WEED DIVERSITY AND SEED BANK STUDIES IN DIFFERENT AGRICULTURE FIELDS IN SOME AREAS OF BHAKTAPUR DISTRICT

A DISSERTATION SUBMITTED FOR THE PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE MASTER DEGREE IN BOTANY

By

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DECLARATION

I, Sharmila Prajapati, hereby declare that the work enclosed here is entirely my own, except where states otherwise by reference or acknowledgement, and has not been published or submitted elsewhere, in whole or in part, for the requirement for any other degree or professional qualification. Any literature, data or works done by others and cited within this thesis has been given due acknowledgement and listed in the reference section.

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RECOMMENDATION

This is to recommend that the Master's thesis entitled "Weed Diversity and Seed Bank Studies in Different Agriculture Fields in Some Areas of Bhaktapur District." is carried out by Sharmila Prajapati under my supervision. The entire work is based on original scientific investigations and has not been submitted for any other degree in any institutions. I, therefore, recommend this thesis work to be accepted for the partial fulfilment of M.Sc. Degree in Botany from Amrit Campus, Tribhuvan University, Kathmandu, Nepal.

.....Bipana.............

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APPROVAL

The thesis work entitled "Weed Diversity and Seed Bank Studies in Different Agriculture Fields in Some Areas of Bhaktapur District." submitted to Department of Botany, Amrit Campus, Tribhuvan University by "Sharmila Prajapati", "5-2-20-51-2013" has been accepted for the partial fulfilment of the requirement for master's degree in Botany from Amrit Campus, Tribhuvan University, Kathmandu, Nepal.

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ABSTRACT

Weeds in agricultural fields reduces crop yields by competating in nutrients, sunlight, and moisture, among other things.Weeds have the ability to produce a huge number of seeds, and propagate rapidly in agricultural fields due to presence of congenial environment and ultimately reduces crop yield. The weeds present in different fields may be different due to agricultural practices and crops grown there. The aim of present study was to compare the weed diversity in different agricultural fields having cultivation of wheat, cabage and potato. Besides this the aim of this study was also to find out differences in seed bank at different agriculture fields of Bhaktapur. To understand this five different sites (Sudal, Wonti, Chitapole, Gundu, and Jhaukhel) of Bhaktapur district were selected as theses places were having similar crops and agricultural practices. From each sites potato, cabbage and wheat fields were selected for weed diversity and seed bank study in January to Februrary of the year 2020 and 2021. The study of weed diversity was conducted using quadrats of $2 \times 2m^2$ in both years whereas the study of seed bank was conducted only in 2021. For seed bank study, soil samples from each field was collected using composite sampling, then the seed germination was observed in the collected soil samples by spreading it on plastic plate along with regular watering after 2^{nd} weeks from February 16^{th} to March 27^{th} 2021. Altogether 49 weed species belonging to 16 families were found in three different agriculture fields. Among them 47 were found in first year and 49 were found in second year. Asteraceae (16) was the dominant family followed by poaceae (8). *Poa annua, Soliva anthemifolia, Stellaria media, Chenopodium album, Persicaria hydropiper* were the most dominant species as their IVI and weed density/m^2 were high in most of the sites except Jhaukhel. *Spergula arvensis* scored highest IVI and highest weed density/m^2 in wheat field of Jhaukhel. The weed density in agriculture fields were increased in second year in compare to first year. From the seed bank study, altogether 1023 seeds of 37 weed species belonging to 15 families were recorded in soil. The dominant families in soil seed bank were Poaceae, Asteracea and Caryophyllaceae. The most abundant species recorded in soil seed bank were *Poa annua, Stellaria media*, *Soliva anthemifolia.* Emergence of *Cynodon dactylon, Poa annua, Stellaria uliginosa* and *Persicaria hydropiper* were not significantly different at P=0.05 in all selected sites in potato field. Emergence of common weeds *Poa annua, Soliva anthemifolia, Stellaria media, Chenopodium album*, *Persicaria hydropiper* were significantly different at P=0.05 in all selected sites in cabbage field and wheat field. Weed seed density of three different agriculture fields in selected sites were insignificantly different. Weed species diversity was high in Gundu whereas it was low in wheat and potato fields of Jhaukhel. But high weed diversity was recorded at cabbage fields of Jhaukhel and low diversity was found in cabbage fields of Wonti. Weed seed bank diversity was high in Gundu and low in Wonti. The similariy index of weeds in agriculture fields and soil seed bank is high in cabbage field of Chitapole and low in wheat field of Jhaukhel. Species richness of soil seed bank followed the same pattern as in fields, with the highest richness in Gundu and lowest richness in Wonti. From both field studies and seed bank study by germination method, weed species richness was found to be high at wheat field and low at cabbage fields. The Shannon diversity index was found to be higher in seed banks than in agricultural field weeds, indicating the importance of seeds in the soil as a reservoir of biodiversity. The similarity index of weeds in cabbage fields and soil seed bank were foud to be highest (86.96%). Some of the weeds like *Rorripa palustris,* and *Amaranthus spinosus,* of which *A. spinosus* is an invasive species, were recorded in the soil seed bank study only but were not found in field study. This finding indicated the possibilities of invasive weed infestation in the agriculture field in future. From this it is evident that the study of a weed seed bank is important as it provided more information about the weed seed infestations at present and also warns us for the future as well.

Key words: Weed, IVI, Seedling emergence, Wheat, Cabbage, Potato

ACRONYMS AND ABBRVIATIONS

%	Percentage
1-D	Simpsons index of diversity
ANOVA	Analysis of Variance
b	Breath
D	Simpson’s diversity index
E	East
et al.	And other
GPS	Global Poastioning System
h	Heigth
H	Shannon Weiner diversity index
IVI	Important value index
l	Length
N	North
No.	Number
^{o}C	Degree Celsius
Per m^2	per meter square
SI	Similarity index
Sp.	Species
V	Volume

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CHAPTER 1. INTRODUCTION

1.1. Background

Unwanted plants known as weeds are competitive, tenacious, harmful, and negatively impact human activity. They are not purposefully sown (Ligenfelter 2009). Weeds can produce a lot of seed, have rapid population expansion, dormancy in the seed, long-term survival of buried seed, adaptations for spreading, multiply under variable condition, and vegetative reproductive structures. One of the characteristics of weeds that makes them common in nature is their capacity to colonize areas that have been interrupted by human activities (Ligenfelter 2009). These qualities make weed a powerful competitor and a dominant plant. As a result, weeds thrive in a number of environments, including agriculture, pastures, rangeland, and woodland, where they compete with natural flora. Weeds decrease crop output either by lowering the amount of product that can be harvested (grain, stover, fodder), or by lowering the amount of crop that is actually harvested (Aldrich 1984).

Due to the varied climate, and a variety of intricate cropping systems, Nepal has a diverse range of weed floras. Nepal's diverse geophysical conditions have created a favorable environment for a wide range of weeds (Sapkota et al 2010). Weeds frequently penetrate human-controlled environments like lawns, parks, orchards, and agricultural areas. Weeds pose a serious threat to the environment because they compete with native plants and reduce production.Weed invasion into natural areas has been linked to human movements throughout our evolutionary history, but as is now widely acknowledged, the rate of this process has recently accelerated significantly (Adair and Groves, 1998). The spread of exotic plants/weeds reduces the native component. It reduces crop yield by competing for water, nutrients, and light with the crop. It grows faster than crops and consumes a large amount of water and nutrients, resulting in significant yield losses. When a crop is harvested from a weedy field, the seeds of the weeds mix with the main crop, lowering the quality of the product and lowers market prices. Also, tillage operations and labor employed for weeding raise cultivation costs, resulting in an economic loss. Problems like insects, and agricultural diseases can be carried by weeds (Frick and Johnson, 2002) and also produce harmful chemicals such as phytotoxic, which reduce the germination and growth of many crop plants (Ahmad et al 2016).

Weeds are a significant problem in agricultural fields because they interfere with the main crop by consuming land and water resources, reducing crop quality and quantity. Weed composition and abundance are influenced by a variety of environmental factors as well as management practices. Many weed species grow under various environmental conditions, depending on their adaptability to the environment. Climate and weather changes influence the distribution, diversity, abundance, and intensity of weeds. (Khanal *et al.,* 2018).

The weed seed bank is a collection of viable weed seeds found on the soil surface and throughout the soil profile (Singh *et al.,* 2012; Begum *et al.,* 2006). As a means of surviving the stresses imposed by control methods, many weed species produce a large number of small seeds and vegetative propagules (Leck and Schutz; 2005). Per square foot, agricultural soils can contain thousands of weed seeds and a dozen or more vegetative weed propagules (Menalled, 2013). Following dispersal, seeds may remain on the soil surface or be buried by biotic and abiotic agents, forming a seedbank that serves as the primary source of weeds in fields. The majority of weeds germinate from viable seeds that have been incorporated into the soil over time. Temperature, water content, compaction, texture, and air content in soil can all influence the timing of germination and the number of germinated seeds (Egley, 1995), as well as physiological aspects of the seeds, particularly seed dormancy (Baskin and Baskin;2006). Many different species make up the soil weed seed bank, and dominant species can account for up to 70-90% of the seed number in soil. The amount of weed seeds produced varies greatly depending on soil type, crops grown, crop rotation, cultivation methods, and herbicide use (Grundy & Jones, 2002). When environmental conditions are favorable, seeds germinate and weeds grow, producing new propagules that enrich the soil seedbank.

The weed seedbank is generally smaller in tropical regions, than at the temperate region. The decline of weed seed bank is generally faster because (a) there is a high seedling recruitment rate due to favorable climate conditions for seed germination, (b) high seed mortality due to predator attack; (c) high relative humidity and higher temperatures, which favor biotic agents; and (d) seedling mortality due to seed germination in short, hot dry periods (Gracia, 1995). Insects, birds, and rodents affect the weed seed bank by feeding the weed seed, while human activity affects the weed seed bank by applying herbicide.

Weed seed tends to be at the soil surface and easy to control when there is no disturbance in the soil and no tillage in the cropping system. Seeds can germinate if they remain on or near the soil surface. Weed seeds spread horizontally and vertically through the soil profile. Clements *et al.,* (1996) demonstrated that soil texture influences weed seed distribution in the soil profile under various tillage systems. Small-seeded weeds, for example, *Kochiascoparia (L.), Cirsium arvense (L.),* and *Chenopodium album* (L.) germinate at very shallow depths in most soils (less than 0.5 inch). Weeds with large seed reserves, such as *Helianthus annus* (L.), can germinate from greater depths. (Hossain and Begum, 2015). Understanding how management practices affect seed vertical distribution is important because it can help us predict weed emergence patterns.

Soil seed banks can play an important role in plant regeneration or restoration after disturbances because they partially reflect the history of plant species. Soil seed bank research has aroused the interest of many people due to its importance in plantation and restoration, biological diversity preservation, and vegetation succession. (Li *et al.,* 2009)

The visible weed infestation on the field surface is linked to the soil seed bank. Weeds are capable of producing a high number of seeds. Seed may remain on the surface after dispersal or may be buried by an abiotic or biotic agent. A soil weed seed bank contains both newly shed weed seeds and older seeds that have been there for several years. As a result, the principal source of weeds in an agro-ecosystem is the soil seed bank. Knowledge of weed seed bank structure will aid in the prediction of weed community structure and dynamic patterns, as well as the implementation of suitable management measures (He *et al.,* 2019). Most plant communities' seed banks have a tremendous reservoir of regenerative potential.The content and pattern of vegetation may be determined by the introduction of new individuals from the seed bank.As a result, a close link between the soil seed bank and plants may be expected. The weed seed bank not only acts as an actual reminder of past cropping system successes and failures, but it may also help producers in predicting the extent to which crop weed competition will effect crop output and quality (Nyamwamu *et al.,* 2020). The survival of seeds in soil, as well as the conditions for germination and establishment of seedlings, may change from species to species, and the variation between seed bank and existing vegetation might be significant. Only communities where annual plants predominate and/or those that are frequently disturbed have demonstrated a significant degree of species composition similarity between seed banks and vegetation (Dessaint *et al.,* 1997)

1.2. Justification

Bhaktapur is surrounded by minor farming towns and villages. In Bhaktapur, 10,240 hectars of land are suitable for agriculture, however only 30% of that area has year-round irrigation facilities (Poudel et.al, 2012). Bhaktapur's areas have been identified as the primary areas for grain and vegetable production. Weeds reduce crop productivity and product quality, hence ecological research on weed diversity in agriculture helps to identify dominant weed species, which can then be employed in weed control. Furthermore, soil seed bank analysis can aid in the prediction of weed infestations, which inturn can be useful for the management of weeds. Weed survey work in bhaktapur was conducted by some researchers (Chaudhary 1979, Ranjit *et al*., 2006, Mallik 2021) before, but the work on seed bank has not been conducted so far in this area. Hence an attempt has been made in this study to predict seed bank based on weed seed germination in soil sample collected from wheat, cabbage and potato field in this study.

1.3. Research questions

- What weed species are prevalent in winter crop fields?
- Does seed density vary by cropping pattern in different agricultural fields?
- Are the composition of weed species in agricultural fields similar to that of soil seed banks?

1.4. Objectives

The main objectives of the study is to compare the weed diversity in different agricultural fields and also to find out differences in seed bank of different agriculture fields of Bhaktapur.

Specific objectives

- To identify the dominant weeds in different agriculture fields.
- To explore the weed seed bank in soil.
- To understand a relationship between weeds in agricultural field and soil seed bank.

1.5. Limitations

1. For weed diversity, plots were laid on the corner of the fields, so there is every chance of missing the areas where weed diversity were more.
2. The soil were collected from the surface to 15cm depth at four corners of the field, so that accurate species and number of weed seed bank of the agriculture field canbe missing.

CHAPTER 2. LITERATURE REVIEW

2.1.Weed diversity in agricultural field

In Nepal, the ecological and floristic survey was started by Numata in 1965 in the eastern part of Nepal and by Chaudhary in 1968 in the southern part of Nepal in wheat field. (Bhatta *et al.*, 2021).

Many researchers identify the different weeds in different agriculture fields. While working at six different sites in Kathmandu Valley (Thankot, Khumaltar, Dharmasrhali, Indrayani, Bhaktapur, and Kritipur), Chaudary (1979) reported 108 angiosperm weeds in wheat fields (14 monocots and 94 dicots) belonging to 36 families. The largest weed species belonged to the Compositae family followed by Graminae. *Chenopodium album, Polygonum sp., Vicia sp., and Cannabis sativa* were reported to most abundant species.

Similarly, a survey of weeds at Kritipur was conducted by Chaudhary and Shrestha (1981) who reported major weeds like *Cannabis sativa*, *Chenopodium album*, *Phalaris minor*, and *Vicia spp* from wheat fields.

Another study conducted by Dangol (1987) recorded 35 weed species representing 33 genera and 16 families at Birganj, Parsa, Nepal. The most common weeds were *Gnaphalium luteo-album, Chenopodium album, Cynodon dactylon, Equisetum debile, Lathyrus aphaca, Anagallis arvensis, Rumex dentatus* and *Lolium temulentum.* Further the work of Dangol and Chaudhary, (1993) recorded thirty weed species belonging to 16 families and 25 genera from wheat fields at Rampur, Chitwan, Nepal. They reported *Cynodon dactylon*, *D. adscendens*, *Ageratum houstonianum, and Chenopodium album* were major weed species at IAAS, Rampur, Nepal, and adjoining areas. Later Dangol (2013) reviewed 34 papers on the common weeds in wheat in Nepal and documented 370 weed species of 210 genera in 54 families and showed that the Asteraceae (69 spp.), Poaceae (52 spp.), Leguminosae (25 spp.), Polygonaceae (19 spp.), Caryophyllaceae (18 spp.), Scrophulariaceae (17 spp.), Euphorbiaceaeand Lamiaceae (14 spp. each), Brassicaceae and Cyperaceae (13 spp.), and Solanaceae (11spp. each) were the dominant families, which accounted for 71.35% of the total weeds. This paper also documented 63 species reported as the main or most common weeds, as well as four species (*Chenopodium album, Cynodon dactylon dactylon, Phalaris minor, and Polygonum plebeium*) as the most commonly reported wheat weeds in Nepal documented 370 species with 210 genera in 54 families.

Joshi (1996) recorded 64 weeds species of wheat field from Kabhre district of Nepal and found 9 weed species like *Persicaria hydropiper, Alopecuros aequalis, Chenopodium album, Polypogon fugax, Phalaris minor, Polygonum plebeium, Avena fatua, Soliva anthemifolia* and *Stellaria uliginosa* as dominant in wheat.But later, Joshi, and Gretzmacher, (1999) recorded a 64 weeds, out of which 10 species were dominant and 20 were co-dominant in the wheat fields of Kabhre district of Nepal. They also recorded higher number of weed species in wheat fields compared to that of rice fields in the same area.

Another exploration work was conducted by Thapa (2001) and documented ninety five species of weed belonging to 31 angiospermic families and one pteridophyte were observed in the upland and lowland field of maize crop at Pokhara valley. Thapa (2001) reported that *Cyperus rotundu., Cynodon dactylon , Gnaphalium affine Chenopodium album* were dominate in weed flora of lowland maize field and *Ageratum conyzoides , Galinsoga parviflora , Bidens pilosa , Commelina diffusa , Cyperus rotundus* in the upland field. Mostly Asteraceae, Poaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Amaranthaceae, Polygonaceae and Solanaceae families were found. Thapa (2001) also documented that seedling of *Oryza sativa* as a weed were largely occurred in the lowland maize field.

The common weeds in the experimental field of Khumaltar, Nepal during 2001/02 were *Phalaris minor, Alopecuros sp., Chenopodium album, Stellaria media, Persicaria hydropiper, Bothio spermum, Rumex sp., Senecio vulgaris* and reported that *Chenopodium album* as the dominant weed at all the wheat field having numbers ranged from 500 to 900 per 0.5m^2 area (NARC, 2002). Also, another study during 2004/05 reported different types of weeds like *Phalaris minor, Alopecuros aequalis, Stellaria media, Chenopodium album, Gnaphalium affenes, Soliva anthemifolia, Anagallis arvensis, Vicia spp.* etc. in wheat field. Among them *Alopecurus aequalis, Chenopodium album, Stellaria media, Soliva anthemifolia* and *Phalaris minor* were common in wheat (NARC, 2006).

