.36 | 2.02± 0.24 | 78± 7.48 | 3.52± 1.76 | 5.31± 2.90 | 80± 8.94 | 2.96± 1.28 | 3.79± 1.95 |
| 16 | *Sonchusarvensis* (L.) | 72± 4 | 1.78± 0.45 | 2.29± 0.61 | 74± 14.96 | 2.18± 1.95 | 2.80± 1.71 | 70± 4 | 1.26± 0.25 | 1.8± 0.36 |
| 17 | *Stellaria Media* | 64± 12 | 2.32± 0.71 | 3.14± 1.02 | 76± 4.89 | 4.56± 3.29 | 5.37± 3.04 | 70± 4 | 2.16± 0.68 | 2.43± 0.64 |
| 18 | Others | 86± 8 | 4.3± 1.27 | 4.52± 1.27 | 92± 4 | 2.98± 1.71 | 3.72± 1.65 | 86± 13.56 | 3.74± 1.07 | 4.30± 0.74 |

**Appendix 2a:** Frequency (%), density (number/$m^2$) and abundance of weeds found in winter crop fields (mustard)

| SN | Species | Kirtipur | | | Bhaktapur | | | Godawari | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **Freq.** | **Density** | **Abun** | **Freq.** | **Density** | **Abun** | **Freq.** | **Density** | **Abun** |
| 1 | *Ageratum conyzoides* L. | 82± 4 | 8.48± 2.28 | 10.60± 2.85 | 94± 4.89 | 8.48± 2.99 | 9.05± 3.36 | 88± 7.48 | 9.7± 1.12 | 10.5± 2.26 |
| 2 | *Ageratum haustonianum* Mill | 68± 17.20 | 3.12± 2.66 | 3.62± 2.28 | 70± 10.95 | 3.4± 2.33 | 4.95± 3.45 | 76± 8 | 4.74± 2.34 | 4.57± 2.13 |
| 3 | *Amaranthus spinosus* L. | 72± 13.26 | 1.54± 0.30 | 2.05± 0.24 | 58± 14.69 | 1.26± 0.61 | 2.05± 0.48 | 52± 11.66 | 1.2± 0.79 | 3.93± 4.47 |
| 4 | *Bidens pilosa* L. | 66± 4.89 | 6.2± 0.84 | 9.37± 0.82 | 80± 14.14 | 7.96± 1.63 | 10.13± 2.12 | 78± 11.66 | 7.48± 1.24 | 7.71± 3.69 |
| 5 | *Capsella bursapastoris* L. | 72± 4 | 2.72± 1.47 | 3.70± 1.82 | 78± 11.66 | 3.34± 1.06 | 4.33± 1.36 | 70± 8.94 | 2.38± 1.26 | 4.88± 2.51 |
| 6 | *Centella asiatica* L. | 62± 4 | 2.46± 1.13 | 4.00± 1.94 | 62± 11.66 | 2.04± 1.50 | 3.0± 1.66 | 62± 4 | 2.32± 1.14 | 2.90± 0.24 |
| 7 | *Chenopodium album* | 70± 6.32 | 1.44'± 0.37 | 2.07± 0.56 | 66± 10.19 | 1.52± 0.54 | 2.13± 0.43 | 68± 7.48 | 1.96± 0.40 | 3.10± 1.19 |
| 8 | *Cynodon dactylon* L. | 58± 9.79 | 2.12± 1.74 | 2.56± 1.39 | 74± 8 | 3.52± 1.65 | 3.94± 1.57 | 70± 10.95 | 3.14± 1.32 | 5.06± 2.53 |
| 9 | *Cyperus rotundus* (L.) Bayer | 92± 4 | 6.64± 1.24 | 7.19± 1.21 | 86± 10.19 | 7.84± 2.74 | 9.33± 3.41 | 86± 4.89 | 7.22± 0.97 | 8.15± 1.31 |
| 10 | *Drymaria cordata* (L.) Whitesnow | 66± 8 | 1.9± 1.32 | 2.7± 1.58 | 72± 13.26 | 4.22± 2.3 | 5.39± 3.09 | 72± 9.79 | 3.32± 1.87 | 3.15± 0.69 |
| 11 | *Eclipta alba* L. ex B.D. Jacks | 70± 12.64 | 2.8± 1.50 | 4.3± 2.75 | 74± 13.56 | 2.6± 1.32 | 3.97± 3.06 | 68± 7.48 | 1.72± 0.53 | 4.20± 4.12 |
| 12 | *Galinsoga parviflora* cav. | 84± 8 | 12.06± 3.62 | 14.72± 5.04 | 86± 18.54 | 10.54± 4.55 | 12.24± 4.04 | 78± 7.48 | 9.6± 1.06 | 11.49± 2.01 |
| 13 | *Gnaphalium affine* D. Don | 76± 10.19 | 3.14± 1.71 | 4.42± 3.24 | 72± 4 | 2.82± 1.32 | 3.29± 1.74 | 66± 4.89 | 4.08± 1.62 | 6.46± 3.27 |
| 14 | *Oxalis corniculata* L. | 70± 10.95 | 3.76± 1.11 | 5.54± 1.98 | 74± 4.89 | 4.42± 2.39 | 4.80± 2.54 | 70± 6.32 | 4.02± 1.69 | 4.54± 1.93 |
| 15 | *Rannunculus repens* L. | 70± 6.32 | 2.82± 2.02 | 3.97± 2.83 | 68± 9.79 | 2.46± 1.60 | 3.54± 2.23 | 72 4 | 2.9± 1.85 | 4.66± 2.87 |
| 16 | *Sonchus arvensis* (L.) | 68± 4 | 2.04± 1.93 | 2.40± 1.75 | 68± 4 | 2.94± 2.02 | 3.72± 1.85 | 66± 8 | 4.14± 2.27 | 4.9± 2.44 |
| 17 | *Stellaria Media* | 68± 4 | 5.54± 2.77 | 6.77± 2.45 | 66± 10.19 | 2.52± 1.23 | 3.41± 1.24 | 66± 8 | 5.18± 3.29 | 5.60± 2.90 |
| 18 | Others | 84± 16.24 | 2.58± 0.39 | 3.14± 0.58 | 86± 10.19 | 3.46± 2.19 | 3.83± 1.99 | 86± 8 | 3.22± 0.73 | 3.53± 0.57 |

**Appendix 2b:** Frequency (%), density (number/m$^2$) and abundance of weeds found in winter crop fields (mustard)

| SN | Species | Chapagaon | | | Dharamsthali | | | Shivapuri | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Freq. | Density | Abun | Freq. | Density | Abun | Freq. | Density | Abun |
| 1 | *Ageratum conyzoides* L. | 88± 4 | 9.12± 9.62 | 10.41± 1.51 | 86± 10.19 | 10.3± 0.45 | 12.16± 1.67 | 86± 10.19 | 9.82± 0.41 | 11.64± 1.90 |
| 2 | *Ageratum haustonianum* Mill | 72± 11.66 | 3.34± 2.21 | 3.96± 2.48 | 78± 7.48 | 5.26± 0.80 | 6.84± 1.38 | 86± 10.19 | 4.98± 0.96 | 6± 1.84 |
| 3 | *Amaranthus spinosus* L. | 56± 16.24 | 1.24± 0.77 | 2.09± 0.89 | 66± 10.19 | 1.8± 0.78 | 2.89± 1.59 | 66± 13.56 | 1.7± 0.68 | 2.77± 1.52 |
| 4 | *Bidens pilosa* L. | 68± 4 | 7.6± 0.99 | 11.23± 1.70 | 80± 10.95 | 7.78± 1.39 | 10.07± 2.64 | 74± 8 | 8.64± 0.40 | 11.77± 0.89 |
| 5 | *Capsella bursapastoris* L. | 70± 8.94 | 2.9± 1.39 | 4.10± 2.09 | 56± 13.56 | 1.66± 1.38 | 2.89± 2.23 | 70± 20 | 1.12± 0.41 | 1.58± 0.28 |
| 6 | *Centella asiatica* L. | 64± 8 | 2.32± 1.14 | 3.73± 2.00 | 66± 13.56 | 2.72± 1.71 | 3.99± 2.25 | 78± 11.66 | 2.7± 1.20 | 3.48± 1.33 |
| 7 | *Chenopodium album* | 66± 14.96 | 1.7± 0.21 | 2.70± 0.63 | 78± 14.69 | 2.12± 0.65 | 2.70± 0.56 | 74± 20.59 | 2.28± 0.65 | 2.91± 0.44 |
| 8 | *Cynodon dactylon* L. | 66± 8 | 3.84± 0.55 | 5.53± 1.26 | 76± 4.89 | 3.58± 1.16 | 4.66± 1.41 | 72± 13.26 | 3.9± 0.41 | 5.28± 1.46 |
| 9 | *Cyperus rotundus* (L.)Bayer | 84± 8 | 7.88± 0.25 | 9.44± 0.73 | 80± 6.32 | 7.36± 0.38 | 9.28± 1.17 | 84± 10.19 | 7.88± 0.60 | 9.53± 1.42 |
| 10 | *Drymaria cordata* (L.) Whitesnow | 82± 9.79 | 3.56± 2.12 | 4.38± 2.57 | 80± 8.94 | 5.02± 2.04 | 6.29± 2.38 | 82± 7.48 | 4.9± 1.61 | 6.08± 2.19 |
| 11 | *Eclipta alba* L. ex B.D. Jacks | 70± 10.95 | 1.72± 0.82 | 2.38± 0.80 | 72± 11.66 | 2.28± 0.77 | 3.15± 0.90 | 76± 13.56 | 1.78± 0.83 | 2.25± 0.73 |
| 12 | *Galinsoga parviflora* cav. | 82± 7.48 | 9.66± 0.74 | 11.80± 0.39 | 78± 11.66 | 8.94± 0.38 | 11.64± 1.30 | 88± 11.66 | 9.68± 0.90 | 11.12± 1.25 |
| 13 | *Gnaphalium affine* D.Don | 72± 7.48 | 2.9± 1.06 | 3.89± 2.17 | 60± 6.32 | 2.96± 1.39 | 4.85± 2.06 | 64± 10.19 | 1.72± 0.2 | 2.78± 0.71 |
| 14 | *Oxalis corniculata* L. | 74± 4.89 | 4.12± 1.37 | 5.67± 2.14 | 68± 4 | 5.26± 1.73 | 7.65± 2.30 | 76± 12 | 5.36± 1.69 | 6.67± 2.37 |
| 15 | *Rannunculus repens* L. | 70± 6.32 | 1.88± 0.38 | 2.47± 0.35 | 74± 4.89 | 2.02± 0.82 | 2.71± 1.01 | 76± 8 | 2.26± 0.70 | 2.59± 0.89 |
| 16 | *Sonchus arvensis* (L.) | 72± 4 | 4.26± 2.44 | 4.75± 2.31 | 72± 13.26 | 2.72± 1.61 | 3.69± 2.00 | 74± 8 | 2.24± 0.93 | 2.92± 1.40 |
| 17 | *Stellaria Media* | 64± 12 | 3.02± 1.79 | 4.23± 2.03 | 78± 4 | 5.54± 1.70 | 7.09± 2.06 | 78± 13.26 | 2.92± 2.11 | 3.73± 2.59 |
| 18 | Others | 88± 4 | 3.34± 0.38 | 3.70± 0.42 | 92± 4 | 3.8± 0.37 | 4.13± 0.43 | 96± 4.89 | 4.14± 0.85 | 4.32± 0.87 |

**Appendix 3:** IVI of common weeds on the winter crop fields of *Triticum aestivum* at different sites of Kathmandu valley

| SN | Species | Kirtipur | Bhaktapur | Godawari | Chapagaon | Dharamsthali | Shivapuri |
|---|---|---|---|---|---|---|---|
| 1 | *Ageratum conyzoides* L. | 30.81± 3.50 C a | 31.34± 1.86 EF a | 30.65± 2.41 F a | 32.54± 2.81 D a | 29.3± 4.46 FG b | 28.8± 4.56 CD b |
| 2 | *Ageratum haustonianum* Mill | 17.44± 4.81 AB ab | 15.31± 6.89 ABC a | 20.37± 1.55 D b | 18.7± 2.47 B ab | 15.46± 7.00ABCD a | 15.6± 7.18 AB a |
| 3 | *Amaranthus spinosus* L. | 8.73± 1.50 A a | 9.94± 2.66 A a | 9.7± 1.50 A a | 9.74± 0.80 A a | 8.54± 1.30 A a | 9.78± 1.45 A a |
| 4 | *Bidens pilosa* L. | 27.69± 5.84 BC b | 26.05± 5.20 DE b | 25.58± 4.51 D a | 26.44± 4.17 C b | 23.96± 3.90 EF a | 25.42± 3.66 BCDb |
| 5 | *Capsella bursapastoris* L. | 14.95± 5.43 A b | 10.43± 2.75 A a | 11.23± 4.01 A a | 11.03± 5.23 A a | 14.36± 4.47 ABCD b | 13.78± 5.36 AB ab |
| 6 | *Centella asiatica* L. | 9.45± 3.39 A ab | 11.38± 2.85 AB b | 10.71± 2.02 A ab | 10.52± 1.85 A ab | 10.96± 2.46 ABC ab | 11.51± 3.34 A b |
| 7 | *Chenopodium album* | 11.44± 1.42 A a | 11.56± 1.66 ABC a | 11.67± 1.16 A a | 11.6± 0.97 A a | 10.05± 1.23 AB a | 10.53± 1.79 A a |
| 8 | *Cynodon dactylon* L. | 14.36± 5.71 A ab | 14.83± 6.80 ABC ab | 15.39± 2.02 B b | 15.91± 1.65 B b | 12.54± 5.83 ABCD a | 12± 5.29 A a |
| 9 | *Cyperus rotundus* (L.)Bayer | 27.33± 3.86 BC b | 24.51± 3.21 D a | 25.37± 1.19 E a | 25.52± 1.51 C a | 25.51± 2.96 F a | 24.92± 2.05 BCDa |
| 10 | *Drymaria cordata* (L.) Whitesnow | 16.31± 6.91 A b | 13.78± 4.74 ABC a | 16.62± 2.87 BC b | 16.09± 3.42 B b | 13.98± 5.45 ABCD a | 13.24± 5.82 AB b |
| 11 | *Eclipta alba* L. ex B.D. Jacks | 10.6± 2.89 A a | 12.71± 5.46 ABCab | 9.99± 3.39 A a | 10.34± 3.20 A a | 10.25± 1.85 AB a | 11.71± 5.03 A a |
| 12 | *Galinsoga parviflora* cav. | 35.36± 5.48 C ab | 33.58± 9.32 F a | 33.58± 2.73 F a | 33.45± 2.63 D a | 34.41± 5.71 G a | 35.64± 9.13 D ab |
| 13 | *Gnaphalium affine* D.Don | 12.4± 4.03 A ab | 11.13± 0.95 AB a | 11.09± 3.80 A a | 10.58± 1.78 A a | 17.18± 6.26 CD b | 13.6± 4.66 AB ab |
| 14 | *Oxalis corniculata* L. | 18.16± 2.77 AB a | 17.75± 5.33 BC a | 19.5± 1.44 CDa | 18.9± 1.53 B a | 18.12± 5.09 DE a | 17.4± 4.62 ABCa |
| 15 | *Rannunculus repens* L. | 10.23± 1.96 A a | 11.87± 3.32 ABCab | 9.62± 1.22 A a | 9.55± 0.96 A a | 15.26± 4.84 ABCD a | 13.12± 5.66 AB ab |
| 16 | *Sonchus arvensis* (L.) | 9.96± 2.44 A a | 11.2± 0.75 AB a | 9.09± 1.45 A a | 9.87± 1.05 A a | 9.84± 4.05 AB a | 10.42± 3.77 A a |
| 17 | *Stellaria Media* | 9.2± 1.01 A a | 18.31± 5.08 C b | 11.89± 3.96 A ab | 11.88± 2.73 A ab | 16.59± 6.50 BCD b | 17.58± 6.74 ABCb |

Value (mean±SD) bearing the same small letter (IVI of individual species in selected sites) in the same rows and capital letter (IVI of all species in selected sites) in same column after mean±

SD do not differ significantly according to ANOVA followed by the Duncan's Multiple Range Test at P=0.05

