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THE DISTRIBUTION AND ECOLOGICAL IMPACTS OF *PARTHENIUM HYSTEROPHORUS* L., (ASTERACEAE), AN INVASIVE SPECIES IN KOMBOLCHA CITY ADMINISTRATION, SOUTH WOLLO, ETHIOPIA

MSc. Thesis

By

Gezahegn Ali Feleke

Adviser: Habte Jebessa (PhD)

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The distribution and ecological impacts of *Parthenium hysterophorus* L., (asteraceae), an invasive species in Kombolcha city administration, South Wollo, Ethiopia

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Gezahegn Ali Feleke

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Approval of the Board of Examiners

Name	Signature	Date
_____ Chairman	_____	_____
_____ Advisor	_____	_____
_____ Examiner	_____	_____

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List of Abbreviations and Acronyms

ATM	After Two Months
Cm	Centimetre
DT	During Transplanting
GIS	Geographical information system
GPS	Global Positioning System
Kg	Kilogram
Km	Kilometre
Km^2	Square kilometre
KCA	Kombolcha City Administration
m^2	Square meter
RRC	Relief and Rehabilitation Centre
SPSS	Statistical package for social science

Abstract

Parthenium hysterophorus L. (Asteraceae) (tribe: Heliantheae), is an erect and much branched annual or ephemeral herb, known for its notorious role as environmental, medical, and agricultural hazards. It invade large areas globally and threatening native biodiversity. P.hysterophonrus is believed to have been introduced to Ethiopia in 1988 at the Eastern part of the country (Deredwa and Harargie). The study was conducted in Kombolcha city administration (KCA), South Wollo, Ethiopia. Since its introduction to the study area (KCA), parthenium weed has been spread in an alarming rate in the rural areas. The main objective of this study is to identify and describe the distribution and ecological impacts of the invasive species P. hysterophorus and to create awareness to the residents on its negative impacts in the ecosystem and biodiversity. The results of the research suggested that parthenium weed have been distributed largely in uncultivated areas, road sides, grazing areas, riversides and farm areas respectively. The impact of P.hysterophoruson other plants is investigated by comparing plant species grown in association with parthenium and plant species grown in the absence of parthenium. Quedrats were used to identify the diversity of species in parthenium infested areas. A total of 37 species were identified and the diversity of species in the infested areas of different samples sites was computed using Shannon's diversity index. The result showed that the diversity of species in parthenum infested areas is low. Hence, creating proper awareness to the residents particularly farmers in the study area on its distribution and negative impacts would be the best option to control further invasion of new valuable lands by P.hysterphorus.

CHAPTER 1

1. Introduction

Parthenium hysterophorus is an alien invasive species. Alien species may spread and grow vigorously when introduced deliberately or unintentionally by gardeners, traders and foresters (Raghubanshi et al., 2005) and threaten biodiversity, ecosystems, economy and human health (Evans, 1997; Levine et al., 2003). *P. hysterophorus* is commonly called congress weed, false rag weed, parthenium weed, feverfew etc. Previous studies have repeatedly shown that invasive species have significant effects on the diversity and structure of plant communities (Chippendale and Panneta, 1994). It has also negative impacts on agriculture, forestry and other human enterprises and on human health. In agricultural system, invasive weeds affect the productive capacity of the land and increase agricultural labour time and affecting human wellbeing by threatening the availability of food.

P. hysterophorus is an annual herb with a deep taproot and an erect stem which is native to North America. It had been distributed to different parts of the world. Some of the countries where parthenium weed is distributed includes: India, Australia, China, Taiwan, Pakistan, Nepal, Sri Lanka, Bangladesh, Vietnam, Pacific Islands, Ethiopia, Kenya, Madagascar, South Africa, Somalia, and several countries of South and Central America (Dipankar and Munan, 2013). *P. hysterophorus* was first reported from Ethiopia in 1988 at Dire- Dawa and Harerge, Eastern Ethiopia (Seifu, 1990) and subsequently found near Dessie, North-eastern Ethiopia as well. This weed has been introduced to Kombolcha city administration (South Wollo, Amhara region, Ethiopia) in recent past years, and cause different problems on biodiversity including plants, animals, and humans and also adversely affects the productivity of animals and plants. *Parthenium* is so aggressive and

devastating, that very little and sometimes no other plant species are seen in areas where it has gained dominance (Adkin, 1996; Kohli *et.al*., 2004).

1.1. Statement of the Problem

Currently there are different types of alien invasive species of plants in Ethiopia as *Prosopis juliflora*, *P.hysterophorus* and *Lantana camara*. These invasive species have allelopathic effects on native plants, that is, they out compete native species and dominate the ecosystem (environment). Even if there are different invasive species in the study area, this study is focused on the distribution and ecological impacts of *P. hysterophorus*.

Parthenium weed has been introduced into many countries around the world (Parsons and Cathbertson, 1992).It was also unintentionally introduced to Ethiopia and spread over large areas of land and is having a significant impact on fodder biomass production on grazing areas (McFadyen, 1992) and community biodiversity (Nguyen *et al*.,2010). *P.hysterophonus* has been spread and grows vigorously in Amhara region South Wollo zone Kombolcha city administration, at urban and rural areas within the past few years. It is called "Kinche Arem" by the local community. It is distributed along road sides, uncultivated areas, grazing areas (grass lands), the sides of rivers and also cropping (farm) areas. Previous studies have repeatedly shown that invasive species have significant effect on affecting biodiversity and structure of plant communities (Chippendale and Panneta, 1994).

In Kombolcha City Administration (KCA), parthenium weed is distributed from the town to the rural areas and inhabits many areas or regions of the city administration. The increased occurrence (distribution) of *P.hysterophorus* is mainly due to lack of control on its distribution, and its prolific seed production, local dispersal by wind and water and its rapid growth to form dense strands. Based on the above situations *P.hysterophorus* becomes a major problematic weed in KCA and its surrounding areas.

Therefore, this study focuses on the distribution and ecological impacts of the invasion of *P.hysterophorus* on plants (including grasses, crop plants, vegetables, etc), animals (animals' health, fodder supply, Milk products, meat quality), and human health. Even if

the distribution and devastating effect of parthenium weed is greatly increased in KCA, there is no any research which was conducted in relation to its distribution, ecological impacts or control of parthenium weedin the study area, and this evidences initiated this research.

Figure 1. *Parthenium* infestation in Kombolcha city administration, Amhara region (Source: Field survey photographs, September 2015)

1.2. Significance of the Study

The research is concerned with the distribution and Ecological impacts of *P.hysterophours* (commonly called parthenium weed or congress weed) in KCA. Hence the study is expected to have various benefits:

- It will help in identifying the main impacts that occurred on the productivity of plants and animals due to invasion of parthenium weed.
- It will provide information on ways how parthenium weed affects ecosystem /or biodiversity.
- The study may help to create awareness within the society (stakeholders) about the negative impacts of *P. hysterophorus* on biodiversity to provide proper solutions in protecting the reduction of biodiversity.
- It will help as a base for other researchers who need to conduct other researches on the same issues including providing proper solutions or

controlling the negative impact of *P. hysterophorus* on biodiversity in the study area.

1.3. Hypothesis

Research hypothesis are corner stone of the study, because they are the main points that determine the research process from the beginning to its end. This research, therefore, has four hypotheses mentioned below.

a. The wide spread distribution of *P. hysterophorus* in the invaded areas of Kombolcha city administration could be by using animals, vehicles, water currents and wind as agents of dispersal.
b. *P. hysterophorus* would affect ecosystem / biodiversity by affecting mainly plant species, and by causing diseases to animals and humans.
c. *P. hysterophorus* could cause reduction of biodiversity by competing for resources with native plant species and by producing chemical substances that affect the growth of plants.
d. *P. hysterophorus* would cause negative impacts in reducing the productivity of plants and animals by reducing the yield of plants and by affecting the quality of meat and milk of animals.

1.4. Scope of the Study

The study must be limited both in scope and depth to manageable size based on the researcher‟s time availability, budget and other factors. On the basis of these situations the scope of the study is delimited to Kombolcha city administration, South Wollo administrative zone, Amhara region, Ethiopia, which has an area of 124.5 km^2 (12,450 hectares) and consists of 5 urban kebles or communes (2,181.1 hectares) and 6 rural kebeles (10,268.89 hectares) with 114,117 total population in which 82,165 (72%) are living in the urban kebeles (small territorial divisions for administrative purpose) and 31,952 (28%) living in the rural kebeles. It is also delimited on the distribution and ecological impacts of *P.hysterophorus* on plants, animals, humans and ecosystem in the study area.

1.5. Objectives

1.5.1. General Objective:

- The General objective of this study is to identify and describe the distribution and ecological impacts of the invasive species *P. hysterophorus* and to create awareness to the residents on its negative impacts on ecosystem and biodiversity.

1.5.2. Specific Objectives:

The specific objectives of the study are:

- To describe the distribution status of *P. hyterophorus* in the invaded areas of Kombolcha city administration.
- To identify the negative ecological impacts of parthenium weed, specifically on plants, animals and humans.
- To identify how and to what extent parthenium weed affects the quantitative yield of crop plants and quality of milk and meat of cattle in the invaded areas of KCA.
- To assess the attitude of the society towards the ecological impacts of *P.hysterophorus* and to create awareness on its impact.

CHAPTER 2

2. Literature Review

2.1. Parthenium

P.hystcrophrous is an alien invasive species that is an annual herb with a deep taproot and an erect stem. The scientific classification of *P. hysterophrous* is:-

- Kingdom – Plantae
- Division – Angiospermae
- Class – Audicots
- Order – Asteraleae
- Family – Asteraceae
- Genus – *Parthenium*
- Species-*hysterophorus*

The genus name *Parthenium* is derived from the Latin word parthenice a reference to the plant now known as *Tanacetum parthenium*(L.) Bernh.or "feverfew;" *hysterophorus* was derived from the Greek *hystera* (womb) and *phoros* (bearing), referring to the prolific seeding habit of the plant (Parsons and Cuthbertson ,1992).According to Kaur et al.,(2014) *P. hysterophorus* L., of the family Asteraceae (tribe: Heliantheae), is an erect and much branched annual or ephemeral herb, known for its notorious role as environmental, medical, and agricultural hazards. Also Holm, et al., (1997) explained that, this noxious invasive species is considered to be one of the worst weeds currently known. Its introduction had been mentioned by Parsons and Cuthbertson, (1992). Parthenium weed has been unintentionally introduced into many countries around the globe. In general parthenium weed is an aggressive annual weed commonly associated with non crop areas but it also spread in to cultivated areas.

The entry of parthenium weed in to Ethiopia is estimated from Kenya and Somalia in to the eastern part of Ethiopia. As stated by Shashe (2007), parthenium weed has been spreading from the eastern route of Ethiopia along the Dire Dawa, Addis Ababa railway presumably between 1974 and 1980. Some believe that the weed might have been

transported into the country with imported or donated grain (Seifu, 1990; Fasil, 1994). Others hold the belief that the weed entered the country during the Ethio-Somali war in 1976/77 through military vehicles (Frew *et al*., 1996), The presence of parthenium in Kenya and Somalia (Njorage, 1986) and the capacity of the seed to travel long distance through wind, water, and other means also suggested the possible entry into Ethiopia from these neighbouring countries.

2.2. Characteristics of Parthenium

A number of characteristics of *P. hysterophorus* as tolerance to a wide range of soil and environmental conditions, prolific seed production, seed persistence in soil seed banks, rapid germination and seedling growth, short or extended life cycles, and an allelopathic capacity are all considered to aid its invasiveness (Navie *et al*., 1996 Nguyen et al., 2010). As parthenium weed matures, it produces many branches with flowers and may eventually reach a height of 2 m (Dhileepan, 2012). Mature stems are longitudinally grooved and covered with fine hairs. Newly emerging leaves are covered with fine hairs. Mature leaves are pale green, deeply lobed, and arranged alternately on the stems and are less hairy than young leaves. *Parthenium* completes its life cycle within 16 to18 weeks. Under favourable conditions, 4-5 generations per year can be completed (Gnanavel, 2013).

Buried seeds can survive for more than a year (Navie *et al*., 1996). Flowers have five petal like ray florets, each bearing a single seed (Kohli *et al*., 2006). Seeds are narrow, diamond shaped, flattened achenes, and dark brown to black in colour with white appendages. The seeds are protected in a straw-coloured fruit covering (2 mm). Inflorescences are grouped in 4 to5 small spherical heads. Generally, only 4 seeds develop in each head (Chippendale and Panetta, 1994).