Bhatta *et al.,* (2005) reported that 55 weed species was found in Radha-4 and Neema varieties of rice seed in paddy field of unweeded plot at Tilachaur in Mahendranagar. Twelve major weeds were found in upland rainfed paddy fields were *Ageratum cornyzoides, Aternanthera sessile, Cynodon dactylon, Cyperus iria, Echinochola colona, Eclipta prostrata, Eleocharis atropurpureta, Fimbristylis miliacea, Ischaemum rugosum, Lindernia opositifiolia and Lindernia procumbens*. The weed biomass was higher in unweeded plot and lower in twice hand weeded plot. The trend of grain yield in both varieties were; weed free plot> twice hand weeded plots>chemical fertilizer and butachlor plots> unweeded plots. Bhatta *et al.,* (2010) studied paddy fields in lowland and upland areas of Mahendranagar, Nepal and documented 61 weed species belonging to 42 genera and 23 families. Later Bhatta *et al.,* (2010) recorded the dominating weed species in paddy fields and they were: *Fimbristylis miliacea, Lindernia oppositifolia, Eleocharis atropurpurea, Ageratum conyzoides, Cyperus iria, Echinochloa crus-galli, Ischaemum rugosum, Echinochloa colona, Cyperus difformis and Schoenoplectus juncoides.* . Besides dicots and monocots, two species of pteridophytes (*Ceratopteris thalictriodes and Marsilea minuta*) were also recorded in lowland paddy field and maximum number of species were found in Cyperaceae followed by Poaceae.

Similarly Ranjit *et al.,* (2006) reported *Alopecus sp., Avena fatau* and *Phalaris minor* are the three major weeds of Bhaktapur area. Further Ranjit *et al.,* (2009) documented that *Phalaris minor, Alopecuros sp., Chenopodium album, Rumex crispus, Persicaria hydropiper, Stellaria media, Cannabis sativa, and Soliva anthemifolia* were the dominant species. Among them, *Chenopodium album, Phalaris minor* and *Alopecuros aqualis* were the dominant species in the wheat field of Khumaltar. They also found that mulching affects the weeds of wheat fields as mulching suppressed the weeds about fifty percent compared to that of without mulching. Wheat yields were also higher in the treatments with straw mulch

Various exploration work in different part of Nepal was conducted by various researcher. Manadher *et al.,* (2007) and studied the paddy field to evaluate effect of weed on crop yield and he found 52 weed species belonging to 32 genera and 15 families infested the paddy. The dominant weeds in the Kritipur paddy field were *Echinochloa colona, E. crusgalli, Cyperus iria* and *Ageratum conyzoides*. Sharma *et al.,*(2010) reported, fourty three species in the Nyeshang valley of upper Manang in wheat field which include four alien species. Sharma *et al.,* (2010) found that *Chenopodium album, Phleum alpinum* and *Convolvulus arvensis* were most dominant species. Sapkota *et al.,* (2010) studied in the wheat farm in Khokana village Lalitpur, Nepal and reported 44 weed species (incl. 4 unidentified) belonging to 18 families were found. They reported *Chenopodium album, Eclipta prostrata, Spergula arvensis and Polygonum plebeium* were most dominant species on the basis of abundance scale with highest Compositae family followed by Graminae.Sapkota *et al.,* (2010) studied in the wheat farm in Khokana village in Kathmandu valley, Lalitpur, Nepal at the altitude of about 1325 m. A total of 44 weed species (incl. 4 unidentified) belonging to 18 families was recorded. The most dominant species on the basis of abundance scale in the study site were *Chenopodium album, Eclipta prostrata, Spergula arvensis and Polygonum plebeium*. Family Compositae presented highest number of species (10 species), followed by Graminae (5).

Tauseef *et al.,* (2012) studied that cotton crop areas along the Khanewl Road were impacted by 27 species from 19 genera and 11 families.*Cyperus rotundus L. and Echinochloa colona (L.)* were found with highest importance value index of 20.9 and 17.3, respectively having highest densities as well in the cotton fields. While in the water channels, two other species i.e. *Marsilea minuta L.* and *Eclipta prostate L.* were found in abundance. Similarly, Dole *et al.,* (2013) also conducted the weed survey and found 30 weed species related to 15 families and 26 generas from the rabbi wheat field in the Marathwada region India. Dominant families were Euphorbiaceae, followed by Asteraceae, Amaranthaceae and Cyperaceae. *Chenopodium album.* Sumeka*r et al (2018) in Garut Regency west java, Indonesia found Galinosoga parviflora, Amaranthus spinosus, Drymaria vilosa* and *Cyperus rotundus* on *Solanum tuberosum* field.

Khanal *et al.,* (2018) reported that *Anagallis arvensis* had highest in wheat mustard ecosystem of agronomy farm of IAAS Paklihawa campus, Rupandehi district. Similarly, the dominance of *Anagalis arvensis* was followed by *Vicia sativa* and *Chenopodium album.*

Singh and Singh (2019) surveyed the rice fields in Fatehgarh District of Punjab and reported 31 weeds belonging to 11 families between June and November 2017. The largest genus was found *Cyperus,* followed by *Euphorbia, Echinochola* and *Eragrostis* and two perennials were found ie *Cyperus rotundus* and *Parthenium hysterophorus.*

During the preharvest condition, Niroula (2013) studied the weeds of wheat field of Biratnagar and recorded sixty eight species of weeds belonging to 22 families and 59 genera. The dominant weed families were Astereaceae and Poaceae. The abundant *species Anagallis arvensis, Polygonum plebium* were recorded in fruiting and seedling stage.Bhatta *et al.,* (2017) recorded 75 weed species in the mustard fields of upland and lowland sites of Mahendranagar, Kanchanpur. The dominant monocot families were Poaceae (16 species) and Cyperaceae (8 species). The dominant dicot families were Asteraceae (8 species), Scrophulariaceae (6 species each) and Leguminosae, Euphorbiaceae (5 species each). On the basis of density and IVI, 21 weed species dominated both the study sites. However, on the basis of density the upland site was more favorable for weeds then the lowland sites. The common dominant weeds at both sites were *Ageratum conyzoides, Alternanthera sessilis, Commelina benghalensis, Cyanodon dactylon, Cyperus rotundus, Orobanche aegyptica, Oxalis corniculata, Phyllanthus urinaria.*Khanal *et al.,* (2018) reported that *Anagallis arvensis* had highest in wheat mustard ecosystem of agronomy farm of IAAS Paklihawa campus, Rupandehi district. Similarly, the dominance of *Anagalis arvensis* was followed by *Vicia sativa* and *Chenopodium album.*Oli *et* *al.,* (2019) studied in wheat field of Biratnagar and found, forty five weed species belonging to 19 families and 39 genera. They also found that *Grangea maderspatana, Paspalum distichum, Polygonum plebeium and Anagallis arvensis* were abundant species and dominant families were poaceae followed by asteraceae.

Mallik, (2021) recently researched the weeds of winter agricultural fields in the Kathmandu valley (some place of Kathmandu, Bhaktapur and Lalitpur district). According to the author, the most frequent weeds in winter crop fields were *Ageratum conyzoides, Bidens pilosa*, *Cyperus rotundus* and *Gallingsoga parviflora*.

2.2. Weed seed bank of agriculture field

The earlier studies of soil seed banks started in 1859 with Darwin, when he observed the emergence of seedlings, using soil samples from the bottom of a lake. However, the first paper published as a scientific research report was written by Putersen in 1882 studying the occurrence of seeds at different soil depths (Roberts, 1981). The weed seed banks have been studied more intensely than the others because of its economic importance. In agroecosystems, where the soil is disturbed frequently, the soil seed bank acts to stabilize and ensure species survival (Roberts, 1981).

Rahman *et al.,* (2006) documented the identification of 67 broad leaf species and five grass weeds in 30 maize fields, though not all were found at every location and some were specific to region or soil type. Depending on the species, the most abundant weeds in the field plots emerged 2.1-8.2% of the seeds of broadleaf species and 6.2-11.9% of the seeds of grass weeds in the soil seed bank in any given year. It revealed a strong linear relationship between the number of seeds in the soil and the number of seedlings. Some species, such as *Trifolium repens*, showed only a weak relationship. There was evidence of asymptotic behavior in the case of *Chenopodium album*, which had the largest seed bank, with seedling emergence leveling off at high seed numbers.

Bhata and Singh (2007) collected soil samples in 2004 and 2005 to determine the soil seed bank in upland and lowland paddy field sites in Far Western Nepal. They discovered 43 weed species belonging to 32 genera and 17 families in lowland soil samples and 46 weed species belonging to 18 families and 34 genera in upland soil samples. In both study sites, the dominant families were Cyperaceae, Scrophulariaceae, and Poaceae. The total number of weeds that germinated in upland soil samples was 517, compared to 503 in lowland soil samples. In the second year of the soil seed bank experiment, 20 weed species emerged at the upland site and

14 species emerged at the lowland site. *Ageratum conyzoides, Cyprus iria, Digiteria sanguinalis, Echniochloa colona, Eleocharis atropurpurea, Elusine indica, Fimbristylis miliacea, Ischaemum rugosum, Lindernia procumbens, Lindernia oppositifolia, Polygonium plebejum, Schoenoplectus juncoides,* etc. This demonstrated that the seeds of these species were more viable.

Ranjit *et al.,* (2007) studied size and composition of weed seed bank in wheat and rice field at agronomy farm khumaltar, Nepal. They found 81 weed species from soil seed bak sample collected. The commom weeds were *Alopecuros aequalis, Digitaria sanguinalis, Echinochloa colona, Phalaris minor, Polypogon fugox, Cyperus difformis, C. dilutus, C. iria, C. sanguinolentus, Fimbristyllis littoralis, Chenopodium album, Coronopus didymus, Lindernia procumbens, Rumex crispus, Soliva anthemifolia, Stellaria media, S. aquatica, Commelina diffusa, Murdania sp. and Ceratopteri thalictroides*.Weed seed bank decrease with increase with soil depth 5cm to 20 cm. Mostly the weed seed bank was highly accumulated in 5 to 10 cm soil depth. Tillage system affect the seed bank size of grass weed but not on sedges and broadleaf. Weed seed bank was also affected by the management such as herbicide that suppressed the grasses and sedge weeds.

Srivastav (2012) conducted surveys in both the dryland and irrigated agroecosystems and discovered that four species were found in the dryland agroecosystem, two species in the irrigated agroecosystem, and ten species were common to both agroecosystems during the winter season. During the rainy season, 7 species were common, 5 were unique to dryland, and 6 were unique to the irrigated agroecosystem. Weed diversity was higher in the dryland agroecosystem than in the irrigated agroecosystem. Dryland agroecosystems accumulated more seeds of broad leafed weeds in soil, whereas irrigated agroecosystems accumulated more grass/sedge seeds. About three-fourth of soil seed bank during winter season was accounted by *Anagallis arvensis* and Chenopodium album in dryland agroecosystem, and by *Chenopodium album* and *Melilotus indica* in irrigated agroecosystem; however, during rainy season *Ammannia baccifera, Echinochloa colona* and *Cyperus rotundus* dominated in both agroecosystems.

Prabhu *et al.,* (2015) investigated the effect of herbicidal treatments on weed seed bank diversity in a fodder cowpea (*Vigna unguiculata* (L.) cropping field. During the winter season, *Melilotus indica, Coronopus didymus, Anagallis arvensis,* and *Spergula arvensis* were found in all of the experiments. Pendimethalin (1.34) at 0-15 cm depth and Quizalofop ethyl + oxyflorfen (1.09) at 15-30 cm depth had higher weed diversity. A significantly smaller size of soil seed bank was discovered in the 15-30 cm soil depth. *Anagallis arvensis* and *Spergula arvensis* accounted for approximately three-fourths of the soil seed bank during the winter season in all treatments.

Khut *et al.,* (2016) conducted an experiment at Estonian University of Life Sciences in 2008 on a 5-field crop rotation of red clover, winter wheat, pea, potato, and barley undersown with red clover. Red clover had the lowest content of annual weed seeds, with 17.7% fewer weed seeds in the soil of the Org II (organic farming based on winter cover crop and manure) system compared to the control (Conv I- conventional farming systems without fertilizer). When compared to other crops, the content of winter annual weed seeds in winter wheat was 50-76% higher. By the end of 2009, the organic carbon content of the soil had increased significantly in both organic systems, resulting in increased activity of organisms that reduce the viability of weed seeds.

Srivastav and Singh (2014) discovered that the amount of seed production diversity in the irrigated agroecosystem was nearly double in the winter season compared to the rainy season. The dryland agroecosystem accumulated more broad-leaved weed seeds, whereas the irrigated agroecosystem accumulated more grass or sedge seeds. *Anagallis arvensis* and *Chenopodium album* accounted for approximately three-fourths of the seeds during the winter season in the dryland agroecosystem and *C. album* and *Melilotus indica* in the irrigated agroecosystem. During the rainy season, however, *Ammannia baccifera*, *Echinochloa colona,* and *Cyperus rotundus* were dominant in both agroecosystems. The changes in the weed seed bank and its diversity were attributed primarily to differences in water management, which tends to reduce species diversity, particularly at lower depths, but results in the dominance of some potentially noxious weeds (e.g. *Phalaris minor* and *Melilotus indica*). An adaptive mechanism in the storage of weed seeds in the dryland agroecosystem may be indicated by approximately doubling the soil seedbank size and greater diversity at a lower depth. Srivastav and Singh (2014) also discovered that soil seed bank decreases as soil depth increases.

Maqsood *et al.,* (2018) discovered 16 weed species in soil samples, with four species accounting for approximately 72% of the total weed seed bank. *Trianthema portulacastrum* had the highest relative abundance (27%) of the sixteen weed species found, followed by weed seeds of Echinochloa colona, which had a relative abundance of 20% of the total weed seeds recorded. Weed seeds of *Digera muricata* and *Sorghum halepense* were found to be 16% and 14% abundant, respectively. The remaining twelve weed species were found to be the least abundant, with a relative abundance of 4%. *Cynodon dactylon, Echinochloa crus-galli,* *Eleusine indica, Digera muricata, Chenopodium album,* and *Rumex obtusifolius* seeds were found to account for only 1% of the presence in the soil weed seed bank. Weed seed density was highest in cultivator × no weeding and chisel plough × no weeding (13,852 and 13,019 seeds m^2, respectively). In soil samples taken from mouldboard plough (MB) plough treated plots, the lowest weed seed density was found at 0-10 cm (6,438 seeds m^{-2}) and the highest weed seed density was found at 10-20 cm (7,418 seeds m^{-2}).

Szewczyk *et al.*, (2020) concluded that seed bank was three times higher in direct sowing than traditional ploughing in wheat field and pea/rape fields. They also reported that the reduction in tillage system, increase in abundance of perennial and invasive species.

Mallik (2021) discovered *Ageratum conyzoides, Bidens pilosa, Cyperus rotundus, Gallingsoga parviflora, Oxalis corniculata, Trifolium repens, Sonchus arvensis, Cynodon dactylon*, and other plants in soil of Bhaktapur and Kritipur.

From the literature review, it was found that the weed diversity at some places of Bhaktapur were recorded, but the seed bank study hasnot been estimated so far. Therefore, in the present study the seed bank has been estimated based on seedling emergence method. Along with seed bank study, the diversity of weeds in different crops (Cabbage, Wheat and Potato) has been selected to study in this research.

CHAPTER 3. MATERIALS AND METHOD

3.1. Study area

Bhaktapur is located in the subtropical zone. Bhaktapur district is an agricultural district. Agriculture has been practiced in a traditional way for many generations. Bhaktapur is known as the grain and vegetable store of valley because of the productive quality of the soil. The five sites (Jhaukhel, Sudal, Chitapole, Wonti and Gundu) were chosen in the Bhaktapur district, which has a predominantly agricultural landscape. From each sites, wheat, cabbage and potato fields were selected. Jhaukhel lies between latitude 27^{0}41’31’’N to 27^{0}41’37’’N and longitude 85^{0}25’43’’E to 85^{0}25’45’’E and elevation lies between 1313m to 1319m. Sudal lies between latitude 27^{0}40’23”N to 27^{0}40’30”N and longitude 85028’19’’E to 85^{0}28’23’’E. Its elevation lies between 1439m to 1341m. Wonti lies between latitude is 27^{0}41’01’’N to 27^{0}41’02’’N and longitude is 85^{0}27’1’’E to 85^{0}27’14’’. Its elevation lies between 1308m to 1310m. Chitapole lies between latitude is 27^{0}39’40’’N to 27^{0}39’43’’N and longitude is 85^{0}28’16’’E to 85^{0}28’20’’E. Its elevation lies between 1312m to 1315m. Gundu lies between latitude is 27^{0}38’6’’N to 27^{0}38’7’’N and longitude is 85^{0}24’50’’E to 85^{0}24’51’’E. Its elevation lies between 1459m to 1460m.

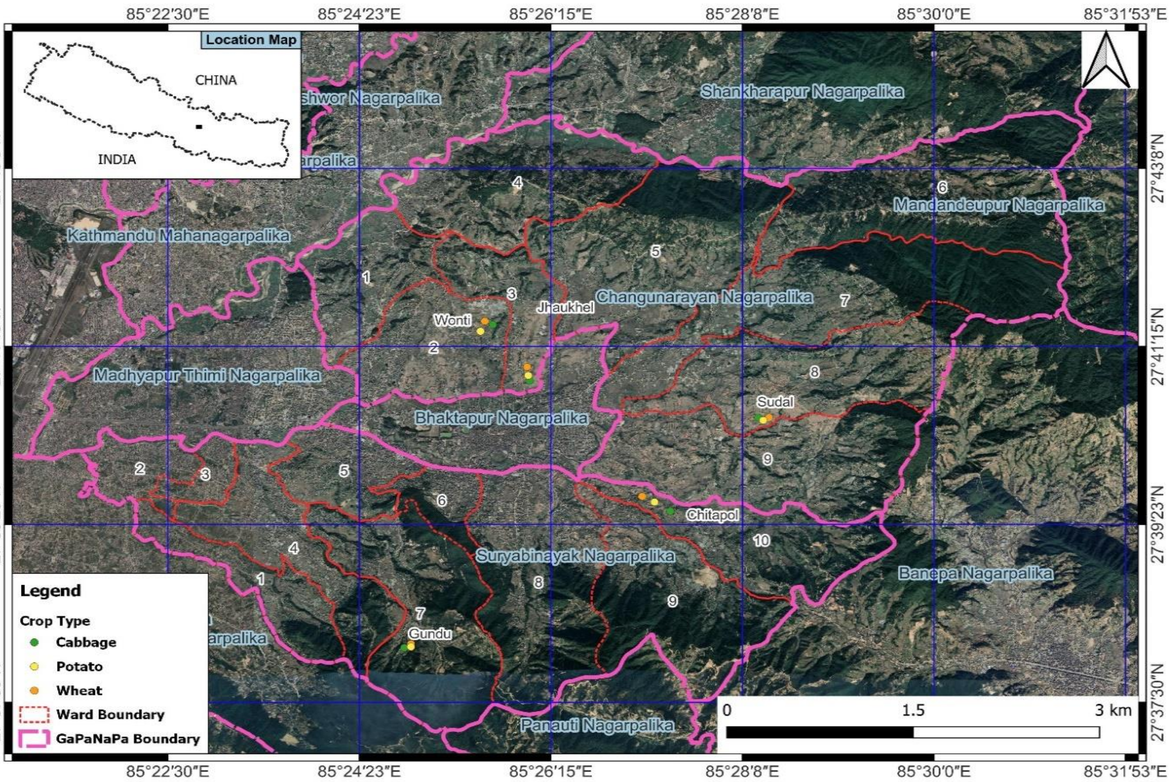

Figure 1: Map showing study sites

3.2. Climate

Bhaktapur's climate falls within Nepal's cool, temperate climatic zone. The wet season in bhaktapur is warm, muggy, and partly cloudy, while the dry season is pleasant and mostly clear. Temperature and precipitation data from the Department of Hydrology and Meteorology (DHM) of Bhaktapur district were analyzed over a ten-year period (2011-2021). The monthly and yearly temperatures were averaged to determine the minimum and maximum monthly temperatures. The mean annual temperature was 19.08^{o}c. The average monthly maximum temperature was 25.37^{o}c and average monthly minimum temperature was 12.79^{0}c (Figure 3.2). The maximum average monthly temperature which was 29.18^{o}c, was found in June and minimum average monthly temperature was 3.56^{o}c which was found in January. The analysis of monthly average precipitation for 10 years shows the highest rainfall was recorded 375 mm in month of July where November and December show the lowest rainfall.