**Appendix 4:** IVI of common weeds on the winter crop fields of *Brassica campestris* at different sites of Kathmandu Valley

| SN | Species | Kirtipur | Bhaktapur | Godawari | Chapagaon | Dharamsthali | Shivapuri |
|---|---|---|---|---|---|---|---|
| 1 | *Ageratum conyzoides* L. | 29.04± 4.55 CD a | 27.42± 4.03 C a | 31.36± 3.83 CDE b | 29.95± 2.85 D a | 30.98± 4.28 F ab | 30.96± 3.27 F ab |
| 2 | *Ageratum haustonianum* Mill | 12.95± 6.73 AB a | 14.36± 5.16 AB a | 17.42± 6.24 ABCD b | 13.6± 5.74 BC a | 18.69± 0.65 DE b | 18.59± 1.85 D b |
| 3 | *Amaranthus spinosus* L. | 9.99± 1.72 A ab | 8.25± 2.53 A a | 7.58± 2.39 A a | 7.92± 2.41 A a | 9.62± 1.51 A ab | 9.51± 1.57 ABab |
| 4 | *Bidens pilosa* L. | 24.1± 3.32 BC a | 27.72± 2.62 ab | 26.26± 4.09 ab | 27.23± 3.17 ab | 25.05± 3.43 a | 28.86± 3.09 ab |
| 5 | *Capsella bursapastoris* L. | 13.76± 5.38 ab | 15.69± 5.00 C b | 12.6± 4.18 BCDE ab | 13.98± 4.95 D ab | 9.23± 5.16 F ab | 8.13± 2.41 EF a |
| 6 | *Centella asiatica* L. | 12.56± 4.16 Ab ab | 10.52± 4.83 AB a | 13.04± 3.20 AB b | 11.59± 2.20 ABC ab | 11.56± 3.93 ABC ab | 12.44± 2.26 BC ab |
| 7 | *Chenopodium album* | 9.69± 1.50 A a | 9.44± 2.26 AB a | 10.64± 1.30 AB a | 10.13± 1.08 AB a | 10.91± 1.81 ABC a | 11.17± 1.87 AB ab |
| 8 | *Cynodon dactylon* L. | 10.53± 5.68 A a | 14.53± 4.01 AB b | 14.03± 4.54 AB b | 16.05± 1.57 C c | 14.43± 3.39 BCD b | 15.69± 1.96 CD bc |
| 9 | *Cyperus rotundus* (L.) Bayer | 24.11± 2.10 BC a | 26.39± 4.10 C ab | 25.1± 3.47 ABCDE ab | 27.21± 3.45 D ab | 23.97± 2.22 F a | 26.08± 2.72 E ab |
| 10 | *Drymaria cordata* (L.) Whitesnow | 11.03± 5.66 A a | 16.79± 6.98ab B ab | 13.82± 3.36 AB ab | 15.17± 4.70 BC ab | 17.71± 3.49 DE ab | 18.07± 2.57 D a |
| 11 | *Eclipta alba* L. ex B.D. Jacks | 14.12± 5.41 AB b | 13.45± 4.69 AB ab | 9.98± 1.65 AB a | 10.12± 2.93 AB a | 11.4± 3.10 ABC a | 10.09± 2.99 AB a |
| 12 | *Galinsoga parviflora* cav. | 39.21± 11.39 D b | 33.04± 7.81 C ab | 31.82± 4.66 DE ab | 32.00± 4.97 D ab | 28.24± 3.38 EF a | 30.61± 3.55 F ab |
| 13 | *Gnaphalium affine* D. Don | 14.44± 3.88 AB ab | 12.84± 4.21 AB ab | 16.51± 4.82 ABCD b | 13.16± 1.99 BC ab | 12.62± 4.06 ABC ab | 9.65± 0.87 ABa |
| 14 | *Oxalis corniculata* L. | 17.07± 4.34 ABC a | 16.49± 4.94 B a | 25.48± 4.33 E b | 16.79± 2.33 C a | 18.43± 2.87 DE a | 18.85± 3.38 D a |
| 15 | *Rannunculus repens* L. | 13.34± 5.46 AB ab | 12.38± 5.24 AB ab | 13.44± 5.74 AB ab | 10.46± 1.07 AB a | 10.34± 1.70 AB a | 10.93± 1.96 AB a |
| 16 | *Sonchus arvensis* (L.) | 10.41± 3.78 A a | 13.41± 6.15 AB a | 15.38± 6.60 ABCD b | 16.37± 7.04 C b | 11.82± 3.68 ABC a | 10.99± 2.04 AB a |
| 17 | *Stellaria Media* | 19.89± 4.64 ABC ab | 12.56± 5.01 AB a | 22.1± 12.08 ABCDE a | 12.96± 4.16 ABC a | 19.31± 4.54 E ab | 12.7± 4.40 BC a |

Value (mean±SD) bearing the same small letter (IVI of individual species in selected sites) in the same rows and capital letter (IVI of alll species in selected sites) in same column after mean±

SD do not differ significantly according to ANOVA followed by the Duncan's Multiple Range Test at P=0.05

## Photo Plate

1) Wheat field infested with different weeds

2) Mustard field infested with different weeds

a) flowering stage;*Galinsoga*

b) vegetative and flowering stage of*Galinsoga*

c) flowering stage of *Ageratumconyzoides*

d) Flowering stage of *Ageratum conyzoides*

e) Flowering, fruiting and senescenes of *Bidens*

f) Fruiting and senescenes stages of *Cyperus*

(a-f) Phenophases of common weeds during winter

a) *Ageratum conyzoides*　　　b) *Bidens pilosa*

c) *Cyperus rotundus*　　　d) *Galinsoga parviflora*

(a-d) Seed recovered by differential floating method

a) differential floatation method　　　(b) Seeds of different weeds extracted from sampled soil

(a) & (b) Weed seed extraction by floatation technique

a) germination stage　　　b) vegetative stage　　　c) mature stage

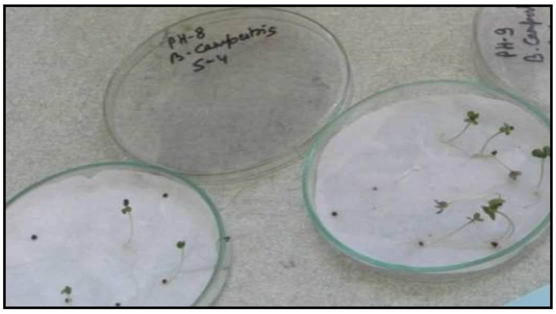
(a-c) Seed estimation by germination method

a) Seed germination of *Bidens pilosa*

b) Seed germination of *Triticum aestivum*

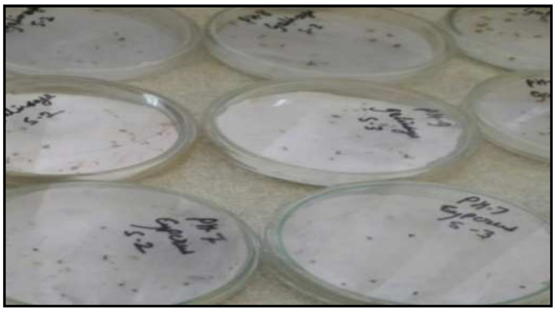
a) & (b) Seed germination on different moisture conditions

Seed germination under light of different colors
(normal, red, yellow, blue, green and dark colour) produced by using cellophane papers

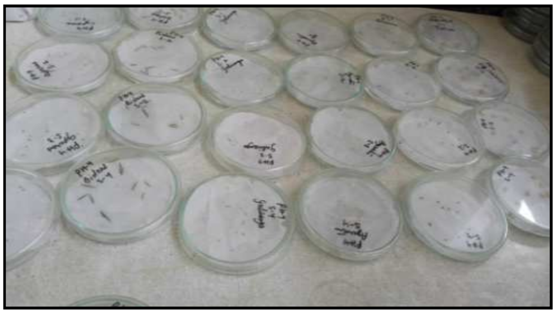


a) Seed germination of *Brassica campestris*

b) Seed germination of *Triticum aestivum*

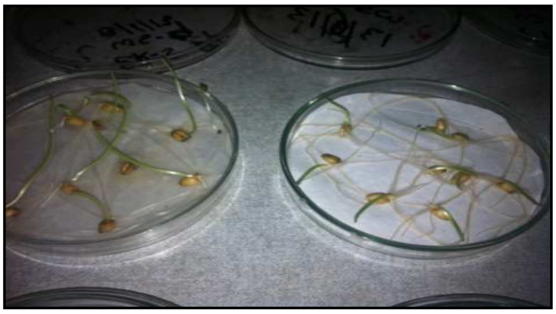


c) Seed germination of *Cyperus rotundus*



d) Seed germination of *Ageratum and Galinsoga*

(a-d) Seed germination on different level of pH



a) *Triticum aestivum* b) *Brassica campestris*

(a) & (b) Seed germination on fertilizer solutions (Urea and Potash)

a) *Triticum aestivum* b) *Brassica campestris*

(a) & (b) Seed germination on fertilizer (urea and potash) separately g/kg amended with soil

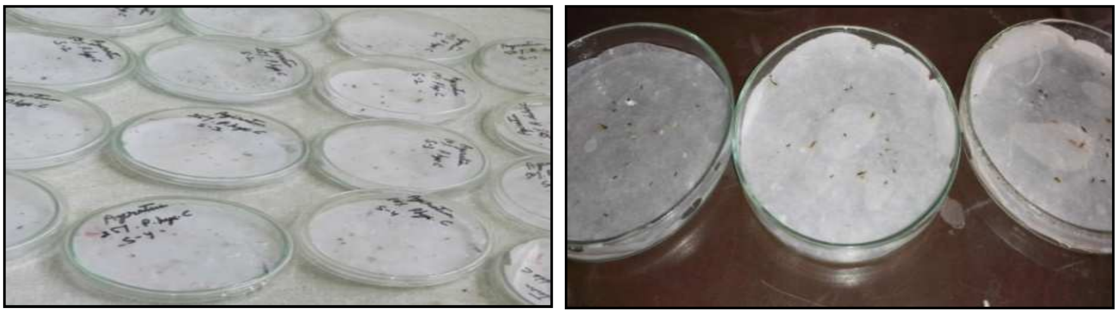
Preparation of compost

Seed germination on aqueous extract of *A. adenophora* (Syn. *E. adenophora*

Seed germination on *A. adenophora* compost extracts

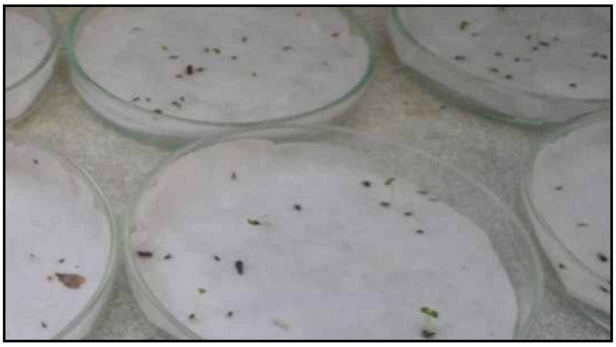
Seed growing on *A. adenophora* compost

Seed germination on aqueous extract of *P. hysterophorus*

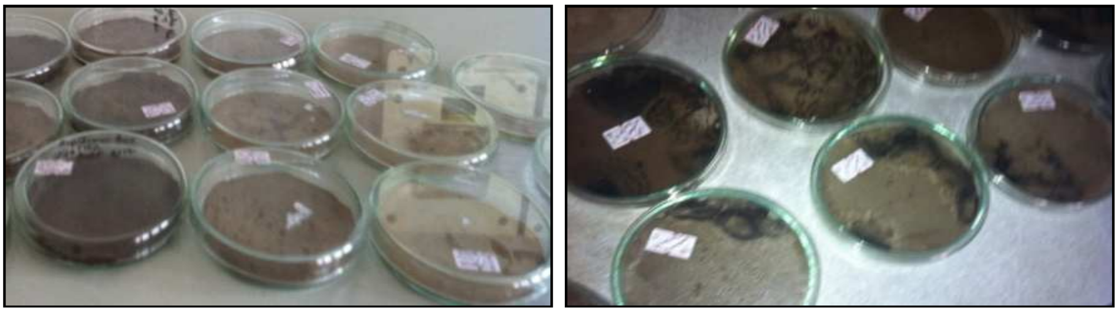


Seed germination on *P. hysterophorus* compost extracts

Mustard and wheat grown on *P. hysterophorus* compost amended with soil



Seed germination on aqueous extract of *A. dubia*



Seed germination on *A. dubia* compost extracts

Weeds growing on *A. dubia* compost amended soil

**Scientification Publications and Seminar Participation**

1) Mallik Baby B.D., Acharya, B.D., Saquib, M., Chettri, M.K. (2020). Seed germination and seedling growth of some crops and weed seeds under different environmental conditions. *Journal of Research in Weed Science, 3* (1), 363-381.
DOI: 10.26655/JRWEEDSCI.2020.3.8

2) Mallik Baby B.D., Acharya, B.D., Saquib, M., Chettri, M.K. (2019). Effect of compost extract, compost of *Parthenium hysterophorus* on seed germination and growth of mustard, wheat and weeds. *Indian Journal of Weed Science*, *51* (2), 169–172.
DOI: 10.5958/0974-8164.2019.00036.4

3) Mallik Baby B.D., Acharya, B.D., Saquib, M., Chettri, M.K. (2018). Effect of aqueous extract and compost of invasive weed *Ageratina adenophora* on seed germination on seed germination and seedling growth of some crops and weeds. *Journal of Biodiversity, Conservations and Bioresources Management*, *4* (2), 11-20.
DOI: https://doi.org/10.3329/jbcbm.v4i2.39843

4) Mallik Baby B.D., Acharya, B.D., Saquib, M., Chettri, M.K. (2014). Allelopathic effect of *Artemisia dubia* on seed germination and seedling growth of some weeds and winter crops. *Ecoprint, 21*, 23-30.
DOI: http://dx.doi.org/10.3126/eco.v21i0.11901 Ecological Society (ECOS), Nepal

ECOPRINT **21:** 23-30, 2014 ISSN 1024-8668
DOI: http://dx.doi.org/10.3126/eco.v21i0.11901
Ecological Society (ECOS), Nepal
www.nepjol.info/index.php/eco; www.ecosnepal.com

# ALLELOPATHIC EFFECT OF *ARTEMISIA DUBIA* EXTRACTS ON SEED GERMINATION AND SEEDLING GROWTH OF SOME WEEDS AND WINTER CROPS

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**ABSTRACT**

Allelopathic effects of aqueous extract of different plant parts (root, stem and leaf) of *Artemisia dubia* on seed germination and seedling growth of two winter crops (*Triticum aestivum* and *Brassica campestries,* and some associated weeds (*Bidens pilosa, Ageratum conyzoides, Galinsoga parviflora* and *Cyperus rotundus*) have been investigated in the present study. Extracts of root, stem and leaves of *Artemisia dubia* showed significant reduction in germination and seedling growth of test crops and weeds. Germination of crop and weed seeds and growth of shoot and root were reduced significantly in test treatments in comparison to the control. The seed germination, shoot length and root length were low at higher concentration. Complete inhibition of seed germination of *Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus* at 5 and 10% leaf extract of *A.dubia* was observed. Allelopathic effects were more pronounced with leaf extract than root or stem extract in most cases.The result indicated difference in allelopathic effect on crop seed and weed seed at higher concentrations.

**Key words**: *Artemisia dubia*, aqueous extract, allelopathy, weed.

## INTRODUCTION

Several species of Asteraceae family are known for having alleolpathic compounds which may reduce seed germination and seedling emergence of other plants (Watban and Salama 2012). Genus *Artemisia* is hardy herbaceous shrub which is widely distributed, and consists species between 200 and 400.

The research information is inadequate on allelopathic effect of potential plants in controlling weeds of vegetables. Leaf extract of *A. dubia* caused an inhibitory effect on germination and growth of barnyard grass (Paudel *et al.* 2005). Such information will help to develop organic herbicides which are environmentally safe and cost effective. Identification of suitable plants with herbicidal properties, with their formulation gains special importance in organic farming. Although many plant species are reported to have allelopathic properties but the information on their compatibility with field crops, effective active ingredient, extraction and utilization technology is lacking. Therefore, present work was carried out to investigate the potentiality of *Artemisia* aqueous extract on seed germination and seedling growth of some winter crops and associated weeds.

As some growth inhibitors have been reported from some other species of *Artemisia*, therefore, it is hypothesized that aqueous extract of *Artemisia dubia* possibly will also reduce seed germination of both winter weeds and winter crops due to their allelopathic effects. The adverse effect on seed germination will be more on weed seeds than on crop seeds because the size and reserve food materials in weed seeds are comparatively less.

## MATERIALS AND METHODS

### Site for seed collection

Experiments were conducted under laboratory conditions at Botany Department, Amrit Campus (Tribhuban University), Kathmandu. The mature weed seeds of *Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora* were collected from Wheat, Mustard and Radish fields and fallow land from different sites of Kathmandu valley in Kirtipur (Machhegaon, Chhobhar), Bhaktapur (Thimi, Lokanthali, Gatthaghar) and Godavari.

### Preparation of extracts of *Artemisia dubia*

*Artemisia dubia* plants were collected from Kirtipur, Bhaktapur and Kathmandu area for preparing the extracts of stem, root and leaf. Collected plants were air dried and then leaf, stem and roots were separated. To prepare aqueous extract, 2 g of grinded air dried leaf, stem and root were soaked in 20 ml distilled water for 24 h separately. The extracts were filtered using Whatman No.1 filter paper and thus 10% stock solution was prepared. From this stock solution, 5%, 2.5%, and 1.0% concentration was prepared by diluting with distilled water.

### Seed germination

Seeds of the dominant weed species (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) and the crop seeds of *B. campestris* and *T. aestivum* were soaked in 2-4% Sodium hypochlorite for 2 minutes separately. The seeds were then washed with distilled water thoroughly. The sterilized petridishes were lined with single Whatman No. 1 filter paper and moistened with 5 ml of treatment solution. Uniform size seeds of the crops (*B. campestris*, *T. aestivum)* and weeds *(A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) were selected and five seeds of each tested species were kept in sterilized petridishes containing 0% (control), 1, 2.5, 5 and 10% concentrations of aqueous extracts for 10 days. For control, seeds were grown in filter paper soaked with distilled water. All these experiments were conducted under normal room temperature. Each treatment was replicated four times. The moisture level in the petridish was maintained by adding distilled water as required.

### Statistical Analysis

To understand significant difference among the data obtained at each treatment, statistical analysis was done by using IBM SPSS Statistics Version 20. The data were subjected to one way ANOVA followed by Duncan's Multiple range test.

## RESULTS

In the present study, seed germination, shoot length and root length was found decreased with the increase in the concentration of aqueous extracts in both crops (*Brassica campestris, Triticum aestivum)* and tested weeds (*Bidens pilosa*, *Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus*) (Tables 1-6). Seed germination of both crops *B. campestris* and *T. aestivum* was found reduced significantly with increase in concentration of root, stem and leaf extract of *A. dubia* (Tables 1 and 2). Insignificant decrease in germination of *Brassica* seeds was observed at 1, 2.5 and 5% root extract but significant reduction was noticed at 5 and 10% concentrations. Similarly, insignificant decrease in *Triticum* seed germination was observed up to 2.5% root and leaf extract treatment. Germination of *Brassica* seeds was found to be higher in root extract than in stem or leaf extracts, but in *Triticum*, reduction in germination of seeds was more with root and stem treatments than with leaf extract. Inhibition of growth i.e. denoted by shoot and root length was highest with leaf extract in *Brassica* but it was more with root extracts in *Triticum* (Table 2).

**Table 1. Effect of root, stem and leaf extracts of *Artemisia dubia* on seed germination (%±SD), shoot and root length (cm±SD) of *Brassica campestris* after 10 days.**

| Concentration | Root extract | | | Stem extract | | | Leaf extract | | |
|---|---|---|---|---|---|---|---|---|---|
| (%) | Germination | Shoot length | Root length | Germination | Shoot length | Root length | Germination | Shoot length | Root length |
| 0 | 100 ±0.00c | 8.05 ±0.37 d | 5.86 ±0.50 e | 80 ±16.32 b | 6.13 ±0.39 c | 4.87 ±0.41c | 90 ±11.54 b | 3.64 ±1.39c | 1.87 ±1.11b |
| 1 | 80 ±16.32 b | 5.71 ±1.39 c | 4.77 ±1.17 d | 75 ±12.14 b | 4.25 ±1.90 b | 3.15 ±1.41b | 85 ±10.00 b | 3.45 ±1.52c | 1.61 ±1.14b |
| 2.5 | 80 ±0.00 b | 4.03 ±1.81 b | 3.59 ±1.28 c | 65 ±19.14 ab | 3.13 ±2.38ab | 2.38 ±1.83ab | 70 ±34.64 ab | 2.20 ±1.75 b | 0.98 ±0.96 a |
| 5 | 75 ±10.00 b | 2.71 ±1.63 a | 2.35 ±1.42 b | 50 ±11.54 a | 2.27 ±2.38a | 1.89 ±1.95a | 50 ±25.81 a | 1.65 ±1.79ab | 0.73 ±0.97a |
| 10 | 60 ±16.32 a | 1.84 ±1.40 a | 1.61 ±1.23 a | 45 ±10.00 a | 1.87 ±2.17a | 1.65 ±1.89a | 40 ±16.32 a | 0.84 ±1.12 a | 0.35 ±0.48a |

Same letters in the same column after Mean ± SD does not differ significantly according to ANOVA followed by Dunkan's Multiple Range Test at P=0.05.