In addition to its prolific seed production the other characteristics contributing to *P.hysterophorus* as an aggressive weed lies on its reproductive ability, four or more successive cohorts of seedlings were known in a single season (Pandey and Dubby, 1989).Under favourable conditions flowering can be initiated within four weeks of seed germination and plants continue to flower for extended periods up to 6-8 months

(McFadyen 1992). After flowering, most leaves die. Fruit development and seed maturation occur within 1 to 2 weeks of flowering. Flowering and fruiting continue even after the complete senescence of leaves. These features indicate that parthenium weed has the ability to affect the sustainable growth, development and distribution of other plants. Parthenium weed can grow and flower over a wide range of temperatures and photoperiods. It occurs in the humid and sub-humid tropics showing a marked preference for black, alkaline, cracking, clay soils of high fertility, but also able to grow on wide variety of soil types from sea level up to 1800 m (Evans, 1987 cited in Adane, 2008). Parthenium weed has several built in properties and efficient behavioural mechanisms that enable it to overcome many ecological adversities and thus continue to survive under stress (Mahadevappa, 1997 cited in Adane, 2008).

The spread of seeds plus their ability to remain viable in the soil for many years poses one of the most complex problems for control (Monaco *et al*., 2001). *Parthenium* seeds do not have a dormancy period and are capable of germinating anytime when moisture is available. Seeds germinate within a shorter period of time and flowering starts after a month and continues up to another three months. In northwest India, *Parthenium* germinates mainly in the months of February to March, attaining peak growth after rains in June-July and produces seeds in September-October. It normally completes its life cycle within 180–240 days. Its growth remains less and stunted from November to January due to severe cold (Aneja,1999).These Characteristics of parthenium weed increases its distribution to colonize wide range of areas and quickly form dense strands in the invaded regions and affect the growth of other plants.

2.3. The Spread and Distribution of Parthenium

Parthenium have been introduced into India and Australia from North America and in the last few years, the weed has emerged as the seventh most devastating weed in Africa, Asia, and Australia (Kaur *et al*., 2014). It is abundantly found in Gojjam, in South and North Gonder with the potential to spread to agricultural districts of Metama and Setit Humera (Fessehaie, 2005). Furthermore, the weed is well established in many districts of South, North, and central Tigray. In one district alone, Alamata, about 10,000 hectares of

the land has been infested with *Parthenium* (Bezabih and Araya, 2002). In much of the low lands of Wollo, parthenium weed has become the most dominant weed. In these areas, the weed has been reported in 42 Woredas. The weed is also a serious problem in the Regional State of Oromia although there is no actual survey data on the total area of land infested in the region. Currently, *Parthenium* is spreading at an alarming rate in Eastern Ethiopia; the central rift valley, and neighbouring localities of Afar Region, East Shewa, Arsi, and Bale in Southern Ethiopia.

As reported by Riaz and Javaid, (2011); Shabbir *et al*., (2012) *Parthenium* is a weed along roadsides, on wastelands and in certain cropping and grassland regions where it negatively affects agricultural production and reducing native plant biodiversity. Also it has now spread over vast areas of land used for livestock production and is having a significant negative impact upon fodder biomass production (McFadyen, 1992) and community biodiversity (Nguyen *et al*., 2010; Belgeri *et al*., 2012). Therefore, this wide spread of the weed to various ecosystems causes significant negative impact on plant and animal species diversity. This time biological invasions operate on a global scale and especially in this century, they are rapidly increasing due to interactions with other global changes such as increasing globalization of markets, explosive rises in global trade, tourism, and exchange of goods (Groombridge 1992).The seeds of *Parthenium* are mainly dispersed through water currents, animals, and movement of vehicle, machinery, grains, stock feed and to a lesser extent by the wind. Most of the long distance spread is through vehicles, farm machinery, and flooding.

The seeds of *Parthenium* have special adaptation that helps them to spread easily in different areas. Parthenium weed seeds are very small and with short wing like structures (Navie *et al*., 1996). This helps them to float and transported in wind. Especially whirl winds can carry a large number of light seeds or *Parthenium* achenes to a long distance and they can be dispersed easily. Animals and humans may also disperse the seeds of parthenium weed by carrying the seeds on their feet, cling to their fur or clothes, or by ingesting the seeds while they eat parthenium weed and removed with their dung (waste). The seeds may move also with surface water, runoff, in natural streams and rivers, in the irrigation and drainage channels, and in irrigating water from ponds. However, scientists

have found great variation in length of time the seeds remain viable in fresh water. For example, some seeds can be stored in fresh water for three to five years and still germinate (Monaco *et al.,* 2001).

Drought and subsequent reduced pasture cover create the ideal situation for the parthenium weed to establish itself. Although parthenium weed is capable of growing in most soil types, it is most dominant in alkaline, clay loam soils. The allelopthic effect of *Parthenium* coupled with absence of natural enemies like insects and diseases are also the two important factors responsible for its wide spread.

2.4. The Impacts of *Parthenium*

P. hysterophorus negatively affects agricultural production and reducing native plant biodiversity (Riaz and Javaid, 2011; Shabbir *et al*., 2012). *P. hysterophorus* is of global significance responsible for severe human and animal health issues, such as dermatitis, asthma and bronchitis, and agricultural losses besides a great problem for biodiversity (Holm et al., 1997). The invasive capacity and alleolopathic properties have rendered *P. hysterophorus* with the potential to disrupt the natural ecosystems. Very sparse or sometimes no other vegetation can be seen in parthenium dominated areas (Lakshmi and Srinivas, 2007). It has been reported to be causing a total habitat change in native grasslands, open woodlands, river banks and flood plains. These weeds rapidly invade new surroundings often replace the indigenous species and pose a serious threat to biodiversity. Among others, *P. hysterophorus* exhibited the ability to invade and adapt to new habitats, thereby reducing the number of native plants. Generally parthenium weed is intended to pose a serious threat to the ecosystem and biodiversity by invading large areas in an alarming rate and damaging plants and animals.

2.4.1. Impacts on Plants

Parthenium contains chemicals, like Parthenin, hysterin, hymenin, and ambrosin, and due to the presence of these chemicals, the weed exerts strong allelopathic effects on different crops in addition to its direct competition for nutrients, water and sunlight.

Parthenin has been reported as a germination and radical growth inhibitor in a variety of dicot and monocot plants (Gunaseelan, 1998).

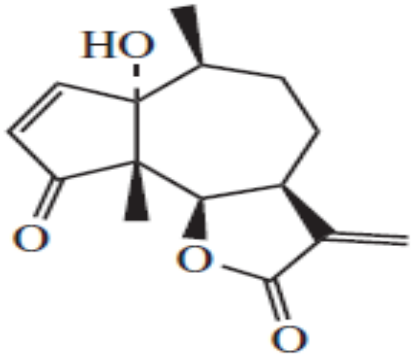

Figure 1. The Structure of Parthenin

Parthenium has a strong ability to affect crop growth through allelopathy. There is a strong evidence (Knox *et al*., 2011) that aqueous extracts of leaf, inflorescence, stem, and root of parthenium weed reduce germination, root/shoot length, root/ shoot dry weights, total seedling dry weight, plant height, leaf area, spikelet and pod number, seed weight, grain yield, water content, chlorophyll contents, enzyme activities, and reducing and non-reducing sugars of cereals, pulses, forages, oilseeds, and vegetables. Also according to Khosla and Sobti (1981) the weed affects nodulation in legumes due to inhibition of activity of nitrogen fixing and nitrifying bacteria, namely, *Rhizobium, Actinomycetes, Azotobacter*, and *Azospirillum*. Also Kanchan and Jayachandra (1981) and Dayama (1986) reported that the growth and nodulation of legumes were inhibited by parthenium weed because of the inhibitory effect of allelochemicals on nitrogen fixing and nitrifying bacteria. These chemicals have been observed to exhibit an inhibitory effect both on the germination and growth of a wide variety of crops including pasture grasses, cereals, vegetables, other weeds and even tree species (Evans, 1997a; Navie *et al*., 1996;). *Parthenium* produces enormous numbers of pollens (on an average 624 million/plant), which are carried away at least to short distance in clusters of 600–800 grains, and settles on the vegetative and floral parts, including stigmatic surface, and inhibiting fruit setting in crops like tomato, beans, capsicum, and maize. Additionally, parthenium weed pollen was found to reduce the chlorophyll content of leaves to which it comes in contact with and can interfere with the pollen germination and fruit set of the nearby species (Kanchan

and Jayachandra, 1980b). Aneja (1999) and Tamado T.et.al., (2002) reported that, in India, *P. Hysterophorus* causes a yield decline of up to 40% in agricultural crops. Sorghum (*Sorghum bicolor* L. Moench) grain yield losses between 40 and 97% have been reported in Ethiopia if parthenium is left uncontrolled throughout the season. Channappagoudar et al., (1990) also reported that the presence of parthenium weed in irrigated sorghum in India reduced grain yields from 6.47 to 4.25 tons/ha (34.3%) and decreased grain weight by 30%. However, its overall impact on the production system is multifaceted, both direct and indirect, thus making it difficult to quantify losses (Evans, 1997a). In addition to its allelopathic effects on crop plants *Parthenium* affects the germination and growth of non-crop plants, it can also cause greater impact in reducing the productivity of plants and animals.

2.4.2. Impacts on Animals

Aneja (1999) stated that, though cattle do not eat *Parthenium*, its effect was observed on them when they walk by or graze through patches of this weed. Such cattle had inflamed under and subsequently suffered from fever and rashes. It is reported that feeding the weed to buffalo and bull calves at different level causes both acute chronic forms of toxicity. Ulcerations are caused both in the mouth and digestive track. Also Lakshmi and Srinivas (2007) stated that parthenium weed is toxic to animals causing dermatitis with pronounced skin lesions on various animals including horses and cattle. If eaten, it is responsible for mouth ulcers with excessive salivation. Significant amount (10–50%) of this weed in the diet can kill cattle. The impact of parthenium weed on livestock production is both direct and indirect by affecting grazing land, animal health, milk and meat quality, and marketing of pasture seeds and grain (Evans, 1997a). In India, for instance, the weed can reduce the pasture carrying capacity by up to 90% (Nath, 1988). Chippendale and Panneta (1994) identified that parthenium weed could completely dominate grazing land, resulting in a weed monoculture and reduced stocking rate of up to 80% in Australia, with a net annual loss of AU$ 16.5 million.

Additionally, it causes anorexia, pruritus, alopecia, diarrhoea, and eye irritation in dogs. It also causes acute illness, when bitter milk and tainted meat from buffaloes, cows and

goats, are fed on grass mixed with *Parthenium* (Aneja, 1991). An autopsy of the dead animals showed punched cut ulcers on the oesophagus and the obosomal folds. Histopathology of the kidney and liver revealed degenerative changes and necrosis. Consumption of milk from the livestock grazing around *Parthenium* invaded freezing land could be hazardous to human being.

2.4.3. Impacts on Humans

Parthenium weed causes different health problems in human beings. The pollen grains, airborne dried plant parts, and roots of *Parthenium* cause various allergies like contact dermatitis, hay fever, asthma, and bronchitis in human beings.

Figure 3. Commonly known parthenium dermatitis; (A, B) Air Borne Contact Dermatitis; (C) Chronic Actinic Dermatitis in a female; (Kaur *et al.,* 2006).

Pollens of *Parthenium* cause asthma (allergic bronchitis) especially on children playing outdoors, adults and old age persons. Contact of plant with the body causes dermatitis and the spread of the problem all over the body causes great discomfort (Wiesner, et al., 2007). There are evidences of allergic papules in school boys when they had volunteered

for uprooting parthenium weed in Hassan (a place or district in India). It has been observed that chances of getting sensitized to the weed are high when a person comes in contact with the weed for a period ranging from 3 to12 months. *Parthenium* is responsible for causing largest number of air borne contact dermatitis in India. Almost every part of the plant except root is reactive. The reaction was mainly over the sun exposed area (Mahadevappa, 2008). McFadyen (1992) indicates that about 15% of individuals regularly exposed to parthenium plant would develop the dermatitis and another 7-15% develop respiratory problem. Affected individuals have no alternative except leaving the area. Other reports revealed that respiratory problems usually start with high fever and then gradually progress to asthma and allergic bronchitis after 3-5 years are increasing. In Ethiopia, it was reported that individuals who remove parthenium weed with hands in infested crops suffer from dermal allergy, fever, and asthma (Taye, 2002). It is also reported that there is an increasing incidence of respiratory allergies in India, with 7% of sample of Bangalore residents were affected by allergenic rhinitis due to parthenium weed pollen, and 42% of patients suffer from nasobronchial allergy (Towers and Subba Rao, 1992). The above all situations show that parthenium weed negatively affect the health of humans by causing different diseases that mainly affects the skin (as dermal allergies) and the respiratory system (as asthma and bronchitis).

2.4.4. Impacts on Biodiversity

The infestation of parthenium weed can degrade natural ecosystem and biodiversity, because it has a very high invasive capacity and allelopathic properties which has the potential to disrupt the growth and distribution of any type of natural vegetation which in turn affects diversity of animals. There was a sharp decline in the native biodiversity index, evenness and *et al.,* species richness over the time, clearly indicating the threat of *Parthenium* on biodiversity. *Parthenium* has been causing a total habitat change in native Australian grasslands, open wood lands, and river banks (McFadyen, 1992; Chippendale and Panetta, 1994). Kohli (2004) reported that three exotic weeds including parthenium adversely affect the structural composition and dynamics of the diversity of the native flora in India. The weed affects not only the species diversity of the native areas, but also their ecological integrity.