Weed diversity in agriculture field was studied during January and Febrauary. Seed germination process from collected soil sample was done up to the March. The maximum average temperature of January, Febrauary and March were 18.49 ^{o}c, 21.08 ^{o}c and 24.74 ^{o}c respectively. The minimum average temperature of January, Febrauary and March were 3.56 ^{o}c, 6.12 ^{o}c and 9.43 ^{o}c respectively. The average precipitation of January, Febrauary and March were 12.85mm, 29.27mm, 35.78mm respectively.

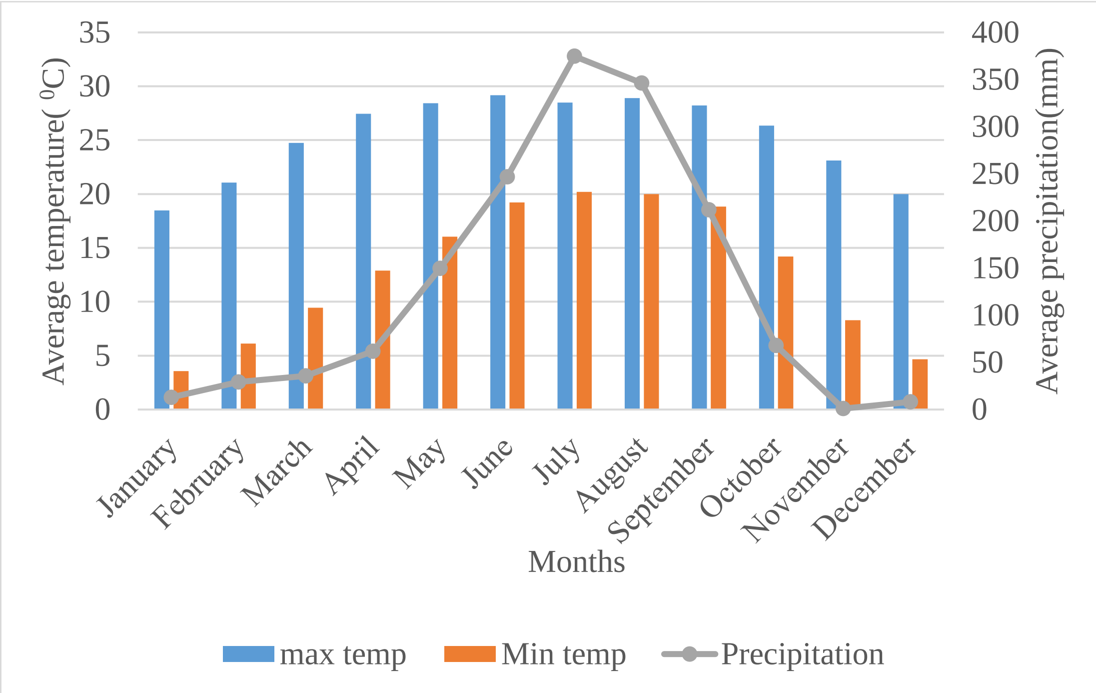

Figure 2: Average monthly maximum (Tmax) and minimum (Tmin) temperature with precipitation recorded in Bhaktapur distict for 10 years (2011-2021). (Source: DHM)

3.3. Methods

3.3.1. Weed diversity

The field's survey was carried out in December in 2020 to ensure accessibility and working strategy in the fields. These survey gives ideas of the crop avaibility on agriculture fields and fields work plan. Then the main field work was carried out during January and February in the year 2020 and 2021.

For weed diversity, systemic sampling was done. The different agriculture fields having Cabbage (*Brassica oleracea var capitata* f. alba), potato (*Solanum tuberosum* Linn.) and wheat (*Triticum aestivum* L.) were selected at five different sites of Bhaktapur i.e at Sudal, Gundu, Wonti, Chitapole and Jhaukhel. Then the quadrats of 2m×2m were laid on four corner of each agricultural field. The weeds within the quadrate were then counted and recorded. The distance between two plots, where the quadrats were laid was at least 20m away from each other. But due to the some hindraces like road on the way, same agricultural fields resulted unequal length of plot. In this way 3 plot was taken from each sites of Bhaktapur. Altogether 12 quadrats were laid in each sites. All total 120 quadrats were laid in all sites of agricultural fields in both years. The geographical location of five different sites (longitude, latitude and altitude) was recorded by using Global Positioning system (GPS) and given in Annex 1. Since all weeds found in the study area was identified, hence no herbarium was made.

3.3.2. Calculation of Ecological indices

The weeds were counted and frequency, density, coverage and IVI was calculated by using method describeb by Zobel *et al.*, (1987).

Frequency (F)

Frequency is the proportion of sampling units containing the species.

$$\text{Frequency (F)} = \frac{\text{No.of quadrat in which species occured}}{\text{Total no.of quadrat studied}} \times 100$$

Relative Frequency (RF)

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

Density (D)

Density of species was a count of the numbers of individuals of each species within the quadrat (Kent and Coker, 1992).

$$\text{Density (D)} = \frac{\text{Total no.of individuals of a species in all quadrates}}{\text{Total no.of quadrat studied}} \times \frac{1}{\text{area of quadrat(m2)}}$$

Relative Density (RD)

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

Coverage(C)

Cover is the area of ground covered or the relative proportion of coverage a particular plant species, vegetation layer, or plant form represents when viewed from above (Nkoa *et al.*, 2015). Coverage of particular weed species was estimated by visually estimating the area cover by the weeds inside the quardates with a categories 0%, 1 to 5%, 5 to 10%, 10 to 25%, 25 to 50%, 50 to 75% and 75 to 100%.

Coverage(C) =$\frac{coverage\ of\ individual\ species}{total\ no.of\ quadrat\ studied}$

Relative coverage (RC)

Relative coverage (RC) =$\frac{Coverage\ of\ individual\ species}{Total\ coverage\ of\ species} \times 100$

Importance Value Index (IVI)

Importance Value Index (IVI) is a reasonable measure to assess the overall significance of a species since it takes into account several properties of the species in the vegetation. Relative frequency, Relative density, and Relative coverage each indicate a different aspect of the importance of a species in a community. Therefore, the sum of these three values gives a good overall estimate of the importance of a species. This sum is called the importance value.

IVI =RF +RD + RC

Where, IVI = Importance Value Index of species

RF = Relative Frequency of species

RD = Relative Density of species

RC = Relative Coverage of species

Diversity of species:

The structures of weed communities and soil seed bank were analyzed using diversity indices:

Simpson's Diversity Index

The Simpson index was introduced by Simpson (1949) in order to measure the degree of dominance of individuals weed species.Simpson's diversity index was calculated according to Simpson (1949) the formula is given as follows:

Simpson’s Index (D) = $\Sigma\ \frac{n(n-1)}{N(N-1)}$

Where,

N = Total number of species collected

n = Number of individuals of a species

The value of D covers from 0 to 1, and according to this index, 0 represents unlimited diversity and 1 represents no diversity; therefore, the higher the value of D, the less diverse a population is, which is extremely unscientific. Simpson's index of diversity is frequently calculated by subtracting the value of D from 1 in this range.

Simpson’s index of diversity= 1-D

Shannon - Wiener diversity index

Shannon - Wiener diversity index is the most popular measure of species diversity because it accounts both for species richness and evenness, and it is not affected by sample size (Kent and Coker, 1992).

The minimum value of H' is 0, which is the value for a community with a single species, and increases as species richness and evenness increases (Manuel and Molles, 2007).

Shannon − Wiener index (H’) = − **Σ**Pi(Ln Pi)

Where,

H’ = Species Diversity Index

Pi = Proportion of individual species

Pi = ni/N

ni = number of individuals of species i,

N = total number of individuals

Similarity index (SI)

The similarity index helps to determine the interspecific association between the species of plant communities (Sorensen, 1948). This index was calculated to know the similarity among the weed species present in different study areas of cabbage, potato and wheat fields.

Sorenson’s Similarity index= $\frac{2C}{A+B} \times 100$

Where, A = Total number of weed species in agriculture fields.

B = Total number of weed species in soil weed seed bank /seeding germination

C = Total number of common species in both agriculture fields and seedling emergence

3.3.3. Soil seed bank analysis

3.3.3.1. Soil sampling

Soil sampling was done by composite sampling from three different agriculture field's i.e (*Brassica oleracea var capitate f.alba, Solanum tuberosum Linn. Triticum aestivum L.*) at five different sites (Sudal, Gundu, Wonti, Chitapole and Jhaukhel). For each agriculture fields, five quadrate were laid down, four at the corner of the field and one at the center of the fields. Soil samples were collected from 15cm depth, 10cm length, and 10cm breadth in two points at each quadrat. The stone, organic debris were removed from the collected soil and composite sampling was done by mixing the soil taken from two point and divided in four parts. Out of four parts and only two part was selected. These two selected parts of soil samples were mixed and collected in a plastic bag for seed bank analysis using the seedling emergence method. In 2021, 75 quadrats were laid down in five distinct sitess (15 quadrats in each). To identify agriculture fields, plots, and sites, the polybags containing soil samples were labeled with permanent marker.

3.3.3.2. Weed emergence in soil collected from different agricultural field of Bhaktapur

Weed seed bank in soil was studied by seedling emergence method. For this a plastic plate with 3cm height and 14cm diameter was taken. Then the plastic plate was marked by permanent marker to identify the soil sample of different plots and sites. Each plastic plates had four perforation at the base to facilitate the drainage of excess water in soil sample. Collected each soil sample was spread on the plate in a thin layer and was kept in a place where sunlight was available. Thus spreaded soil samples were watered daily to make the soil moist. The seed germination was observed in the collected soil samples after 2nd weeks from February 16th to March 27th 2021. The identified seedlings were counted and removed. The unidentified seedling were not pulled out until the flowering. The monitering for weed seedling emergence was done in every two week. Soil sampled was stirred after each assessment after 3 weeks to stimulate seed germination by bringing it to surface which might have been buried. The Simpson's index of diversity and Shannon Weiner index of the data obtained from the number of seedling emergence from each site for each crops were also calculated.

3.3.3.3. Weed seed bank estimation

Weed seed bank density was estimated according to Takim *et al.,* (2013). The number of weed seeds in the seedbank (Y) per land area (m^2) was estimated by multiplying the number of seed in soil sample (G) by invese ratio of volume of collected soil to volume of soil in $1m^2$ area sampled to depth of the auger (15 cm)

Volume of collected soil (V1) = l × b × h where l=length b=breath h= depth of sampling

V1= 10cm × 10cm × 15cm = $1500cm^3$ =0.0015 m^3

Volume of soil from $1m^2$ sample (V2) = l × b × h

V2 = 100 × 100 × 15 =150000cm = 0.15 m^3

Estimated seed density/m^2 can be calculated by

Y = (G/V1) × V2, Where, Y= estimated density of weeds / m^2 to depth of 15 cm

G= number of emerged weed seedling / soil sample

3.4. Statistical analysis

To understand the significant difference in emergence of weed seeds from the soil collected from five different places of cabbage, potato and wheat fields, one way ANOVA was conducted and was followed by Duncan's multiple range test at p=0.05 significance level. To evaluate if the weed density among wheat, potato and cabbage fields differ or not, a non parametric Kruskal Wallis test was done by using IBM SPSS Statistics 21 software.

CHAPTER 4. RESULTS

4.1. Weed diversity in agricultural field

Altogether 49 weed species belonging to 16 families found from three different agriculture fields were recorded during this study. In first year, 47 weed species belonging to 16 families were recorded and in second year 49 weed species belonging to 16 families were recorded in same field. *Vicia hirusta* and *Digitaria sp*. were only found in second year. Dominant weed species were *Poa annua, Soliva anthemifolia, Stellaria media, Chenopodium album, Persicaria hydropiper*. Most leading family was Asteraceae (16) followed by Poaceae (8). Beside this there were Caryophyllaceae (5), Amaranthaceae (3), Fabaceae (3), Polygonaceae (3), Brassicaceae (2), Oxalidaceae (2), Plantagenace (2), Primulaceae (2), Araliaceae (1), Apiaceae (1), Acanthaceae (1), Mazaceae (1), Equisetaceae (1), and Cannabaceae (1) shown in figure 3.

Altogether 46 weed species were found in wheat fields. A total of 44 weed species was found in wheat field in first year whereas 46 weed species were recorded in second year. *Mazus japonicas, Vicia angustifolia* were absent in first year.The most common species in the wheat fields were *Poa annua, Chenopodium album, Soliva anthemifolia, Conyza canadensis, Stellaria media, Persicaria hydropiper, and Avena fatau*.Altogether 32 weed species were found in potato fields. Among them 30 species were found both years. *Drymeria diandra* and *Sonchus oleraceous* was only found in first year and *Equisetum sp* and *Sagina sp*. was only present in second year and absent in first year.The common weeds found in the potato fields were *Chenopodium album, Cynodon dactylon, Persicaria hydropiper, Poa annua, Soliva anthemifolia, Stellaria uliginosa and Stellaria media* among the selected five sites.A total 28 species was found in cabbage fields. In first year, only 20 weeds species were recorded and in second year, 28 weed species were found. *Ageratum houstonium, Avena fatua, Capsella bursa pastoris, Digitaria sp., Equisetum sp., Gallingsoga paviflora, Oxalis corniculata, Plantago majore* were absent in first year. The common weeds in cabbage fields were *Chenopodium album*, *Poa annua*, *Soliva anthemifolia* and *Stellaria media*.

The species richness was high in wheat fields followed by potato fields then cabbage fields. Among the five sites, species richness was high in Gundu whereas low in Wonti. Altogether 37 weed species were found in first year at Gundu and 38 weed species were found in second year whereas in Wonti, 10 weed species were found in first year and 17 weed species were found in second year. In Sudal 33 weed species were found in both years and in Chitapole 17 and 19 weed species were found in first year and second year respectively whereas in Jhaukhel 25 and 22 weed species were found in first year and second year respectively.

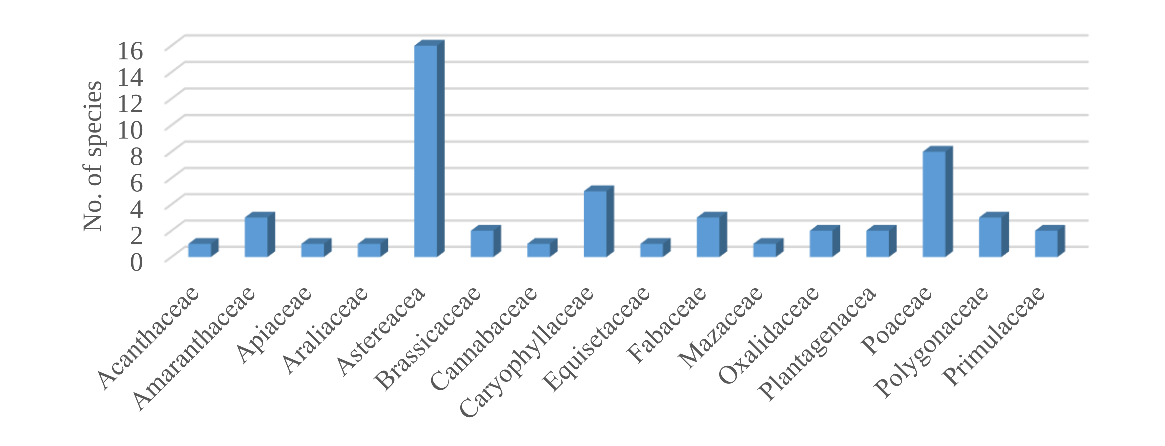

Figure 3: The number of species in different families present in three different agricultural field of selected dites of Bhaktapur.

4.1.1. IVI of weeds in different agriculture fields of first year and second year.

IVI of all weed species in wheat, potato and cabbage fields at five different sites in first and second years are given in Annexes II, III and IV. IVI of common and dominant weed species at particular sites is described below.

4.1.1.1. IVI of weed species at Sudal

The IVI of common dominant weeds in wheat, potato and cabbage fields at Sudal were *Alopecurus sp., Chenopodium album, Poa annua, Persicaria hydropiper, Soliva anthemifolia, Stellaria media, and Stellaria uliginosa*. In wheat field, 26 species were found in first year whereas 25 species were found in second year. Among them *Poa annua (*79.70*)* and *Soliva anthemifolia* (59.75) scored highest IVI. Similarly in second year as well *Poa annua* (85.84*)* and *Soliva anthemifolia* (56.24) scored highest IVI in wheat field of Sudal. In both years, 16 weed species were recorded in potato field. *Poa annua* and *Soliva anthemifolia* recorded highest IVI in both years. Altogether, 9 weed species were found at cabbage field in first year and 18 species were found in second year. *Persicaria hydropiper* and *Poa annua* scored highest IVI in both years. The IVI of most common dominant weed species in wheat, cabbage and potato fields at Sudal in the second year is given below in figure 4.