**Table 2. Effect of leaf, stem and root extracts of *Artemisia dubia* on seed germination (%±SD), shoot and root length (cm±SD) of *Triticum aestivum* after 10 days.**

| Concentration | Root extract | | | Stem extract | | | Leaf extract | | |
|---|---|---|---|---|---|---|---|---|---|
| (%) | Germination | Shoot length | Root length | Germination | Shoot length | Root length | Germination | Shoot length | Root length |
| 0 | 85 ±19.14 c | 8.89 ±0.45e | 6.12 ±0.34 e | 100 ±0.00 c | 9.00 ±1.18 c | 5.27 ±0.27 b | 100 ±0.00 b | 10.28 ±0.34d | 7.58 ±1.05c |
| 1 | 80 ±0.00 c | 7.60 ±0.49d | 5.16 ±0.46 d | 75 ±10.00 b | 6.19 ±3.71 b | 4.31 ±2.75 b | 100 ±0.00 b | 8.58 ±2.98 c | 6.56 ±0.84 c |
| 2.5 | 70 ±11.54 bc | 4.54 ±2.36c | 3.89 ±2.01 c | 70 ±20.00 ab | 5.77 ±2.52 b | 4.26 ±1.86 b | 85 ±10.00 ab | 5.18 ±2.45 b | 3.92 ±1.76b |
| 5 | 55 ±10.00ab | 3.48 ±2.09 b | 2.92 ±1.75 b | 55 ±10.00 ab | 3.21 ±3.04a | 2.25 ±2.20a | 75 ±30.00 ab | 3.90 ±3.10 ab | 3.15 ±2.50 ab |
| 10 | 40 ±23.09 a | 2.31 ±1.76 a | 1.96 ±1.53 a | 50 ±20.00 a | 2.65 ±2.73a | 1.66 ±1.71 a | 60 ±16.32 a | 3.11 ±2.44 a | 2.49 ±2.08 a |

Same letters in the same column after Mean ± SD does not differ significantly according to ANOVA followed by Dunkan's Multiple Range Test at P=0.05.

Insignificant effect on seed germination was observed up to 2.5% root, stem and leaf extract in *Bidens pilosa* (Table 3) and up to 1% of root, stem and leaf extract in *Ageratum conyzoides* (Table 4). In both weeds, seed germination decreased significantly (P=0.05) with their higher concentrations. The length of shoot and root of seedlings decreased significantly (P=0.05) in all treatments with increase in concentration (Tables 3 and 4). Leaf extract of 5 and 10% concentration was found to be more detrimental for germination of seeds of *Ageratum conyzoides* and no germination was observed.

**Table 3. Effect of leaf, stem and root extracts of *Artemisia dubia* on seed germination (%**±SD), **shoot and root length (cm±SD) of *Bidens pilosa* after 10 days.**

| Concentration | Root extract | | | Stem extract | | | Leaf Extract | | |
|---|---|---|---|---|---|---|---|---|---|
| (%) | Germination | Shoot length | Root length | Germination | Shoot length | Root length | Germination | Shoot length | Root length |
| 0 | 85 ±10.00 **c** | 4.94 ±1.70**d** | 3.85 ±1.38**c** | 85 ±10.00 **c** | 4.35 ±1.92**c** | 3.47 ±1.54**c** | 80 ±16.32 c | 7.81 ±1.21**c** | 6.36 ±1.42**c** |
| 1 | 70 ±11.54**bc** | 4.00 ±1.74 **cd** | 3.17 ±1.41**bc** | 75 ±10.00 **bc** | 3.32 ±1.97**bc** | 2.49 ±1.50**b** | 70 ±11.54 **bc** | 4.61 ±3.15**b** | 3.96 ±2.68**b** |
| 2.5 | 65 ±19.14 **bc** | 3.42 ±1.76**bc** | 2.77 ±1.45**b** | 70 ±11.54 bc | 2.75 ±1.87**ab** | 2.03 ±1.46**ab** | 65 ±13.00 **bc** | 4.50 ±3.41**b** | 4.05 ±2.80**b** |
| 5 | 55 ±10.00 **ab** | 2.70 ±1.64**ab** | 2.32 ±1.41**b** | 60 ±16.32**ab** | 2.22 ±1.87**ab** | 1.64 ±1.39**ab** | 50 ±11.54 **ab** | 3.24±3.45**a b** | 2.41 ±2.57**a** |
| 10 | 40 ±16.32 **a** | 1.88 ±1.96**a** | 1.34 ±1.40**a** | 50 ±11.54 **a** | 1.53 ±1.59**a** | 1.11 ±1.23**a** | 35 ±10.00**a** | 0.71 ±2.32**a** | 1.55 ±2.30**a** |

Same letters in the same column after Mean ± SD does not differ significantly according to ANOVA followed by Dunkan's Multiple Range Test at P=0.05.

**Table 4. Effect of leaf, stem and root extracts of *Artemisia dubia* on seed germination (%**±SD), **shoot and root length (cm±SD) of *Ageratum conyzoides* after 10 days.**

| Concentration | Root extract | | | Stem extract | | | Leaf extract | | |
|---|---|---|---|---|---|---|---|---|---|
| (%) | Germination | Shoot length | Root length | Germination | Shoot length | Root length | Germination | Shoot length | Root length |
| 0 | 80 ±16.32 d | 2.29 ±1.40b | 1.62 ±1.11b | 75 ±10.00 c | 2.17 ±1.41b | 1.44 ±1.03b | 70 ±20.00 b | 2.00 ±0.52c | 1.22 ±0.25b |
| 1 | 75 ±10.00 cd | 2.07 ±1.56b | 1.44 ±1.10b | 65 ±19.00 bc | 1.80 ±1.31b | 1.20 ±0.97b | 50 ±11.54ab | 1.19 ±0.34b | 1.02 ±0.05a |
| 2.5 | 60 ±0.00bc | 1.74 ±1.24 b | 1.29 ±0.95b | 50 ±11.54 ab | 1.60 ±1.42b | 1.15 ±0.73b | 35 ±19.14a | 1.30 ±1.11ab | 1.11 ±0.01a |
| 5 | 50 ±11.54 b | 1.60 ±0.81a | 1.51 ±0.57a | 45 ±19.14 ab | 1.50 ±0.79a | 1.33 ±0.57a | NG | NG | NG |
| 10 | 30 ±11.54 a | 1.35 ±0.39a | 1.19 ±0.21a | 40 ±0.00a | 1.35 ±0.38a | 1.32 ±0.38a | NG | NG | NG |

Same letters in the same column after Mean ± SD does not differ significantly according to ANOVA followed by Dunkan's Multiple Range Test at P=0.05.NG = No germination

Seed germination of *Galinsoga parviflora* and *Cyperus rotundus* decreased with increase in concentration of root, stem and leaf extracts of *A. dubia* (Tables 5 and 6). In both weeds, seed germination in root extract was more than in extracts of stem and leaves. Lowest percentage of seed germination was observed with leaf extract treatment indicating its more allelopathic effects than root or stem. Significant decrease in shoot length and root length of seedlings were observed with high concentrations. Germination of *Galinsoga* seed was completely inhibited with 10% stem and leaf extract of *A. dubia* (Table 5). Similarly complete inhibition of seed germination with 10% root stem and leaf was observed in *Cyperus rotundus* (Table 6).

**Table 5**. **Effect of leaf, stem and root extracts of *Artemisia dubia* on seed germination (%**±SD) **shoot and root length (cm±SD) of*Galinsoga parviflora* after 10 days.**

| **Concentration** | **Root extract** | | | **Stem extract** | | | **Leaf extract** | | |
|---|---|---|---|---|---|---|---|---|---|
| **(%)** | **Germination** | **Shoot length** | **Root length** | **Germination** | **Shoot length** | **Root length** | **Germination** | **Shoot length** | **Root length** |
| 0 | 75 ±10.00 c | 1.73 ±1.32b | 1.39 ±1.03 c | 65 ±19.14 d | 1.64 ±1.05c | 1.28 ±1.00b | 60 ±28.28 c | 1.40 ±0.93c | 1.20 ±0.44b |
| 1 | 65 ±10.00c | 1.49 ±1.39b | 1.29 ±0.87 bc | 50 ±11.54 cd | 1.36 ±0.84 bc | 1.17 ±0.82b | 45 ±19.14 bc | 1.16 ±0.77bc | 1.11 ±0.44b |
| 2.5 | 45 ±10.00 b | 1.40 ±1.35 b | 1.20 ±0.77 bc | 40 ±0.00bc | 1.30 ±0.74 bc | 1.08 ±0.75b | 20 ±16.32ab | 1.17 ±0.37ab | 1.02 ±0.09a |
| 5 | 40 ±16.32 ab | 1.32 ±0.81a | 1.11 ±0.51 ab | 30 ±11.54 ab | 1.28 ±0.47 ab | 1.03 ±0.47 a | 15 ±10.00 a | 1.20 ±0.52a | 1.00 ±0.07a |
| 10 | 25 ±10.00 a | 1.22 ±0.30a | 1.10 ±0.19 a | NG | NG | NG | NG | NG | NG |

Same letters in the same column after Mean ± SD does not differ significantly according to ANOVA followed by Dunkan's Multiple Range Test at P=0.05;.NG = No germination

**Table 6. Effect of leaf, stem and root extracts of *Artemisia dubia* on seed germination (%**±SD) **shoot and root length (cm±SD) of *Cyperus rotundus* after 10 days.**

| **Concentration** | **Root extract** | | | **Stem extract** | | | **Leaf extract** | | |
|---|---|---|---|---|---|---|---|---|---|
| **(%)** | **Germination** | **Shoot length** | **Root length** | **Germination** | **Shoot length** | **Root length** | **Germination** | **Shoot length** | **Root length** |
| 0 | 70 ±11.54 c | 1.65 ±0.89c | 1.48 ±0.66d | 65 ±10.00 c | 1.42 ±0.98c | 1.33 ±0.88c | 60 ±16.32 c | 1.39 ±0.52c | 1.30 ±0.25c |
| 1 | 50 ±25.81 c | 1.54 ±0.80c | 1.37 ±0.59 cd | 55 ±19.14 c | 1.36 ±0.92 c | 1.24 ±0.73c | 45 ±10.00 c | 1.23 ±0.52b | 1.17 ±0.21b |
| 2.5 | 25 ±19.14 b | 1.38 ±0.85c | 1.29 ±0.44 bc | 30 ±11.54 b | 1.25 ±0.88 bc | 1.20 ±0.48b | 25 ±10.00 b | 1.18 ±0.34a | 1.07 ±0.13ab |
| 5 | 20 ±0.00ab | 1.27 ±0.44b | 1.18 ±0.25ab | 15 ±10.00 ab | 1.22 ±0.48 ab | 1.17 ±0.26ab | 15 ±10.00 ab | 1.12 ±0.08a | 1.04 ±0.04a |
| 10 | NG | NG | NG | NG | NG | NG | NG | NG | NG |

Same letters in the same column after Mean ± SD does not differ significantly according to ANOVA followed by Dunkan's Multiple Range Test at P=0.05;.NG = No germination

Comparing seed germination of *Brassica campestries* in leaf extract (where the allelopathic effect was high) with other tested weed (Tables 1 and 3-6), it was observed that adverse effect on seed germination is low in *B. campestries* than in other tested weeds. Similarly, from comparison of seed germination of *Triticum astivum* (in root and leaf extracts) and other weeds (Table 2-6), it was noted that adverse effect on *Triticum* seed germination was less than in studied weeds.

**DISCUSSION**

In the present study it was found that seed germination, shoot length and root length decreased in extract of vegetative parts (leaf, stem and root) of *Artemesia* but the effect of leaf extract was more pronounced. Putnam (1988) listed 6 classes of allelochemicals namely alkaloids, bezaoxaziones, cinnamic acid derivatives, Cyanogenic compounds, ethylene and others. More amount of volatile phytotoxic compounds have been recorded from green leafy part in *Artemesia californica (*Halligen 1973) and possibly such phytotoxic chemicals are also present in *A. dubia* and this may be the reason for more allelopathic effect of leaf on seed germination.

The germination of seeds, root and shoot length of crop plant *B. campestris* and *T. aestivum* was inhibited by the aqueous extract of weed *A. dubia*. Among the different treatments, the seed germination was more reduced in 5% and 10% concentration of root, stem and leaf extracts. Similar effects were obtained by Watban and Salama (2012) of *Artemisia monosperma* extract on *Phaseolus vulgaris*. Similarly, decrease in germination, growth and chlorophyll contents in *T. aestivum* was reported by Deef and El-Fattah (2008) when grown on the aqueous extract of *Artemesi aprinces.* Study of the allelopathic effects of some selected weeds (*Phalaris minor L., Chenopodium murale L., Sonchus oleraceus L., Cyanodon dactylon L.* and *Convolvulus arvensis L.*) on seed germination and seedling growth of wheat (*Triticum aestivum L.*) also showed similar inhibitory effects on seed germination; seedling length and seedling dry weight of crop, which increased progressively on increasing the concentration of extracts of weed plants (Gupta and Mittal 2012).

Seed germination and seedling growth of weeds *Bidens pilosa, Ageratum conyzoides Galinsoga parviflora* and *Cyperus rotundus* grown in the aqueous extract of *A. dubia* also revealed the reduction with increase in concentrations. Katoch *et al.* (2012) have also reported that the inhibition of seed germination and seedling growth were dependent on concentration and numerically more inhibition was observed at higher concentration. In present study significant reduction of shoot and root length occurred in all concentrations of leaf extract, which were also observed by many earlier workers while working on other weeds indicated that leaves have more powerful inhibitory allelopathic effect than other vegetative parts (Kanchan 1975, Tefera 2002, Maharjan *et al.* 2007). Passim and Rodrigues (1999) also mentioned that the aqueous extract of *Artemisia velotrum* reduced the seed germination, shoot and root length of some crops (*Zea mays*, *Glycine max*) and weeds like *Bidens pilosa, Galinsoga parviflora, Sida rhombifolia, Amaranthus retroflexus, Ipomoea aristolochiaefolia,* and *Cenchrus echinatus.*

There is total inhibition of seed germination of *Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus* with higher concentration of leaf extract. Work by Mittal and Kohli (2010) mentioned that Artemisia oil has bioherbicidal properties as it causes phytotoxicity and interfere with the growth and physiological processes of some weed species. Similarly, in the present sudy, more allelopathic effects were found with leaf extract followed by stem and then root in most cases except in *Triticum aestivum*. Quartey *et al.* (1997) also revealed that leaves of *Artemisia afra* had the most inhibitory effect on seed germination compare to other parts of plant. The aerial parts contain high inhibitory allelochemicals (Gill *et al.* 1996) which may interfere with the processes of plant growth. These allelochemical may be reducing cell division or auxin induced growth of roots (Gholami *et al*. 2011).

Comparison of seed germination of *Brassica campestries* and *Triticum aestivum* with other studied weeds revealed that seed germination in crops was less adversely affected than in weeds. This might possibly be due to large seed size and more reserve food material present in crop seed than in weed seeds.

From the study it can be concluded that the aqueous extract of vegetative parts, particularly leaf contained more growth inhibiting allelochemicals. According to the study the shoot and root length of weeds (*Bidens pilosa, Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus*) and crops *(Brassica campestris* and *Triticum aestivum)* are significantly reduced at high concentration of *Artemisia dubia* extract. Comparison of seed germination percentage in crops and weed seeds revealed that seed germination is less adversely reduced in crops than in weeds. Artemesinine, a sesquiterpene lactone extracted from *Artemisia annua L.* is a potent plant growth inhibitor (Javaid and Anjum 2006). Similar allelochemicals may be present in *A. dubia* as both of them belong to the same genus. Thus, there is possibility for extraction and using of such allelochemicals from *Artemesia dubia* directly or to develop environment friendly bio-herbicides to control weeds.

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# EFFECT OF AQUEOUS EXTRACT AND COMPOST OF INVASIVE WEED *Ageratina adenophora* ON SEED GERMINATION AND SEEDLING GROWTH OF SOME CROPS AND WEEDS

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## Abstract

A study was conducted to investigate the effects of invasive weed *Ageratina adenophora* on the seed germination and seedling growth of *Triticum aestivum*, *Brassica campestris* and on weeds *Ageratum conyzoides*, *Bidens pilosa*, *Galinsoga parviflora and Cyperus rotundus*. The aqueous extracts of *Ageratina* plant's part root, stem and leaf; and compost extract of *Ageratina* on different concentrations (control, 1, 2.5, 5 and 10%) were used to determine its effect on the seed germination, shoot and root length of *Triticum aestivum*, *Brassica campestris* and some common weed seeds under laboratory condition. The compost of *A. adenophora* at different doses viz. 0, 10, 20, 40 and 50g compost/kg soil was also applied to study the effect on the seed germination and seedling growth of *B. campestris* and *T. aestivum* and some weed seeds. The aqueous and compost extracts of *Ageratina* caused significant reduction in the seed germination and seedling length (shoot and root) which increased progressively on increasing the concentration of invasive plant's extract. The stem and leaf extracts of *A. adenophora* have more inhibitory effect on the germination percentage of winter crops as compared to root extract on the test crop seeds under study. In the compost of *A. adenophora,* the weeds showed more reduction in comparison to the crop plants *B. campestris* and *T. aestivum*.