The global extent and rapid increase in invasive species is homogenising the world‟s flora and fauna (Mooney and Hobbs, 2000) and recognized as a primary cause of global biodiversity loss (Czech and Krausman, 1997). The allelopathic potential of *P. hysterophorus* is believed to play an important role in changing of environments by removing the different species of plants that were found before infestation.

The threats of parthenium weed on the structure and diversity of plant communities have been shown by different investigations. Allelochemicals released from parthenium are capable of changing the physicochemical characteristics of the soil. It affects the moisture content, temperature, pH, organic matter, carbon, nitrogen and phosphorus content and soil microbial activity (Daizy, *et al*., 2002). The change in property of the soil due to introduction of allelochemicals affects the reproduction, growth and survival of other nearby plants (Asad and Rukhsana, 2006). Generally *Parthenium* is intended to pose a serious threat to biodiversity by invading new surroundings and by reducing or totally replacing the native species in *parthenium* infested areas.

CHAPTER 3

3. Materials and Methods

3.1. Description of the Study Area

3.1.1. Location

The study was carried out in Amhara region of Ethiopia in KCA which is one of the weredas /districts of South Wollo Administrative Zone. It is located at latitude and longitude of 11˚5'N 39˚ 44'E /11.083˚N 39.733˚E. (Source: Wikipedia, the free encyclopaedia). It is found 375 km North of Addis Ababa and 505 km East of Bahir Dar which is the capital city of the Amhara regional state. It has an area of 124.5 Km^2 /12450 hectares/.

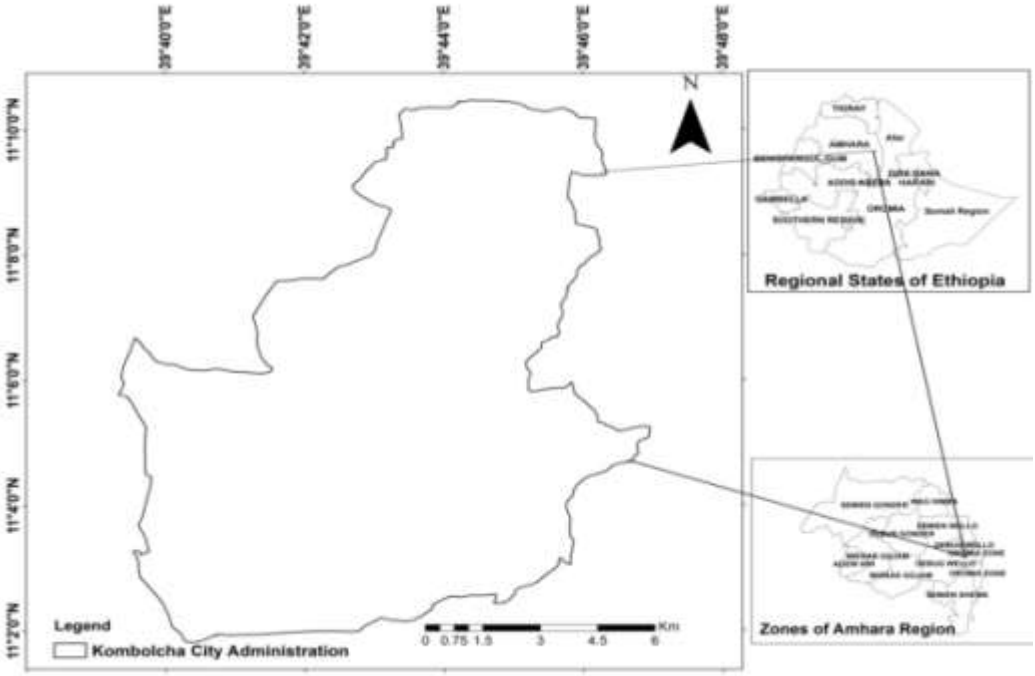

Figure 4. Map of Kombolcha city administration

*This GIS map of the study area doesn't show the recently added kebeles of Kombolcha city administration, it is preferred to locate the exact location of the sample sites for quadrates in figure 9.

It is bordered by Kalu wereda in the East and South, Dessie Zuria Wereda in the West and South west, Tehulederie Wereda in the North and Dessie town in North West.

3.1.2. Climate

Kombolcha is characterised by an average high temperature and a two seasons of rain fall hence, there are two rainy seasons, these are Kiremt /July to September which is the long rainy season and Belg /February& March, the short rainy season. As the information or data obtained from Kombolcha meteorology agency (Figure 5) more than72% of the annual rain fall (the highest precipitation) in the study area is during the long rainy season (July to September). October, November, December and June are drier months. The highest annual rain fall was recorded in 2010, which was 1313.6 mm and the lowest annual rain fall was recorded in1984 which was 598.5 mm based on rain fall data of KCA from 1984-2014. The average annual temperature of the area is 20.1^{O}C. Even if there are two cropping seasons in the rural areas of the study area, the highest cropping season is Kiremet (the long rainy season).

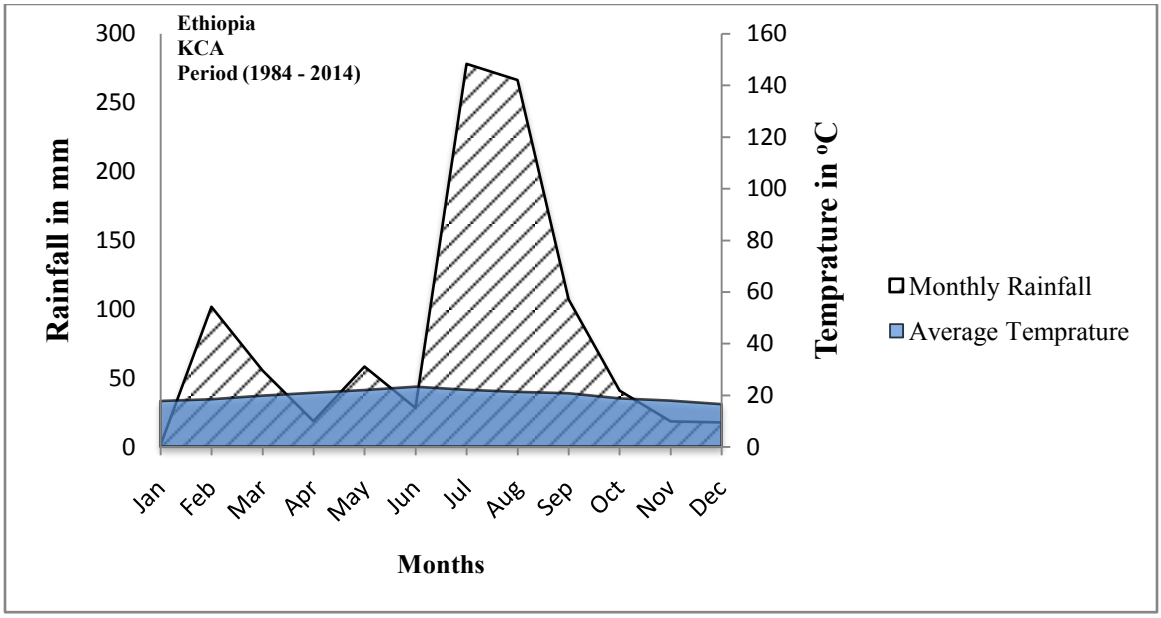

Figure: 5 – Climate diagram for kombolcha city administration 1984 – 2014 (rainfall and temperature)

(Source: Kombolcha meteorology agency, 2015)

3.1.3. Vegetation

The major natural vegetation of the study area is characterized by grassland (grazing areas), small forests containing mainly acacia trees and shrub species. The large part of the study area is covered with agricultural farm area. The most common types of crops cultivated in the study area are crops as maize, sorghum, wheat, chick peas and teff. Also varieties of vegetables as salad, cabbage, tomato, onion, potato, sweet potato and carrot are cultivated and harvested in large amount using both Kiremt & Belg rain, as well as by irrigation using Borkena River and other small rivers in the area as Werka and Harawle.

3.1.4. Topography

The landscape of KCA consists of plains, gorges, slopes and hilly topography. The elevation of Kombolcha town and its surroundings range from 1842m to 1915m above sea level in the alluvial plains of the town to the elevation more than 2000m above sea level (Source: Wikipedia, the free encyclopaedia).

3.2. Methodologies

3.2.1. Reconnaissance survey

A visit of preliminary survey /observation was conducted on September 14, 2015 before the actual research work, to observe the distribution of parthenium weed at different kebeles /regions of the study area and also the impacts that occur in the ecosystem and on biodiversity. Later a second formal survey was done starting from September 16, 2015 to gather data by catching images as photographs and video on the distribution and impacts of parthenim weed on ecosystem. The distribution and impacts of the weed in the rural and urban areas of the study area was surveyed /observed. The observation included its distribution on none crop /uncultivated areas, cultivated/farm areas, along road sides, grass lands or grazing areas, at the sides of rivers (river banks) and in the small forests in the study area and around construction sites (as shown in figure 6).

A **B**

C **D**

Figure 6. The distribution of parthenium weeds at different sample sites in Kombolcha city administration **A**= uncultivated area, B=cultivated area, C=construction site, and D= road side. (Source: Field survey photographs September, 2015)

3.2.2. Experiment

3.2.2.1. Experiment on the Impact of Parthenium on Tomato (Solanum lycopersicum)

To evaluate the impact of parthenium weed on the growth and productivity of tomato, an experiment was carried out by growing tomato on small area of land which was divided in to two small blocks of land (plots), each with 60cm width and 3.5m length ($2.1m^2$).

Procedures for the test

On the first plot (Plot I) 12 tomato seedlings were transplanted in two rows with an interval of 40 cm between, by growing 6 parthenium weeds with the tomato seedlings and left to grow. On the second plot (Plot II) tomato seedlings were transplanted in the same way as the first one, but in the absence of parthenium weed. The test plant and the weeds were kept moist to grow properly in both experimental (plot I) & control groups (plot II) for the duration. The growth performance of the test plants was evaluated by measuring their stem length and stem width during transplanting and after two months of growth.

Tomato species were selected as test species due to the availability of the seedling during the time and most sample respondents for questionnaire had responded that tomato plant is one of the vegetables in the area which is highly affected by parthenium weed.

During transplanting After one month

After two months

Figure 7. Tomato plants growing with parthenium weeds (plot I) and tomato plant growing in the absence of parthenium (plot II). (Source: Photos of the experimental and control plots, 2016)

3.2.2.2. Test on the Effect of Parthenium on Milk

This simple test had been carried out to evaluate the effect of parthenium weed on producing of yoghurt, based on the following procedure.

Procedure;

A cow was kept to feed in grazing areas infested with parthenium for three days. At the third day the cow was milked, the milk was tasted and left to be curdling for three days. Secondly, the same cow was kept for three days by supplying grass which was taken from un- infested areas. At the third day the same cow was milked and the milk was tasted with the same person and left to be curdling for three days. The differences in relation to taste of the milk and texture of the yoghurt were evaluated.

3.2.3. Sampling techniques

3.2.3.1. Probability Sampling

The targeted populations of the study were household heads of KCA, both from rural and urban kebeles. The sampling technique used to select samples for questionnaire to get the available information was probability sampling/proportional stratified sampling depending on the extent of distribution of parthenum weeds at each kebele and „*Got'(sub kebele division* or the smaller terrestrial division for administration purpose in rural areas*)*. During this sampling process a two stage sampling was used to select sample respondents of households. Primarily three of the six rural kebeles (Metene 010, Abakolba 07 and Galesa 011) and three urban kebeles (01, 02, 04) were selected based on the higher infestation level of the areas with parthenium weed and one of the remaining rural & two of the five urban kebeles which were having low infestation of the weed were identified to determine the number of sample respondents with the exception of two rural kebeles (Mutigrar and Erfo) which are not infested with *Parthenium*. Each „*Got' (sub-kebele division)* and „*ketena'*(sub kebele division or the smaller terrestrial division for administration purpose in urban areas) was selected depending on the infestation level from each kebele. Secondly lists of household heads of each „*Got' o*f the rural kebele were taken from each kebele administration and from Ketenas of urban Kebeles of KCA, where there is *Parthenium* infestation and the samples were selected from the list of household heads based on the proportion of distribution of parthenium weed in each kebele. Among the total residents or household heads from *Parthenium* infested areas of the study area 80 samples were selected for questionnaire.

Table 1: Number of samples (household heads) from Urban and Rural kebeles

Kebele	No. of samples selected	Remark
Kebele 1	6	Urban kebele
Kebele 2	6	Urban kebele
Kebele 3	4	Urban kebele
Kebele 4	6	Urban kebele
Kebele 5	4	Urban kebele
Kebele 7 (Abakolba)	16	Rural kebele
Kebele 9 (TiyuAmba)	7	Rural kebele
Kebele 10 (Metene)	16	Rural kebele
Kebele 11 (Galesa)	15	Rural kebele
Total	80	

Sixty four (80%) of the sample respondents were male and the remaining 16 (20%) were females. In terms of educational level 18 (22%) were illiterate and 62 (78%) were literate, from grade 5 to diploma.