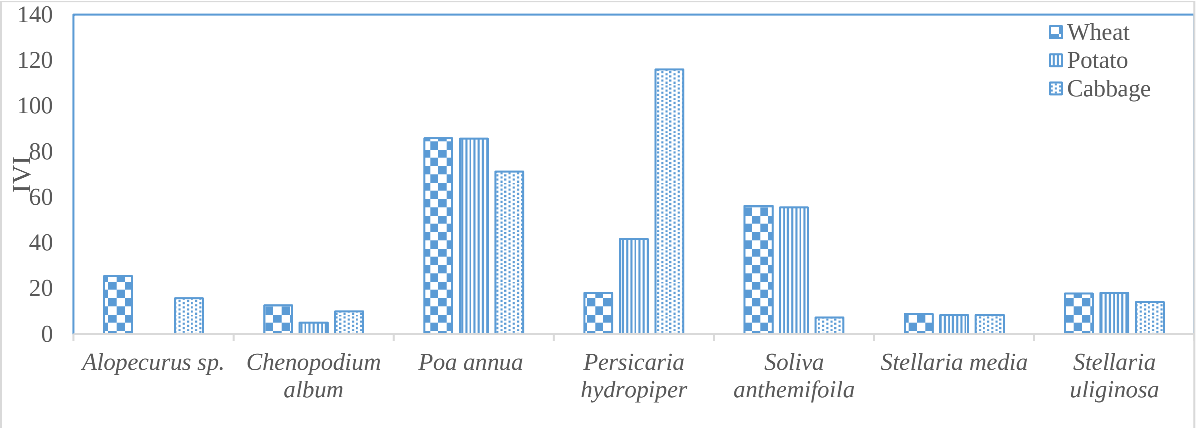

Figure 4: IVI of common dominant weeds in wheat, cabbage and potato at Sudal in second year

4.1.1.2. IVI of weed species at Wonti

The IVI of common dominant weeds in wheat, potato and cabbage fields at Wonti were *Cannabis sativa, Chenopodium album, Poa annua, Persicaria hydropiper, Soliva anthemifolia, and Stellaria media.* In wheat field of Wonti, 9 weed species were found in first year whereas 13 species were found in second year. Among them *Stellaria media* and *Chenopodium album* scored highest IVI in both years in wheat fieldof Wonti. In both years, 8 weed species were recorded in potato field. *Stellaria media* and *Poa annua* were the species having highest IVI in potato field. Altogether, 6 weed species were found at cabbage field in first year and 8 species were found in second year. *Stellaria media* (165.02) and *Poa annua* (61.21) scored highest IVI and in first year. In second year, Stellaria *media* (149.10) and *Soliva anthemifolia* (35.85) scored highest IVI in cabbage field. The IVI of most common dominant weed species in wheat, cabbage and potato fields at Wonti in the second year is given below in figure 5.

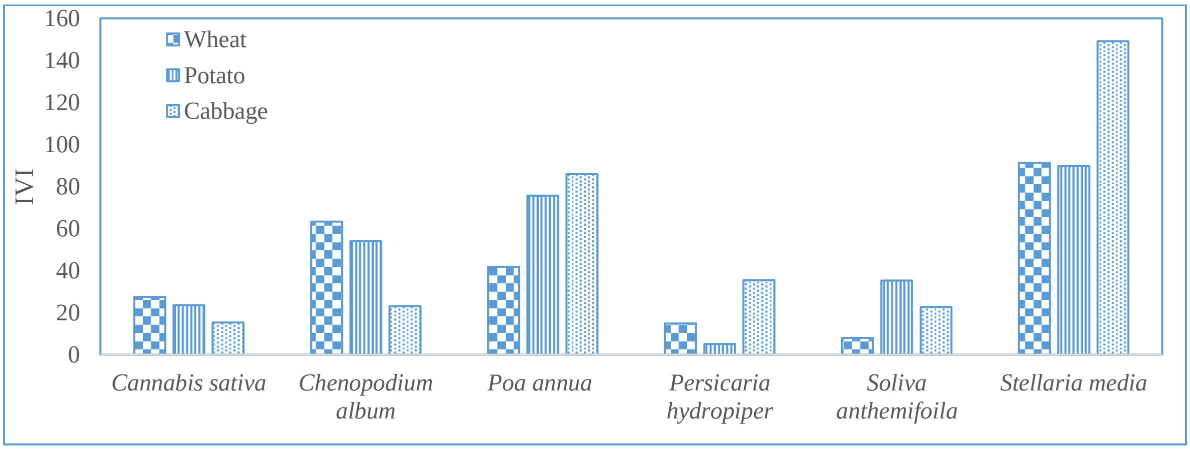

Figure 5: IVI of common dominant weeds in wheat, potato and cabbage at Wonti in second year

4.1.1.3. IVI of weed species at Chitapole

The IVI of common dominant weeds in wheat, potato and cabbage fields at Chitapole were *Ageratum conyzoides, Chenopodium album, Poa annua, Persicaria hydropiper, Rumex crispus, Soliva anthemifolia, and Stellaria media.* In wheat field of Chitapole, 11 weed species were found in first year whereas 17 species were found in second year.. Among them *Stellaria media* and *Poa annua* scored highest IVI in wheat field. In potato field 14 weed species were recorded in first year and 12 weed species were recorded in second year. *Stellaria media* and *Poa annua* recorded highest IVI in potato field. Altogether, 5 weed species were found at cabbage field in first year and 10 species were found in second year. *Stellaria media* and *Rumex crispsus* scored highest IVI in cabbage field. The IVI of most common dominant weed species in wheat, cabbage and potato fields at Chitapole in the second year is given below in figure 6.

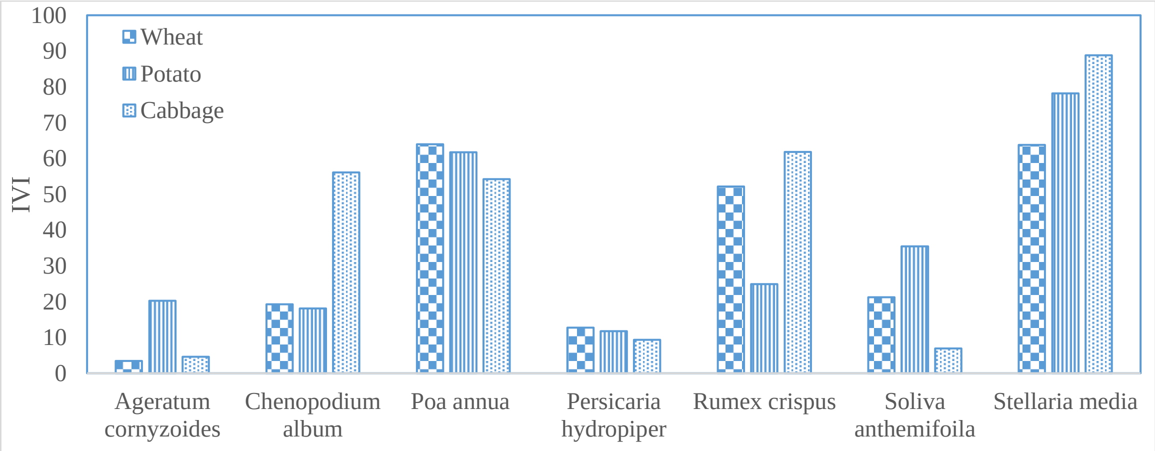

Figure 6: IVI of common dominant weeds in wheat, potato and cabbage at Chitapole in second year

4.1.1.4. IVI of weed species at Gundu

The IVI of common dominant weeds in wheat, potato and cabbage fields at Gundu were *Chenopodium album, Poa annua, Persicaria hydropiper, Soliva anthemifolia, Stellaria media, Trifolium repens and Stellaria uliginosa.* In wheat field of Gundu, 31 weed species were found in both years. Among them *Poa annua* and *Soliva anthemifolia* scored highest IVI in wheat field. In potato field, 20 weed species were recorded in first year and 22 weed species were recorded in second year. *Chenopodium album* and *Poa annua* scored highest IVI in potato field. Altogether, 11 weed species were found at cabbage field in first year and 18 species were found in second year. *Poa annua* and *Soliva anthemifolia* scored highest IVI in cabbage field. The IVI of most common dominant weed species in wheat, cabbage and potato fields at Gundu in the second year is given below in figure 7.

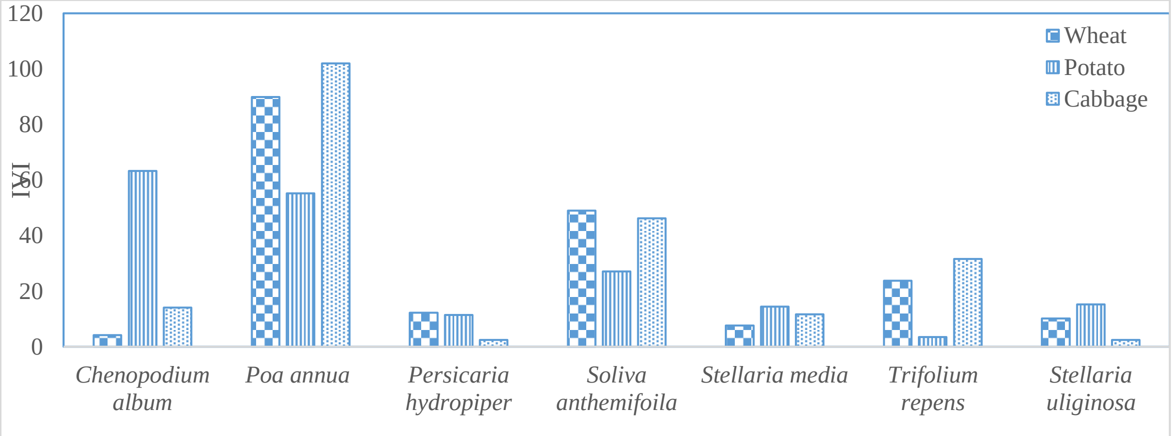

Figure 7: IVI of common dominant weeds in wheat, potato and cabbage at Gundu in second year

4.1.1.5. IVI of weed species at Jhaukhel

The IVI of common dominant weeds in wheat, potato and cabbage fields at Gundu were *Chenopodium album, Poa annua, Persicaria hydropiper, Soliva anthemifolia, Stellaria media, and Spergula arvensis.* In wheat field of Jhaukhel, 15 weed species were found in first year whereas 14 species were found in second year. *Spergula arvensis* and *Poa annua* recorded highest IVI in wheat field. In potato field 20 weed species were recorded in first year and 13 weed species were recorded in second year. Poa *annua* and *Stellaria media* scored highest IVI in potato field. Altogether, 11 weed species were found at cabbage field in first year and 12 species were found in second year. *Poa annua* and *Alopecurus sp.* scored highest IVI in cabbage field. The IVI of most common dominant weed species in wheat, cabbage and potato fields at Jhaukhel in the second year is given below in figure 8.

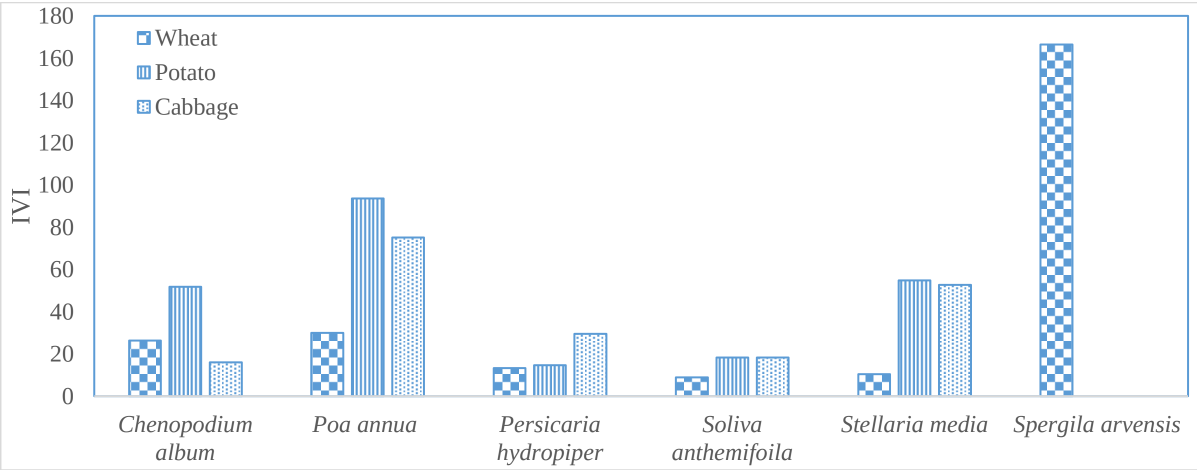

Figure 8: IVI of common dominant weeds in wheat, potato and cabbage at Jhaukhel in second year

4.1.2. Density/m^2 of common weeds found in different agricultural fields.

Wheat fields

The common weeds found in the wheat field were *Avena fatau, Chenopodium album, Conyza canadensis, Poa annua, Persicaria hydropiper, Soliva anthemifolia* and *Stellaria media.* Among 46 weed species in wheat field recorded, density of *Poa annua, Chenopodium album, Soliva anthemifolia, Stellaria media* were high.The density of *Poa annua* was high in Sudal, Gundu and Jhaukhel. Density of *Stellaria media* was high at Wonti and Chittapol. Most of the density of weeds found in wheat field increased in second year than in first year.The density of all weeds in wheat field are given in annex V. Total weed density was found to be highest at Sudal in wheat fields (Fig. 9).

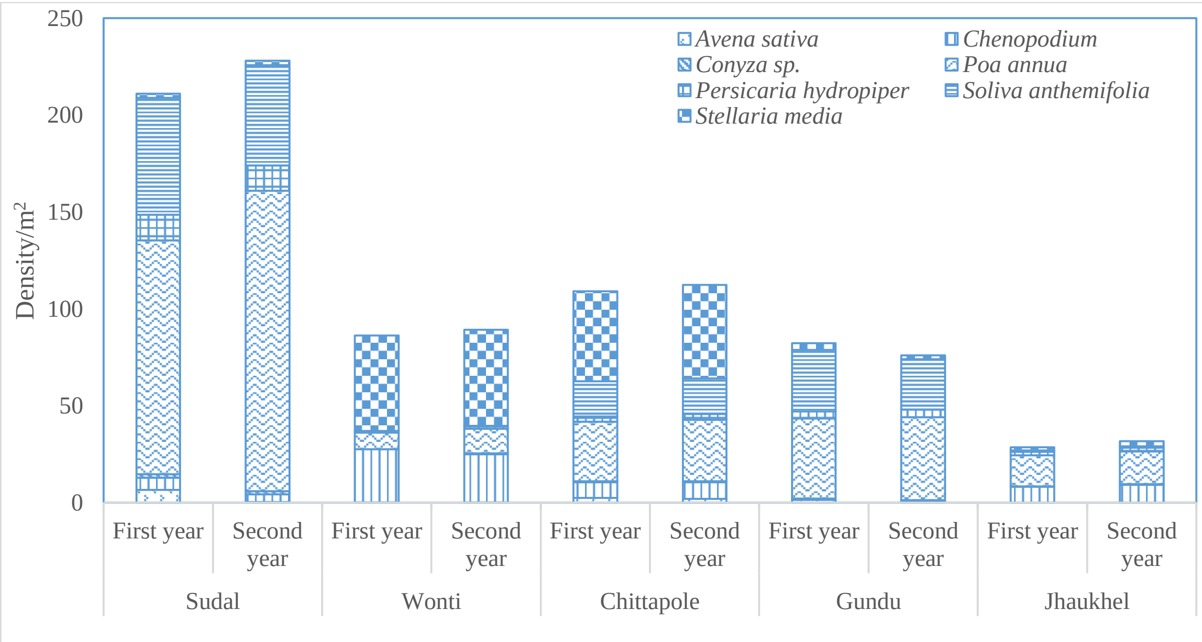

Figure 9: Density/m^2 of weeds found in wheat fields in first year and second year

Potato fields

The common weeds found in the potato field were *Chenopodium album, Cynodon dactylon, Poa annua, Persicaria hydropiper, Soliva anthemifolia, Stellaria uliginosa* and *Stellaria media.* In potato field, density of *Poa annua* were mostly high at all places, except in Wonti and Chitapole. Density of *Stellaria media* was high in Wonti and Chitapole. The weed density of all common species increased in the second year compare to the first year except the *Chenopodium album* of Wonti. Density of all species found in potato fields are given in annex VI. Total weed density in potato fields were found to be high at Sudal (Fig 10).

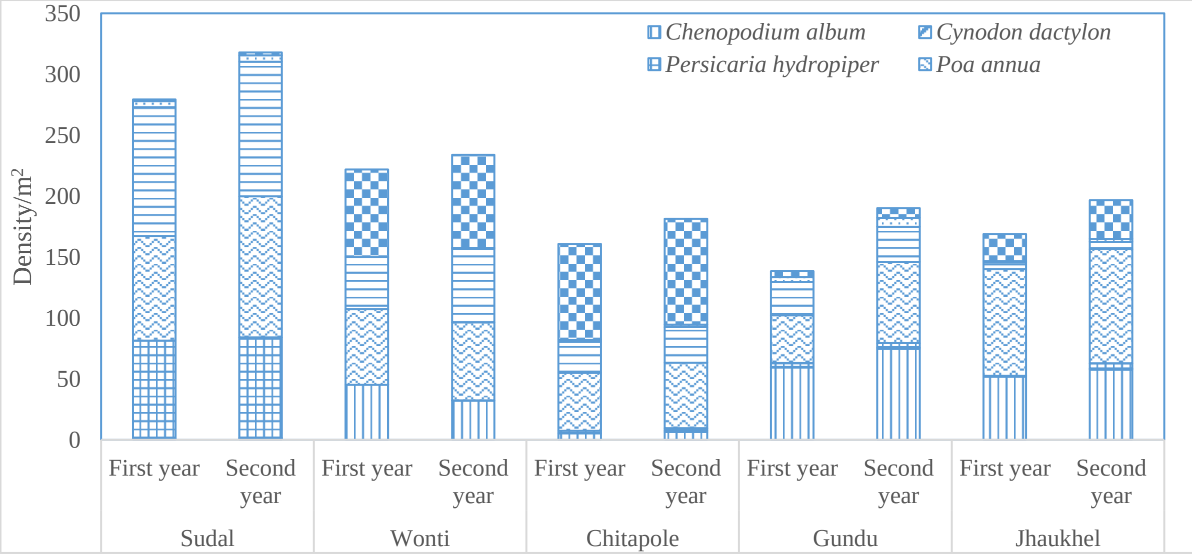

Figure 10: Density/m^2 of weeds found in potato fields in first year and second year

Cabbage fields

The common species in cabbage field were *Chenopodium album*, *Poa annua*, *Soliva anthemifolia* and *Stellaria media* Density of *Poa annua* was found greater among all the species. *Poa annua* showed high density in Sudal, Gundu and Jhaukhel whereas *Stellaria media* has high density inChitapole. The density of all the species increased in second year than in first year except the density of *Poa annua* and *Solvia anthemifolia* of Gundu decreased in second year.Density of all species are given in annex VII. Total weed density at cabbage fields was highest at Gundu (Fig. 11).