***Key words*:** Invasive, aqueous extract, compost, allelopathy, inhibition.

## INTRODUCTION

A total of 190 invasive alien species under 112 genera belonging to 47 families has been recorded from the Indian Himalayan region (Kumar *et al*. 2016, Sekar *et al*. 2012). In China 25 out of 33 highly noxious weeds have significant allelopathic impact on surrounding plants. The release of biochemicals called allelochemicals, reduce the seed germination and seedling growth of surrounding plants (Ferguson *et al*. 2013). The plant species belonging to family Asteraceae produce the substances that are toxic to germination and growth of other plant species (Tripathi *et al.* 1981). Invasive plant parts have allelopathy to continue for their ecological accomplishment.

The allelochemicals discharged from a plant are due to volatilization, leaching, exudation and decomposition (Gill *et al*. 1993). The allelopathic activities of the crude methanol extract of *Chromolaena. odorata*, on the seed germination and seedling growth of tomato have been observed by Tijani and Fawusi (1989).

*Ageratina adenophora* of Asteraceae family is a troublesome, aggressive, toxic perennial weed. It threatens bio, eco, agro and forestry systems in the tropical and subtropical regions. *Ageratina adenophora* (syn.name- *Eupatorium adenophorum*) weed came to Nepal through Mexico is one of the serious weeds in Asia. It quickly spreads across the terai, midhill and low mountain areas (Bisht *et al.* 2016).

Kumar *et al.* (2016) reported that the loss of plant diversity in both crop and forest areas over the last two to three decades is due to invasive plant. *Parthenium hysterophorus*, *Ageratina adenopha*, *Lantana camara*, *Ageratum conyzoides* and *Bidens pilosa* are degrading valuable crop and fodder plants (especially herbs and grasses). The leachates of *A. adenophora* plant damage cell membrane and influence the endogenous compounds like abscisic acid, indole 3-acetic acid and zeatinriboside of the roots of upland rice (Zheng *et al.* 2012).

The present work was carried out to understand the allelopathic influences of *Ageratina adenophora* on winter crops like mustard (*Brassica campestris*), wheat (*Triticum aestivum*) and four common weeds (*Ageratum, Bidens, Cyperus* and *Galinsoga*) by using their plant parts (root, stem and leaves) aqueous extract, compost extract and compost.

## MATERIAL AND METHODS

The invasive plant *Ageratina adenophora* and mature selected weed seeds were collected from selected sites around Kathmandu valley in Nepal, before flowering in May-June 2014. The matured seeds of *Bidens pilosa*, *Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus* were also collected from different sites around Kathmandu valley like Kirtipur and Bhaktapur areas in the months of March and April 2014. In Kirtipur (Machhegaon, Chhobhar, Chhugaon, Dhapla and near Tribhuban University and in Bhaktapur- Lokanthali (Near- Manohara Khola), Thimi, Gatthaghar, Sano Thimi and Balkot the samples were collected from fallow land and from the wheat and mustard fields.

The seeds of selected crops and weeds were collected, cleaned and dried. The nutrients like protein test method following AOAC (2012), carbohydrate and fat (test method- CFL Manual) per seed was analyzed at the Department of Food Technology and Quality control, Central Food Laboratory, Babarmahal, Kathamandu, Nepal.

The soil texture, pH, humus content in the soil of experimental site was conducted in the laboratory condition. The NPK test was conducted by Forest and Soil Science, Department of Forest Research and Survey, Nepal.

The plant parts (viz. root, stem and leaves) were separated, air dried and ground to make powder. To prepare aqueous extract, 2g of ground air dried leaves, stem and root were separately soaked in 20 ml distilled water for 24 hours. The extract was filtered using Whatman No.1 filter paper and 10% stock solution was prepared. From this stock solution, 5, 2.5 and 1.0% concentrations were prepared by diluting with distilled water.

A pit of 60.96 cm x 91.44 cm x 91.44 cm (length x breadth x depth) was prepared at shady place and was filled with layers of *Ageratina* plant altering with soil. It was left for seven months (March to September, 2015). This decomposed compost was ready to use. From this compost the experiment on compost extract at laboratory was conducted.

Two grams of air dried compost were soaked in 20 ml distilled water for 24 hours. The extract was filtered using Whatman No.1 filter paper and 10% stock solution was prepared. From this stock solution, 5, 2.5 and 1.0 % concentrations were prepared.

*Seed germination experiment*

**i)** Weed seeds of *A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora* and the crop seeds of *B. campestris* and *T. aestivum* were soaked, separately in 2-4% Sodium hypochlorite for two minutes. The seeds were then washed with distilled water thoroughly. The sterilized petridishes were lined with single piece of Whatman No. 1 filter paper and moistened with 5ml of treatment solution. The crops (viz. *B. campestris* and *T. aestivum*) and uniform size weed seeds of *A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora* were selected and ten seeds of each species were kept in sterilized petridishes containing control, 1, 2.5, 5 and 10% concentrations of **(a)** aqueous extract and **(b)** compost extracts for 10 days. For control, seeds were grown in a piece of filter paper soaked with distilled water. All these experiments were conducted under normal room temperature with five replications. The moisture level in the petridish was maintained by adding distilled water as required.

**ii)** The seed germination experiment was also conducted in poly bag (35.56 × 17.78 cm) by using different concentrations (viz. 10, 20, 40 and 50 g/kg soil) of *A. adenophora* compost in the month of

November, 2015. There were five replications of each treatment (10 selected seeds of weed and crops were sown). Seed germination and seedling growth were recorded after 30 days. The nutrient like protein, carbohydrate and fat per seed was analyzed at the Department of Food Technology and Quality Control, Central Food Laboratory, Kathmandu, Nepal.

Statistical analysis was done by using SPSS statistical version 20. The data were subjected to one way ANOVA followed by Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

The soil of experimental site was sandy loam and loamy type having 6.2 pH and 0.88% humus. Total N.P.K. were recorded 0.140, 0028 and 0.018%, respectively. The crop *T. aestivum* showed more content of moisture, protein, crude fiber and carbohydrate (viz. 0.54, 0.66, 0.30 and 3% per seed, respectively) than *B. campestris* (viz. 0.03, 0.08, 0.007 and 0.09% per seed, respectively) and other weed seeds of *A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*. Fat content was more in *B. campestris* (0.16%) than in *T. aestivum* (0.13%) and other weeds. Crude fiber was the highest in *T. aestivum* and lowest in *Brassica*. Among the weeds the protein content ranged from 0.009 to 0.02 %, fat from 0.001 to 0.01% and carbohydrate from 0.018 to 0.103%.

*Ageratina adenopnora aqueous extract*

The seed germination, shoot and root length of germinated seeds mostly decreased with the increase in the concentration of *Ageratina* root, stem and leaf aqueous extract in both tested crops *B. campestris* and *T. aestivum*, and weeds *A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora* (Tables 2 and 3).

*Seed germination*

*i.a) Impact of aqueous extract on the seed germination of crops*- the seed germination of *B. campestr* is reduced insignificantly in 2.5 and 5% of *A. adenophora* root and stem extract, respectively but in leaf extract it was 5 and 10% (Table 3). The seed germination of *Brassica* seed was higher in stem extract than in root and leaf extracts. The shoot and root length of the germinated seeds of *B. campestris* reduced significantly in all treatments in comparison to the control. Mostly, insignificant reduction in the shoot and root lengths of seedlings was 5 and 10% in root and stem extracts, respectively. In leaf extract, the root length of *B. campestris* decreased significantly in all treatments, but insignificant reduction was observed in 1 and 2.5% concentrations (Table 1).

Reduction in the percentage germination of *Triticum* seeds was more on root extract than in stem and leaf extract treatments. Significant decrease in seed germination was 5 and 10% in root and leaf extracts. The shoot and root length of *T. aestivum* seedlings reduced significantly in all treatments. The root length was reduced significantly in all treatments of *A. adenophora* plant parts (Table 1).

Impact of the aqueous extract of *A. adenophora* was more or less similar on all weeds. The seed germination of *A. conyzoides* decreased insignificantly with all treatments in root extracts. Reduction was the same in stem and leaf extracts and decreased significantly ($p=0.05$) with their higher concentrations. There was complete inhibition at 10% of stem and leaf extracts. Seed germination in leaf extract was less than in root or stem extract with 1% concentration, but the seed germination was reduced insignificantly ($p=0.05$) at 2.5 and 5% concentration of stem extract. The shoot length of seedlings decreased significantly at root, stem and leaf extracts (Table 2).

The seed germination of the weed *B. pilosa* decreased insignificantly at 1 and 2.5% concentrations of the root, stem and leaf extracts of *A. adenophora*. The percentage of germination declined significantly in all the treatments up to 2.5% of root, stem and leaf extracts of *A. adenophora*. The shoot and root length of the seedlings decreased significantly (p=0.05) in all treatments with increase in concentration (Table 2).

**Table 1. Effect of root, stem and leaf extracts of *A. adenophora* on the seed germination (SG mean ±SD), shoot length (SL mean ±SD ) and root length (RL mean ±SD) of crops (*B. campestris* and *T. aestivum*) after 10 days.**

| Species | Plant organs | | Concentration (%) 0 | 1 | 2.5 | 5 | 10 |
|---|---|---|---|---|---|---|---|
| *Brassica campestries* | Root extract | SG (%) | 92.5±5.00 c | 85±5.77 c | 72.5±5.00 b | 67.5±9.57 b | 55±5.77 a |
| | | SL(cm) | 11.63±2.25 e | 8.76±2.47d | 5.32±2.15 c | 4.11±1.05 b | 2.21±0.49 a |
| | | RL(cm) | 9.01±0.92 e | 8.36±2.06 d | 4.65±1.01 c | 2.91±0.47 b | 2.21±0.49 a |
| | Stem extract | SG(%) | 92.5±5.00 c | 85±5.77bc | 75.5±5.77 b | 67.5±5.00 a | 60±0.16 a |
| | | SL(cm) | 6.49±0.62 d | 5±0.73 c | 3.94±0.86 b | 3.68±0.45 ab | 3.4±0.42 a |
| | | RL(cm) | 5.63±0.62d | 4.83±0.51 c | 3.14±0.78 b | 2.96±0.66 b | 2.58±0.74 a |
| | Leaf Extract | SG(%) | 95±5.77 d | 80±8.16 c | 70±8.16 bc | 60±11.54 ab | 52.5±5.00 a |
| | | SL(cm) | 6.89±0.51 e | 5.82±0.51 d | 4.24±0.19 c | 3.38±0.36 b | 2.21±0.23 a |
| | | RL(cm) | 4.14±0.45 d | 3.45±0.31 c | 3.3±0.10 c | 2.4±0.32 b | 1.85±0.22 a |
| *Triticum aestivum* | Root extract | SG(%) | 90±8.16 d | 82.5±9.57cd | 72.5±5.00 bc | 65±5.77 ab | 55±10.00 a |
| | | SL(cm) | 11.83±1.69 d | 9.44±1.97 c | 7.9± 1.45 b | 4.45±0.88 a | 4.08±1.00 a |
| | | RL(cm) | 7.57±0.68 d | 5.72±1.58 c | 4.47±0.41 b | 3.56±0.94 a | 3.51±0.54 a |
| | Stem extract | SG(%) | 95±5.77 d | 85±5.77 cd | 77.5±5.00 bc | 70±11.54 b | 55±5.77 a |
| | | SL(cm) | 14.27±1.51 e | 11.98±1.50 d | 9.13±0.83 c | 7.81±0.96 b | 4.21±0.50 a |
| | | RL(cm) | 12.5±1.47 e | 9.6±1.24 d | 7.89±1.04 c | 7.16±0.78 b | 3.77±0.37 a |
| | Leaf Extract | SG(%) | 95±5.00 c | 85±5.77 bc | 80±11.54 bc | 67.5±15.00 ab | 60±5.00 a |
| | | SL(cm) | 9.46±0.63 e | 7.88±0.45 d | 6.25±0.09 c | 4.47±1.00 b | 3.35±0.40 a |
| | | RL(cm) | 6.15±0.69 e | 5.08±0.57 d | 4.58±0.55 c | 3.64±0.43 b | 3.2±0.17 a |

Mean ±SD in the same column followed by the same letter does not differ significantly according to Duncan's Multiple Range Test at p=0.05 followed after ANOVA.

The application of *A. adenophora* plant part extract severely affected the germination, seedling growth of weed the of *C. rotundus.* The seed germination of *C. rotundus* was reduced as the concentration increases, but insignificant reduction was observed in all treatments of stem extract. Total inhibition was observed at 5 and 10% treatments on stem and leaf extracts. The growth of *C. rotundus* seedling was inhibited at higher concentration of aqueous extract (Table 2). The germination percentage of the seed of *G. parviflora* decreased with increase in concentration of the root, stem and leaf extracts of *A. adenophora.* Seed germination in the root extract was more than in the stem and leaf extracts. The leaf extract showed more allelopathic effects than the root or stem extracts. Total inhibition was observed in 5% concentration in stem extract and 5 and 10 % leaf extract. Shoot and root length exhibited insignificant reduction in 1, 2.5, 5 and 10% root extract in comparison to the control. At leaf extract significant reduction was observed in shoot and root lengths (Table 2).

*ib) Effects of A. adenophora compost extract on the seed germination and seedling growth of crops and weeds*- Crop and weed seed germination and seedling growth under laboratory conditions with different concentrations of compost aqueous extract ranging from 1 to 10% showed different responses. Seed germination, shoot and root lengths decrease more in the weed seeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) than in the crops *B. campestris* and *T. aestivum* with the increase in concentration of *A. adenophora* compost extract (Table 3).

The seed germination of the crop *B. campestris* showed insignificant reduction with 1, 2.5 and 5% of compost extracts, but seed germination was completely inhibited at 10% *A. adenophora* compost extract. The seed germination of *T. aestivum* reduced significantly (p=0.05) at 1%, but at higher concentrations (2.5, 5 and 10%) reducion was insignificant. The seed germination of weed *A. conyzoides* and *G. parviflora* reduced insignificantly up to 2.5 %. The seeds of *B. pilosa* showed insignificant reduction with 1, 2.5 and 5% concentrations. The total inhibition of seed germination of *Bidens* weed was observed at 10%. The seed germination of *C. rotundus* was reduced insignificantly at 1% concentration of *Ageratina* compost extract in control (Table 3).

**Table 2. Effect of root, stem and leaf extracts of *A. adenophora* on the seed germination (SG mean ±SD), shoot length (SL mean ±SD) and root length (RL mean ±SD) of weeds (viz. *A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) after 10 days.**

| Species | Plant organs | | Concentration (%) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2.5 | 5 | 10 |
| *Ageratum conyzoides* | Root extract | SG (%) | 67.5±15.00 a | 57.5±9.57 a | 57.5±5.00 a | 55±5.77 a | 52.5±9.57 a |
| | | SL(cm) | 2.94±0.21 e | 2.76±0.18 d | 1.76±0.12 c | 1.55±0.11 b | 1.29±0.05 a |
| | | RL(cm) | 2.54±0.36 e | 1.79±0.23 d | 1.5±0.13 c | 1.23±0.09 b | 1.07±0.07 a |
| | Stem extract | SG(%) | 72.5±9.57 c | 65±5.77 c | 55±10.00 ab | 50±8.16 a | NG |
| | | SL(cm) | 1.87±0.50 c | 1.67±0.35 c | 1.19±0.30 b | 0.92±0.11 a | NG |
| | | RL(cm) | 1.68±0.45 d | 1.54±0.31 c | 1.04±0.28 b | 0.74±0.09 a | NG |
| | Leaf Extract | SG(%) | 75±5.77 c | 55±5.77 b | 52.5±5.00 ab | 45±5.77 a | NG |
| | | SL(cm) | 1.81±1.04 d | 1.12±0.42 c | 0.91±0.20 b | 0.84±0.08 a | NG |
| | | RL(cm) | 1.61±0.08 c | 1±0.23 b | 0.77±0.18 ab | 0.71±0.07 a | NG |
| *Bidens pilosa* | Root extract | SG(%) | 80±8.16 c | 75±5.77 c | 70±11.54 bc | 62.5±5.00ab | 55±5.77 a |
| | | SL(cm) | 9.18±1.85 e | 7.96±1.55 d | 6.32±0.32 c | 5.27±0.40 b | 4.38±0.27a |
| | | RL(cm) | 8.36±1.68 d | 7.06±1.43 c | 4.36±0.59 b | 3.42±0.16 a | 2.92±0.55 a |
| | Stem extract | SG(%) | 80±11.54 c | 72.5±5.00 bc | 67.5±5.00 bc | 62.5±9.57 ab | 52.5±9.57 a |
| | | SL(cm) | 8.33±0.51 e | 7.03±1.38 d | 5.65±1.57 c | 4.73±1.09 b | 2.63±0.21 a |
| | | RL(cm) | 7.4±0.79 e | 6.31±1.74 d | 3.68±1.08 bc | 3.1±0.70 b | 2.28±0.24 a |
| | Leaf Extract | SG(%) | 85±5.77 b | 75±5.77 ab | 67.5±9.57 ab | 57.5±26.29 a | 55±5.77 a |
| | | SL(cm) | 8.5±1.07 e | 6.76±0.66 d | 5.7±1.51 c | 4.27±0.84 b | 2.89±0.64 a |
| | | RL(cm) | 6.7±1.55 c | 5.76±1.23 b | 5.11±1.53 b | 2.86±0.48 a | 2.53±0.58 a |
| *Cyperus rotundus* | Root extract | SG (%) | 65±5.77 c | 62.5±5.00 bc | 55±5.77abc | 50±11.54 ab | 47.5±9.57 a |
| | | SL(cm) | 1.44±0.05 e | 1.27±0.05 d | 0.85±0.05 c | 0.65±0.09 b | 0.45±0.05 a |
| | | RL(cm) | 1.26±0.06 e | 1.13±0.09 d | 0.65±0.06 c | 0.43±0.10 b | 0.25±0.05 a |
| | Stem extract | SG(%) | 62.5±5.00 a | 57.5±9.57 a | 55±5.77 a | NG | NG |
| | | SL(cm) | 1.43±0.42 b | 1.08±0.40 a | 0.91±0.09 a | NG | NG |
| | | RL(cm) | 1.26±0.37 c | 0.92±0.35 b | 0.73±0.07 a | NG | NG |
| | Leaf Extract | SG(%) | 75±5.77 b | 57.5±9.57 a | 55±5.77 a | NG | NG |
| | | SL(cm) | 1.5±0.08 b | 1.25±0.27 a | 1.21±0.10 a | NG | NG |
| | | RL(cm) | 1.35±0.07 c | 1.15±0.25 b | 0.86±0.19 a | NG | NG |
| *Galinsoga parviflora* | Root extract | SG(%) | 72.5±5.00 c | 62.5±5.00 bc | 60±8.16 ab | 55±10.00 ab | 50±8.16 a |
| | | SL(cm) | 1.69±0.06 c | 1.46±0.32 b | 1.32±0.28 b | 1.21±0.28 a | 1.21±0.11 a |
| | | RL(cm) | 1.52±0.04 c | 1.25±0.27 b | 1.18±0.25 b | 0.98±0.32 a | 1±0.09 a |
| | Stem extract | SG(%) | 57.5±5.00 a | 55±5.77 a | 52.5±9.57 a | 52.5 ±5.00 a | NG |
| | | SL(cm) | 1.96±0.73 c | 1.27±0.19 b | 1.03±0.14 ab | 0.94±0.06 a | NG |
| | | RL(cm) | 1.43±0.66 c | 1.07±0.14 b | 0.82±0.13 a | 0.78±0.09 a | NG |
| | Leaf Extract | SG(%) | 70±11.54 b | 65±5.77 ab | 52.5±5.00 a | NG | NG |
| | | SL(cm) | 1.4±0.62 a | 1.28±0.28 a | 1.18±0.06 a | NG | NG |
| | | RL(cm) | 1.31±0.50 b | 1.16±0.24 ab | 1±0.08 a | NG | NG |

Mean ±SD in the same column followed by the same letter does not differ significantly according to Duncan's Multiple Range Test at p=0.05 followed after ANOVA. NG-No Germination.