3.2.3.2. Purposive Sampling

Purposive sampling was applied to select a total of eight individuals (samples) for interview. Five of them were selected from the common society or farmers /key informants living for more than 30 years in the study area (age range between40-65 years old). The selection of samples was based on their awareness on the distribution or aggressive colonization of *Parthenium* on their grazing lands, agricultural fields, uncultivated areas and its impact in affecting the growth and distribution of other plants, and its negative impacts on livestock and human health. The remaining three samples for interview were experts, in which two of them are selected from Kombolcha city administration urban agricultural office and one from Kombolcha plant health clinic /weed management expert which are able to give valuable information on the raised issue.

3.2.3.3. Quadrat Sampling

Quadrat sampling technique was used by taking sample quadrats at different areas or sites in the study area. The sample sites for quadrats were selected based on infestation level. Highly infested areas from different regions of the study area were selected for quadrats. Five sample sites were selected for quadrat sampling. These sample sites for quadrat were from uncultivated areas (located, 11˚06'N and 39˚43'E), cultivated or farm areas (11˚06' N and 39˚46'E), grass lands (11˚03' N and 39˚44'E), river banks (11˚05'N and 39˚43'E) and road sides (11˚05' N and 39˚41'E). The above locations of the sample sites were identified by GPS and are indicated on the map of the study area below which is drawn using Arc GIS soft ware, version 10.2.

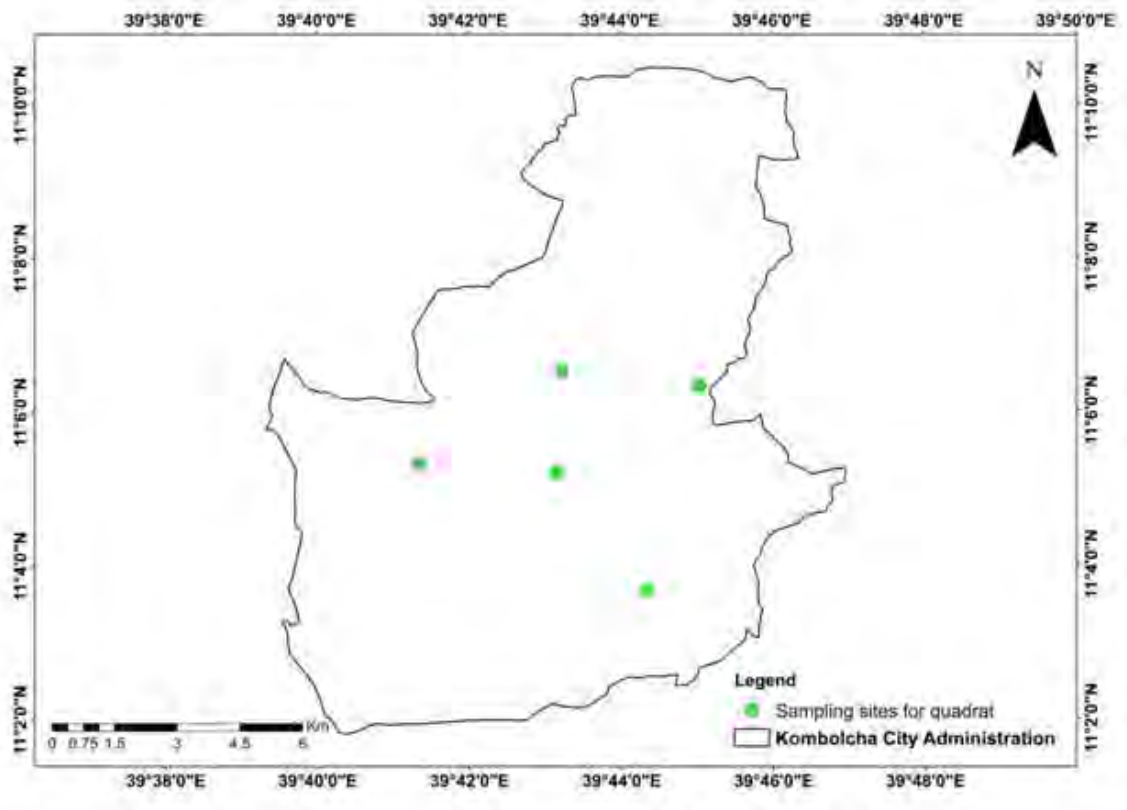

Figure 8. Map of Sampling Sites for Quadrat in the Study Area

Forty quadrats were used from the different sample sites; five quadrats from each sample site were taken. Each quadrat was 1 m by 1m area /1m^2. (Source: Methods in EEC (BIO 221B),Dr. Jim Baxter). All the plants that were found in each quadrat were counted by recording each type of plant species and their number including *P.hysterophorus*.

- The different species of plants that were counted and recorded were identified by the researcher using the books called flora of Ethiopia, Honeybee flora of Ethiopia, Herbs and shrubs, and using identified preserved weed and grass species in Kombolcha plant health clinic, that are identified by the experts of the clinic.
- Some of the counted plants in which their scientific names were not identified were preserved and identified in the National herbarium of Ethiopia Addis Ababa University.

A

B

*A=at river bank *B=at grass land

Figure 9. Quadrate sampling; Counting and recording the different species of plants, (Source: Photos during counting and recording in quadrate sampling, April, 2016**)**

The number of individual plant species of each quadrate is important to characterize the density of parthenium weed and to identify how much it affects the growth of other plants in *Parthenium* infested regions of the study area. The diversity and species evenness were analysed using Shannon‟s diversity index, based on the data from quadrats.

3.3. Data Analysis

The responses of sample respondents from the questionnaires were tabulated. The tabulated responses and the survey /observation made on the overall impact of *Parthenium* were analyzed using different statistical tools and with the help of SPSS (statistical program for social sciences) v.21 soft ware and interpreted. Hence, descriptive statistical tools as frequency and percentage were used to interpret the quantitative data. The diversity of species in *Parthenium* infested sample sites selected for quadrats from the study area were compared using Shannon diversity index ($H' = -\sum Pi \ln (pi)$) to assess the impact of parthenium on the growth and distribution of other plants.

$$H' = -\sum Pi \ln (pi)$$

Where: H‟= Shannon‟s diversity index

∑= Summation

Pi= the proportion of individuals of the i^{th} species

ln= log base 10

The species evenness was also calculated based on the results obtained from Shannon‟s diversity index as: '

$$E = \frac{H'}{H'max}$$

Where:

E=Evenness

H‟=Shannon‟s diversity index

H_{max}=Maximum diversity possible

The average stem length & stem width of tomatoes (*S. lycopersicunm*) in both parthenium infested and parthenium free plots of the experiment were calculated by using one of the measures of central tendency the Mean.

$$\overline{X} = \frac{\sum_{i=0}^{n} Xi}{N}$$

Where:

$\overline{X}$ = Mean

∑ = Summation

X_i = Individual value of X

N = Total number

To see whether there is significant difference or not on the growth of tomato plants between plot I (experimental group) and plot II (control group) paired samples T-test were used and the significant values are interpreted.

CHAPTER 4

4. Results and discussions

4.1. Spread and Distribution of Parthenium Weed

4.1.1. Introduction and Spread of Parthenium Weed

Regarding the time of introduction of *P. hysterophorus* in to the study area, residents/sample respondents varied considerably on their perception. According to responses from questionnaires, 50% of the sample household heads and all the interviewees pointed out that *P.hysterophorus* infestation of Kombolcha city administration took place at the beginning of 1990s, but 36.3% of the respondents also suggested that parthenium weed had been introduced to kombolcha city administration in 1980s (see figure 10 below).

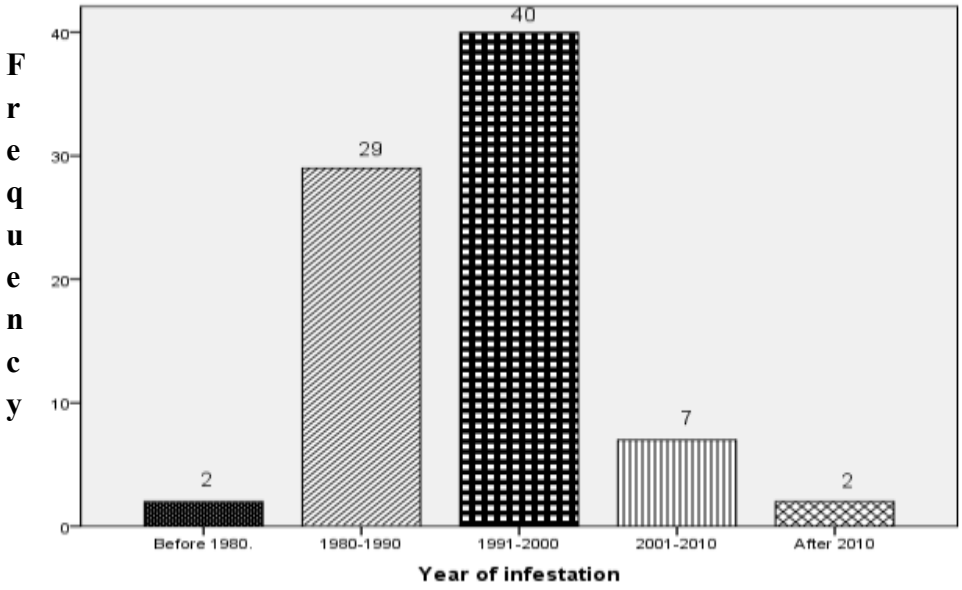

Figure 10. Time of introduction of *P.hysterophorus* in to the study area (Kombolcha city administration)

Additionally, the interviewed samples (Key informants and experts) expressed that *Parthenium* first appeared in the study area, around the old air port, RRC /Relief and

rehabilitation Center (Kombolcha branch) and along the road sides to the entrance of Kombolcha town from Addis Ababa. They also revealed that the weed had been spread in an alarming rate to Metene, Abakolba, Galesa kebeles (West,North and North west of Kombolcha town, respectively), along the sides of Borkena River, in uncultivated areas and along the road sides to the new Kombolcha airport. This idea is in agreement with the idea forwarded by Riaz and Javaid, (2011); Shabbir et al., (2012) which stated that, *Parthenium* is a weed along roadsides, on wastelands and in certain cropping and grassland regions where it negatively affects agricultural production and reducing native plant biodiversity.

Around fifty one percent (51%) of the respondents and most interviewees pointed out that the introduction of *P.hysterophorus* to the study area was mainly through grain aids imported from abroad and 33.9% of the respondents also suggested that it introduced through vehicles crossing the area. Some respondents (10.4%) also responded that the cause for its entrance is unknown (See Table 2 below). Based on the result shown in the table below it is possible to deduce that the weed had been introduced to the study area through grain aids imported from abroad and by using vehicles as agent of entrance to the study area.

Table 2. The causes for the introduction of *Parthenium* to the study area

Causes of introduction	Number of respondents	Percent
Through grain aids	59	51.3
Through vehicles	39	33.9
The cause is unknown	12	10.4
Others	5	4.3
Total	115	100.0

Most of the respondents (around 82 %) suggested that the suitable areas for infestation & high distribution of parthenium weed are mainly uncultivated areas, grazing areas (grass lands), road sides, river banks and farm areas. This is in agreement with what Shabbir et

al. (2012) reported that *Parthenium* is a weed along roadsides, on wastelands and in certain cropping and grassland regions where it negatively affects agricultural production and reducing native plant biodiversity (see figure 11 below).

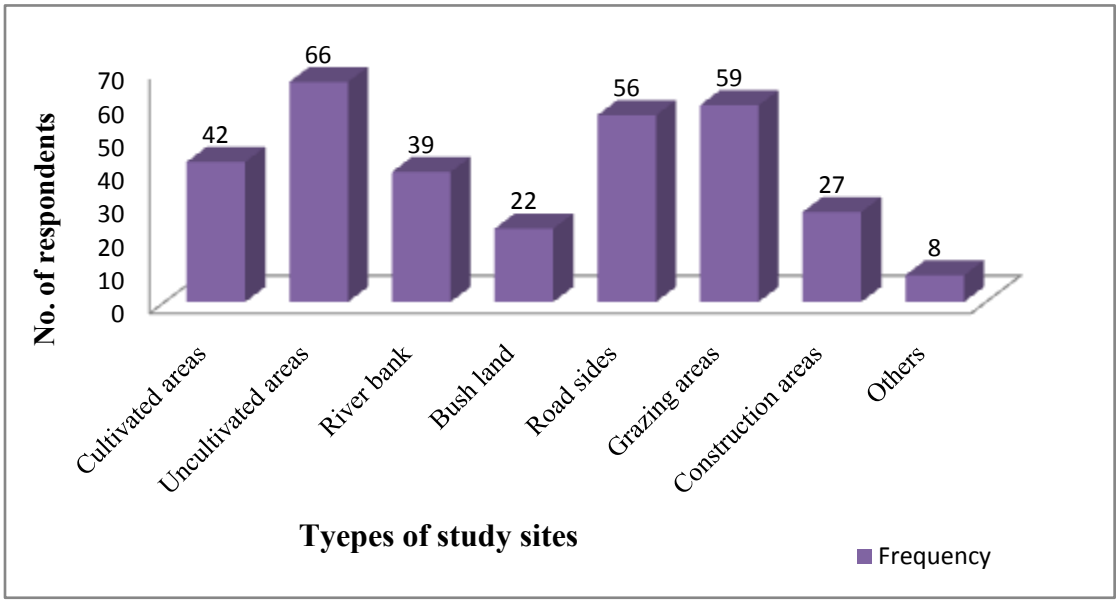

Figure 11. Types of areas suitable for the distribution of *Parthenium* in KCA

Based on the above data, the sequence of rate of infestation of parthenium weeds in the study area were uncultivated areas, grazing areas, road sides, cultivated /farm areas, river banks, around construction sites and bush lands, respectively from higher infestation to lower infestation level.