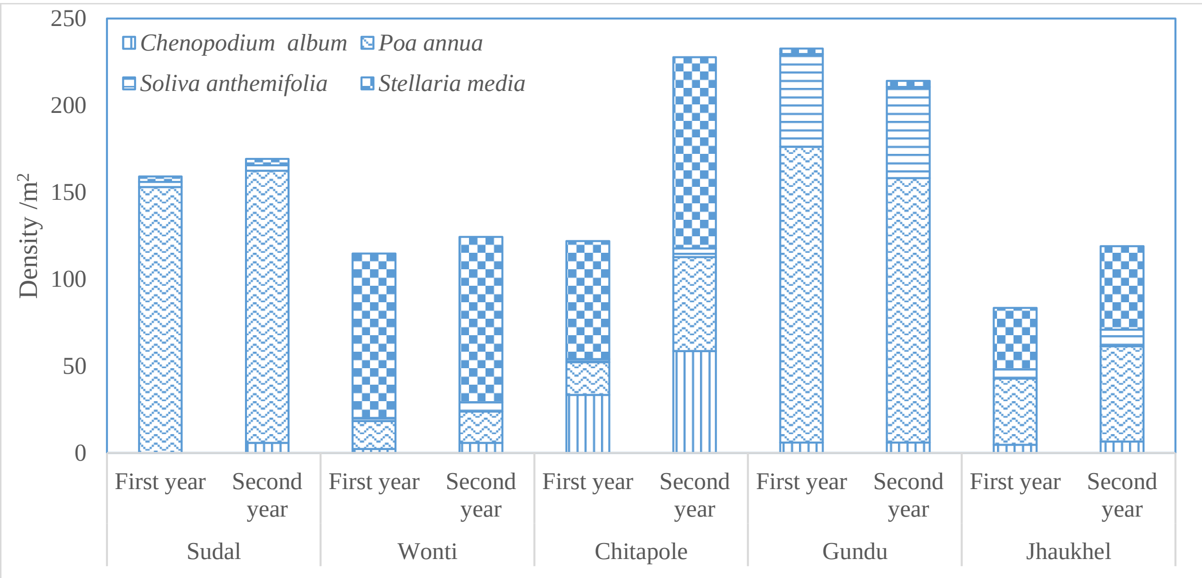

Figure 11: Density/m^2 of weeds found in cabbage fields in first year and second year

4.1.3. Biodiversity indices of weeds in different agriculture fields.

Cabbage fields

In cabbage fields, the Simpsons index of diversity and Shannon Weiner index was higher in second year in comparision to first year in most of the selected five different sitess except at Jhaukhel where Simpson index of diversity remain same in both years. In both years Shannon Weiner diversity and Simpson index of diversity was highest in Jhaukhel and lowest in Wonti. (Table 1).

Table 1: Biodiversity indices of cabbage field in different areas.

Cabbage field	1st year		2nd year	
Sites	Simpson index of diversity(1-D)	Shannon Weiner index (H)	Simpson index of diversity (1-D)	Shannon weiner index (H)
Sudal	0.56	0.97	0.59	1.12
Wonti	0.33	0.68	0.43	0.94
Chitapole	0.7	1.33	0.74	1.47
Gundu	0.6	1.28	0.66	1.43
Jhaukhel	0.78	1.73	0.78	1.75

Wheat fields

In wheat field, the highest Simpson index of diversity value was recorded in Gundu (0.80) in first year and Chitapole (0.8) in second year. The Shannon weiner index was found to be highest in Gundu in both years i.e 2.15 in first year and 1.99 in second year. Jhaukel showed the lowest Simpsons index of diversity value i.e 0.57 in first year and 0.43 in second year The lowest Shannon weiner index was found in Wonti (1.15) in first year and Jhaukhel (0.97) in second year (Table 2)

Table 2: Biodiversity indices of wheat field in different areas.

Wheat field	1st year		2nd year	
Sites	Simpson index of diversity(1-D)	Shannon weiner index (H)	Simpson index of diversity(1-D)	Shannon weiner index (H)
Sudal	0.70	1.66	0.67	1.02
Wonti	0.60	1.15	0.70	1.38
Chittapol	0.78	1.68	0.80	1.89
Gundu	0.80	2.15	0.76	1.99
Jhaukhel	0.57	1.23	0.43	0.97

Potato fields

The Simpson index of diversity in potato fields at Sudal and Wonti was found to be identical in both years. Similarly, the Shannon Weiner index of Wonti was found to be similar in both years.In both years, The Simpson index of diversity was highest in Gundu and lowest in Chitapole and Jhaukhel in first year, and only in Jhaukhel in second year.Similarly, Shannon Weiner index was highest in Gundu and lowest in Jhaukhel in both years. (Table 3)

Table 3: Biodiversity indices of potato field in different areas.

Potato field	**1st year**		**2nd year**	
Sites	**Simpson index of diversity(1-D)**	**Shannon weiner index (H)**	**Simpson index of diversity(1-D)**	**Shannon weiner index (H)**
Sudal	0.71	1.44	0.71	1.47
Wonti	0.75	1.45	0.75	1.45
Chitapol	0.7	1.56	0.72	1.59
Gundu	0.79	1.91	0.78	1.9
Jhaukhel	0.7	1.39	0.68	1.44

4.2. Soil seed bank of agriculture field

A total of 1023 seeds of 37 weed species, belonging to 15 families were recorded in soil seed bank samples from 0 to 15cm depth during germination period (Table 4, 5, 6). Asteraceae (6), Poaceae (4), Caryophyllaceae (4), Amarantheceae (3), Brassicaceae (3), Fabaceae (2), Polygonaceae (2), Rosaceae (1), Araliaceae (1), Solanaceae (1), Primulaceae (1), Plantagenaceae (1), Cannabaceae (1), Mazaceae (1), and Oxalidaceae (1) were recorded during seed bank study shown in figure 12. Among them, the dominant families were Poaceae, Asteraceae and Caryophyllaceae.The most abundant species were *Poa annua, Stellaria media* and *Soliva anthemifolia* in collected soil sample from three different agriculture field.

Species richness was high in potato fields whereas low in cabbage fields. 31 weed species was found in potato fields and 30 in wheat field and 26 in cabbage fields. In case of the sites species richness was high in Gundu and low in Wonti. A total of 31 species was found in Gundu whereas in Wonti 14 weed species was found. The cumulative seed density over all study was 101689 seed density/m^2. The stage with greatest abundance of germinated seed was found in the field of wheat of Gundu (10660 seed density/m^2) and the least was found in field of cabbage of Wonti (3800seed density/m^2).

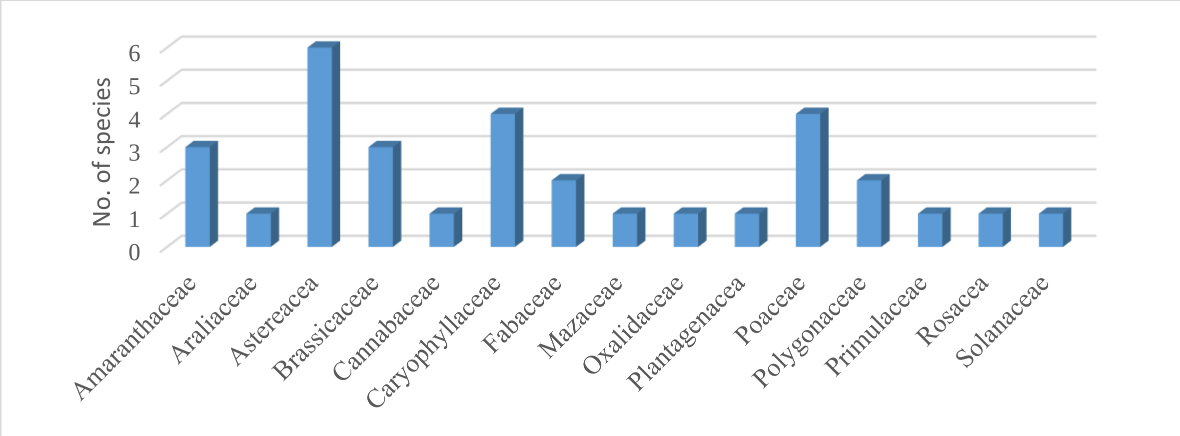

Figure 12: The numberof species in different families present in collected soil sample from three different agriculture field in selected sites.

4.2.1. Weed emergence in soil collected from different agriculture fields of Bhaktapur

Cabbage fields

Ageratum conyzoides was not significantly different in cabbage fields of Sudal, Chittapole, and Gundu, but was absent in Wonti and Jhaukhel. *Agerataum houstonianum* and *Anagallis arvensis* were found only in Gundu, and *Alopecurus sp*. was found only in Sudal and Jhaukhel. *Avena fatau* were significantly indifferent in all the area except the Jhaukhel as it was absent. *Amaranthus spinosus, Cardamine pratensis* and *Capsella bursa pastoris* were only found in Jhaukhel, Chittapole and Gundu respectively. *Chenopodium album* was highly significant at Sudal and Chittapole than the other places. *Cynodon dactylon* was not significantly different in all area except in Wonti as it was absent in this place. *Digitaria sp., Rorripa palustris* were only present in Wonti and Jhaukhel respectively. *Gnaphalium affine, Oxalis corniculata, Plantago major*, *Spergula arvensis* and *Trifolium repens* were present in only Gundu. Emergence of *Polygonum plebium* in Chitapole was significantly different with Sudal and Wonti whereas insignificant with Gundu and absent in Jhaukhel. *Poa annua* was found significantly high in Sudal and Chitapole in comparision to other areas. *Persicaria hydropiper* was highly significant in Gundu than other selected areas. The emergence of *Rumex crispus* of Jhaukel wass significantly different with Wonti and Chittapole and absent in Sudal and Gundu. *Stellaria uliginosa* of Gundu was significantly different with other areas except in Wonti as it was absent there. *Stellaria media* was highliy significant in Chitapole than other areas. *Sagina sp.* was only present in Sudal and Gundu. *Solivia anthemifolia* was highly signifant in Sudal and Gundu. (Table 4). Weed emergence was highest (68.2) in Sudal and lowest in Wonti (38) in cabbage field among five different selected sites.

Table 4: Weed emergence in soil collected from different cabbage fields of Bhaktapur. Identical letter after mean± SD in a row denotes insignificant difference at p=0.05 according to Duncan multiple range test followed after one way ANOVA.

Cabbage fields	**Weed emergence/plate(Mean±S.D)**				
Name of the species	**Sudal**	**Wonti**	**Chitapole**	**Gundu**	**Jhaukhel**
Ageratum conyzoides L.	5.4±8.76a		1.2±0.44a	4.4±2.61a	
Ageratum houstonianum Mill.				1±0.71	
Alopecurus sp.	2.2±1.79				4.8±2.49
Amaranthus spinosus L.					1.6±1.34
Anagallis arvensis L.				1±0	
Avena fatau L.	3.4±3.5a	2.4±1.67a	1.2±0.44a	2.4±1.67a	
Cannabis sativa L.				1±0	
Cardamine pratensis L.			3.2±4.38		
Chenopodium album L.	6.8±3.56b	3±1.87a	7±4.06b	3.4±2.07ab	1.2±0.45a
Cynodon dactylon (L.) Pers	3±3.46a		3±3.92a	1±0a	1.8±1.30a
Digitaria sp		1.4±2.19			
Gallinsoga paviflora Cab.				1±0	
Oxalis corniculata L.				1.4±0.55	
Persicaria hydropiper L.	6.6±2.5bc	1.4±0.89a	3.2±1.3ab	8.6±4.67c	3±1.87ab
Plantago majore L.				1±0	
Poa annua L.	17±4.69bc	8±4.06a	17.2±4.60bc	22±7.91c	11.6±6.23ab
Polygonum plebeium R. Br	1.2±0.45a	1±0a	2.8±1.79b	2.2±1.09ab	
Rorripa palustris (L.)			1.2±0.45		
Rumex crispus L.		1.2±0.45a	1±0a		9.8±2.05b
Sagina sp.	1±0			8.4±4.51	
Soliva anthemifolia Juss.	13.8±5.97c	10.2±3.11bc	6.2±4.76ab	12±5.5bc	2±1a
Spergula arvensis L.				1.4±0.55	
Stellaria media (L.) Vill	5.8±6.14a	8.8±6.06ab	13.8±1.64b	5.6±2.88a	9.4±2.07ab
Stellaria uliginosa Murray	2±1.73a		1±0a	5.2±3.11b	1.6±0.89a
Trifolium repens L.				3.2±2.95	
Total weed seed/ m^2	68.2	38	62	86	46.8

Note: ANOVA was not conducted when the variables were less than three.

Wheat fields

In wheat field, *Ageratum conyzoides* of Gundu was significantly different with sudal and Chitapole. *Alopecurus sp., Cynodon dactylon* and *Avena* fatua was highly significant in Chitapole. Emergence of *Alopecuus sp*.and *Cynodon dactylon* was significantly different in both Gundu and Chitapole but insignificant in Sudal.There was not significant difference in *Avena fatua* at Wonti, Chittapole and Gundu. *Ageratum houstonianum, Amaranthus spinsus, Capsella bursa pastoris, Fragaria sp, Galinsoga parviflora, Hydrocotyle rotundifolia* were present only on Gundu. *Alternanthera sessilis, Cardamine pratensis* and *Rorripa palustris* were only found in Chittapole and *Cannabis sativa* was only found in Wonti. *Chenopodium album* was highly significant in Wonti. *Chenopodium album* of Sudal was not significantly difference with Wonti but *Chenopodium album* of Sudal and Wonti was significantly difference with rest of other places. *Digitaria sp.* was absent in Sudal and Wonti and was significantly indifferent in rest of selected places. *Gnaphalium affine* was found highly significant in Sudal and absent in Wonti and Jhaukhel. *Oxalis corniculata* was highly significant in Gundu. There was not significant difference of *Oxalis corniculata* in sudal, Gundu and Jhaukhel. There was significant difference of *Persicaria hydropiper* of Sudal with rest of the places. *Phalaris minor* was only present in sudal and Wonti. *Polygonum plebium* was only found in sudal and Gundu. *Plantago majore* was not significantly difference with Sudal, Wonti and Gundu. *Poa annua* was highly significant at Gundu. *Poa annnua* of Wonti and Gundu were significantly different whereas rest of the places were insignificantly different. *Rumex crispus* was only present in Wonti and Jhaukhel. *Stellaria uliginosa* of sudal was significantly different with gundu and Chitapole. *Stellaria media* was highly significant in chitapole. *Stellaria media* of Gundu was significantly difference with rest of the other places except in Sudal as it was absent in that place. *Sagina sp.* was only found i n Gundu and Chitapole. *Trifolium repens* was only found inGundu and *Spergula arvensis* was found in Gundu and Jhaukhel. There was signicance difference in *Soliva anthemifolia* of Gundu with rest of the other places. *Vicia angustifolia* was only present in Sudal and Gundu. (Table 5). Weed emergence was highest (106.6) in Gundu and lowest in Wonti (52.4) in wheat field among five different selected sites.

Table 5: Weed emergence in soil collected from different wheat fields of Bhaktapur. Identical letter after mean± SD in a row denotes insignificant difference at p=0.05 according to Duncan multiple range test followed after one way ANOVA.

Wheat	**Weed emergence/plate(Mean±S.D)**				
Name of species	**Sudal**	**Wonti**	**Chhitapole**	**Gundu**	**Jhaukhel**
Ageratum conyzoides L.	3.2±3.19a		1.8±1.79a	11.4±5.13b	
Ageratum houstonianum Mill.				7.6±6.15	
Alopecurus sp.	5.8±5.8ab		11.6±7.54b	1±0a	
Alternanthera sessilis (L.) DC.			1.2±1.10		
Amaranthus spinosus L.				1±0	
Avena fatua L.		3±2.9a	9.4±12.03a	2.6±2.6a	
Cannabis sativa L.		3.2±2.86			
Capsella bursa pastoris (L.) Medik				1±0	
Cardamine pratensis L.			1.4±1.52		
Chenopodium album L.	9.8±5.71b	10.2±4.08b	2.4±3.1a	3.2±1.79a	1.2±0.45a
Cynodon dactylon (L.) Pers	9±4.12ab		13.2±8.93b	3.2±3.3a	
Digitaria sp			2.4±3.13a	2.4±3.13a	1.2±0.44a
Fagaria sp				1±0	
Gallinsoga paviflora Cab.				4±3.31	
Gnaphalium affine D. Don	1.2±0.44a		1±0a	1±0a	
Hydrocotyle rotundifolia Roxb. ex DC.				1±0	
Oxalis corniculata L.	1.6±0.89a			2.6±1.67a	1.4±0.89a
Phalaris minor Retz.	5.6±5.32	6±6			
Plantago majore L.	1.6±0.89a	1.4±0.89a		1.2±0.45a	
Poa annua L.	16±8.57ab	11.6±3.9a	14.4±4.6ab	23±7.6b	15±4.12ab
Persicaria hydropiper L.	6.8±4.2b	1.2±0.44a	1±0a	1.4±0.89a	1.4±0.89a
Polygonum plebeium R. Br	1±0			1.4±0.89	
Rorripa palustris L.			1±0		
Rumex crispus L.		1±0			1.20±0.45
Sagina sp.			2.8±3.03	5.6±2.88	
Soliva anthemifolia Juss.	12.2±4.15a	3.4±4.83a	6.2±1.3a	2.3±12.96b	10±7.38a
Spergula arvensis L.				1±0	19.8±7.01
Stellaria media (L.) Vill		11.6±3.9b	14.6±5.4b	2.2±2.68a	8.8±5.3b

Stellaria uliginosa Murray	6.2±2.3b		2.4±1.67a	2.4±1.67a	
Trifolium repens L.				1.40±0.56	
Vicia angustifolia L.	1±0			1±0	
Total weed seed/ m^2	81.2	52.4	86.8	106.6	59.4

Note: ANOVA was not conducted when the variables were less than three.

Potato fields

In potato field, *Ageratum conyzoide* of Gundu was significantly different with Chitapole and Jhaukhel. *Alopecurus sp* was only present in Sudal and Gundu. *Ageratum houstonianum, Biden pilosa, Galinsoga parviflora, Hydrocotyle rotundifolia, Oplimensus sp, Oxalis corniculata, Plantago majore, Spergula arvensis* and *Trifolium repens* were only found in Gundu. *Avena fatau* was only present in sudal and Wonti. *Altenanthera sessilis* was insgnificanlt different in Sudal, Chitapole and Jhaukhel. *Amarantus spinosus, Gnaphalium affine, Mazus japonicas and Solanum nigrum* were only found in Chitapole. *Capsella bursa pastoris* was only present in Chitapole and gundu. *Cardamine pratensis* was insignificantly different in all the selected places except in Wonti as it was absent in that place. *Cannabis sativa* was only present in sudal and Wonti. There was no significant difference in *Chenopodium album* of Chhhaling, Gundu and Jhaukhel. *Conyza canadensis* was only present in Sudal and Gundu. *Cynodon dactylon* was absent in Wonti and insignificantly different inrest of the other places. *Digitaria sp*. was only found in jhaukhel. *Poa annua, Persicaria hydropiper* and *Stellaria uliginosa* were insignificantly different in all the selected areas. *Poa annua* was highly significant in chitapole and *Persicaria hydropiper* was highly significant in Gundu. *Polygonum plebium* was only found in Chitapole and Jhaukhel. *Rumex crispus* was absent in Jhaukel and insignificanly difference in rest of the paces. *Stellaria media* was significantly different in Sudal and Chitapole whereas isignificant in rest of other places. *Sagina sp.* was only found in Sudal and Gundu. *Soliva anthemifolia* was highly significant in Chitapole. There was significance difference of *Soliva anthemifolia* of Jhaukel with other place except Wonti (Table 6). Weed emergence was highest (93.8) in Gundu and lowest in Wonti (44.6) in potato field among five different selected sites.