The shoot length was reduced significantly, but root length of *B. campestris* reduced significantly with 1 and 2.5% concentrations. In *T. aestivum*, the shoot and root lengths reduced significantly at all concentrations (viz. 1, 2.5, 5 and 10%). The shoot and root lengths of weed's shoot and root length reduced significantly with increasing concentrations of compost extracts. The *Bidens* seed germination and shoot lengths were reduced insignificantly, but root length reduced significantly at higher concentration (2.5 and 5%) (Table 3).

**Table 3. Effect of *A. adenophora* compost extract on the seed germination (SG mean ±SD), shoot length (SL mean ±SD) and root length (RL mean ±SD) of selected crop and weed seeds after 10 days.**

| Species | | Concentration (%) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2.5 | 5 | 10 |
| *Brassica campestris* | SG (%) | 75±5.77 b | 62.5 ±5.00 a | 57.5±5.00 a | 55± 5.77 a | NG |
| | SL(cm) | 6.59 ±0.24 d | 3.78 ±0.22 c | 2.41 ±0.61 b | 2.09 ±0.11 a | NG |
| | RL(cm) | 5.50 ±0.12 d | 3.00 ±0.60 b | 2.23 ±0.55 b | 2.20 ±0.02 a | NG |
| *Triticum aestivum* | SG(%) | 77.5±5.00 c | 70±11.54 bc | 62.5±5.00 ab | 60±11.54 ab | 55±10.00 a |
| | SL(cm) | 7.81±0.38 e | 6.89±0.13 d | 5.83±0.39 c | 4.94±0.10 b | 3.26±0.91 a |
| | RL(cm) | 7.66±0.29 e | 6.51±0.50 d | 5.41±0.14 c | 4.62±0.49 b | 3.04±0.48 a |
| *Ageratum conyzoides* | SG(%) | 57.5±9.57 a | 55±12.90 a | 52.5±5.00 a | NG | NG |
| | SL(cm) | 3.21±0.07 c | 2.87±0.06 b | 1.68±0.42 a | NG | NG |
| | RL(cm) | 3.06±0.05 c | 2.91±0.19 b | 1.31±0.30 a | NG | NG |
| *Bidens pilosa* | SG(%) | 77.5±5.00 b | 57.5±9.57 a | 55±5.77 a | 52.5±5.00 a | NG |
| | SL(cm) | 3.55±0.13 d | 2.55±0.56 c | 1.28±0.46 b | 0.99±0.06 a | NG |
| | RL(cm) | 2.60±0.10 c | 2.18±0.39 b | 1.13±0.36 a | 1.00±0.03 a | NG |
| *Cyperus rotundus* | SG(%) | 57.5±5.00 a | 52.5±9.57 a | NG | NG | NG |
| | SL(cm) | 1.81±0.08 b | 1.00±0.07 a | NG | NG | NG |
| | RL(cm) | 1.66±0.10 b | 0.89±0.13 a | NG | NG | NG |
| *Galinsoga parviflora* | SG(%) | 67.5±9.57 a | 55±12.90 a | 50±14.14 a | NG | NG |
| | SL(cm) | 2.48±0.11 c | 1.81±0.20 b | 0.84±0.22 a | NG | NG |
| | RL(cm) | 2.11±0.09 c | 1.46±0.24 b | 0.45±0.06 a | NG | NG |

Mean ±SD in the same row followed by the same letter does not differ significantly according to Duncan's Multiple Range Test at P=0.05 followed after ANOVA. NG-No Germination.

*ii) Effects of Ageratina compost amended with soil on seed germination and seedling growth*

The seed germination of *B. campestris* and *T. aestivum* reduced insignificantly with 10, 20 and 40 g compost/kg soil concentration. The seed germination of *B. campestris* was completely inhibited at 50 g/kg soil treatment (Table 4).

The seed germination of weeds *B. pilosa* and *G. parviflora* reduced insignificantly at 10 and 20 g compost/kg soil treatments. The seed germination of *A.conyzoides* and *C. rotundus* was completely inhibited at higher concentration of compost (viz. 20, 40 and 50 g/kg soil) (Table 4).

The shoot and root length of *B. campestris* significantly increased with 10 compost/kg soil concentration, but reduced significantly at high concentrations (20 compost/kg and above).The shoot and root lengths of *T. aestivum* showed not much differences in compost 10 g/kg soil in both crops. The shoot and root length of weeds *A. conyzoides*, and *C. rotundus* showed significant reduction at 10g compost/kg soil concentration, but in case of *B. pilosa* shoot and root length significantly reduced in 10, 20 and 40g compost/kg soil concentrations in comparison to control. In *G. parviflora* significant reduction was observed in 10 and 20 g compost/kg soil concentrations in comparison to control, but insignificant reduction in between 10 and 20 g compost/kg soil concentrations (Table 4).

The alkaloids are more in leaves comparatively over the stem and root of the same plant species (Achakzai *et al*. 2009). Forty five volatile compounds are found in *Ageratina adenophora* plants. The compounds identified from the stem and leaves of this species are octacosanoic acid, hydroxycinnamic acid, ferulicacid, cafeicacid etc. (Subba 2012). The presence of flavonoid glycosides in the leaves was also reported by Nair *et al.* (1995). Seed germination in *T. aestivum* was higher in stem than the root and leaf extracts of *A. adenophora*. Seed germination was observed in stem and leaf extract even at higher concentration (2.5-10%), in comparison to root extract. Seed germination was reduced significantly in comparison to control, but the germination of both crops was observed even at higher concentration. The shoot and root lengths of both crops were significantly reduced in the aqueous extract of *A. adenophora* plant's part.

**Table 4. Effect of *A. adenophora* compost (amended with 0, 10, 20, 40 and 50 g/kg soil) on the seed germination (SG mean** ±SD**), shoot length (SL mean** ±SD**) and root length (RL mean** ±SD**) of selected crops and weed seeds after 30 days.**

| **Species** | | **Concentration(g/kg soil)** | | | | |
|---|---|---|---|---|---|---|
| | | **0** | **10** | **20** | **40** | **50** |
| *Brassica campestris* | SG (%) | 60±8.16 a | 55±10.00 a | 52.5±5.00 a | 50±0.00 a | NG |
| | SL(cm) | 16.58±1.96 c | 17.25±1.09 c | 12.71±1.36 b | 4.41±1.49 a | NG |
| | RL(cm) | 14.40±2.11 c | 15.10±1.34 c | 11.53±1.16 b | 3.46±0.91 a | NG |
| *Triticum aestivum* | SG(%) | 62.5±9.57 a | 57.5±5.00 a | 55±12.90 a | 52.5±5.00 a | 50±11.54 a |
| | SL(cm) | 17.99±0.50 c | 17.59±0.91 c | 13.20±4.37 b | 5.60±1.54 a | 4.44±0.19 a |
| | RL(cm) | 17.41±0.56 c | 17.10±0.73 c | 12.68±4.23 b | 5.27±1.49 a | 4.25 ±0.19 a |
| *Ageratum conyzoides* | SG(%) | 55±12.90 a | 52.5±5.00 a | NG | NG | NG |
| | SL(cm) | 3.15±0.24 b | 2.14±0.10 a | NG | NG | NG |
| | RL(cm) | 2.92±0.25 b | 1.75±0.41 a | NG | NG | NG |
| *Bidens pilosa* | SG(%) | 57.5±5.00 b | 55±5.77 ab | 52.5±5.00 ab | 50±0.00 a | NG |
| | SL(cm) | 13.19±0.79 d | 8.94±0.79 c | 3.62±0.98 b | 2.30±0.19 a | NG |
| | RL(cm) | 12.37±0.55 d | 8.74±0.91 c | 3.21±0.93 b | 2.02±0.21 a | NG |
| *Cyperus rotundus* | SG(%) | 55±10.00 a | 52.5±5.00 a | NG | NG | NG |
| | SL(cm) | 3.86±0.44 b | 3.01±0.27 a | NG | NG | NG |
| | RL(cm) | 3.55±0.45 b | 2.97±0.53 a | NG | NG | NG |
| *Galinsoga parviflora* | SG(%) | 65±5.77 b | 55±5.77 ab | 39±23.41 a | NG | NG |
| | SL(cm) | 4.64±0.70 b | 3.01±0.27 a | 2.81±0.07 a | NG | NG |
| | RL(cm) | 4.32±0.71 b | 2.77±0.29 a | 2.51±0.16 a | NG | NG |

Mean ±SD in the same row followed by same letter does not differ significantly according to Duncan's Multiple Range Test at P=0.05 followed after ANOVA; NG-No Germination.

The weeds *A. conyzoides* and *C. rotundus* were fully inhibited at higher concentration in leaf extract. In 1% aqueous concentration, the seed germination of *A. conyzoides* was higher in stem extract. In *B. pilosa* seed germination reduced significantly as the concentration increases, but was not completely inhibited even at higher concentration as found in the case of other weeds.

This may be due to the size of the seed. Katoch (2012) also reported that the large seed size was least sensitive to germinate and growth. The *C. rotundus* and *G. parviflora* were completely inhibited at 10% aqueous stem and leaf extract of *A.adenophora.* A number of researchers reported that large amount of allelochemicals released from the leaves which inhibit the growth (Zhao *et al.* 2009). The antioxidant activities of methanol, extracts from the leaves of *Ageratina* also inhibited the seed germination and seedling growth of other species (Ralte 2014).

The compost extract of *A. adenophora* showed detrimental effect more in the weeds studied than winter crops. Seed germination of *B. campestris* was inhibited at higher concentration, but *Triticum* did not. *Ageratum* and *Galinsoga* significantly reduced at lower concentration, but completely inhibited at higher concentration. In *B. pilosa,* seed germination was also inhibited at higher concentration. The seed germination of *C. rotundus* was observed only at lower concentration of *Ageratina* compost extract. Similar results found by Zhang *et al.* (2008) showed that the aqueous leachates of the stems and leaves of *A. adenophora* inhibited seed germination and seedling growth of *Neocheiropteris palmatopedata.* The inhibitory effects increased with increasing leachate concentrations.

The reduction of seed germination, seedling growth of *B. campestris* and *T. aestivum* increases with the increase of concentration in the soil amended compost of *A. adenophora*. It might be due to the allelochemicals released by *Ageratina* plant residues into the soil. It affects the germination and seedling growth processes by reducing cell division or auxin induced growth of roots (Katoch 2012, McCalla and Haskins 1964). At higher concentration (50g compost/kg soil), the seed germination of *B. campestris* fully inhibited, but *Triticum* germinated. In comparison to *Brassica* and other weed seeds, nutrient content (carbohydrate and protein) and seed weight per seed were higher in *T. aestivum (*Table 1). Presence of defensins and more nutrient content in seed possibly overcome the adverse impact of phenolic compounds on the seed germination of *T. aestivum*. The seed germination, shoot and root length of *A. conyzoides* and *C. rotundus* were germinated at lower concentration only (10g compost/kg). Besides *B. pilosa* and *G. parviflora* totally inhibited at higher concentrations (5 and 10g compost/kg soil). It might be possible due to the additive and synergistic effects become significant at lower concentration (Einhelling and Rasmussen, 1978). *G. parviflora* germination was higher in sandy and loamy soil and able to germinate in 4-10mm depth (De Cauwer *et al.* 2013). *Eupatorium adenophorum* plant was rich in phenolic compound like 2-hydroxycoumaric acid which inhibited the crop and surrounding plant's seed germination and seedling growth (Zheng *et al*. 2012).

It can be concluded that the plant part of *A.adenophora,* particularly stem and leaves contains more allelochemicals than root. The allelochemicals of *A.adenophora* severely affected seed germination as well as shoot and root length of all tested weeds and crops. Aqueous extract of *A. adenophora* had more inhibitory effect on the growth of shoot as well as root. Seed germination, shoot length and root length of *A. conyzoides*, *G. parviflora* and *C. rotundus* were fully suppressed. *B. pilosa* was less reduced in *A. adenophora* extract. The seed germination of *B. campestris* and weeds *A. conyzoides, G. parviflora* and *C. rotundus* were completely suppressed at higher concentrations, but the crop *T. aestivum* could germinate and survived even at 50 g compost/ kg soil treatment. Seed germination was higher in crops than in weeds indicating that there is a possibility of using the compost of *A. adenophora* in wheat and mustard fields as utilizes the invasive weeds as compost and reduces the population of other weeds due to its allelopathic effect.

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# Effect of compost extract, compost of *Parthenium hysterophorus* on seed germination and growth of mustard, wheat and weeds

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**ABSTRACT**

This study was conducted at Research laboratory, Botany Department Amrit Campus, Kathmandu, Tribhuvan University, Nepal, in the year 2015-2016 to investigate the allelopathic effects of compost extract and soil amended with compost invasive weed *Parthenium weed* on seed germination and seedling growth of two crops *Triticum aestivum*, *Brassica campestris* and some common weeds (*Ageratum conyzoides*, *Bidens pilosa*, *Galinsoga parviflora* and *Cyperus rotundus*). *Parthenium hysterophorus* was collected before flowering and matured seeds of *Bidens pilosa*, *Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus* were collected from different sites around Kathmandu valley like Kirtipur and Bhaktapur areas. The compost extract of *Parthenium* of different concentration (control, 1, 2.5, 5 and 10%) and *Parthenium* compost (control, 10, 20, 40 and 50 g compost/kg soil) were used to determine its effect on seed germination, shoot and root length of *T. aestivum* and *B. campestris* and selected common weed seeds under laboratory condition. The compost extracts of *Parthenium* caused significant reduction in seed germination, seedling length (shoot and root length) of selected crops and weeds. The selected common weeds showed more reduction in germination and vegetative shoot and root length in comparison to crop plants (*B. campestris* and *T. aestivum*) in the soil amended with the compost of *Parthenium*.

## INTRODUCTION

*Parthenium hysterophorus* is an invasive weed, commonly known as carrot grass, bitter weed or star weed and belongs to the family Asteraceae. In rainy season, *P. hysterophorus* completes its life cycle within 16-18 weeks (Maharjan *et al.* 2014). *Parthenium* had been ranked top ten among the list of worst weed in the Global Invasive Species Database (Callaway and Ridenour 2004). Ecological impact and economic loss due to rapid expansion of *Parthenium* has become a regional environmental issue of tropical world (Bhowmik *et al.* 2007, Sushilkumar 2014). In Nepal, this species entered probably in 1950s from India. Herbarium specimens of this plant were collected from Trishuli valley of Nuwakot district, a small city north to Kathmandu, in 1967 (Tiwari *et al.* 2005). In Nepal, this plant has already invaded the maize, sugarcane and mustard fields (Shrestha 2014), while in India, this weed has been reported to infest all type of crops and orchards (Sushilkumar 2014).

Singh *et al.* (2003) explored the allelopathic properties of unburnt (UR) and burnt (BR) residues of *P. hysterophorus* on the growth of winter crops, radish and chickpeas. Soil amended with UR and BR extracts, revealed the phytotoxic effects towards test crops, UR crude extracts being more active showed toxic effects on the growth. These effects were attributed to the presence of phenolics (Singh *et al.* 2003). Parthenin has also been reported as a germination and radical growth inhibitor in a different species of dicot and monocot plants (Patel 2011). The present study attempts to find out the allelopathic influences of compost extract and compost of *P. hysterohorus* on some common weeds and winter crops. It is hypothesized that both the compost extract and compost will have inhibitory effects on winter weeds and crops affecting its germination and growth as well.

## MATERIALS AND METHODS

### Preparation of extract

*Parthenium hysterophorus* was collected from different selected sites around Kathmandu valley, Nepal, before flowering in May-June, to prepare compost. Mature seeds of *Bidens pilosa*, *Ageratum conyzoides*, *Galinsoga parviflora* and *Cyperus rotundus* were collected from different sites around Kathmandu valley like Kirtipur and Bhaktapur areas in the month of March and April in 2015 for seed germination experiments.

A pit of 2x3x3 feet was prepared at shady place and was filled with layers of *Parthenium* plants altering with soil. It was left for seven months (from March to September, 2015) to become compost. Experiment on compost extract at laboratory was conducted from this compost. To prepare compost extract, compost was air dried then 2 g of compost were soaked in 20 ml distilled water for 24 hours. The extract was filtered using Whatman No.1 filter paper and thus 10% stock solution was prepared. From this stock solution, 1.0, 2.5, 5.0 and 10.0% concentration was prepared. The *Parthenium* compost was also tested by amending 10, 20, 40 and 50 g compost in 1.0 kg soil of Kirtipur and Bhaktapur, separately, in polybag (size 14"x7)

### Seed germination

The dominant weed seeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) and the crop seeds of *B. campestris* and *T. aestivum* were soaked in 2% sodium hypochlorite for 2 minutes separately. The seeds were then washed with distilled water thoroughly. Ten seeds of each species were kept in sterilized Petri-dishes containing control, 1.0, 2.5, 5.0 and 10.0% concentrations of compost extracts for 10 days. For control, seeds were grown in filter paper soaked with 5 ml distilled water. All these experiments were conducted under normal room temperature with five replications. The moisture level in the Petri-dish was maintained by adding distilled water as required.