In relation to the distribution and impacts of *Parthenium* at different sites of the study area, a total of 37 species were identified from the data obtained from quadrats (See table 3 below) to study the distribution and impacts of parthenium weed in the study area. The data were taken from different sample sites in the study area using quadrats from road sides, river banks, uncultivated areas, cultivated areas and grass lands. Eight quadrats were taken from each sample site and the different species of plants were counted and recorded.

Digitaria abyssinica and *Cynedon species* in road sides, *Bidens pilosa* and *Digitaria abyssinica* around river banks, *Cynedon species, Snowdonia polystachia, Verbena*

officinalis in uncultivated areas, *Eragrostis tef* and *Cynedon species* in cultivated (farm) areas and *Cynedon species* in grass lands (grazing areas) were more common when compared with the other species of plants in each sample site with the exception of *P.hysterophorus. Parthenium* comprised 43.05% of the total number of species in the infested sample sites in the study area, the other species (36 species) of plants comprised only about 56.95% of the total number of species as recorded in the sample sites selected for quadrats.

Table 3. The data obtained from quadrats

No.	Species name	Number of each species in each sample site					No. of individuals
		Road sides	River banks	Uncultivated areas	Cultivated areas	Grazing areas	
1	*Achyranthes aspera*	0	20	16	12	0	48
2	*Amaranthus spinosus*	0	0	15	0	13	28
3	*Andropogon abyssinicus*	10	0	0	0	0	10
4	*Argemone mexicana*	10	9	30	0	0	49
5	*Bidens pilosa*	25	74	18	0	65	182
6	*Brachiaria species*	0	6	14	0	0	20
7	*Calotropis procera*	0	0	0	0	20	20
8	*Capsella bursa*	24	10	0	0	0	34
9	*Commelina latifolia*	11	0	5	0	7	23
10	*Convolvulus arvensis*	15	0	0	0	0	15
11	*Conyza bonariensis*	0	30	0	0	0	30
12	*Cynedon spp.*	131	25	138	50	316	660
13	*Cyperus esculentus*	0	0	0	0	47	47
14	*Cyperus rotundus*	0	0	0	0	6	6
15	*Datura stramonium*	29	14	8	0	0	51
16	*Digitaria abyssinica*	275	78	0	0	55	408
17	*Dinebra retroflexa*	0	15	0	0	0	15
18	*Eleusine floccifolia*	30	0	0	0	62	92
19	*Eragrostis tef*	0	0	0	125	0	125
20	*Erucastrum abyssinicum*	0	0	0	0	23	23
21	*Galinsoga parviflora*	4	0	9	0	0	13
22	*Hyparrahenia antistroidas*	0	0	0	0	65	65
23	*Justicia schimperiana*	25	10	35	0	5	75
24	*Lantana camara*	7	5	5	0	0	17
25	*Medicago polymorpha*	12	0	20	0	40	72
26	*Parthenium hysterophorus*	425	328	654	155	502	2064
27	*Phalaris pharadoxa*	0	0	32	0	35	67
28	*Sesbania sasban*	0	10	0	0	25	35
29	*Snowdenia polystachya*	0	10	72	8	13	103
30	*Solanum indicum*	5	18	19	0	10	52
31	*Sonchus asper*	18	0	8	0	0	26

32	*Sorghum bicolor*	0	0	8	36	0	44
33	*Staria pumila*	0	9	25	0	0	34
34	*Trifolium rueppellianum*	25	0	0	0	64	89
35	*Verbena officinalis*	0	0	63	0	36	99
36	*Xanthium strumarium*	0	0	15	0	10	25
37	*Xanthium spinosum*	9	0	19	0	0	28
	Total	1090	671	1228	386	1419	4794

Parthenium is more abundant and had the highest density from all the species of plants identified in all sample sites of infested areas. Based on the results obtained from Shannon‟s diversity index, the computed values of each sample site was 1.926 (Road sides), 1.911(River banks), 1.899(Uncultivated areas), 1.405(Cultivated or farm areas) and 2.196 (Grazing areas) which are low values except for grazing areas (see Appendix III). These values indicate that the diversity of species in the sample study sites is low, except in grazing areas (2.196). According to Kent and Coker (1992), the Shannon-Weiner diversity index normally varies between1.5 and 3.5 and rarely exceeds 4.5. Shannon diversity index is high when it is between 2.0 and 3.0, low when between1.0 and 2.0 and very low when it is smaller than 1.0. Therefore, since the computed values of Shannon's diversity index for the above data are low, this low species diversity in the sample sites shows that, few species or one species dominate *Parthenium* infested regions of the study area. The values for species evenness (0.54, 0.53, 0.53, 0.39, and 0.61) also show that species evenness is low in the sample sites of the study area because high evenness is closer to the value of 1.0. From the data in table 3 above, over closely 49 % of the individuals in river bank site and around 53 % of the individuals in uncultivated site belong to one species, *P. hysterophorus* in *Parthenium* infested area. This domination of areas with one or few species leads to the loss of other species of plants in the infested areas which directly affects ecosystem and biodiversity.

In relation to the distribution of parthenium weed at the different sample sites of the study area, it was highly distributed in uncultivated areas, grass lands, along road sides, river banks and cultivated areas, respectively from its higher distribution in the infested areas. This result (from quadrat sampling) is in consistent to the results obtained from respondents of questionnaires and interviewees with the exception of reversal of sequences between river banks and cultivated (farm) areas.

4.1.2. Agents for the Distribution of *Parthenium*

According to the responses from sample respondents and interviewees, parthenium weed had distributed to the different Kebeles of the study area through wind, water current, vehicles, animals and humans (See table 4 below). The high distribution that occurs in uncultivated areas may be through wind and animals, through water along river banks, through vehicles along road sides, through animals‟ dung & animals' movement in grazing areas.

Table 4: Methods of the distribution of parthenium weed

Methods of distribution	Number of respondents	Percent	Cumulative Percent
Through animals	56	21.1	21.1
Through vehicles	42	15.8	37.0
Through humans	33	12.5	49.4
Through wind	54	20.4	69.8
Through water current	58	21.9	91.7
Through construction materials	22	8.3	100.0
Total	265	100.0	

4.1.3. Causes for the Fast Distribution of Parthenium

Based on the response of sample respondents and the reconnaissance survey made by the researcher at the beginning of the study, the rate of the current distribution of parthenium weed in the study area is *high* mainly at Metene, Abakolba, Galesa Kebeles and open spaces in the town (urban Kebeles) as in Kebele 1 (Abisha ager), Kebele 2 (kuas meda), Kebele 4 (Ayer marefia, Kuteba and Cherkacherk). Also, there is high distribution around Borkena river bank, and around entrance and exit of the main road from Addis Ababa that crosses Kombolcha town.

The respondents and most interviewees revealed that the high and fast distribution of parthenium weed was due to; the ability of the seed to stay for longer period of time in the soil without becoming damaged, its ability to out compete native plant species which leads to dominate the area by damaging them, its ability to withstand drought which helps the weed to survive when there is scarcity of water, grow and reproduce in low moisture, its ability to grow in different soil types which enables it to grow everywhere and its high reproductive ability by producing large number of seeds at a time (see table 5 below). Similar investigation in relation to its fast distribution (aggressiveness) based on its reproductive ability is given by Pandey and Dubby (1989); McFadyen (1992), which stated that the success of *P.hysterophorus* as an aggressive weed lies on its reproductive ability, four or more successive cohorts were known in a single season.

Table 5: The main causes for high and fast distribution of parthenium

Causes for high distribution	Number of responses	Percent	Cumulative Percent
Ability of the seed to stay longer in soil	52	19.6	19.6
Its ability to withstand drought	58	21.8	41.4
Its ability to outcompete native plant species	35	13.2	54.6
Its ability to spread in many ways	45	16.9	71.5
Its high reproductive ability	44	16.5	88.0
Its ability to grow in different soil types	32	12	100.0
Total	266	10 0.0	

Additionally, the respondents suggested that the other reason for its high & fast distribution in the study area is due to lack of taking control and prevention measures by the residents and concerned bodies. In this case, unless effective measures will not take place by creating awareness about the negative impacts of parthenium weed to the residents and other stakeholder, the ecosystem will be changed and covered with *Parthenium.*

4.1.4. Respondents' perceptions about *P.hysterophorus* invasion

Majority of the household heads (respondents) had admitted that, they weren‟t sufficiently aware of the negative impacts of parthenium weed on biodiversity, and also the local community. That is, the extent of awareness of the residents on its negative impact was low (not high) as around 66 % of the respondents agreed (see table 6 below).

Table 6: Extent of awareness on the negative impact of parthenium

Level of awareness	Number of respondents	Percent	Cumulative Percent
High awareness	22	27.5	27.5
Sufficient awareness	5	6.3	33.8
Low awareness	53	66.3	100.0
Total	80	100.0	

This situation or lack of sufficient awareness in the society on the negative impacts of parthenium weed on biodiversity, human and animal health have had its influence on the residents in relation to taking progressive measures in controlling the fast spread of parthenium weed. Therefore, sufficient awareness may have to be created to the residents particularly for farmers and other stakeholders to control the distribution of this invasive weed.

Closely seventy four percent (73.8%) of the respondents pointed out that *P.hysterophorus* has no benefit (use) for humans & biodiversity (see Appendix IV). But 26.2% of the respondents for questionnaire and all the interviewed experts suggested that *Parthenium* had its own benefits to the ecosystem, by being used to control soil erosion, serve as wind break and used as fodder for animals when there is lack of forage or during dry seasons. Therefore, even if parthenium weed is highly aggressive as well as invasive weed, it has also positive impacts on the ecosystem in relation to the response of the experts.

4.2. Impact of Parthenium Weed

4.2.1. Impact of *Parthenium* on Growth and Distribution of Plants

All the sample respondents (100%) pointed out that *P.hysterophorus* (*kinche arem*) affected the growth and distribution of other native plant species in the infested areas (see Appendix V). They also suggested that the extent of its effect on the growth & distribution of other plants is very high.

Majority of the respondents (i.e. 68.8%) pointed out and confirmed that the growing form of parthenium weed has the greater negative impact in affecting the growth & distribution of other plants in *Parthenium* infested areas (see table 7 below), which in turn affects ecosystem and biodiversity. However, 31.2% of the sample respondents revealed that both growing and dried forms of *Parthenium* affects the growth of plants. The growing form of *Parthenium* is the weeds which is alive and grow in the infested areas currently, and the dried form is those that had been died and accumulated (found) in the infested areas.

Table 7: The form of parthenium that affects the growth of plants

Form of parthenium	Number of respondents	Percent	Cumulative Percent
Growing form of Parthenium	55	68.8	68.8
Both growing &dried forms	25	31.3	100.0
Total	80	100.0	

The growth form of parthenium weed competes for resources with the other plants that grow in the infested areas which causes lack of resources or nutrients which later affects the growth and distribution of native species. It also results shading effect on other plants that grow beneath it and inhibit their growth; additionally, there would be other factors that could affect the growth and distribution of other native plant species which needs further investigation.

In *Parthenium* infested areas, the presence of the weed *highly* affects the growth and distribution of different plants (see Appendix VI). According to sample respondents and key informants for interview, crop plants, grasses and vegetables are greatly affected by parthenium weed, respectively, from seriously damaged to mild (see Appendix VII). Different types of crop plants are affected by *Parthenium* infestation. However, among the crop plants which are commonly grown in the study area, the respondents and interviewees revealed that wheat, *teff*, barely, oat, and chickpeas are highly affected, and crop plants as maize and sorghum are averagely affected by the weed. But Aneja, (1999) and Tamado *et.al*. (2002) reported that, in India, *P. Hysterophorus* causes a yield decline of up to 40% in agricultural crops. Sorghum (*Sorghum bicolor* L. Moench) grain yield losses between 40 and 97% have been reported in Ethiopia if *Parthenium* is left uncontrolled throughout the season, which shows that Sorghum is largely affected by *Parthenium* unlike the result of this study. Hence, monocot cereal plants are largely influenced by parthenium weed than other crop plants in the study area which are main sources of food or diet by the community.