Table 6: Weed emergence in soil collected from different potato fields of Bhaktapur. Identical letter after mean± SD in a row denotes insignificant difference at p=0.05 according to Duncan multiple range test followed after one way ANOVA.

Potato	**Weed emergence/plate(Mean±S.D)**				
Name of species	**Sudal**	**Wonti**	**Chhitapole**	**Gundu**	**Jhaukhel**
Ageratum conyzoides L.			3.2±3.19a	8±3.67b	2±2.24a
Alopecurus sp.	6.6±4.4				3.8±3.27
Ageratum houstonianum Mill.				1.8±1.79	
Avena fatau L.	3±2.8	1.6±1.34			
Alternanthera sessilis (L.) DC.	2.6±3.05a		1.4±0.89a		1±0a
Amaranthus spinosus L.			2.2±2.17		
Bidens pilosa L.				1±0	
Capsela bursa pastoris (L.) Medik.			1.4±0.89	1.6±0.55	
Cardamine pratensis L.	1.8±1.3a		1.4±0.89a	1±0a	1.8±1.3a
Cannabis sativa L.	1.4±0.89	2.6±2.6			
Chenopodium album L.		5.8±3.96a		6.6±4.51a	6.6±4.51a
Conyza Canadensis (L.) Cronq.	1±0			1±0	
Cynodon dactylon (L.) Pers	11±12.27a		2.4±1.67a	2±1a	3.4±4.28a
Digitaria sp.					1.2±0.4
Galinsoga parviflora Cab.				5.6±3.44	
Ghanaphalium affine D. Don			1±0		
Mazus japonicas (Thunb) Kuntz			1±0.71		
Hydrocotyle rotundifolia Roxb. ex DC.				2.2±2.68	
Oplsmensus sp				1±0	
Oxalis corniculata L.				1.2±0.45	
Plantago majore L.				1±0	
Poa annua L.	14±10.19a	8±7.07a	17.6±6.19a	14.8±4.3a	13.8±6.65a
Persicaria hydropiper L.	1.2±0.45a	1.8±1.79a	2.4±3.13a	4.6±2.3a	3.2±4.92a
Polygonum plebeium R. Br			1±0		1±0
Rumex crispus L.	2.8±2.17a	1.6±1.34a	3.6±3.9a	1.2±0.44a	
Stellaria uliginosa Murray	5.2±6.9a	1.4±0.54a	4.2±3.56a	6.8±2.28a	3.8±3.8a
Stellaria media (L.) Vill	3.4±3.78a	12±3bc	17.6±5.03c	8.4±6.73ab	5.8±3.89ab
Spergula arvensis L.				3.4±3.36	

Sagina sp.	1±0			9.2±7.73	
Soliva anthemifolia Juss.	5.1±6.72c	9.8±3.8ab	13.2±4.76c	11.4±2.4c	4±2.24a
Solanum nigrum L.			1±0		
Trifolium repens L.				1.2±0.45	
Total weed seed/ m^2	71	44.6	74.8	93.8	51.4

Note: ANOVA was not conducted when the variables were less than three.

4.2.2. Seed bank density/m^2 of weeds emerged from soil sample collected from different agriculture field

The seed bank density/m^2 was highest in wheat field followed by potato field and then by cabbage fields in five different sites (Table 7, 8, 9, 10, 11).

4.2.2.1. Seed bank density/m^2 of weeds emerged in soil sample of Sudal.

The common weeds that emerged from seed bank of Sudal were *Alopecurus sp.*, *Cynodon dactylon*, *Poa annua*, *Persicaria hydropiper*, *Soliva anthemifolia and Stellaria uliginosa* in three agriculture fields. *Poa annua and Soliva anthemifolia* showed highest seed density in wheat fields of Sudal whereas *Polygonum plebium* and *Vicia angustifolia s*howed lowest seed density. *Cynodon dactylon, Soliva anthemifolia and Poa annua* showed highest seed density whereas *Sagina sp* showed lowest seed density in potato field. Similarly in cabbage field, highest seed density was found in *Poa annua* and *Soliva anthemifolia* whereas lowest in *Sagina sp* (Table 7).

Table 7: Weed seed bank density/m^2 in Sudal in different agriculture fields

Sudal	**Wheat field**	**Potato field**	**Cabbage field**
Name of species	**Density/m^2**	**Density/m^2**	**Density/m^2**
Ageratum cornyzoides L.	320		540
Alopecurus sp.	580	660	220
Alternanthera sessils (L)Dc		260	
Avena fatua L.		300	340
Cannabis sativa L.		140	
Cardamine pratensis L.		180	
Chenopodium album L.	980		680
Conyza Canadensis L.Cronq.		80	
Cynodon dactylon (L.) Pers	900	1100	300
Ghanaphalium affine D.Don	120		

Oxalis corniculata L.	160		
Persicaria hydropiper L.	680	100	660
Phalaris minor Retz.	580		
Plantago major L.	160		
Poa annua L.	1600	1400	1700
Polygonum plebeium R. Br.	100		120
Rumex crispus L.		260	
Sagina sp.		80	100
Soliva anthemifolia Juss.	1220	1600	1380
Stellaria media (L.) Vill		340	580
Stellaria uliginosa Murray	620	520	200
Vicia angustifolia L.	100		
Total weed seeds/m^2	8120	7020	6820

4.2.2.2. Seed bank density/m^2 of weeds emerged in soil sample of Wonti

Avena fatua, Chenopodium album, Poa annua, Polgonum hydropiper, Rumex crispus, Stellaria media and Soliva anthemifolia were the common weed species emerged from the soil sample of Wonti. In case of Wonti, the highest weed seed density was found in *Stellaria media* in the potato field and lowest in *Stellaria uliginosa*. In wheat field, high weed seed density was found in *Poa annua* and *Stellaria media* and lowest in *Rumex crispus*. In cabbage fields, *Soliva anthemifolia* and *Stellaria media* showed high weed seed density whereas, *Polygonum plebium* showed lowest seed density (Table 8).

Table 8: Weed seed bank density/m^2 in Wonti in different agriculture fields

(Wonti)	**Wheat field**	**Potato field**	**Cabbage field**
Name of species	**Density/m^2**	**Density/m^2**	**Density/m^2**
Avena fatua L.	300	160	240
Cannabis sativa L.	320	260	
Chenopodium album L.	1020	580	300
Digitaria sp			200
Phalaris minor Retz.	580		
Plantago major L.	140		
Poa annua L.	1160	800	800
Persicaria hydropiper L.	120	180	140

Polygonum plebeium R.Br.			100
Rumex crispus L.	100	160	120
Soliva anthemifolia Juss.	340	980	1020
Stellaria uliginosa Murray		140	
*Stellaria media (*L.) Vill	1160	1200	1020
Total weed seeds/m^2	5240	4460	3800

4.2.2.3. Seed bank density/m^2 of weeds emerged in soil sample of Chitapole

The common weeds emerged from the soil sample of Chitapole were *Stellaria media, Stellaria uliginosa, Soliva anthemifolia, Persicaria hydropiper, Poa annua, Cynadon dactylon, Ageratum conyzoides, and Cardamine pratensis* in three different agricultural fields. In Chitapole, weed seed density was found high in *Cynodon dactylon, Poa annua and Stellaria media* and low in *Ghanaphalium affine, Persicaria hydropiper* and *Rorripa plaustris* in wheat fields. Weed seed density of cabbage and potato was high in *Poa aanua and Stellaria media*. Weed seed density was low in *Ghanaphalium affine, Polygonum plebium and Solanum nigrum* in potato fields and *Stellaria uliginosa and Rumex crispus* in cabbage fields (Table 9).

Table 9: Weed seed bank density/m^2 in Chitapole in different agriculture fields

(Chitapole)	**Wheat field**	**Potato field**	**Cabbage field**
Name of species	**Density / m^2**	**Density / m^2**	**Density / m^2**
Ageratum conyzoides L.	180	320	120
Alopecurus sp.	1140		
Alternanthera sessilis (L.) Don.	140	140	
Amaranthus spinosus L.		220	
Avena fatua L.	920		120
Cannabis sativa L		140	
Cardamine pratensis L.	160	140	320
Chenopodium album L.	240		700
Cynodon dactylon (L.) Pers	1320	240	300
Digitaria sp	240		
Ghanaphalium affine D.Don.	100	100	
Mazus japonicas (Thunb).Kuntze		120	
Poa annua L.	1440	1760	1720
Persicaria hydropiper L.	100	240	320

Polygonum plebeium R.Br.		100	280
Rorripa plaustris L.	100		120
Rumex crispus L.		360	100
Sagina sp.	300		
Solanum nigrum L.		100	
Soliva anthemifolia Juss.	620	1320	620
Stellaria uliginosa Murray	240	420	100
Stellaria media (L.) Vill	1460	1760	1380
Total weed seeds/m^2	8680	7480	6200

4.2.2.4. Seed bank density/m^2 of weeds emerged in soil sample of Gundu

The common weeds emerged from the soil sample of Gundu were *Trifolium repens, Stellaria media, Spergula arvensis, Soliva anthemifolia, Sagina sp, Stellaria uliginosa Persicaria hydropiper, Poa annua, Plantago majore, Cynadon dactylon, Oxalis corniculata, Ageratum conyzoides, Ageratum houstonianum and Capesella bursa pastoris* in three different agricultural fields. The high seed density was found in *Poa annua, Soliva anthemifolia and Ageratum conyzoides* whereas low in *Vicia angustifolia, Spergula arvensis, Alopecurus sp.,Amaranthus spinosus, ,Capsella bursa pastoris, Chenopodium album, Cynodon dactylon, Digitaria sp,Fragaria sp.,Ghanaphalium affine, Spergula arvensis,Hydrocotyle rotundifolia* and *Vicia angustifolia* in Gundu in wheat field.. Similarly, the high seed density was found in *Poa annua* in potato and cabbage fields whereas low seed density was found in *Bidens pilosa, Cardamine pratensis ,Conyza Canadensis, Plantago major and Oplismensus sp* in potato fields and *Anagallis arvensis,Capsella bursa pastoris, Cynodon dactylon, Ghanaphalium affine* and *Plantago major* in cabbage fields (Table 10)

Table 10: Weed seed bank density/m^2 in Gundu in different agriculture fields

(Gundu)	**Wheat field**	**Potato field**	**Cabbage field**
Name of species	**Density/m^2**	**Density/m^2**	**Density/m^2**
Ageratum cornizoids L.	1140	800	400
Ageratum houstonianum Mill.	760	180	120
Alopecurus sp.	100		
Amaranthus spinosus L.	100		
Anagalis arvensis L.			100
Avena fatua L.	260		240

Bidens pilosa L.		100	
Cannabis sativa L.	100	160	100
Cardamine pratensis L.		100	
Chenopodium album L.	320	120	340
Conyza Canadensis (L.) Cronq.		100	
Cynodon dactylon (L.) Pers	320	200	100
Digitaria sp	240		
Fragaria sp.	100		
Gallinsoga paviflora Cab.	400	560	
Ghanaphalium affine D. Don	100		100
Hydrocotyle rotundifolia Roxb. ex DC.	100	220	
Oplismenus sp		100	
Oxalis corniculata L	260	120	140
Plantago major L.	120	100	100
Poa annua L.	2300	1480	2200
Persicaria hydropiper L.	140	460	860
Polygonum plebeium R.Br.	140		220
Rumex crispus L.		120	
Stellaria uliginosa Murray	240	680	520
Sagina sp.	560	920	840
Soliva anthemifolia Juss.	2300	1140	1200
Spergula arvensis L.	100	120	140
Stellaria media (L.) Vill	220	840	560
Trifolium repens L.	140	120	320
Vicia angustifolia L.	100		
Total weed seeds/m^2	10660	8840	8600

4.2.2.5. Seed bank density/m^2 of weeds emerged in soil sample of Jhaukhel.

The common weeds emerged from the soil sample of Jhaukhel were *Stellaria media, Stellaria uliginosa, Soliva anthemifolia, Persicaria hydropiper, Poa annua,* and *Chenopodium album* in three different agricultural fields. In the wheat fields of Jhaukhel, the high weed density was found in *Spergula arvensis* and low weed density was found in *Chenopodium album*, *Digitaria sp*, *Rumex crispus, Oxalis corniculata,* and *Persicaria hydropiper*. *Poa annua* has high seed density in potato field and cabbage field and *Alternanthera sessilis*, *Polygonum plebeium* had low seed density in potato field. In cabbage fields, *Chenopodium album* has low weed seed density (Table 11)

Table 11: Weed seed bank density/m^2 in Jhaukhel in different agriculture fields

(Jhaukhel)	Wheat field	Potato field	Cabbage field
Name of species	**Density/m^2**	**Density/m^2**	**Density/m^2**
Ageratum cornyzoids L.		200	
Alopecurus sp.		380	480
Alternanthera sessilis L.Dc.		100	
Amaranthus spinosus L.			160
Cardamine pratensis L.		180	
Chenopodium album L.	120	660	120
Cynodon dactylon (L.) Pers		340	180
Digitaria sp.	120	120	
Oxalis corniculata L.	120		
Poa annua L.	1500	1380	1160
Persicaria hydropiper L.	120	320	300
Polygonum plebeium R.Br.		100	
Rumex crispus L.	120		980
Soliva anthemifolia Juss.	980	400	200
Spergula arvensis L.	1980		
Stellaria uliginosa Murray		380	160
Stellaria media (L.) Vill	880	580	940
Total weed seeds/m^2	5940	5140	4680

Chi square obtained from Kruskal Wallis test for seed density/m^2 among different fields of the same sampling sites

A Kruskal Wallis H test showed that there was no stasticalliy significant difference between seed density of three different agriculture fields in selected sites as P value is greater than standard p value i.e.P=0.05

Sites	Potato	Cabbage	Wheat	Chi square	Significance
Sudal	501±506	568±501	580, ±465	0.701	Not significant
Wonti	495± 408	437±391	487±426	0.297	Not significant
Chitapole	467±584	476±517	543±523	0.209	Not significant
Gundu	397±406	452±527	426±613	0.333	Not significant
Jhaukel	395±343	468±402	660±712	0.153	Not significant

4.2.3. Biodiversity indices of weeds emerged in soil samples in different areas

Cabbage field

In seed germination method, the lowest value of Simpson index of diversity was found in Wonti (0.79) and highest was found in Gundu (0.88**).** Shannon weiner diversity index was lowest in Wonti (1.67) and highest in Gundu (2.47).

Table 12: Biodiversity indices of weed seed bank in cabbage field

Selected sites	Simpson index of diversity	Shannon weiner index
Sudal	0.85	2.01
Wonti	0.79	1.67
Chitapol	0.84	2.12
Gundu	0.88	2.47
Jhaukhel	0.84	1.99

Wheat field

In wheat field, Gundu, Chitapole and Sudal showed highest Simpsons index value i.e.0.88 and lowest was found in Jhaukhel (0.78**).** Shannon diversity index was higher in Gundu (2.58) and lowest in Jhaukhel (1.69).

Table 13: Biodiversity indices of weed seed bank in wheat field

Selected sites	Simpson index of diversity	Shannon weiner index
Sudal	0.88	2.27
Wonti	0.84	2
Chittapol	0.88	2.36
Gundu	0.88	2.58
Jhaukhel	0.78	1.69

Potato field

In seed germination method, lowest Simpsons index was found in Wonti (0.83) and highest was found in Gundu (0.91) at the potato field. Similarly. Gundu (2.61) showed highest Shannon weiner index and Wonti (1.9) showed lowest Shannon weiner index.

Table 14: Biodiversity indices of weed seed bank in potato field

Sites	Simpson index of diversity	Shannon weiner index
Sudal	0.86	2.22
Wonti	0.83	1.9
Chittapol	0.85	2.06
Gundu	0.91	2.61
Jhaukhel	0.87	2.28

4.3. Comparision of weed seed bank and existing weeds in fields

During survey 49 weed species were present in crop field and 37 species were present in seed bank, only few species were spread in seed bank. In agricultural field 16 families were found whereas in collected soil sample 15 families were found. The most leading families were Asteraceae, Poaceae, and Caryophyllaceae in both agricultural field and in seed bank analysis. Altogether 13 families were common in agricultural field and in seed bank study. Asteraceae, Poaceae, Caryophyllaceae, Amarantheceae, Brassicaceae, Fabaceae, Polygonaceae, Araliaceae, Primulaceae, Plantagenaceae, Cannabaceae, Mazaceae, and Oxalidaceae. Equisetaceae, Apiaceae and Acanthaceae were only present in agriculture field and Rosaceae and Solanaceae were only present in seed bank analysis.

Species richness of soil seed bank followed the same pattern as in fields, with the greatest richness in Gundu and lowest richness in Wonti. Weed species richness was high in wheat field and low in cabbage fields in both crop field and seed bank.Diversity indices was mostly high in Gundu, in wheat and potato field which was same as in seed bank analysis. But in cabbage field the diversity indices was high in Jhaukel whereas in seed bank analysis diversity was high in Gundu.Similarly diversity was least in Jhaukhel in wheat field and potato field but in soil collected sample from wheat field and potato field, diversity was low in Wonti. But in cabbage field diversity was low in Wonti which is similar to seed bank of cabbage field. It means the species diversity was low in Wonti in cabbage field of agriculture field and soil collected sample. The species diversity was high in Gundu in wheat and potato field of agricultural field and in soil collected sample.

Poa annua, Soliva anthemifolia, Stellaria media, Persicaria hydropiper, Chenopodim album were most common weed species in agricultural fields and in collected soil sample. The high density was found in mainly *Poa annua, Soliva anthemifolia, Stellaria media* in both agricultural fields and in collected soil sample.The density of weeds were high in collected soil sample than in agriculture fields. The weeds density of species like C*ynodon dactlon, Ageratum conyzoides, Ageratum houstonianum* were very low in agriculture fields but high in weed seed emergence. Mostly *Cynodon dactlon and Ageratum conyzoides* were dominated in weed seed emergence of Chitapole and Gundu respectively.

Rorripa palustris and *Amaranthus spinosus* was found during weed seed emergence but absent in agriculture field. *Rorripa palustris* was emerged in the soil collected from wheat and cabbage field of Chitapole whereas *Amaranthus spinosus* was germinated in the soil collected from potato and cabbage field of Jhaukhel.*Acmella sp, Ageratina adenophora, Artemesia vulgaris, Blumea lacera, Conyza canadensis, Dichracephala benthami, Drymeria diandra, Equisetum sp., Justicea diffusa, Primula sp., Senecio vulgaris, Sonchus oleraceua, Veronica sp* were absent in seed bank germination. Shrestha *et al.*, listed 26 invasive alien plant species found in Nepal. Among them six invasive species were found in all three agriculture fields. They were *Ageratina adenophora, Ageratum cornyzoides, Ageratum houstonianum, Bidens pilosa, Spergula arvensis and Alternanthera philoxeroides.* In seed bank germination, *Ageratum cornyzoides, Ageratum houstonianum, Bidens pilosa, Spergula arvensis, Alternanthera philoxeroides* and *Amaranthus spinosus* were found.