The seed germination experiment was conducted in polybag by using different concentration of *P. hysterophorus* compost (10, 20, 40 and 50 g/kg soil) in the month of November 2015. The soil for this experiment was sandy loam type having 6.2 pH and humus 0.88%. The nutrients NPK of the soil was recorded 0.14,0, 0028, 0.018% respectively.There were five replications of each treatment (10 seeds of selected seeds of weed and crops were sown separately). The germination and seedling growth was recorded after 40 days. The soil without compost was taken as control.

Statistical analyses were done by using SPSS statistical version 20. The data were subjected to one way ANOVA followed by Duncan's Multiple Range Test

## RESULTS AND DISCUSSION

Seed germination, shoot and root length decreased more in the tested weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora*) than in selected crops (*Brassica campestris* and *Triticum aestivum*) with an increase in concentration of *Parthenium* compost extract (**Table 1**). *Parthenium* compost extract showed insignificant reduction on seed germination of *B. campestris* with 1.0 and 2.5% , but it was reduced significantly with 5.0%. Seed germination was completely inhibited at 10% *Parthenium* compost extract. Seed germination of *T. aestivum* was enhanced significantly (P=0.05) at 1.0 and 2.5% compost extract treatment, but at higher concentrations (5 and 10%), it reduced significantly. Seed germination of weeds *A. conyzoides* and *G. parviflora* reduced insignificantly up to 5%, but seeds of *Bidens pilosa* showed significant reduction with 2.5 and 5% treatments. Total inhibition of weed was observed at 10%. No seed germination of *Cyperus rotundus* was observed even at lower concentrations of *Parthenium* compost extract (**Table 1**).

The shoot and root length of *B. campestris* reduced significantly with increase in concentration of *Parthenium* compost extract. In *T. aestivum*, the shoot and root length increased significantly at 1% concentration, but reduced significantly at higher concentration (5 and 10%). Shoot and root length of weed seedlings reduced significantly with increasing concentrations of compost extracts (**Table 1**).

Seed germination of crops *B. campestris* and *T. aestivum* increased insignificantly with 10 and 20 g/kg soil treatment with compost of Parthenium, but it reduced significantly with high concentrations in compost amended with soil. Seed germination of *B. campestris* was totally inhibited at 50 g/kg soil treatment (**Table 2**).

Seed germination of weeds *A. conyzoides, B. Pilosa* and *G. parviflora* reduced at 10 and 20 g/kg soil treatment. Seed germination of *Cyperus rotundus* was completely inhibited at all treatments of (**Table 2**).

The shoot and root length of *B. campestris* and *T. aestivum* significantly increased with 10 and 20 g/kg compost, but it reduced significantly with high concentrations (40 g/kg and above) in both crops. The shoot and root length of weed *A. conyzoides* reduced significantly with 10 and 20 g/kg soil treatment, but in case of *B. pilosa* and *G. parviflora* it reduced significantly with 20 g/kg soil treatment only (**Table 2**).

The reduction in seed germination and seedling growth in *B. campestris* was possibly due to presence of significant amount of phenolics the largest group of secondary metabolites in *P. hysterophorus* plant (Singh *et al.* 2005, Safdar *et al.* 2014). Altogether about 47 phytocomponents; 3 terpenoids, 14 fatty acids, 4 hydrocarbons, 7 alcohols, 5 phytosterols, and 14 other metabolites are reported in leaf of *Parthenium* (Ahmed *et al.* 2018).

Lesser detrimental effect of *Parthenium* compost extract was observed in *T. aestivum* than in *B. campestries*. Afridi *et al.* (2015) reported that the effect of allelochemicals on seed germination tested were unfavorable on the seed germination of *T. aestivum* and other species. The insignificant changes in *Triticum* seed germination shoot and root length with lower concentrations may be due to secondary metabolites cysteine rich proteins- defensins present in endosperm of *Triticum* (Freeman and Beattie 2008).

Seed germination of *Brassica* was more or less remained same up to 2.5% compost extract treatment but it was enhanced up to 5% in *T. aestivum*. Similarly, soil amended with *Parthenium* compost also showed insignificantly different seed germination of *Brassica* up to 20 g/kg soil treatment and up to 40 g/kg soil treatment in case of *Triticum*. Seed germination of *T. aestivum* increased slightly at 10 and 20 g/kg treatments. Presence of plenty of micronutrients such as Fe, Zn, Mn and Cu and macro nutrients including NPK in *Parthenium* compost makes it two times richer than farmyard manure (Krishna Murthy *et al.* 2010, Sushilkumar *et al.* 2005), and this possibly might have acted as the promoter for seed germination and seedling growth in low concentrations. But at high concentrations, the allelochemicals found in *Parthenium* might be responsible for the inhibition of cell division, gibberelline and indolacetic acid functions (Tomaszewski and Thimann 1966).

Various types of terpenoids, (9 in roots, 3 in stem and 3 in leaf) are also found in *Parthenium* (Ahmed *et al.* 2018). The noxious behavior of this weed was thought to be due to the sesquiterpene lactone parthenin, which is synthesized by this plant and play a role of allelopathic interference with surrounding plants (Belz 2007). Possibly these terpenoids interfere with enzymatic activity and reduces seed germination of crops as well as weeds at higher concentrations.

Allelochemicals of *P. hysterophorus* severely affected the seed germination, shoot and root length of all tested weeds and crops at higher concentration. The *C. rotundus* was totally inhibited in all tested concentration of *Parthenium* compost extract and compost amended soil. The seed germination of *Brassica* and weeds *A. conyzoides* and *G. parviflora* were fully suppressed at higher concentrations, but the crop *Triticum* could germinate and can survive at higher concentration. The enhancement of seed germination and seedling growth of *Triticum* (up to 40 g compost/kg soil) and *Brassica* (up to 20 g compost/ kg soil) indicate that there is a possibility of using the compost of *Parthenium hysterophorus* to reduce the associated weeds in wheat and mustard fields.

**Table 1. Seed germination (% ±SD), shoot and root length (cm ±SD) of selected crop and weed seeds growth on *Parthenium* compost extract (control, 1, 2.5, 5, 10% concentration)**

| Species | | *Parthenium* compost extract (%) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2.5 | 5 | 10 |
| *Brassica campestris* | SG | 75±10.00 b | 75±5.77 b | 70±5.67 b | 67.5±5.00 a | NG |
| | SL | 3.25±1.93 d | 2.63±1.53 c | 1.96±1.22 b | 1.46±1.03 a | NG |
| | RL | 3.34±1.96 d | 2.68±1.59 c | 1.74±1.09 b | 1.13±0.84 a | NG |
| *Triticum aestivum* | SG | 67.5±5.00 b | 85±5.77 cd | 80.5±0.00 cd | 70± 11.54 b | 50±21.60 a |
| | SL | 3.92±2.61 b | 5.63±2.40 c | 4.36±2.38 b | 3.65±1.92 b | 1.03±1.01 a |
| | RL | 3.76±2.50 b | 5.54±2.38 c | 4.1±2.24 b | 3.46±1.85 b | 0.93±0.92 a |
| *Ageratum conyzoides* | SG | 57.5±5.00 a | 52.50±9.57 a | 50.00±12.58 a | 48±11.57 a | NG |
| | SL | 1.95±1.72 c | 0.69±0.68 b | 0.69±0.67 b | 0.51±0.50 a | NG |
| | RL | 1.27±1.18 c | 0.60±0.55 b | 0.58±0.57 b | 0.44±0.43 a | NG |
| *Bidens pilosa* | SG | 62.5±5.00 b | 65± 12.90 b | 52.5±16.32 a | 50±14.14.00 a | NG |
| | SL | 2.81±2.09 c | 1.69±1.30 b | 1.107±1.104 b | 0.94±0.86 a | NG |
| | RL | 2.59±1.94 b | 1.32±1.13 a | 1.04±1.03 a | 0.89±0.81 a | NG |
| *Cyperus rotundus* | SG | 55±5.77 | NG | NG | NG | NG |
| | SL | 1.06±1.03 | NG | NG | NG | NG |
| | RL | 0.89±0.88 | NG | NG | NG | NG |
| *Galinsoga parviflora* | SG | 55±5.77 a | 52.5±5.00 a | 50±8.16 a | 47.5±9.57 a | NG |
| | SL | 1.90±1.77 b | 0.82±0.79 a | 0.70±0.68 a | 0.43±0.41 a | NG |
| | RL | 1.78±1.66 a | 0.73±0.70 b | 0.61±0.59 b | 0.34±0.33 a | NG |

SG-seed germination; SL-Shoot length; RL-Root length; NG- No Germination; Same letters in the same column after Mean ±SD does not differ significantly according to ANOVA followed by Duncan's Multiple Range Test atP=0.05

**Table 2. Seed germination (% ±SD), shoot and root length (cm ±SD) of selected crop and weed seeds growth on soil amended with *Parthenium* compost at (0,10,20,40 and 50g compost/kg soil concentration)**

| Species | | Soil amended with Parthenium compost (g/kg) | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 10 | 20 | 40 | 50 |
| *Brassica campestris* | SG | 60±14.14 b | 65±12.50 b | 70±8.16 ab | 60±0.00 a | NG |
| | SL | 8.16±7.21 b | 12.31±8.84 b | 19.9±10.19 b | 6.25±5.10 a | NG |
| | RL | 6.44±5.92 b | 10.92±7.93 b | 10.33±5.87 b | 5.14±4.11 a | NG |
| *Triticum aestivum* | SG | 57.5±5.00 ab | 70±11.54 bc | 68±14.14 bc | 65±5.77 ab | 52.5±12.58 a |
| | SL | 9.26±7.73 b | 14.64±9.83 c | 17.23±11.48 c | 9.86±7.72 b | 3.68±3.56 a |
| | RL | 7.66±6.47 b | 11.71±7.83 c | 12.31±9.03 c | 8.24±6.42 ab | 3.30±3.20 a |
| *Ageratum conyzoides* | SG | 55±5.77 a | 52.5±5.00 a | 45±5.00 a | NG | NG |
| | SL | 2.25±2.14 b | 1.05±1.02 a | 0.90±0.86 a | NG | NG |
| | RL | 1.90±1.76 b | 0.96±0.92 a | 0.82±0.79 a | NG | NG |
| *Bidens pilosa* | SG | 55±12.90 b | 50±8.16 ab | 47.5±9.57 a | NG | NG |
| | SL | 2.27±2.19 b | 2.01±1.94 b | 1.26±1.21 a | NG | NG |
| | RL | 2.00±1.94 b | 1.84±1.79 b | 1.04±1.02 a | NG | NG |
| *Cyperus rotundus* | SG | 52.5±9.57 a | NG | NG | NG | NG |
| | SL | 1.21±1.16 a | NG | NG | NG | NG |
| | RL | 1.09±1.05 a | NG | NG | NG | NG |
| *Galinsog parviflora* | SG | 55±5.77 a | 52.5 ±5.00 a | 50±8.16 a | NG | NG |
| | SL | 1.69±1.62 b | 1.32±1.27 b | 0.71±0.68 a | NG | NG |
| | RL | 1.63±1.54 b | 1.24±1.19 b | 0.61±0.59 a | NG | NG |

SG-seed germination; SL-Shoot length; RL-Root length; NG- No Germination; Same letters in the same column after Mean±SD does not differ significantly according to ANOVA followed byDuncan's Multiple Range Test at P=0.05


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Original Research

# Seed germination and seedling growth of some crops and weed seeds under different environmental conditions

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**ABSTRACT**

Seed germination of some crops (*Brassica campestris* and *Triticum aestivum*) and weed seeds (*Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora*) was studied under different environmental conditions like moisture (concentrations 3, 6, 9, 12, 15ml), temperature (5, 10, 15, 20 and 25˚C), pH (value 4, 5, 6, 7, 8 and 9) and light (normal, red, yellow, blue, green and dark color). For the crops too much lower or higher moisture was not favorable for germination and growth. Experiments under different moisture conditions showed that *C. rotundus* and *G. parviflora* do not require more moisture to germinate and grow. Seed germination of both crops enhanced insignificantly at 15 to 20˚C treatments. Seed germination of all weed seeds was insignificantly high at 10 to 15˚C. The percentage of seed germination of both crops increased significantly in normal and green light. Seed germination of *A. conyzoides*, *C. rotundus* and *G. parviflora* was insignificantly different in normal, red, yellow and green light. Germination of all weed seeds was completely inhibited by blue and dark light. The shoot and root length of weed *A. conyzoides* was found to be significantly high (P=0.05) in yellow light treatment, but in *B. pilosa*, it was high in red and green light. Similarly in *C. rotundus*, shoot and root length were high in normal light but in of *G. parviflora* it was high in green light treatment. Seed germination and seedling growth were higher in pH5-7 in most cases.

## Introduction

Weeds are native and non-native plants growing in unwanted place. It spread very fast and are competitive in natures; it competes for water, soil, nutrients, light, and space so it reduced the crop quality and yield in agricultural ecosystem (McErlich and Boydston, 2013). The weed competes in different ways; fast-growing weeds compete for light while low growing weed competes for water and nutrients with the crops (Schonbeck, 2013). Weeds possess special ability in growth, which

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permits adaptation in various conditions and very fast growth that give them advantages over crop (Paudel et al. 2017). Weeds reduce the crop yield either by reducing the amount of harvestable product or crop actually harvested In Nepal, weeds are an unending problem of loss in crop yield in agricultural land (Paudel et al. 2017).

Among the different weeds, majority belongs to family Asteraceae. *Ageratum conyzoides* of the family Asteraceae is present in Nepal not as an invasive weed (Kaur et al. 2012; Waterhouse 1993; Ranjit and Bhattrai, 1988) but as the worst weed. It is common weed germinated in agricultural fields in tropical and subtropical regions (Feng et al. 2002; GISD, 2016). *Bidens pilosa* is a noxious weed of family Asteraceae of the tropical region (Bartolome, 2013). The plant can control photoperiod depends on the time of year. The flowering period is between 10 and 14 short days. Gibberellic acid, chlormequat, and 2,4-D had no effect on *B. pilosa* in a long-day (Kirszenzaft and Felippe, 1978). *B. pilosa* reproduced vegetatively (Huang et al. 2012), which might partially dominate and colonized habitats.

*Cyperus rotundus* is a perennial plant belonging to the family Cyperaceae and found in tropical and subtropical regions (Sayed et al. 2007; Xu et al. 2009). The flowers of *Cyperus* are many but produce a small number of seeds. The main source of propagation of *Cyperus* is not by only seeds but also by the rhizome, tuber and basal bulb. *Cyperus rotundus* is highly competitor for different crops (Baloch et al. 2015). It is the common weeds of wheat and mustard field in Nepal. *Galinsoga parviflora* occurs in different types of soil but it easily grows in damp and rich soil (Warwick and Sweet, 1983). The peripheral achenes of *G. parviflora* live in soil as a seed bank and remained viable for a longer time than the central achenes (Kucewicz et al. 2014; Espinosa et al. 2003). In Nepal, there are 370 weeds in the field of *Triticum aestivum* L. in which 69 sps. of weeds belongs to Asteraceae family, Poaceae (52 spp.), Leguminosae (25 spp.), Polygonaceae (19 spp.), Caryophyllaceae (18 spp.), Scrophulariaceae (17 spp.), Euphorbiaceae and Lamiaceae (14 spp. each), Brassicaceae and Cyperaceae (13 spp.), and Solanaceae (11 spp. each) were the dominant families, which accounted for 71.35% of the total weeds. The most commonly reported weeds of wheat in Nepal are *Ageratum conyzoides*, *Bidens pilosa*, *Cyperus rotundus* and *Galinsoga parviflora* (Dangol, 2013). In Nepal the wheat yield have also been reported to decrease up to 50% by weeds and sometimes even more when weed population and density were higher (Ranjit et al. 2009). In the case of the Chitwan area of Nepal, Dangol and Choudhary (1994) have reported 30 weed species from wheat fields. Ranjit (2002) and Shah (2013) had reported the broadleaf weeds are the major problems in the agricultural field. Sapkota et al. (2010) reported a total of 44 weed species representing 18 families from wheat fields of Khokana and a new weed *Vicia* sp. was reported along with other dominant weed like *Chenopodium album*, *Polygonum plebeium* and *Spergula arvensis*.

Wheat is considered as the most important cereal crop after rice in Nepal. Of the total cultivated area in the country (2,968,000 ha), rice is cultivated in 1,544,990 ha and wheat in 669,014 ha. Eighty four per cent of the wheat cultivation area falls under rice-wheat rotational system (Singh and Paroda, 1994). Many weeds have been identified in the wheat crop weeds like *Phalaris minor*, *Chenopodium album*, *Cyperus rotundus*, *Convolvulus arvensis*, *Cnicus arvensis, Parthenium hysterophorus*, *Chromolena adenophora*, *Ageratum conyzoides* and *Galinsoga parviflora* have recently become the most consistently troublesome weed in the winter crop field. In Nepal, yield loss in wheat ranged from 15% to 70% (Ranjit, 1997). Mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm oil. The global production of mustard and its oil is around 38–42 and 12–14 mt, respectively (Patel et al. 2017). Weeds cause an alarming decline in crop production ranging from 15-30% to a total failure in rapeseed-mustard yield (Patel et al. 2017; Shekhawat et al. 2012). In mustard field interference of weeds causes yield losses up to 45%. A variety of weed affects these crops but the extent of damage in terms of yield and resources is location specific (Singh et al. 2013). The effective management of weed seeds distribution can be understood by knowing the weed seed germination ecology. Seed sizes and the environmental factor of weed seeds affected the associated plants (Tanveer et al. 2013). The seed germination, morphology (Powell 2010), seed sizes (Kidson and westoby, 2000) are the important feature for seed establishment. Some plants grow in lower pH level and some at higher pH level. The pH is not the sign of fertility but affects the uptake of fertilizer nutrients. So, it affects the germination of seeds (Ward, 2015).

The various environmental conditions like temperature, moisture light and pH affects the germination and growth of both crops and weeds (Auld and Ooi, 2009; Rawal et al. 2015a,b; Shrestha et al. 2017). Some species are not affected by favorable condition until a certain factor breaks the dormancy (Monoroe, 2018; Reece et al. 2011). Germination of plants occurs at a particular time of the year at different habitat (Cochrane et al. 2011; Shrestha et al. 2017). Some weed seeds are sensitive to light for germination and will emerge when they are close to the soil surface (Milberg et al. 2000). Hence to understand the environmental conditions which favor germination of winter crop like mustard and wheat and also on some weeds associated with them. The experiments was conducted in the laboratory related with different environmental conditions which helps to manage the seed germination and seedling growth of some associated weeds of the agricultural field (*B. campestris* and *T. aestivum*).