Respondents revealed that fruits as orange, mango, banana, papaya and guava that grow in the study area are affected less by parthenium weed when compared with the impact on vegetables (see Appendix VIII). Vegetables such as tomato, salad, carrot, onion, pepper, cabbage and potato are highly affected with parthenium weed (see figure 12 below).

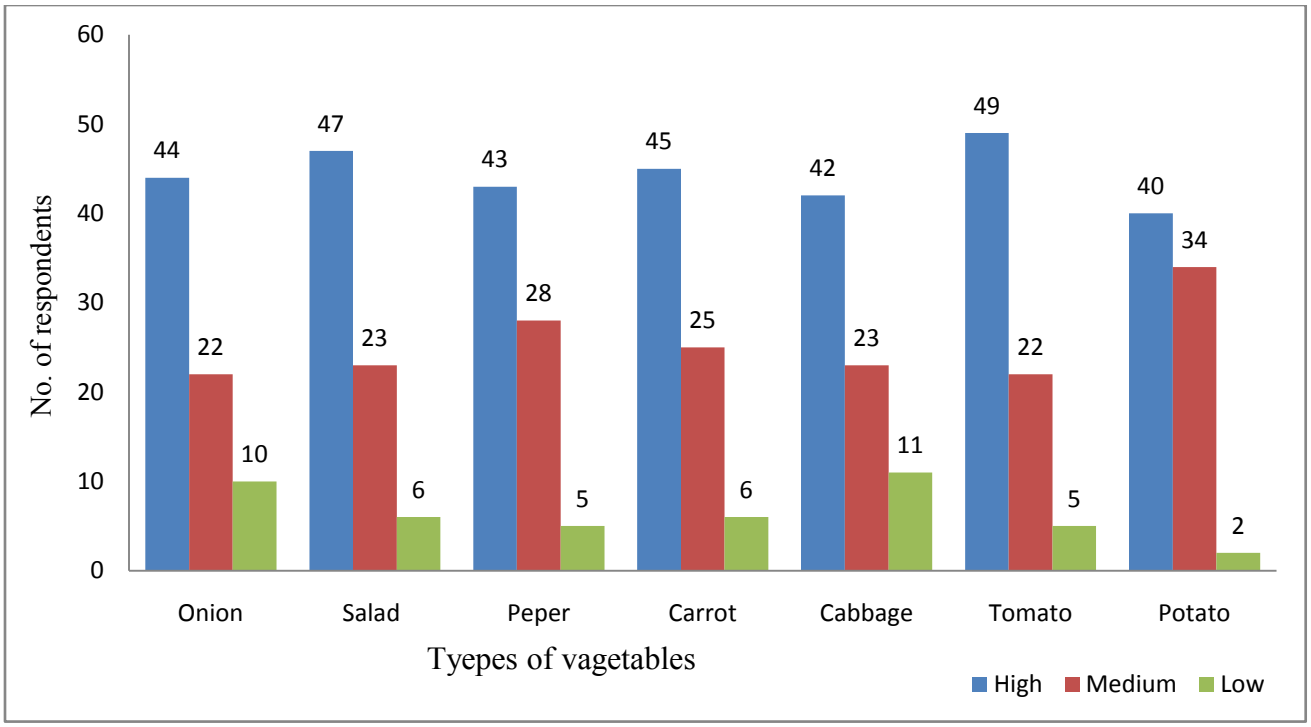

Figure 12. Number of respondents who rated impact of parthenium on vegetables

These plants (vegetables) are the main sources of income for farmers that live in the rural areas of Kombolcha city administration. Therefore, the reduction in growth and productivity of these plants affected the livelihood of the society, i.e. it affects income level of the residents (farmers) in the infested areas. Among these vegetables tomato takes the highest rank of being affected by *Parthenium* (see figure 12 above).

4.2.1.1 The Impact of *Parthenium* on Growth and Productivity of Tomato

Based on the experiment carried out on the impact of *P.hysterophorus* on the growth and productivity of plants, the test species (tomato plants) that were planted in two plots (plot I, i.e. experimental group, and plot II, i.e. control group) were measured immediately after being transplanted and later after two months of growth. The stem length (height) and stem width were measured and the values were recorded as shown in the table below.

Table 8: Stem lengths and stem widths of the tomato plants during transplanting and after two months of growth in experimental & control plots

Plot I							Plot II						
Tomato plant	Stem length in cm.			Stem width in cm.			Tomato plant	Stem length in cm.			Stem width cm.		
	DT	ATM	Df	DT	ATM	Df		DT	ATM	Df	DT	ATM	Df
1	7.5	55	47.5	0.25	0.8	0.55	1	6	69	63	0.3	1.0	0.7
2	6.5	51	44.5	0.2	0.7	0.5	2	6	55	49	0.25	0.6	0.35
3	6.5	37	30.5	0.2	0.5	0.3	3	6.5	72	65.5	0.2	0.9	0.7
4	7	32	25	0.25	0.6	0.35	4	6	59	53	0.25	0.9	0.65
5	6	48	42	0.3	0.8	0.5	5	7.5	68	60.5	0.2	1.1	0.9
6	6.5	61	54.5	0.2	1.0	0.8	6	7.5	64	56.5	0.2	1.0	0.8
7	7	49	42	0.25	0.7	0.45	7	6.5	57	50.5	0.2	0.8	0.6
8	6.5	56	49.5	0.25	0.7	0.45	8	6.5	78	71.5	0.3	1.1	0.8
9	6.5	63	56.5	0.3	0.8	0.5	9	6.5	66	59.5	0.25	0.9	0.65
10	6	55	49	0.2	0.9	0.7	10	7	72	55	0.25	1.0	0.75
11	7.5	54	46.5	0.25	0.7	0.45	11	6	68	62	0.3	0.9	0.6
12	7	56	49	0.25	0.6	0.35	12	7	73	66	0.2	1.2	1.0
Total	80	617	537	2.9	8.8	5.9		79	801	722	2.9	11.4	8.5
Mean	6.67	51.4	44.75	0.24	0.73	0.49		6.58	66.5	60.17	0.24	0.95	0.71

* DT= During Transplanting, *ATM=After Two m=Months *Df= Difference

During transplanting, the stem length of tomato plants of plot I and plot II was almost the same, because the mean stem length of both plots were nearly equal (i.e. 6.67cm and 6.58cm,with only 0.09 cm variation). After Two Months (ATM) of transplanting, the stem growth of the test plants in *Parthenium* containing plot (Plot I) was affected by 22.97% when compared with the stem length of tomatoes grown in *Parthenium* free plot (Plot II) based on the data shown in table 8 above. On the same data, paired samples T-test was applied to reveal the significant difference between the two plots.

According to this test, the significant value for the two plots during transplanting (DT) was 0.660(see Appendix IX) which is greater than the significant level ($p>0.05$),

therefore, there is no mean difference in stem length during transplanting of tomato plants between plot I and plot II, i.e. there is no significant difference between the experimental and control group during transplanting. But when the data obtained After Two Months (ATM) of transplanting were applied to paired samples T-test, p value becomes less than the significant level ($p<0.05$) which is 0.000 (see Appendix X). This shows that there is significant difference between test plants of plot I and plot II. Therefore, these result showed that *Parthenium* had affected the growth of tomato plants in the experimental group (plot I).

The stem width of the tomato plants also affected by parthenium weed by 22.8% in *Parthenium* containing plot compared with tomatoes grown in *Parthenium* free plot or control group, based on the data obtained from the experiment. Likewise, when these (the same) data had been applied to paired samples T-test, the computed significant value (p-value) becomes 0.003(see Appendix XI) which is less than 0.05($p<0.05$). The significant value $p<0.05$ for stem width of the test plants or tomatoes shows that, there is significant difference between the stem width of the test plants in plot I & plot II. This result also indicates that *Parthenium* had affected the development of stem width of the test plant in plot I when compared with plot II.

At harvesting, based on the measured values of the fruits of tomato, there was also significant difference between the fruits of tomato from *Parthenium* containing plot (plot I) and *Parthenium* free plot (plot II). The largest fruit from *Parthenium* containing plot measured 85 grams and from *Parthenium* free plot measured 105 grams. It had 20 grams variation. When the total amount of fruits of tomato were measured after harvesting the ripened fruits at a time from both plots separately, the total mass of tomatoes from plot I measured 3.5kgs and from plot II (control group) measured 4.9kgs. The mass or weight of fruits of tomato from *Parthenium* containing plot is lower by 28.57% than tomato fruits from *Parthenium* free plot. Therefore, *P.hysterophorus* has also the ability to affect quantitative yield of tomato plants. This result is in consistent with the analysis given by Nitshanthan et al. (2013), which stated that the average fruit weight in the *Parthenium* site was the lowest when compared with *Parthenium* free site.

Parthenium weed also affected the growth of other weeds in the study (experimental) plot. As counted from *Parthenium* free plot after two and half months of transplanting, a total of 406 weeds of mainly three species were grown in *Parthenium* free plot (plot II) and a total of 289 weeds of the same species in *Parthenium* containing plot (plot II).

Table 9. Types and number of weeds grown in plot I and plot II

Type of weed	Number of weeds in plot I	Number of weeds in plot II
Galinsoga parviflora	214	188
Amaranthus hybridus	139	63
Snowdonia polystachya	46	34
Others	7	4
Total	406	289

The number of weeds grown in *Parthenium* containing plot was less than weeds grown in *Parthenium* free plot. This result showed that the weed has the ability to influence the growth of other weeds in *Parthenium* infested areas.

4.2.2. Impact on Animals (Livestock)

Eighty eight percent (88%) of the sample respondents and most of the interviewed key informants and experts pointed out that the livestock feed (forage) is not adequate in their area (see Appendix XII). They also suggested that the main cause for inadequacy or reduction of livestock feed in the study area was due to the high infestation level of parthenium weed (see Appendix XIII). Due to this, the area became over grazed. The grass species in the grazing areas diminished and became dominated by the parthenium weed. Therefore the animals (livestock) are now forced to feed on parthenium. Based on the survey on animals that feed on *P. hysterophorus* and the responses of interviewed samples, most animals depend to feed on the leaves and younger parts of the shoot of this weed. When the animals feed on *Parthenium*, it affects the quality and quantity of livestock products as milk and meat (see table 10 below).

Table 10. The main negative effects of *Parthenium* on animals in the study area

Impacts	No. of respondents	Percent	Cumulative Percent
Reduce the quantity of livestock product	45	20.9	20.9
Reduce the quality of livestock products	51	23.7	44.7
Declines the reproduction of livestock	9	4.2	48.8
Reduce livestock feed (forage)	62	28.8	77.7
Causes different diseases to livestock	48	22.3	100.0
Total	215	100.0	

The respondents and interviewees also suggested that parthenium weed affect the health of animals that feed in the infested areas. According to them, the animals that feed in *Parthenium* infested areas suffered from itching and wound that occurred on their skin. In agreement with this result, Lakshmi and Srinivas (2007) stated that parthenium weed is toxic to animals causing dermatitis with pronounced skin lesions on various animals including horses and cattle.

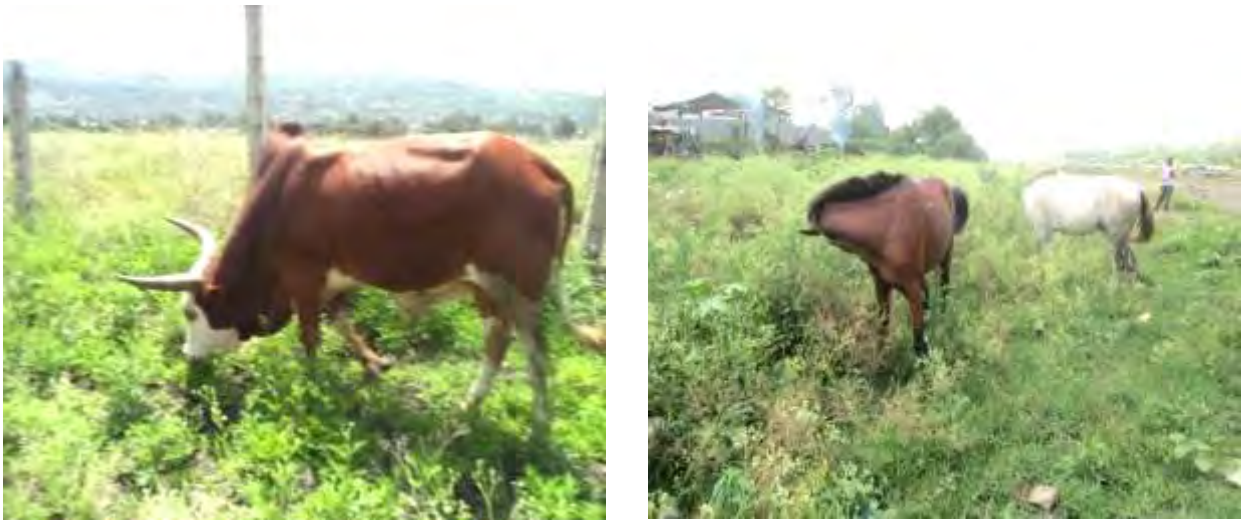

Figure13. Animals feeding in parthenium infested area. (Source: Photos during survey, September, 2015)

The sample respondents and interviewed samples revealed that among the different domestic animals that live and feed in *Parthenium* infested regions of the study area, the main domestic animals which are largely affected by the impact of this weed are cattle, sheep, goats and horses respectively.