4.4. Sorenson's similarity index between weeds recorded in fields and weed seedling emergence from soil sample collected from the same agriculture fields

In comparison to others, the similarity index between weeds recorded in cabbage fields and seedling emergence in soil samples obtained from Chitapole and Gundu was relatively high. In case of wheat and potato field, the SI (%) recorded between the weed present in the fields and seedling emergence from the soil samples collected from the same fields was high at Wonti.The similarity index was low in wheat field of Jhaukhel i.e 60.80% in comparision to others. The similarity index of weeds in agriculture field and weed emerged in soil seed bank was shown in (Table 15).

Table 15: Similarity index (SI %) of weeds in agriculture fields (cabbage, wheat and potato) and weed seedling emerged in soil samples collected from the same fields

Places	**Cabbage fields SI (%)**	**Wheat fields SI (%)**	**Poato fields SI (%)**
Sudal	66.67	66.67	66.67

Duwakot	70.59	81.82	82.35
Chitapole	86.96	66.67	78.57
Gundu	86.49	72.72	73.17
Jhaukhel	81.81	60.87	76.92

CHAPTER 5. DISCUSSIONS

5.1. Weed diversity in agriculture field

In the present study, the asteraceae family had the most weed species, followed by the poaceae family which is similar to Sapkota *et al.,* (2010) where asteraceae has become the dominant family, followed by poaceace in wheat field at Khokana, Lalitpur. Similar result is also found in Joshi and Gretzmacher *et al.,* (1999), in wheat fields at Kavre. In the present study wheat fields had the most weed species than cabbage and potato fields. Similarly, Joshi and Gretzmacher *et al.,* (1999) recorded more weed species in wheat fields than at rice fields.

Poa annua, Soliva anthemifolia, and *Stellaria media* had the highest IVI values among the observed weed community.It is possible due to the quick seedling growth, ability of vegetative propagation, absence of special requirements for germination, ability to generate flower in short intervals, and ability to produce a high number of viable seeds under a wide variety of environmental conditions (Warwick and Sweet, 1983). These characteristics helps in the establishment of soil seedbanks and common weeds in the agricultural areas. The lowest IVI values represented by *Cyanodon dactylon*, *Acemella sp, Angallis arvensis,Ageratum conyzoides,Ageratum houstonianum*, *Ageratina adenophora,Primula sp.,Drymeria diandra* and *Veronica sp.* reflects that they were the rarest species among the weed community. Sapkota *et al.,* (2010) reported *Chenopodium album, Eclipta prostrata, Spergula arvensis,* and *Polygonum plebeium* as the most dominant species on an abundance scale in wheat field at Khokana Lalitpur, whereas in the current study *Chenopodium album* and *Spergula arvensis* were dominant in wheat fields of Wonti and Chitapole, respectively. The IVI score of weeds species ranged from 1.78 to 165.02. Because of their high proliferative ability and rapid colonization, annual weeds predominated at the study site (Booth *et al.,* 2003). Because of the climate, soil, and farming methods used, IVI was unique (Pala *et al.,* 2020). In the wheat field, the highest IVI was found in *Poa aanua, Stellaria media, Chenopodium album, Soliva anthemifolia* in selected five different sites but in Jhaukhel, *Spergula arvensis* had high IVI which might be due to organic matters and farming practices.

Mostly weeding is not done in wheat field in Nepal. Weed diversity was greater in wheat field among three agriculture field in Gundu and Chhitapole. But in Jhaukhel weed diversity in wheat field was low due to low availability of moisture in soil. Irrigation system in wheat fields were not practiced in selected study fields whereas the cabbage and potato fields were well irrigated. Aboveground weed species diversity was greater in irrigated agroecosystems than in dryland agroecosystems (Srivastav, 2012). So this difference in irrigation practices could be the reason for high weed diversity in potato fields than in wheat fields of Wonti and Jhaukhel. The high diversity of weed in potato and cabbage fields of some areas might be due to the irrigation system, which were irrigated from natural sources that also might have been contaminated with weed seeds. The cabbage field except Jhaukhel were less diverse than potato field due to the domination of some weed species like *Poa annua* and *Stellaria media.* The low diversity was mainly found in Jhaukhel and Wonti, it may be due to the sandy loam soil, and low availability of moisture whereas in Gundu, the high diversity was found due to availabity of moisture, organic matter and soil texture. The concentration of organic matter, the nature of sandy soil, and farming practices such as fertilizer application, irrigation, and chemical spraying were the main factors that determined the weed communities (Ahamad *et. al*., 2016).

Organic farming increased the diversity of weed species in winter wheat (Ulber, 2010). Gundu had a high species richness because it was mostly organically farmed. Nepalese farmers typically do not practice weeding in their wheat fields, and the degree of weed succession in their fields is invariably cumulative year after year (Joshi and Gretzmacher; 1999). Hence, wheat fields had a higher species richness of weeds than in cabbage and potato fields.

Weed density/m^2 was also reduced in some fields in second year when compared to first year, it was caused by the combustion of rice crop residue. Crop residues can generate enough heat when burned to kill weed seeds in the upper soil layer of 0-1 cm. The loss of seed viability occurred as a result of the residue burn plot, which reduced the weed seed and density (Gangwar *et al.,* 2006). Unlike most crop plants, some weed species were well adapted to higher soil moisture levels, while others were not. Weed interference in annual cropping systems can be highly variable from year to year as well as spatially heterogeneous (Mcdonald *et al.,* 2009). Weed seed dispersed easily if the weeds were mostly persistent and abundant, and stayed dormant in the soil for a long time (Bukun, 2004). This is why weed density increased in second year compared to first year.

Crop rotation, fertilization, and technology application (particularly herbicide use) were major factors influencing weed community diversity (Andreasen and Streibig, 2011). Weed species that dominate the weed flora at different soil acidity and nutrient content in soil affected crop weed infestations (Skuodien and Repien, 2009; Karcaukiene *et al.*, 2016).Almost all of the farmers use both organic and chemical fertilizers depending on availability.Herbicides were not used in winter crop but were mostly used in paddy fields. Hand weeding was use for removal of weeds. Pestcides were used in cabbage fields and potato fields but not used in wheat fields.

Weed infestation could also be dependent on tillage system. In wheat fields, the tillage system was found to be reduced i.e. tilled only once while in cabbage and potato field, convectionally ploughed tillage system i.e tilled more than two or three times times. It was mostly done with a hand hoe or a wooden plow. Weed infestation was higher in wheat fields with a reduced tillaged system than in cabbage and potato fields with a covectionally ploughed tillaged system in our study. Similarly, in studies by Woniak *et al.*, (2015) and Vakali *et al.*, (2011), spring wheat and barley weed infestation was higher in no-till and reduced tillage fields than in conventionally ploughed fields.

Dangol (2013) identified *Chenopodium album, Phalaris minor, Cynodon dactylon, Polygonum plebium,* and *Vicia sativa* as major weeds in wheat fields in Nepal's hilly and terai regions, which were also found in the current study. *Chenopodium album, Phalaris minor, Polygonum plebium,* and *Vicia sativa* were also mentioned as problematic weeds in wheat fields in Nepal's Terai and hlly regions. In the Kathmandu Valley, *Cannabis sativa* was reported as one of the most troublesome weeds in wheat. These *Cannabis sativa* was also present in Sudal and Wonti in agricultural field where as absent in rest of other sites of study fields.

The differences in altitude, climate, soil types, and field management practices used in different agricultural fields could be the cause for differences in weed species distribution, abundance, and dominance (Getachew et al, 2018). Similarly, the composition of weed species differed between agricultural fields, indicating that weed growth, population density, and distribution vary from place to place, depending on soil and climatic factors that affect weed flora, as well as farmers' management practices (Getachew *et al.,* 2018).

5.2. Weed emergence in soil from different agriculture field

The germination method, according to Cardina and Sparrow (1996), is the best for predicting weed emergence because it is most similar to field conditions. Some seeds, such as Cyperaceae, Scrophulariaceae, and Poaceae, remain dormant for approximately 12 months before reappearing in the following cropping season, while others may remain dormant for up to two years (Bhatta and Singh, 2007). Emergence of *Cynodon dactylon, Poa annua, Stellaria* *uliginosa* and *Persicaria hydropiper* werenot significantly different at P=0.05 in all selected sites in potato field due to the ability of these weeds to adapt in such temperature and soil moisture available in selected areas.. Emergence of common weeds *Poa annua, Soliva anthemifolia, Stellaria media, Chenopodium album*, *Persicaria hydropiper* from collected soil sample were significantly different at P=0.05 in all selected sites in cabbage field and wheat field. Various weed seed species emerge in different climatic zones. Weed seed can cause issues in many cultivated plants, and their density can vary. Soil texture, climate, and pH all influence seed longevity and seedling emergence (Lowry *et al.,* 2021). The availability of nutrients in the soil influences weed competition (Lowry *et al.,* 2021). So due to the different soil texture, pH and soil nutrients affects the emergence of weeds. Chemical weed control practices reduce the population of sensitive species while having no effect on herbicide-resistant species (Berbec and Szewczyk, 2019). Weed seed germination and seedling emergence can also be influence by soil temperature, soil water potential, exposure of light, nitrates concentration, soil pH, fluctuating temperatur and gaseous environment of the soil (Travlous *et al*., 2020). Crop rotation may also affect soil seed bank species. Organic farms typically use more complex crop rotations, which provides an ideal environment for weeds to germinate, flower, and produce seeds (Berbec and Szewczyk, 2019).

Weed seeds of *Poa aanua, Soliva anthemifolia,* and *Stellaria media* predominated in the current study because the value of weed seed density of these three species was higher in the selected farm field. Because of the weed's high seed production capacity, some weed species had higher soil seed bank density. (Bhatta and Singh, 2007). Weed species predominate in soil weed seed banks due to their reproductive capability, superior mechanism of seed distribution, and tolerance to human and environmental impact (Nyamwamu *et al.,* 2020). Weed seed density/m^2 wasnot stastisically significant at P= 0.05 in three different agriculture field. It might be due to the similar soil temperature, soil water potential, exposure of light, nitrates concentration, soil pH, and gaseous environment of the soil.

Weed seed species diversity was found to be higher in wheat fields where a reduced tillage system was used, and lower in cabbage fields where a convectional tillage system was used. The species diversity in the soil seed bank of systems that cause less soil disturbance, i.e., reduced and zero tillage systems, was found to be high (Feldman *et al.,* 1997). Cardina *et al.,* (2002) discovered that crop rotations had a greater impact on the amount of seeds in the soil than tillage methods. The increased frequency of tillage operations reduced the species diversity of weed seeds (Cardina *et al.*, 1991; Borin *et al.,* 1995).

Shannon index is highest when species are evenly distributed or all species have the same priority, according to Zanin *et al.,* (1992). When the proportion of species is even (pi), the area with more species has higher biodiversity. Weed seed diversity and weed seed density in soil samples was also high in wheat fields because weeding was not in practice, but low in cabbage fields because weeding was in regular practiced and done before the flowering stage. Mostly hand weeding was a common practice in these areas. Besides hand weeding, pesticides were mostly used in cabbage fields. The weed seed diversity were high in Gundu and low in Wonti similar to the diversity of agriculture fields.Weed seed diversity were low in wheat field of Wonti and Jhaukhel as availability of moisture was less and wheat field were not irrigated.

The number of invasive species were greater in the soil seed bank than at the crop fields, which might be due to the exposure of weed seeds at the time of seed bank germination experiment. The soil samples collected from 0 to 15 cm depth were wide spreaded on the plates.

Weed seeds on agricultural fields are affected by crop management systems (like chemical input and tillage system) (Menalled *et al,* 2001). Weed seed distribution in different soil layers was influenced by soil texture (Skuodiene *et al.,* 2018). Skuodiene *et al.,* 2018 also reported that the number of weed seed was greater in loam soil than in sandy loam soil at 0-10cm depth, which was similar to our current study in which loamy soil was found in Gundu where the number of weed seed was higher and low in Wonti where sandy loam soil was found.

In the present study the species richness of weed seed recorded from seed bank was less than the weeds in agriculture field. This could be due the fact that soil sample for seed bank study was take from a small area of 10cm x10cmx10 cm but the species richness of weed species were counted from 2mx2m surface area. Because of the availability of resources such as N, P, and water, seeds germinate more in the field and contribute less to the soil seed bank. The weed seed bank may be depleted due to a variety of factors such as seed and seedling losses in the field as a result of the activities of microorganisms, insects, birds, and other animals (Nyamwamu *et al.,* 2020). According to Zhang *et al.,* (1998), there is no scientific basis for determining the precise, quantitative, and qualitative relationship between segetal flora on the field and the soil seed bank. This is because only a small percentage of seeds find suitable conditions for germination under field crop conditions. As a result, the number of species observed in the agriculrural field is always less than the number of species deposited in the soil as seeds.Therefore weed seed density is greater in soil than the weed density in agriculture field. Above-ground communities are more susceptible to disturbance factors such as weather and agrotechnical practices, whereas soil seed banks appear to be more resistant to those factors

(Berbec and Szewczyk, 2019). Vandvik *et al.,* (2016) discovered that the species composition of the current weed infestation is dependent on the species composition of the soil seed bank. Therefore the similarity index of weeds in agriculture field and soil weed seed bank in three agriculture field was greater than 60%.

CHAPTER 6. CONCLUSIONS

A total of 49 weed species were recorded from the selected agricultural fields at five selected sites. In the first year (i.e 2020), 47 weed species were reorded, while 49 weed species were found in the second year (2021). Asteraceae, Poaceae and Caryophyllaceae were most dominant families in both weed desity study in agricultural fields as well as soil seed bank study. *Poa annua, Soliva anthemifolia,* and *Stellaria media* were the most common species in both years, with high weed density and IVI. Weed density increased in the second year compared to the first, indicating that weed interference was increasing day by day in agricultural fields. Weeds was also more prevalent in wheat fields than cabbage and potato fields in Gundu and Chitapole. The species richness was higher in wheat fields and lower in cabbage fields. In terms of the selected five areas, Gundu had a high species richness while Wonti had a low species richness. Among the five selected areas, Gundu had the highest weed diversity while Wonti had the lowest. Simpson's diversity index was highest in wheat fields, as there were no weeding practices in wheat field at all sites. Seed germination procedures were used to estimate weed seed banks in the soil samples collected from different agricultural fields. Emergence of 37 weed species were recorded in soil taken from wheat, cabbage and potato fields of five different sites. *Poa annua, Soliva anthemifolia,* and *Stellaria media* were the dominant species due to their high seed density, which were similar to that of agricultural field study. Weed seed density was not significantly different in selected three agriculture fields in five different sites.The agricultural field study recorded higher species richness than the soil weed seed bank study. The Shannon diversity index was found to be higher in seed banks than in agricultural field weeds, indicating the importance of seed bank study to predict weed infestations in future. Similarity index between weed species of agriculture fields and soil weed seed banks was highest in cabbage field of Chitapole (86.96%) and lower in wheat field of Jhaukhel (60.87%). Some of the weeds like *Rorripa palustris,* and *Amaranthus spinosus,* of which *A. spinosus is* an invasive species, were recorded in the soil seed bank study only but were not found in field study, indicated their presence in the agriculture field. From this it is evident that the study of a weed seed bank is important as it provides prior information about the weed infestations.

CHAPTER 7. RECOMMENDATIONS

As seed bank study provides prior information about the presence of different viable seeds of weeds in the soil, which might not be present in the list of above ground weed diversity, but may germinate and establish later when get an opportunity, for instance *Rorripa palustris*, and *Amaranthus spinosus* in the present study. Thus, from this study it is recommended that both above ground weed density and below ground weed seed bank density as well as their diversity need to be considered for proper weed management in agricultural fields.

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CHAPTER 9. ANNEXES

Annex I. The geographic position of different plots at five different sites

Chitapole	**Latitude**	**Longitude**	**Altitude (m)**
Wheat	27 °39’40”N	85 °27’16”E	1312
Cabbage	27 °39’43”N	85 °27’20”E	1315
Potato	27 °39’40”N	85 °27’18”E	1313
Gundu	**Latitude**	**Longitude**	**Altitude (m)**
Wheat	27 °38’7”N	85 °24’50”E	1459
Cabbage	27 °38’8” N	85 °24’53”E	1460
Potato	27 °38’6” N	85 °24’51”E	1459
Sudal	**Latitude**	**Longitude**	**Altitude (m)**
Wheat	27 °40’30” N	85 °28’23”E	1341
Cabbage	27 °40’23”N	85 °28’19”E	1339
Potato	27 °40’25”N	85 °28’22”E	1340
Wonti	**Latitude**	**Longitude**	**Altitude (m)**
Wheat	27 °41’2” N	85 °26’1”E	1308
Cabbage	27°41’1”N	85 °26’3”E	1310
Potato	27°41’2 “N	85 °26’4”E	1308
Jhaukel	**Latitude**	**Longitude**	**Altitude (m)**
Wheat	27°41’31”N	85 °25’43”E	1317
Cabbage	27°41’34”N	85 °25’45”E	1313
Potato	27°41’37” N	85 ° 25’44”E	1314

Annex II: IVI of weed in wheat fields during first year and second year at different places places of Bhaktapur.