**Materials and Methods**

*Collection of crop and weed seeds*

Two crop seeds (*B. campestris* and *T. aestivum*) were bought from agroshop in Kathmandu, Nepal. Mature weed seeds of *A. conyzoides, B. pilosa, C. rotundus* and *G. parviflora* were collected from selected sites of Kirtipur (Chobhar, Dhapla, Near Tribhuvan University, Machhegaon and Chhugaon) and Bhaktapur (Lokanthali, Gathhaghar, Balkot, Sano Thimi and Thimi) in the month of March and April 2014. These are the common weeds in both crop fields.

*Seed germination*

Weed seeds (*A. conyzoides*, *B. pilosa, C. rotundus* and *G. parviflora*) and the crop seeds of *B. campestris* and *T. aestivum* were treated with 2% Sodium hypochlorite for 2 minutes separately for surface sterilization. Then the seeds were washed with distilled water thoroughly. The sterilized petri dishes were lined with single Whatman No. 1 filter paper and moistened with 5ml distilled water. The crops (*B. campestris, T. aestivum)* and weeds *(A. conyzoides*, *B. pilosa, C. rotundus and G. parviflora*) seeds of uniform size were selected and ten seeds of each species were kept in sterilized petri dishes.

*Environmental conditions*

*a) Temperature:* Five replications of petri dishes containing 10 sterilized seeds of selected crops and weed seeds were kept in incubator maintaining different temperatures level (5, 10, 15, 20, 25˚C) separately for 10 days.

*b) Moisture*: Five replications of petri dishes containing 10 sterilized seeds of selected crops and weed seeds were kept in filter paper soaked with 3, 6, 9,12 and 15ml distilled water for 10 days.

*c) Light*: The petri dishes containing 10 sterilized seeds of crops and weeds were covered by cellophane papers of different colors like red, yellow, blue, green and black polyethylene (for dark condition). For control, the petri dishes containing crop and weed seeds were grown in filter paper soaked with 5ml distilled water in normal light without any covering. All these experiments were conducted under normal room temperature (20$^{o}$C) with five replications. The moisture level in the petri dish was maintained by adding distilled water as required. Seed germination and seedling growth were recorded after 10 days.

*d) pH*: To study the effect of pH on seed germination of two winter crops (*B. campestris* and *T. aestivum*) and some weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*), five replications of ten seeds were kept in Whatmen No. 1 paper in petri plates. The solutions with different pH values of 5, 6, 7, 8 and 9 were prepared using 0.1 HCl and 0.1 KOH. The seeds were kept in room temperature (20$^{o}$C). The weeds were found in winter crops fields (Wheat and Mustard). The experiment was conducted on the month of November.

## Results and Discussion

### *Moisture*

The effects of different amount of moisture on seed germination, shoot and root length are given in Figure 1. Seed germination of winter crops *B. campestris* and *T. aestivum* reduction were highest at 6 ml and 9 ml treatment, respectively, and significant reduction was at 15ml treatment. Seed germination of weed seeds like *A. conyzoides* and *B. pilosa* were mostly high at 3 ml and 6 ml treatments. Seed germination of *C. rotundus* and *G. parviflora* were insignificantly different in all treatments. No seed germination was observed at 15ml treatment in both weeds (Figure 1a).

Shoot and root length of both germinated crop seeds were significantly high at 6 ml treatment. Similarly, shoot and root length of germinated seeds of *A. conyzoides* and *B. Pilosa* were significantly high at 6 ml treatment but in case of *C. rotundus* and *G. parviflora*, it was significantly high at 3ml treatments. This indicated that *C. rotundus* and *G. parviflora* do not require more moisture to germinate and grow (Figure 1 b and c).

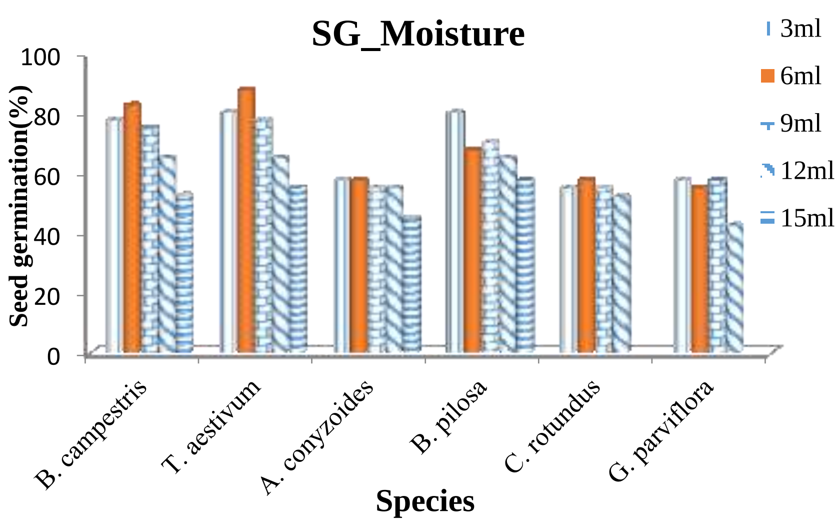


**Figure 1a.** Seed germination (SG %) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different moisture conditions (3, 6, 9, 12 and 15 ml).

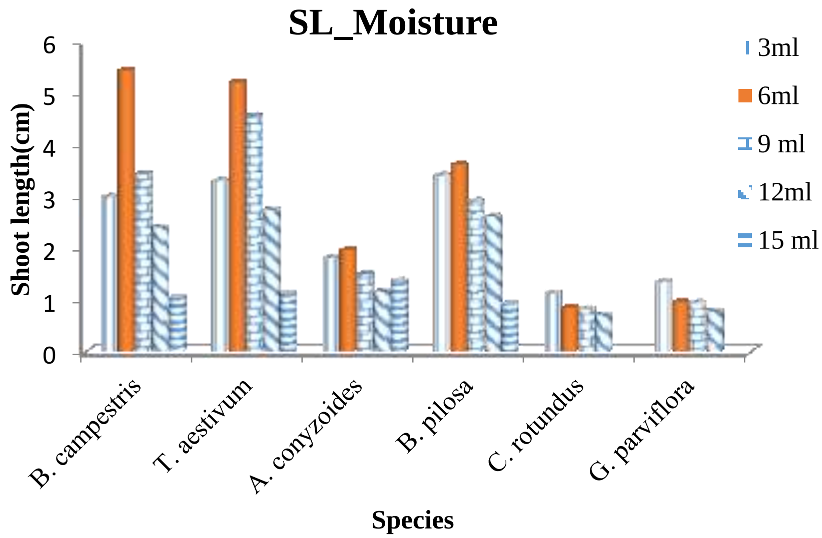


**Figure 1b.** Shoot length (SL cm) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different moisture conditions (3, 6, 9, 12 and 15 ml).

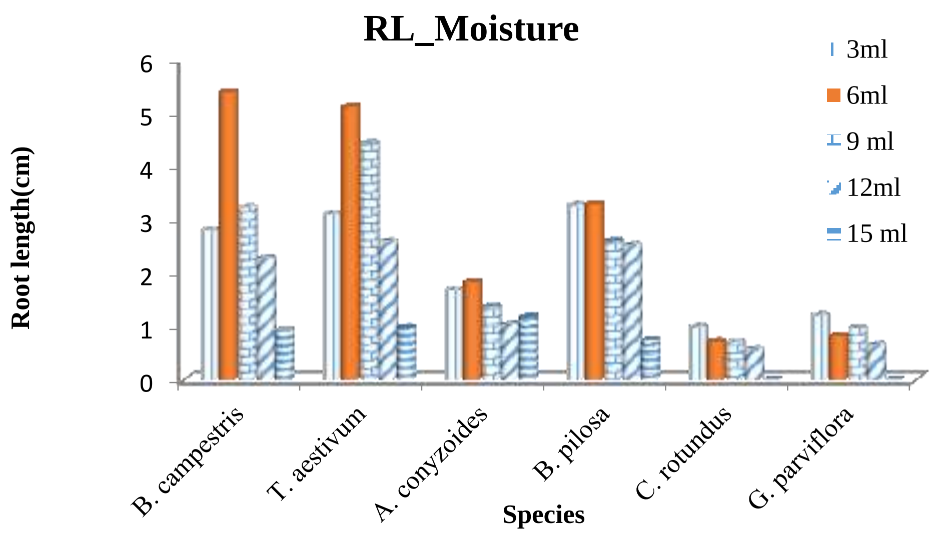


**Figure 1c.** Root length (RL cm) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different moisture conditions (3, 6, 9, 12 and 15 ml).

Seed germination in both the crops (*B. campestris* and *T. aestivum*) was highest in 6ml and 9ml treatments and reduced significantly in 15ml treatment. Similar results were also observed for *Phaseolus vulgaris*, *Spinacea oleracea* (Orphanos and Heydecker, 1968) and *Beta vulgaris* (Heydecker et al. 1971). Similarly, seed germination of *Cyperus* and *Galinsoga* completely inhibited with 15ml treatment. This may be due to formation of a water film over the seed's surface and free water in the substrate block the hilum opening (Carpenter, 1991) as seeds were completely immersed in water with 15ml treatment. The water film might have act as a barrier to osmotic diffusion and result reduced the germination, shoot and root length in both the crops. At high moisture content, seeds also lost viability (Oliviera and Valio, 1992). Tubers and seeds of *C. rotundus* were stay dormant to survive in dry seasons. These species are able to multiply rapidly through tubers (Coleman et al. 2018).

***Temperature***

Seed germination of crops (*B. campestris* and *T. aestivum*) and selected weed seeds are at different temperatures given resulting in Figure 2 a. Seed germination of both crops enhanced insignificantly at 15 to 20˚C treatments. Seed germination of all weed seeds was insignificantly high at 10 to 15˚C (Figure 2 a).

Shoot and root length of germinated both crop seeds were found to be significantly high at 15 to 20˚C. Shoot and root length of germinated weed seeds also increased significantly high at 15 to 20˚C, except in *B.pilosa*, where it increased at 10 to 15˚C. This indicated that low temperature enhances the growth *B. pilosa* more than other weeds (Figure 2 b and c).

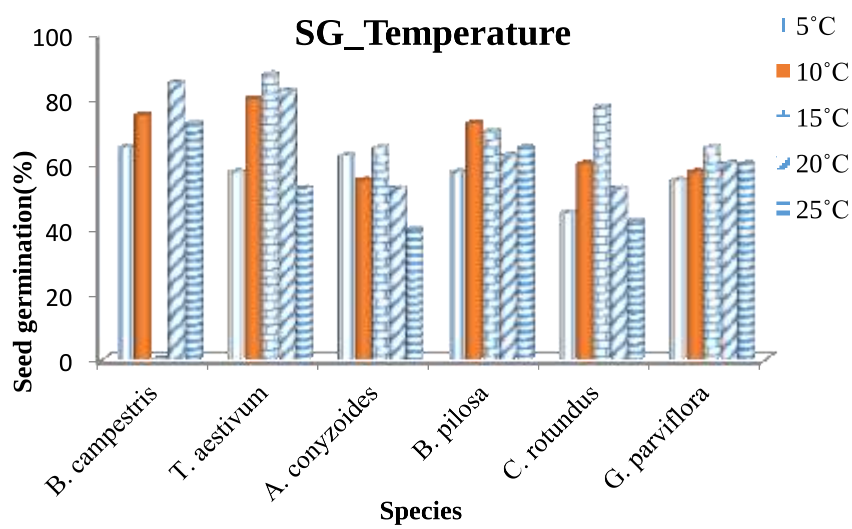


**Figure 2a.** Seed germination (SG %) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different temperature conditions (5, 10, 15, 20 and 25˚C).

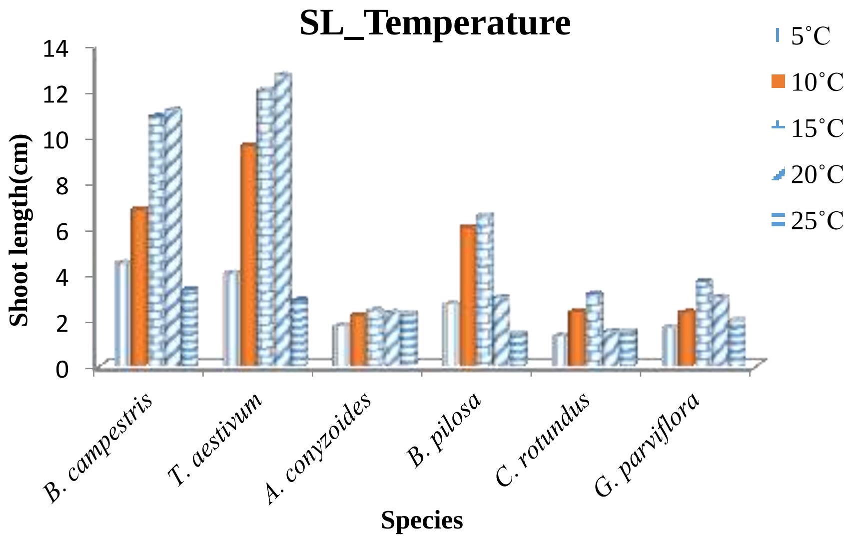


**Figure 2b.** Shoot length (SL cm) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*)on different temperatures (5, 10, 15, 20 and 25˚C).

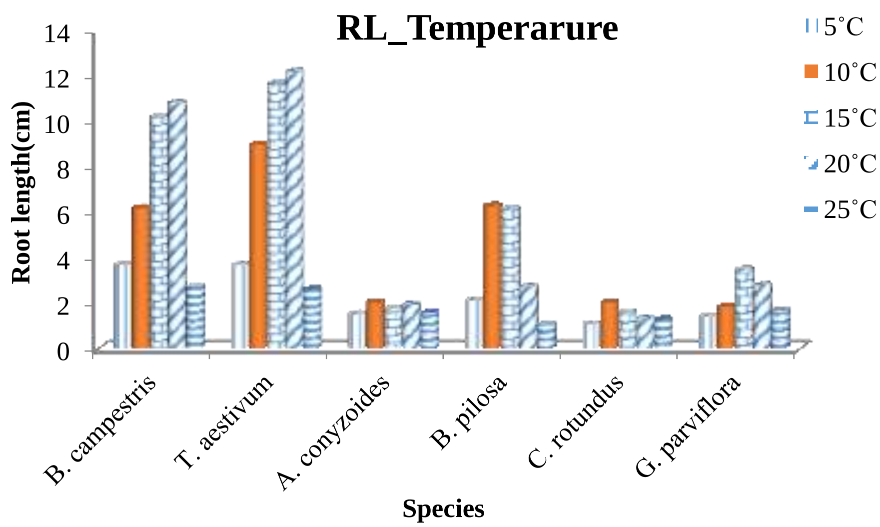


**Figure 2c.** Root length (RL cm) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different temperatures (5, 10, 15, 20 and 25˚C).

Germination of seeds and seedling growth depends on favorable environment conditions. Temperature is one of the most important environmental conditions for seed germination and seedling growth (Fenner and Thompson, 2005). Germination of two winter crops (*B. campestris* and *T. aestivum*) was higher at 15-20˚ C in the present study and reduced at 25˚C indicating that the high temperature is not favorable for them to germinate. All tested weeds (*A. conyzoides*, *B. pilosa*, *C.*

*rotundus* and *G. parviflora*) were germinated at all the treatments of temperature, indicating their tolerance to a wide range of temperature. These weeds are quite common in winter as well as summer crops and (Thapa 2001; Zhao et al. 2016; Assang et al. 2011) had been reported that high temperature availability will increase atmospheric water demand which could lead to additional water stress from increased water pressure deficits. In the present study, the winter crops *B. campestris* and *T. aestivum* showed reduced germination with high temperature which may be due to water stress.

***Light***

The percentage of seed germination of both crops *B. campestris* and *T. aestivum* increased significantly (P=0.05) in normal and green light. Seed germination of *A. conyzoides*, *C. rotundus* and *G. parviflora* was insignificantly different in normal, red, yellow and green light. The seed germination of *B. pilosa* increased slightly at normal light than in all other colored light (Figure 3 a). The shoot and root length of both the crops *B. campestris* and *T. aestivum* was increased significantly (P=0.05) at normal light. The shoot and root length of weed *A. conyzoides* was found to be significantly high (P=0.05) in yellow color light treatment, but in *B. pilosa,* it was high in red and green light. Similarly in *C. rotundus*, shoot and Root length were high in normal light but in of *G. parviflora* it was high in green light treatment (Figure 3 b and c).

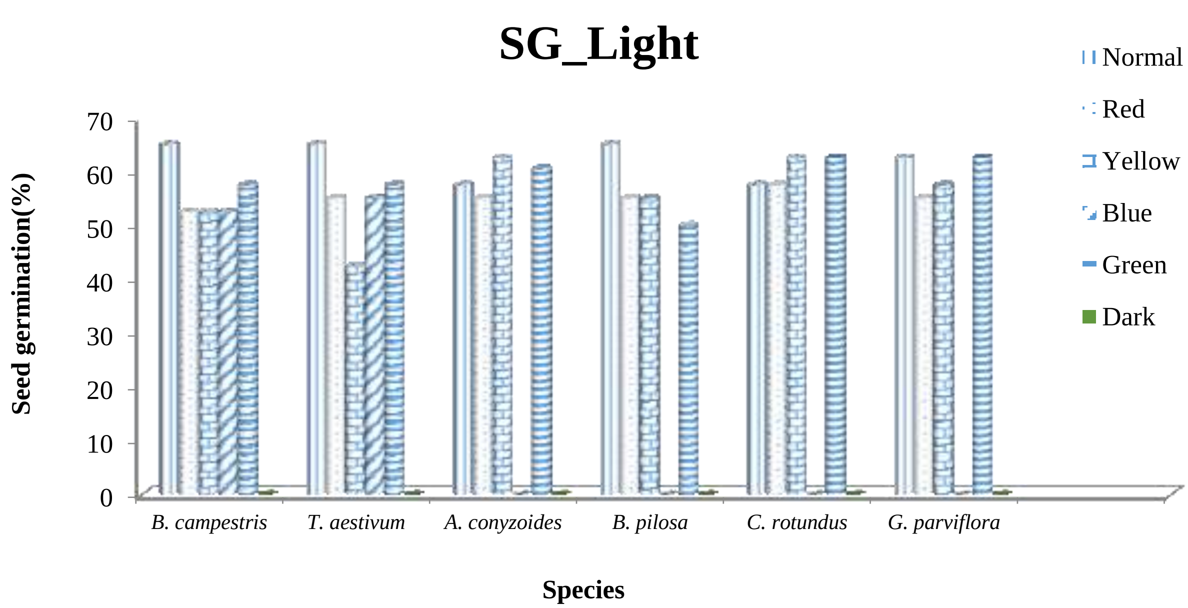


**Figure 3a.** Seed germination (SG %) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different colors of light (normal, red, yellow, blue, green and dark).