In relation to the impact of parthenium weed on wild animals, about 92% of the respondents pointed out that they haven‟t seen wild animal which were affected by parthenium weed (see Appendix XIV). The remaining sample respondents suggested that they have observed wild animals which were affected by the infestation of the weed, such as foxes, birds and rabbits. From this, it can be inferred that parthenium weed had no significant impact on wild life in the infested areas.

4.2.3. Impacts on Humans

Majority of the respondents for questionnaires and the interviewed key informants and experts suggested that parthenium weed causes different diseases to the communities living in the infested areas. As suggested by 55.5% of the respondents, people living in the infested areas and those who do have contact with parthenium weed are largely affected by dermatitis or skin allergy(see table 11 below). Their skin had wounded and it results itching. Similar investigation in Australia showed that many individuals were

affected by dermatitis through human population density in the parthenium affected area (McFadyen, 1992). Additionally, 38.3 % of the respondents revealed that it also caused disease of the respiratory system called asthma (see table 11 below).This is also in consistent with the investigation of Holm et al. (1997) which stated that *Parthenium* is a weed of global significance responsible for severe human and animal health issues, such as dermatitis, asthma and bronchitis. In Ethiopia, it was reported that individuals who remove parthenium weed with hands in infested crops suffer from dermal allergy, fever, and asthma (Taye, 2002).

Table 11. Kinds of human disease caused by *Parthenium* in the study area

Diseases	No. of respondents	Percent	Cumulative Percent
Dermatitis or allergy	71	55.5	55.5
Asthma	49	38.3	93.8
Diarrhoea	8	6.3	100.0
Total	128	100.0	

4.2.4. Impact on Biodiversity

According to the interview made with key informants of the study area and experts from Kombolcha urban agricultural office and weed expert from Kombolcha plant health clinic, the infestation and distribution of parthenium weed was mainly aggravated by the aid of different dispersal agents as animals‟ dung, animals‟ movements, wind, vehicles, and water current and human activities. As mentioned previously *P.hysterophorus* affected the local biodiversity at different regions in KCA as in uncultivated areas, road sides, river banks, cultivated areas and grass land (grazing areas). In *Parthenium* infested areas the weed reduced the total biodiversity of the study area by reducing their distribution, abundance & by changing the ecosystem, because when grazing areas are invaded with parthenium weed it reduced growth and abundance of the different species

of grasses and leading the area to be dominated by the weed. This in turn affected the survival and productivity of livestock. Therefore, *Parthenium* does have high negative impact on species richness and species evenness in the infested areas. Kohli et al., (2004) reported that three exotic weeds including parthenium adversely affect the structural composition and dynamics of the diversity of the native flora.

4.3. Impacts of *Parthenium* on Productivity of Plants and Animals

4.3.1. Impact on Productivity of Plants

Almost ninety nine percent (98.8 %) of the sample respondents and all of interviewed key informants and experts agreed that parthenium weed has affected the productivity of crop plants in the past ten years in the study area (see appendix XV). The respondents also pointed out that parthenium weed affects the productivity of plants in different ways (see table 12 below), such as by reducing growth of crop plants (36.1% of the respondents) i.e. crop plants would have stunted growth than those that grow in non infested farm lands, by reducing the quality of crops (size of seeds) as responded by 31.7% of the respondents and by reducing the quantity or yield of crops (32.2% of the respondents). Therefore, the responses confirmed that parthenium weed reduced the productivity of crop plants or yield of plants in the study area in the past 10 years. Similar investigation showed that the presence of parthenium weed in irrigated sorghum in India reduced grain yields from 6.47 to 4.25 tons/ha (34.3%) and decreased grain weight by 30% (Channappagoudar *et al.,* 1990). Thus parthenium weed had greater impact in affecting the quality and quantity of crop plants in *Parthenium* infested areas

Table 12. Perception of respondents on the effect of *Parthenium* on crop plants

Ways of impact	No. of respondents	Percent	Cumulative Percent
By reducing the quality of crops (size of seeds)	58	31.7	31.7
By reducing the quantity of crops	59	32.2	63.9
By affecting the growth of crop plants	66	36.1	100.0
Total	183	100.0	

The reduction on productivity of crop plants will affect the food security status of the family and as a whole the food security of the society in *Parthenium* infested regions of the study area.

4.3.2. Impact of *Parthenium* on Animals' Productivity

Infestation of parthenum weed had also a great impact on the productivity of animals (domestic animals). The respondents pointed out that the extent of its impact is *high* as 56.3% of the respondents suggested (see Appendix XVI). According to them, the main impact of *Parthenium* on animals‟ productivity that live in the infested areas is that it affects the quality of milk and meat.

4.3.2.1 Impact of *Parthenium* on Milk Quality

Based on the data obtained from sample respondents for questionnaires (open-ended questions) and interviewees concerning the impact of parthenum weed on productivity of animals, the milk obtained from cows that feed on parthenum weed has bitter taste, this result is in agreement with the previous study of Aneja, (1991). It has also problem in the formation of yoghurt and there is change in colour of the milk. It has reduces the quantity of the milk, and additionally the calves that feed on the milk affected by parthenium suffer from diarrhoea.

Depending on the experiment carried out on milk to evaluate the effect of parthenium weed on yoghurt production and change in taste of the milk, it was found out that the milk that was milked from a cow that was kept to feed on *Parthenium* infested areas for three days was bitter in taste, its colour was also slightly changed and became yellowish white instead of the normal white colour of a milk and became unable to curdle properly to make yoghurt when it was left for three days to form yoghurt. But the milk that was milked from the same cow which was left to feed grass free from parthenium weed, the milk was not with bitter taste when tasted with the same person, no change in colour and the milk curdled properly and produced yoghurt when observed at the 3rd day. This implies that parthenum affects the formation of yoghurt and it also changed the taste (normal flavour) and colour of milk.

4.3.2.2. Impact of parthenum on meat quality

Majority of the sample respondents (as responded for open-ended questions) as well as the interviewees pointed out that parthenum affects the quality of meat. They also pointed out that the meat obtained from animals (cattle, sheep & goats) that feed on parthenum infested areas had bitter taste and affect the umami (a very savoury flavour) of meat. This result is in agreement with the idea which stated that the impact of parthenium weed on livestock production is by affecting animal health, milk and meat quality (Evans, 1997). This result needs further investigation by conducting experiment to proof the data obtained from respondents.

CHAPTER 5

5. Conclusions and recommendations

5.1. Conclusions

Parthenium hysterophorus is an alien invasive species which was first introduced to Kombolcha city administration early in 1990s through grain aids imported and vehicles crossing the area. This study tried to show that *P. hysterophorus* has been distributed in Kombolcha city administration in an alarming rate and results serious damages on biodiversity, ecosystem and affect human‟s and domestic animals‟ health living in the infested areas. It is widely distributed in uncultivated areas, grazing areas (grass lands), road sides, farmlands or cultivated areas and river banks respectively than other areas. *Parthenium* has been spread through wind, water current, vehicles, animals and humans. The main causes for its high and fast distribution is due to the ability of the seed to stay for longer period of time in the soil, its ability to out compete native plant species, its ability to withstand drought, its ability to grow in different soil types and its reproductive ability by producing large number of seeds at a time.

Parthenium weed causes significant impacts on the growth and distribution of plants and productivity of animals in KCA. The following are summarized lists of negative impacts of *P. hysterophorus* in the study area. Such as; a) affecting the growth and distribution of other plants and decrease plant diversity, b) reducing forage for livestock and decrease livestock size, c) causing health problems on humans and other animals, d) decreasing the productivity of crop plants and vegetables, e) affecting the quality and quantity of animal products as meat and milk.

5.2. Recommendations

Based on the results obtained from the study, the following recommendations are forwarded. These are:

- Long-term and wider research should be conducted on the impact of *P. hysterpohporus* on crop yield, human and domestic animals‟ health and biodiversity of native plant species.
- There should be a wider research on how to combat this invasive species and reduce its distribution and impact.
- Awareness should be created to the residents in the infested areas particularly to farmers on the negative impacts of parthenium weed on productivity of plants and animals, and on its effect on biodiversity and human health.
- Appropriate discussions should be conducted among the stakeholders (the city administration administrators, agricultural office experts, plant health clinic experts and farmers) in providing solution to control the current fast distribution of parthenium weed.

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Appendices

Appendix I. Household Questionnaire

Part I: Spread and distribution

1. When do you think that P. hysterophorus (kinche arem) was introduced in to your surrounding?
   - A. Before 1970 E.C, ☐
   - B. 1970__ 1980 E.C ☐
   - C.1981__ 1990 E.C ☐
   - D.1991__ 2000 E.C ☐
   - E. After 2000 E.C ☐
2. What could be the cause for its introduction into your surrounding?
   - A. Through emergency grain aids ☐
   - B. Through vehicles crossing the area ☐
   - C. Intentionally by humans ☐
   - D. The cause is unknown ☐
   - E. Others (Please specify) _____
3. In which types of areas does the weed can be distributed?
   - A. Cultivated areas ☐
   - B. Uncultivated areas ☐
   - C. River bank ☐
   - D. Bush land ☐
   - E. Road sides ☐
   - F. Grazing areas ☐
   - G. Construction areas ☐
   - H. Others (please specify)_____

4. Considering alternatives of question number 4, list the areas sequentially, beginning from the area where there is dense parthenium weed vegetation to the area containing sparse weed vegetation.

   i. _____

   ii. _____

   iii. _____

   iv. _____

5. What are the main ways for the distribution of partthenium (Kinche arem) in your surrounding (kebele)?

   A. Through animals ☐

   B. Through vehicles ☐

   C. Through humans ☐

   D. Through wind ☐

   E. Through water (erosion or river) ☐

   F. Others (Please specify) _____

6. How do you rate the current distribution of parthenium in your kebele?

   A. Very high ☐

   B. High ☐

   C. Average ☐

   D. Low ☐

   E. Very low ☐

7. If your answer for question no. 7 is "high" or" very high", what do you think are the main causes for such kind of high and fast distribution?

   A. Ability of the seed to stay longer in soil seed bank ☐

   B. Its ability to withstand drought ☐

   C. Its ability to outcompete native plant species ☐

   D. Its ability to spread in many ways ☐

   E. Its high reproductive ability ☐

   F. Its ability to grow in different soil types(habitats) ☐

   G. Others (please specify) _____

Part II: Impacts of parthenium weed on plants, animals and humans

8. Does the parthenium weed affect the growth and distribution of other plants?

   A. Yes ☐ B. No ☐

9. If your answer for question no.8 is "Yes", what are the main impacts of the weed on other plant species?

   i. _____

   ii. _____

   iii. _____

   iv. _____

   v. _____

10. If it affects the growth and distribution of other plants, to what extent it affects plants?

    A. Very highly ☐

    B. Highly ☐

    C. Medium ☐

    D. Lowly ☐

    E. Very lowly ☐

11. Which situation or form of parthenium affects biodiversity (plants and animals)?

    A. Growing form of parthenium ☐

    B. Dried form of parthenium ☐

    C. Both forms of parthenium affect biodiversity ☐

12. Which groups of plants are greatly affected by the growth of parthenium weed in the area?

    A. Grasses ☐

    B. Crop plants ☐

    C. Vegetables ☐

    D. Small bushes ☐

    E. Tree plants ☐

    F. Others (please specify) _____

13. Write the name of the above group of plants in order of vulnerability (from seriously damaged to mild).

i. _____

ii. _____

iii. _____

iv. _____

v. _____

14. If the weed affects crop plants, what could be the status or level of vulnerability of the following crop plants?

Types of crop plants	Level of vulnerability (damage)		
	High	Medium	Low
Sorghum			
Maize			
Teff			
Wheat			
Oat			
Barely			
Lentil			
Bean			
Pea			
Chick pea			
Other (please specify) _____			

15. Does parthenium affect fruits and vegetables?

A. Yes ☐ B. No ☐

16. If your answer for question no.16 is "Yes", show the status or level of effects on each kind of fruits and vegetables.

Fruits and vegetables Type	Level of affection (damage)		
	High	Medium	Low
Orange			
Mango			
Banana			
Papaya			
Zeytun/Guava			
Onion			
Salad			
Pepper			
Carrot			
Cabbage			
Tomato			
Potato			
Other (please specify) _____			

17. How do you rate the current negative impact of parthenium on plant species richness and species evenness in your kebele?