Wheat field		**Sudal**		**Wonti**		**Chitapole**		**Gundu**		**Jhaukhel**	
Name of weed	**Family**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Acmella sp.	Astereacea	2.30	2.21								
Ageratina adenophora(Spreng)	Astereacea							2.61	1.92		
Ageratum conyzoides L.	Astereacea	2.25	4.71				3.48	8.68	9.44	3.89	3.92
Ageratum houstonianum Mill.	Astereacea	2.23	2.21					1.78	1.93		
Alopecurus sp.	Poaceae	27.18	25.32				6.22	2.71	3.75		
Alternanthera sessilis (L.)DC.	Amarantheacea	2.23	2.21								
Alternanthera philoxeroides ((Mart) Griseb.	Amaranthaceae	2.28	2.25				2.86				
Anagallis arvensis L.	Primulaceae							6.41	6.25		
Artemesia vulgaris L	Astereacea	2.23	2.23								
Avena fatua L.	Poaceae	15.48	4.41	5.80	4.06	5.46	4.22	9.51	7.79		
Bidens pilosa L.	Astereacea	2.25	2.25					5.58	1.87	7.85	7.97
Blumea lacera (Burm.f.) DC.	Astereacea							6.41	2.23		
Cannabis sativa L.	Cannabaceae			26.74	27.45						
Capsella bursa pastoris (L) Medik	Brassicaceae					7.27	5.49				
Cardamine pratensis L.	Brassicaceae					4.21	5.99			12.51	12.39
Centella asiatica (L.) Urban.	Apiaceae	4.62	4.96							3.96	
Chenopodium album L.	Amaranthaceae	15.80	12.48	74.17	63.24	19.07	19.3	2.3	4.22	31.88	26.35
Conyza canadensis (L.) Cronq.	Astereacea	5.54	7.23		17.33	11.11	5.84	1.78	1.93	3.89	3.92
Cynodon dactylon (L.) Pers	Poaceae	2.23	8.09				7.24	6.2	2.17		
Dichrocephala benthamii C.B.Clarke	Astereacea							3.36	3.81		
Drymeria diandra Blume.	Caryophyllaceae							5.18	6.13		
Equisetum sp	Equisetaceae							3.88	2.11		

Gallinsoga paviflora Cab.	Astereacea							3.52	1.87		
Gnaphalium affine D.Don	Astereacea	8.11	6.78				13.34	5.61	4.40	3.96	3.92
*Hydrocotyle rotundifolia*Roxb.exDC.	Araliaceae							17.39	11.58		
*Justicea diffusa*Willd.	Acanthaceae							2.72	1.99		
Mazus japonicas (Thunb). Kuntze	Mazaceae						6.07				
Oplismenus sp	Poaceae									3.89	4.46
Oxalis corniculata L.	Oxalidaceae	10.37	5.48					15.25	13.87	3.96	3.92
Phalaris minor Retz.	Poaceae	2.67	3.25	7.81	7.39						
Plantago majore L.	Plantagenacea	2.67	3.16		3.93			3.72	3.87		
Poa annua L.	Astereacea	79.70	85.84	47.95	41.85	65.01	63.93	70.71	89.90	43.21	30.01
Persicaria hydropiper L.	Polygonaceae	19.63	18.07	7.22	14.80	17.21	12.75	10.89	12.26	15.33	13.24
Polygonum plebeium R. Br	Polygonaceae	2.23	5.12						4.10		
Primula sp	Primulaceae							1.78	4.40		
Rumex crispus L.	Polygonaceae	3.43	3.16	20.25	11.87	64.15	52.13				
Sagina sp.	Caryophyllaceae							3.83	2.05		
Senecio vulgaris L.	Astereacea	6.32	6.37								
Soliva anthemifolia(Juss)	Astereacea	59.75	56.24	5.14	8.05	28.52	21.26	46.21	49	9.45	8.96
Sonchus oleraceus (L.) L	Astereacea	2.96								7.85	4.01
Spergula arvensis L.	Caryophyllaceae							5.94	3.19	137.62	166.52
Stellaria media (L.) Vill	Caryophyllaceae	5.42	8.78	104.9	91.27	70.06	63.82	12.69	7.59	10.76	10.41
Stellaria uliginosa Murray.	Caryophyllaceae	6	17.81			7.93	6.07	8.79	10.12		
Trifolium repens L.	Fabaceae	4.11						17.40	23.80		
Vicia angustifolia L.	Fabaceae				3.93						
Vicia hirusta S.F Gray	Fabaceae				4.83			9.7			

Annex III: IVI of weed in potato fields during first year and second year at different places of Bhaktapur.

Potato field		Sudal		Wonti		Chitapole		Gundu		Jhaukhel	
Name of weed	**Family**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Acemella sp.	Astereacea									6.42	6.08
Ageratina adenophora(Spreng)	Astereacea								1.92	3.33	
Ageratum cornyzoides L.	Astereacea					18.98	20.29	5.5	3.92	7.33	8.21
Alopecurus sp	Poaceae					2.37				2.8	7.72
Alternanthera sessilis (L) DC	Amaranthaceae	14.14	18.12			2.37	5.81			2.8	6.61
Bidens pilosa L.	Astereacea	5.55	7.56					5.83	7.3	6.6	
Cannabis sativa L.	Cannabaceae	12.8	10.31	24.13	23.59						
Cannabis sativa L	Brassicaceae					11.32	8.16	25.51	28.41		
Cardamine pratensis L.	Brassicaceae	6.03	8.38			10.66	12.17	10.5	6.79	15.32	
Chenopodium album L.	Amaranthaceae	3.19	4.94	42.75	54.05	18.43	18.13	70.95	63.29	49.65	51.72
Conyza Canadensis (L.) Cronq.	Astereacea									8.8	12.57
Cynodon dactylon (L.) Pers	Poaceae	2.59	4.58			6.98	11.19	5.46	6.71	4.58	4.38
Drymeria diandra Blumea	Caryophyllaceae							3.17			
Equisetum sp.	Equisetaceae								1.86		
Gallinsoga paviflora Cab.	Astereacea	5.22	7.19							7.34	
Hydrocotyle rotundifolia Roxb. ex DC.	Araliaceae							3.1	2.62		
Mazus japonicas (Thunb) Kuntz	Mazaceae	2.63	4.91			11.51					
Oplimensusus sp	Poaceae							3.06	4.22	2.77	
Oxalis corniculata L.	Oxalidaceae							7.35	11.12	4.45	
Oxalis latifolia Kunth.	Oxalidaceae							3.61	4.08		
Plantago majore L.	Plantagenacea	10.98	11.39							2.73	6.61
Poa annua L.	Poaceae	73.8	85.62	71.18	75.67	63.3	61.73	49.66	55.18	96.42	93.65
Persicaria hydropiper L.	Polygonaceae	56.83	41.52	4.73	5.12	10.89	11.78	14.84	11.48	6.03	14.69
Rumex crispus L.	Polygonaceae	8.98	7.87	4.73	5.06	19.6	24.86	12.1	9.28		
Sagina sp.									7.65		

Soliva anthemifolia Juss.	Astereacea	67.34	55.48	50.84	35.22	32.36	35.47	31.76	27.12	14.73	18.36
Sonchus oleraceus (L.)L	Astereacea									6.49	
Spergula arvensis. L.	Caryophyllaceae							5.28	9.23		
Stellaria uliginosa Murray	Caryophyllaceae	12.48	17.98	5.14	11.61	10.66	12.26	16.96	15.29	5.85	14.6
Stellaria media (L.) Vill	Caryophyllaceae	6.18	8.26	80.15	89.68	80.56	78.15	16.17	14.38	45.53	54.79
Trifolium repens L.	Fabaceae	6.99	5.87					4.27	3.53		
Veronica sp	Plantagenacea							4.92	4.65		

Annex IV: IVI of weed in cabbage fields during first year and second year at different places of Bhaktapur.

Cabbage field		**Sudal**		**Wonti**		**Chitapole**		**Gundu**		**Jhaukhel**	
Name of weed	**Family**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Ageratum conyzoides L.	Astereacea		5.83				4.6	3.54	5.29		
Ageratum houstonianum Mill.	Astereacea		8.64								
Alopecurus sp	Poaceae	12.38	15.66	7.04	9.06					54.43	54.3
Avena fatua L.	Poaceae		2.88								
Bidens pilosa L.	Astereacea	10.16	6.11						4.57		
Cannabis sativa L.	Cannabaceae			19.83	15.25						
Capsella bursa pastoris (L.) Medik	Brassicaceae								4.53		
Cardamine pratensis L.	Brassicaceae						4.57			9.78	9.9
Chenopodium album L.	Amaranthaceae		9.89	21.01	23.09	68.85	56.12	19.1	14.06	17.18	16.04
Cynodon dactylon (L.) Pers	Poaceae	15.44	8.58				5.53		4.55	7.46	9.25
Digitaria sp.	Poaceae		2.86								
Equisetum sp.	Equisetaceae		2.89								
Gallinsoga paviflora Cab.	Astereacea		2.88								
Gnaphalium affine D. Don	Astereacea	5.13	5.73						2.29		
Mazus japonicas (Thunb) Kuntz	Mazaceae									19.6	17.94
Oxalis corniculata L.	Oxalidaceae		5.7						4.59		

Plantago majore L.	Plantagenacea								2.26		3.08
Poa annua L.	Poaceae	84.03	71.24	61.21	35.85	49.67	54.18	113.34	101.94	83.02	75.18
Persicaria hydropiper L.	Polygonaceae	133.56	115.88		35.41		9.3	3.56	2.48	22.36	29.5
Polygonum plebeium R. Br.	Polygonaceae				9.53			5.98	4.78		
Rumex crispus L.	Polygonaceae					75.03	61.85			10.92	10.7
Sagina sp.	Caryophyllaceae							12.26	9.82		
Soliva anthemifolia Juss.	Astereacea	14.04	7.16	25.9	22.71	8.17	6.95	48.77	46.23	23.12	18.28
Spergula arvensis L.	Caryophyllaceae							30.39	34.12		
Stellaria uliginosa Murray	Caryophyllaceae	12.55	14				8.02		2.45	3.14	3.11
Stellaria media (L.) Vill	Caryophyllaceae	12.65	8.28	165.02	149.1	98.28	88.85	13.18	11.64	48.99	52.71
Trifolium repens L.	Fabaceae							31.07	31.62		
Vicia angustifolia L.	Fabaceae							15.89	12.78		

Annex V: Density/m^2 of weeds found in wheat field

Wheat field	**Sudal**		**Wonti**		**Chittapole**		**Gundu**		**Jhaukhel**	
Name of weed	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Acmella sp	0.31	0.19								
Ageratina adenophora(Spreng)							0.25	0.06		
Ageratum conyzoides L.	0.19	0.50				0.81	2.69	2.31	0.13	0.19
Ageratum houstonianum Mill.	0.13	0.19					0.19	0.13		
Alopecurus sp.	28.38	29.69				1.19	0.38	0.13		
Alternanthera philoxeroides (Mart) Griseb.	0.25					0.19				
Alternanthera sessile	0.13	0.19								
Anagallis arvensis L.							1.31	1.50		
Artemesia vulgaris L.	0.13	0.25								
Avena fatua L.	6.56	0.38	0.13	0.19	2.50	2.00	1.44	0.56		

Bidens pilosa L.	0.19	0.31					0.13	0.06	0.31	0.56
Blumea lacera (Burm. f) DC.							0.44	0.44		
Cannabis sativa L.			1.31	2.31						
Cannabis sativa L.					0.38	0.38				
Cardamine pratensis L.					0.63	1.19			1.06	1.44
Centella asitica (L.) Urban	0.38	0.50							0.19	
Chenopodium album L.	6.25	3.94	27.44	24.75	8.13	8.50	0.50	0.63	8.31	9.31
Conyza Canadensis (L.) Cronq.	1.88	1.56		0.56	0.44	0.56	0.19	0.13	0.13	0.19
Cynodon dactylon (L.) Pers	0.13	2.56				2.06	1.38	0.38		
Dichrocephala benthamii C.B. Clarke.							0.13	0.19		
Drymeria diandra Blumea							1.38	1.38		
Equisetum sp							0.44	0.31		
Gallinsoga paviflora Cab.							0.31	0.25		
Gnaphalium affine D.Don.	1.69	1.38				3.44	0.56	0.50	0.19	0.19
Hydrocotyle rotundifolia Roxb. ex DC.							7.88	5.19		
Justicea diffusa Willd.							0.69	0.19		
Mazus japonicas (Thunb)Kuntze						0.94				
Oplismenus sp.									0.13	0.94
Oxalis corniculata L.	4.69	1.25					4.00	4.44	0.19	0.19
Phalaris minor Retz.	0.69	0.75	0.75	0.94						
Plantago majore L.	0.69	0.69		0.06			0.25	0.25		
Poa annua L.	120.6	155.0	8.56	12.63	30.81	31.81	41.31	42.81	16.00	16.88
Persicaria hydropiper L.	13.19	13.13	0.81	1.25	2.63	2.88	3.69	4.00	1.88	2.00
Polygonum plebeium R. Br	0.13	1.63						0.50		
Primula sp.							0.19	0.50		
Rumex crispus L.	0.94	0.75	1.75	4.69	39.38	38.75				

Sagina sp.							0.69	0.25		
Senecio vulgaris L.	1.63	1.63								
Soliva anthemifolia Juss.	60.38	51.69	0.13	0.31	18.06	18.44	31.69	25.94	0.63	0.69
Sonchus oleraceus (L.)L	0.31								0.31	0.31
Spergula arvensis L.							1.06	0.81	49.69	103.1
Stellaria media (L.) Vill	2.13	2.38	49.19	49.63	46.56	48.13	3.50	1.94	1.69	2.69
Stellaria uliginosa Murray	1.38	4.81			0.94	0.94	3.13	2.38		
Trifolium repens L.	1.00						6.56	7.00		
Vicia angustifolia L.				0.06						
Vicia hirusta S.F Gray				0.31			2.69			

Annex VI: Density/m^2 of weeds found in potato field

Potato field	**Sudal**		**Wonti**		**Chittapole**		**Gundu**		**Jhaukhel**	
Name of weed	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Acemella sp.									0.31	0.31
Ageratina adenophora(Spreng)								0.19	0.38	
Ageratum cornyzoides L.					4.75	5.88	0.56	0.56	1.94	3.00
Alopecurus sp.					0.19				0.19	2.00
Alternanthera sessilis (L.) DC	3.88	4			0.19	0.63			0.19	0.56
Bidens pilosa L.	0.69	0.94					0.63	1.38	0.63	
Cannabis sativa L.	1.88	2.63	4.75	5.56						
Cannabis sativa L.					2.38	6.25	16.38	18.81		
Cardamine pratensis L.	0.81	2			1.63	1.94	2.19	1.56	2.00	
Chenopodium album L.	1.25	1.44	45.13	32.13	5.38	6.25	59.38	74.50	51.88	57.44
Conyza Canadensis (L.) Cronq.									0.50	0.63
Cynodon dactylon (L.) Pers	0.13	0.25			0.31	1.25	0.50	1.38	0.31	1.25

Drymeria diandra Blumea							0.50			
Equisetum sp.								0.06		
Gallinsoga paviflora Cab.	0.38	0.56							0.44	
Hydrocotyle rotundifolia Roxb. ex DC.							0.38	0.44		
Mazus japonicas (Thunb.) Kuntze	0.25	0.50			2.31					
Oplismenus sp.							0.31	0.56	0.13	
Oxalis corniculata L.							5.63	5.88	2.38	
Oxalis latifolia Kunth.							0.75	0.94		
Plantago majore L.	2.06	2.69							0.06	0.56
Poa annua L.	85.94	115.69	62.00	63.88	47.50	53.81	39.06	66.88	87.50	93.75
Persicaria hydropiper L.	80.00	82.44	0.06	0.31	1.63	2.00	3.19	3.31	0.38	4.13
Rumex crispus L.	2.00	2.00	0.06	0.19	4.25	6.08	1.50	1.69		
Sagina sp.								0.69		
Soliva anthemifolia Juss.	105.6	110.44	42.63	60.50	25.56	29.00	27.50	28.75	5.50	5.88
Sonchus oleraceus (L.)									0.44	
Spergula arvensis L.							0.69	2.25		
Stellaria media (L.) Vill	1.25	2.44	71.81	76.31	78.75	86.88	4.88	7.88	22.50	31.81
Stellaria uliginosa Murray	5.13	5.25	0.19	0.75	1.63	2.13	3.81	7.25	0.81	2.31
Trifolium repens L.	1.69	2					1.88	1.81		
Veronica sp.							0.56	0.88		

Annex VII: Density/m^2 of weeds found in cabbage field

Cabbage field	Sudal		Wonti		Chittapole		Gundu		Jhaukhel	
Name of weed	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**	**1st year**	**2nd year**
Ageratum conyzoides L.		0.50				0.20	0.75	1.06		
Ageratum houstonianum Mill.		0.61								
Alopecurus sp.	18.75	18.89	0.81	1.56					30.06	39.81
Avena fatua L.		0.17								
Bidens pilosa L.	0.19	0.39						0.28		
Cannabis sativa L.			1.56	1.69						
Cannabis sativa L.								0.17		
Cardamine pratensis L.						0.10			2.38	3.38
Chenopodium album L.		5.83	2.31	5.81	33.44	58.70	6.00	6.00	4.75	6.50
Cynodon dactylon (L.) Pers	0.19	0.28				1.30		0.22	0.75	1.50
Digitaria sp.		0.11								
Equisetum sp.		0.22								
Gallinsoga paviflora Cab.		0.17								
Gnaphalium affine D.Don	0.31	0.44						0.17		
Mazus japonicas (Thunb) Kuntz									3.44	4.50
Oxalis corniculata L		0.11						0.33		
Plantago majore L.								0.12		0.31
Poa annua L.	153.1	156.67	16.00	18.13	18.75	54.00	113.3	170.25	152.2	54.94
Persicaria hydropiper L.	217.5	186.11		1.06		0.70	0.31	0.28	7.00	8.31
Polygonum plebeium R. Br				0.31			0.25	0.44		
Rumex crispus L.					36.25	68.00			4.44	3.11

Sagina sp.							0.88	1.67		
Soliva anthemifolia Juss.	2.81	3.11	1.88	5.31	1.88	5.00	53.25	52.44	5.25	9.44
Spergula arvensis L.							19.63	31.89		
Stellaria media (L.) Vill	3.13	3.56	94.50	95.00	67.81	110.10	3.19	3.39	35.38	48.13
Stellaria uliginosa Murray	3.88	3.72				2.00		0.17	0.13	0.38
Trifolium repens L.							31.38	36.61		
Vicia angustifolia L.							3.56	3.17		

CHAPTER 10. PHOTOPLATES

10.1. Weed infestation in study area

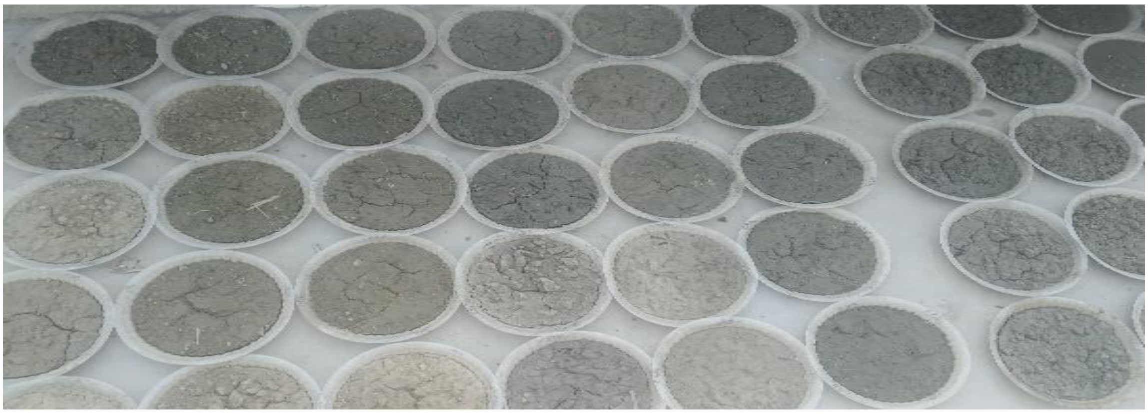
Potato field

Wheat field

Cabbage field

10.2. Soil collection

Collection of soil sample



Soil samples from different agriculture fields for seed emergence study.

Weed emergence in soil samples

10.3. Some dominant weed speceies found in agriculture fields.

Poa annua

Stellaria media

Spergula arvensis

Solvia anthemifolia

Persicaria hydropiper

Chenopodium album