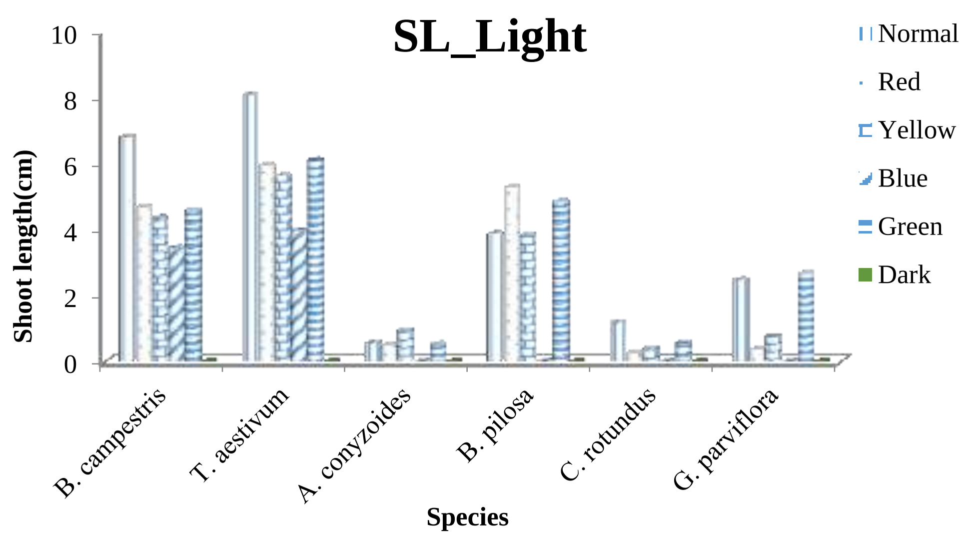


**Figure 3b.** Shoot length (SL cm) of two crops (*B. campestris* and *T. aestivum*) and four weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different colors of light (normal, red, yellow, blue, green and dark).

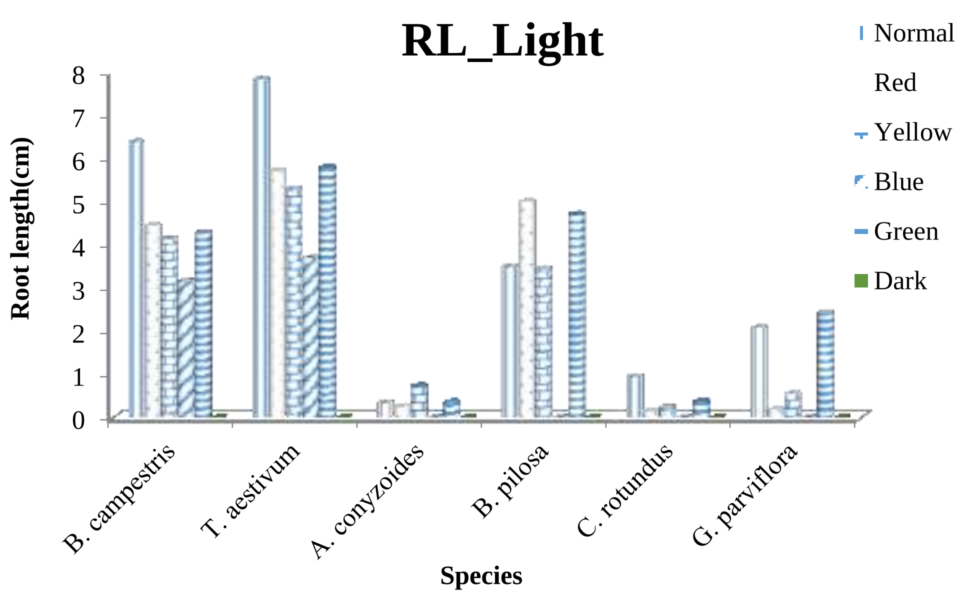


**Figure 3c.** Root length (RL cm) of crops (*B. campestris* and *T. aestivum*) and weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different colors of light (normal, red, yellow, blue, green and dark).

Light is one of the important factors for seed germination and seedling growth. The seeds of both crops germinated in all light conditions (even in blue light), but weed seeds could not germinate in blue light. Seeds that require light for germination are usually small (Cann, 2014). Milberg et al. (2000) suggested that light response and seed mass must have coevolved as an adaptive features to ensure seed germination of small seeded species only when close to the soil surface. On the other hand, a phylogenetic component of light promoted germination - regardless of seed size- has also been suggested as phytochromes are well known to mediate light promoted germination. Phytochromes are also known to increase the amount of bioactive gibberellins in seeds (Cann, 2014) and this might have initiated germination process. In the present study, both the crops and weed could not germinate in dark. This show that light is one of the environmental conditions that are required for seeds germination and seedling growths of tested seeds because phytochrome play a significant role in determining the time of germination (Kołodziejek and Patykowski, 2015). In seed germination experiment conducted for 131 taxa of Campanulaceae by Koutsovoulou et al. (2014), found that the seed germination was higher in light in comparison to darkness.

The wheat and mustard seeds germinated in blue light, more or less similar to red, yellow or green light. In wheat (Xu et al. 2009) and in *Brassica napus* (Chatterjee et al. 2006) Cryptochromes/ a blue/ultraviolet-A light sensing photoreceptors have been reported. In wheat two cryptochrome genes - TaCRY1 and TaCRY2 have been identified, and which might be involved in the abscisic acid signaling pathway in addition to their role in primary blue light signal transduction (Xu et al. 2009). Possibly in *Brassica campestries* also the cryptochrome act as photoreceptor to initiate seed germination in blue light. Mostly, seed germination was high in red light and low or no germination in blue light, which is in consistence with general observation that the red light promotes germination while blue light inhibits it (Batty et al. 1989). All the selected weeds could not germinate in blue light. Blue light is usually referred to as radiation with wavelength between 400 and 500nm. Different phytochromes activates at different wavelengths of light. Under wavelength 700 nm both phytochrome A and B are active. However, phytochrome A functions optimally around 600 to 690 nm and at wavelength larger than 700nm it becomes inactivated while phytochrome B remains active (Phytochrome, 2013). As blue light ranges from 400-500nm, both phytochromes might have remained inactive and this might have inhibited the germination in the selected weeds.

Besides this, the seed germination in wheat and mustard might be due to the higher concentration of endogenous gibberellins than the abscisic acid. The gibberellin synthesis occurs when the seeds absorb moisture, this hormone diffuse across the endosperm to the aleurone layer (in case of wheat), which then produce and release the hydrolytic enzyme require to digest the stored food of endosperm. The stored starch was breakdown by enzymes to its smaller unit glucose, protein to amino acid etc. which are then translocated to the embryo. The embryo used them for the growth of radical and plumule during germination (Bhattrai, 2007).

***pH***

Seed germination of both crops (*B. campestris* and *T. aestivum*) and two weeds (*A. conyzoides* and *B. pilosa*) were high significantly at pH 7. The germination of *C. rotundus* seed was insignificantly high at pH 6 whereas in *G. parviflora*; it was significantly high at pH 6 treatment (Figure 4 a). Seeds of *A. conyzoides* and *B. pilosa* could not germinate in low acidic (pH5) and alkaline condition in (pH9). Similarly, seeds of *C. rotundus* could not germinate in alkaline conditions, pH 8 and 9 (Figure 4 a). The shoot and root length of germinated crop seed of *B. campestris* was found to be significantly high in acidic condition at pH 5 but in *T. aestivum* it was significantly high in alkaline condition of pH8. The shoot and root length of most of the weed seeds (*A. conyzoides*, *C. rotundus* and *G. parviflora*) were found to be significantly high in slightly acidic condition pH 6 except *B. pilosa* where it was significantly high in alkaline condition of pH 8 (Figure 4 b and c).

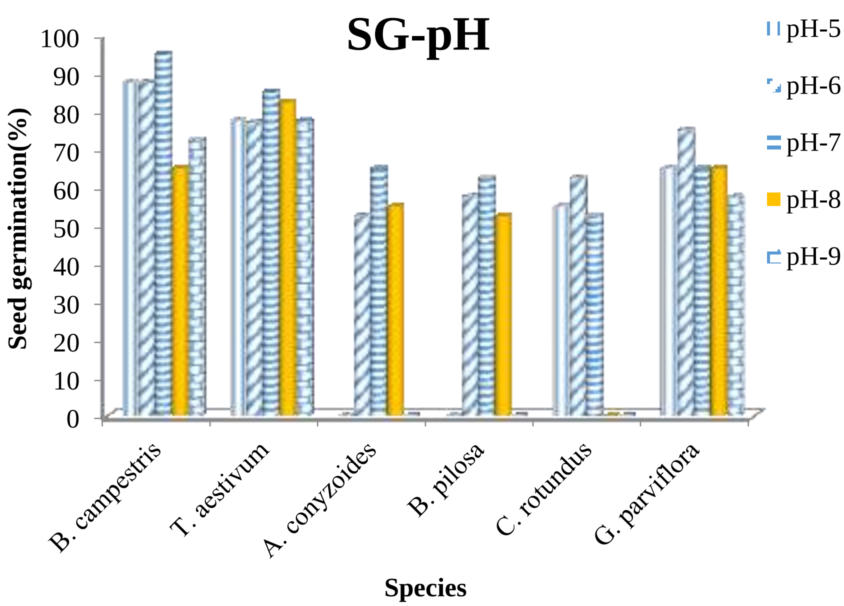


**Figure 4a.** Seed germination (SG %) of crops (*B. campestris* and *T. aestivum*) and weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different levels of pH (5, 6, 7, 8 and 9).

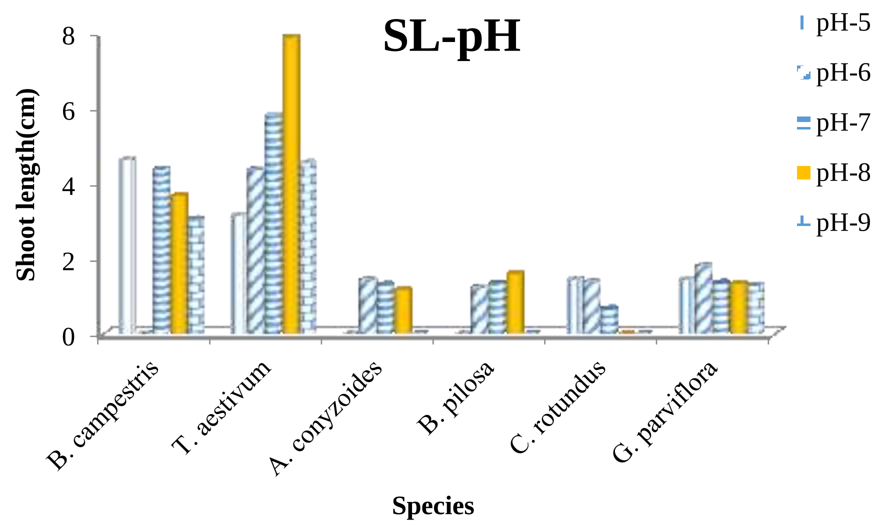


**Figure 4b.** Shoot length (SL cm) of crops (*B. campestris* and *T. aestivum*) and weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different levels of pH (5, 6, 7, 8 and 9).

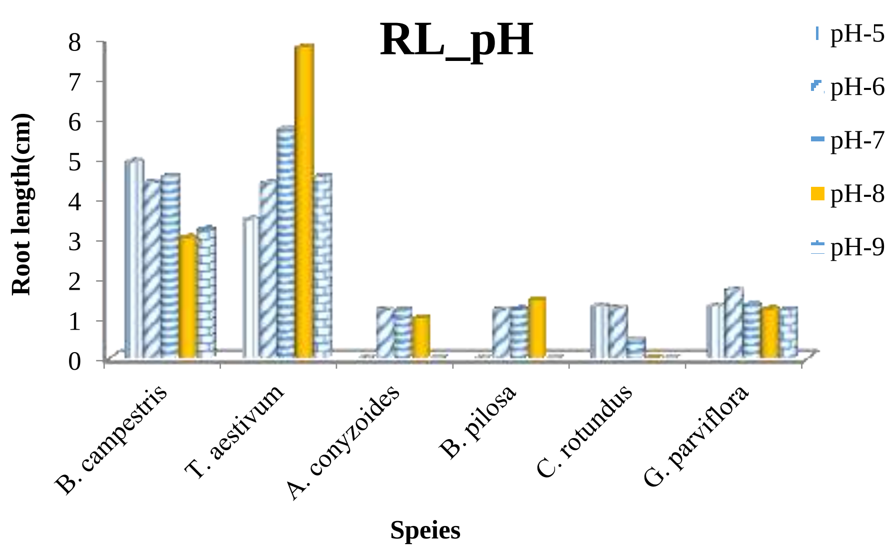


**Figure 4c.** Root length (RL cm) of crops (*B. campestris* and *T. aestivum*) and weeds (*A. conyzoides*, *B. pilosa*, *C. rotundus* and *G. parviflora*) on different levels of pH (5, 6, 7, 8 and 9).

Both crops and some weeds could germinate from pH 5 to 9, similar results were also reported by Mathews (2012), Hannaway and Larson (2004) that Mustard can adapt in sandy to clay soil and also germinate in the range of pH 4.8 to 8.5. *T. aestivum* have comparatively large seeds with storage of reserve food materials. It appears that both the winter crops have high membrane integrity and could resist high range of pH. Weeds like *A. conyzoides*, *B. pilosa* and *C. rotundus* might have low membrane integrity as a result could not germinate at high pH (McCauley et al. 2017).

The seedling growths (shoot and root length) were approximately same in all seed germination experiments (in moisture, temperature, light and pH) in laboratory conditions might be during their early morphogenesis stages, it strongly depends on the resources stored in the seeds and that these resources determine the magnitude of the response to substrate nutrients. The differences can show when the seed germination experiment will be done in the field because the seed can also take the nutrients from soil in different ratio (Maskova and Hermen, 2018).

## Conclusion

Based on the germination, it can be concluded that study of all selected weeds are suppressed with high moisture (i.e., with 15 ml treatment). Seed germination of the entire studied weeds are suppressed in blue light and dark conditions. The high moisture (15ml petridish) showed adverse effects on the seed germination, shoot and root length of *C. rotundus* and *G. parviflora* and also significantly reduced the seed germination of both crops (*B. campestris* and *T. aestivum*) and weed seeds of *A. conyzoides* and *B. pilosa*. Seed germination of both crops and four common weed seeds under different temperatures (5, 10, 15, 20 and 25˚C) showed enhanced seed germination, shoot and root length of both crops at 15 to 20˚C treatments but those of weeds were high at 10 to 15˚C. The percentage of seed germination of both crops *B. campestris* and *T. aestivum* increased significantly in normal and green light. The seed germination, shoot and root length in crop seed of *B. campestris* was found to be significantly high in acidic condition at pH 5 but in *T. aestivum* it was significantly high in alkaline condition of pH8. The shoot and root length of most of the weed seeds (*A. conyzoides*, *C. rotundus* and *G. parviflora*) were found to be significantly high in acidic condition pH 6 except in *B. pilosa* where it was significantly high in alkaline condition of pH 8.

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## Conflicts of Interest

Authors declare no conflict of interest.

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at Kathmandu on January 10-12, 2017.

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| **Dr. Bishwa Nath Oli**<br>Secretary, Ministry of Population and Environment | **Dr. Nir Krakauer**<br>Co-Chair, Conference Organizing Committee<br>PI: USAID-IPM-IL-Biodiversity Project | **Prof. Naba R Devkota**<br>Director of Research<br>Agriculture and Forestry University | **Prof. Mohan Siwakoti**<br>Secretary, Conference Organizing Committee<br>Head, Central Dept. of Botany, TU | **Prof. Pramod K Jha**<br>Chair, Conference Organizing Committee<br>Nepal Coordinator & Co-PI<br>USAID-IPM-IL-Biodiversity Project |

INTERNATIONAL CONFERENCE ON

# MOUNTAINS IN THE CHANGING WORLD

OCTOBER 09-10, 2018 | KATHMANDU, NEPAL

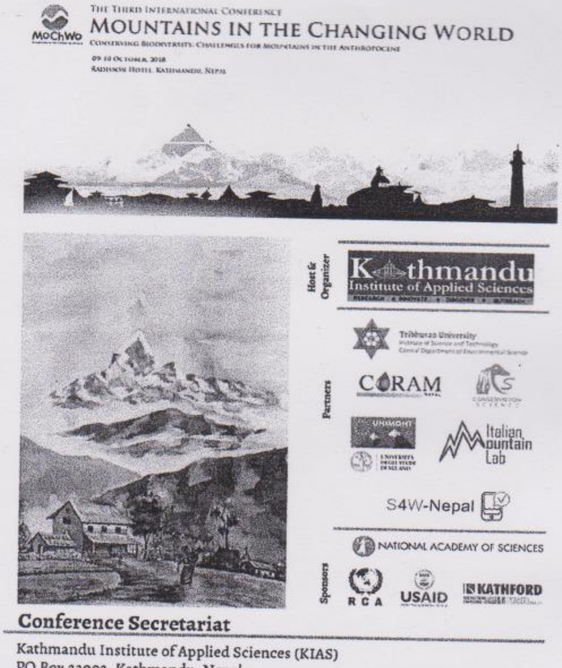
## CONFIRMATION OF PARTICIPATION & PRESENTATION

**Babita Mallik**

I confirm your participation in the 3rd International Conference on *Mountains in the Changing World (MoChWo)* at Hotel Radisson in Kathmandu, Nepal, October 09-10, 2018. The theme of the conference was "Conserving biodiversity: Challenges for the mountains in the anthropocene".

I acknowledge your presentation on *"Responses of Triticum aestivum, Brassica campestries and some weeds to the compost of invasive species Ageratina adenophora and Parthenium hysterophorus"*.

Thank you for accepting our invitation.




Dr. Prakash K. Paudel, Convener
October 09, 2018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