    A. Very high ☐
    B. High ☐
    C. Average ☐
    D. Low ☐
    E. Very low ☐

18. Is livestock feed (forage) adequate in your area?

    A. Yes ☐ B. No ☐

19. If your answer for question no.19 is "No", why is it not adequate?

    A. Due to parthenium infestation ☐
    B. Due to infestation by other weeds ☐

20. What are the main negative impacts of parthenium on animals (live stock)?

A. Reduce the quantity of live stock products ☐
B. Reduce the quality of live stock products ☐
C. Declines the reproduction of live stock ☐
D. Reduce live stock feed (forage) ☐
E. Causes different diseases to livestock ☐
F. Others (please specify)_____

21. Which types of domestic animals are greatly affected by P.hysterophorus in your surrounding? List the name of the animals sequentially in order of vulnerability. (From seriously affected to mild).

i. _____
ii. _____
iii. _____
iv. _____

22. Have you ever seen wild animals that have been affected by P.hysterophorus in your surrounding?

A. Yes ☐ B. No ☐

23. If your answer is "Yes" for question no.23, which wild animals are greatly affected?

A. Rabbits ☐
B. Hyenas ☐
C. Foxes ☐
D. Birds ☐
E. Others (Please specify) _____

24. In what way(s) parthenium weed affects the wild animals?

A. By causing disease on wild animals ☐
B. By killing them ☐
C. By reducing their fertility ☐
D. By damaging their habitat ☐
E. Other ways(please specify) _____

25. What are the main impacts (disadvantages) of the weed on the surrounding people (community)?

    A. Reduce productivity& affects the food security of the family ☐
    B. Decreases the income level of the community ☐
    C. Increases labour cost for its control ☐
    D. Causes diseases to the community ☐
    E. Causes death to the community ☐
    F. Others (Please specify) _____

26. If one of the impacts of parthenium on humans is disease, what kinds of diseases occur on humans?

    A. Dermatitis or Allergy ☐
    B. Asthma ☐
    C. Diarrhea ☐
    D. Others (Please specify) _____

Part III: Impacts on productivity of plants and animals

27. Do you think that parthenium weed affects the productivity of crop plants in the past 10 years?

    A. Yes ☐ B. No ☐

28. If the answer for question no. 28 is "Yes", how it affects crop plants productivity?

    A. By reducing the quality of crops ☐
    B. By reducing the quantity of crops ☐
    C. By affecting the growth of crop plants ☐
    D. Others (Please specify)_____

29. If it affects the productivity of crop plants, to what extent it affects the food security status of your family?

    A. Very highly ☐
    B. Highly ☐
    C. Averagely ☐
    D. Lowly ☐
    E. Very lowly ☐

30. To what extent the weed affects the productivity of animals?

A. Very highly ☐
B. Highly ☐
C. Medium ☐
D. Lowly ☐
E. Very lowly ☐

31. What are the impacts of parthenium on milk quality (productivity)?

i. _____
ii. _____
iii. _____
iv. _____

32. What are the impacts of the weed on meat quality?

i. _____
ii. _____
iii. _____
iv. _____

33. Did you were aware on the negative impacts of parthenium weed on biodiversity?

A. Yes ☐
B. No ☐

34. If your answer for question no.36 is "Yes", to what extent?

A. Highly aware ☐
B. Moderately aware ☐
C. Lowly aware ☐

35. Does parthenium weed have any use for humans or biodiversity?

A. Yes ☐ B. No ☐

36. If your answer for question no.35 is "Yes", what are the uses parthenium?

A. Used as fodder for animals
B. Serve as wind break
C. Control soil erosion
D. Increase soil fertility
E. Others(Please specify) _____

Appendix 2. Interview Guide

1. What are the most dominant alien invasive weeds in your surrounding? Among these dominant weeds which one is the most dangerous one? Why?
2. When did parthenium weed (kinche arem) introduce in to your surrounding?
3. What is the ideal situation for the parthenium weed (kinche arem) to establish & distribute itself in the area?
4. Mention the main ways of distribution of parthenium?
5. How is the current status of its distribution when compared with the past 10 years? (High /low)
6. What are the main types of plants that are largely affected by parthenium weed?
7. Mention the main types of crop plants that are highly destroyed due to the presence of parthenium weed in your surrounding?
8. What are the main types of animals that are largely affected by parthenium weed?
9. Mention the impacts of parthenium on growth and reproductivity of plants?
10. What are the main impacts of parthenium weed on animals?
11. Mention the impacts in terms of:

    Meat quality

    Milk quality and productivity

    Animals and human health

12. Does parthenium weed have any use for the community? If so mention them?

Appendix, 3 Shannon's diversity index for the data obtained from sample sites (Quadrats)

No.	Species name	Pi*ln(Pi) values in each sample site				
		Road side	River banks	Un cultivated area	Cultivated area	Grazing area
1	*Achyranthes aspera*		-0.105	-0.056	-0.108	
2	*Amaranthus spinosum*			-0.053		-0.042
3	*Andropogon abyssinicus*	-0.042				
4	*Argemon mexican*	-0.042	-0.056	-0.089		
5	*Bidens pilosa*	-0.087	-0.243	-0.063		-0.139
6	*Brachiaria species*		-0.042	-0.049		
7	*Calotropis procera*					-0.059
8	*Capsella bursa*	-0.088	-0.063			
9	*Commelina latifolia*	-0.046		-0.022		-0.026
10	*Convolvulus arvensis*	-0.056				
11	*Conyza bonariensis*		-0.139			
12	*Cynedon spp.*	-0.254	-0.122	-0.245	-0.264	-0.334
13	*Cyperus esculentus*					-0.112
14	*Cyperus rotundus*					-0.022
15	*Datura stramonium*	-0.095	-0.081	-0.03		
16	*Digitaria abyssinica*	-0.347	-0.25			-0.126
17	*Dinebra retroflexa*		-0.084			
18	*Eleusine floccifolia*	-0.097				-0.137
19	*Eragrostis tef*				-0.365	
20	*Erucastrum abyssinicum*					-0.066
21	*Gelinsoga parviflora*	-0.022		-0.035		

22	*Hyparathenia anthistroidas*					-0.142
23	*Justitia schimperiana*	-0.087	-0.063	-0.1		-0.017
24	*Lantana camara*	-0.031	-0.035	-0.022		
25	*Medicago polymorpha*	-0.049		-0.066		-0.1
26	*Parthenium hysterophorus*	-0.367	-0.349	-0.336	-0.366	-0.367
27	*Phalaris paradoxa*			-0.095		-0.092
28	*Sasbania sasban*		-0.063			-0.072
29	*Snowdonia polystachya*		-0.063	-0.167	-0.081	-0.042
30	*Solanum indicum*	-0.026	-0.097	-0.063		-0.035
31	*Sonchus aspera.*	-0.069		-0.031		
32	*Sorghum bicolor*			-0.031	-0.221	
33	*Stria pumila*		-0.056	-0.078		
34	*Trifolium rueppellianum*	-0.087				-0.139
35	*Verbena officinalis*			-0.152		-0.092
36	*xanthium strumarium*			-0.053		-0.035
37	*Xanthium spinosum*	-0.034		-0.063		
	Total	-1.926	-1.911	-1.899	-1.405	-2.196
	Shannon‟s diversity index ($H_{,,}$)	1.926	1.911	1.899	1.405	2.196
	Mean ($\bar{X}$)	0.54	0.53	0.53	0.39	0.61

Appendix IV. Responses of respondents on the use of *Parthenium* for humans or biodiversity

	Frequency	Percent	Cumulative Percent
Yes	21	26.3	26.3
No	59	73.8	100.0
Total	80	100.0	

Appendix V. Perception of respondents toward the effect of Parthenium on the growth and distribution of other plants

	Frequency	Percent	Cumulative Percent
Yes	80	100.0	100.0

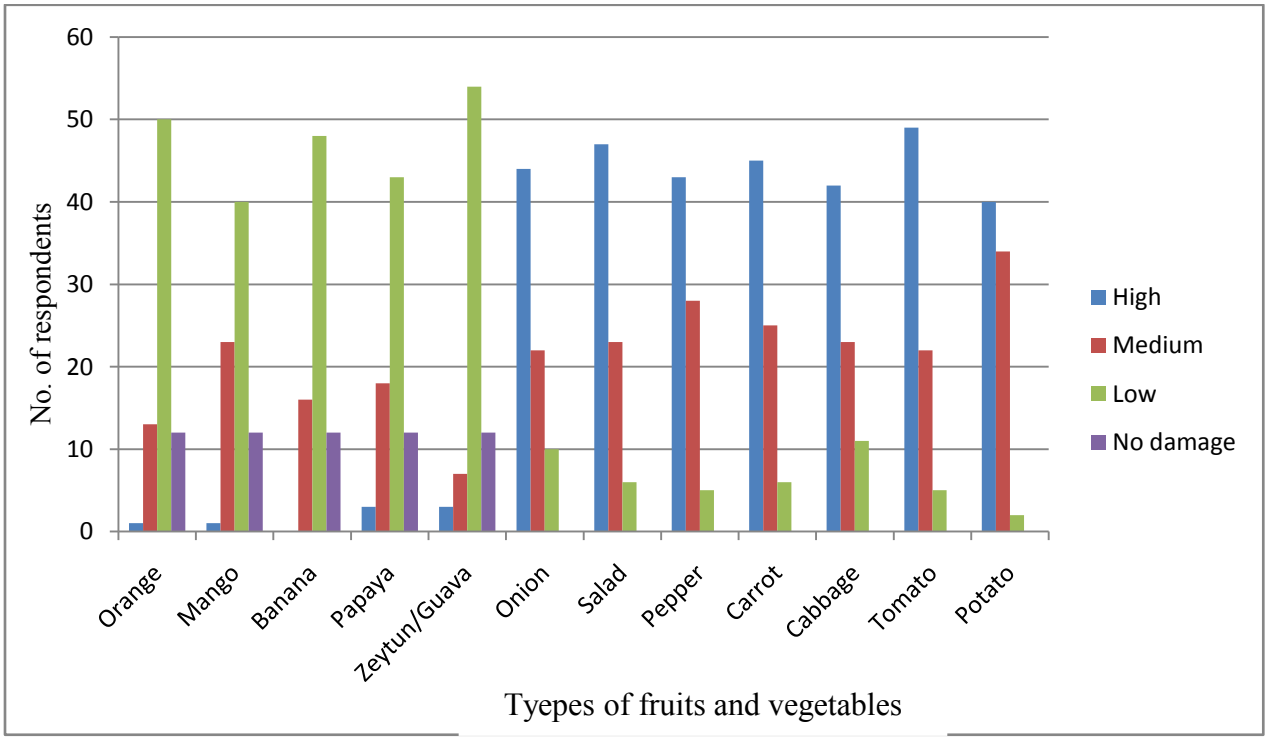
Appendix VI. Extent of effect of Parthenium on the growth and distribution of other plants in the study area

Extent of impact	Frequency	Percent	Cumulative Percent
Very highly	52	65.0	65.0
Highly	18	22.5	87.5
Medium	10	12.5	100.0
Total	80	100.0	

Appendix VII. The groups of plants that are greatly affected by the growth of Parthenium in the study area

Group of plants affected	Frequency	Percent	Cumulative Percent
Grasses	63	35.4	35.4
Crop plants	62	34.8	70.2
Vegetables	37	20.8	91.0
Small bushes	11	6.2	97.2
Tree plants	5	2.8	100.0
Total	178	100.0	

Appendix VIII. The impact of Parthenium on fruits and vegetables



Appendix IX. Paired Samples T-Test for stem length DT

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Stem length _ DT _ Plot II – Stem length _DT _ Plot I	-.12500	.95644	.27610	-.73269	.48269	-.453	11	.660

Appendix X. Paired samples test for stem length ATM

	Paired Differences					t	Df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Stem length _ ATM _ Plot II – Stem length _ATM _ Plot I	-15.33	9.93006	2.8665	-21.6425	-9.02408	-5.349	11	.000

Appendix XI. Paired Samples T-test of stem width ATM

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Stem width _ ATM _ Plot I & Stem width _ ATM _ Plot II	-.21667	.19462	.0561	-.34033	-.09301	-3.856	11	.003

Appendix XII. Adequacy of livestock feed (forage) in the study area

Adequacy of forage	Frequency	Percent	Cumulative Percent
Yes	9	11.3	11.3
No	71	88.8	100.0
Total	80	100.0	

Appendix XIII. Reasons for inadequacy of livestock forage in the study area

Reasons for inadequacy of forage	Frequency	Percent	Cumulative Percent
Due to parthenium infestation	57	80.3	80.3
Due to infestation by other weeds	8	11.3	91.5
Due to construction	6	8.5	100.0
Total	71	100.0	

Appendix XIV. Wild animals affected by *Parthenium* in the study area

	Frequency	Percent	Cumulative Percent
Yes	6	7.5	7.5
No	74	92.5	100.0

Appendix XV. Perception of respondents toward effects of *Parthenium* on the the productivity of crop plants

	Frequency	Percent	Cumulative Percent
Yes	79	98.8	98.8
No	1	1.3	100.0
Total	80	100.0	

Appendix XVI. The extent of Impact of *Parthenum* on Animals' Productivity

	Frequency	Percent	Cumulative Percent
Very highly	20	25.0	25.0
Highly	45	56.3	81.3
Medium	11	13.8	95.0
Lowly	4	5.0	100.0
Total	80	100.0	