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Developing an eco-friendly and bio-managment stratergy against parthenium hysterophorus (l.) in Arusha, Tanzania

Mtenga, Neema

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DEVELOPING AN ECO-FRIENDLY AND BIO-MANAGMENT STRATERGY AGAINST *Parthenium hysterophorus* (L.) IN ARUSHA, TANZANIA

Neema C. Mtenga

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Life Sciences of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

This study aimed at studying the suppressive effects of *Sorghum bicolor*, *Tagetes erictus* *Amaranthus spinous* and *Sorghum arundinaceum* and *Cassia tora* on germination and development of *Parthenium hysteroporus* L. under controlled experiments from March 2018 to November 2018 in Arusha Tanzania. Two experiments involving seed-seed interaction and effects of plant extract on carrot-weed were established. Results showed that seeds of *S. bicolor*, *T. erictus A. spinous and S. arundinaceum* showed strong inhibition effects ($p<0.001$) on *Parthenium hysteroporus* L. seed germination, biomass, plant height and root length. Similarly, the results from the plant extracts at 25% to 100% (v/v) concentration of *A. Indica, T. erictus, A. spinous* and *S. bicolor* inhibited germination rate, shoot and root length elongation, fresh and dry biomass of *Parthenium* weed. These findings provides basis towards developing an effective alternative eco-friendly approach and bio-herbicide for managing *Parthenium* weed in Tanzania.

DECLARATION

I, Neema Mtenga do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Neema C. Mtenga Signature..... Date..04/04/2019.....

The above declaration is confirmed

Dr. Ernest Mbega Signature .....Date..... 04-04-2019

Prof. Patrick Ndakidemi Signature .....Date..04/04/2019

Prof. Thadeo Tarimo Mokiti Signature .....Date..04/04/2019

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CERTIFICATION

This is to certify that, the dissertation titled "Developing an Eco-friendly and Bio-management Strategy Against *Parthenium hysterophorus* (L.) in Arusha Tanzania" submitted by Neema Mtenga (TM358/T.16) in partial fulfilment of the requirements for the award of Master's degree of Life Sciences at Nelson Mandela African Institution of Science and Technology.

Dr. Ernest Mbega Signature ..... Date 04-04-2019

Prof. Patrick Ndakidemi Signature ..... Date 04/04/2019

Prof. Thadeo Tarimo Mokiti Signature ..... Date 04/04/2019

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS

CO_2	Carbon dioxide
O_2	Oxygen
ABCD	Airborne Contact dermatitis
CAD	Chronic actinic dermatitis
WBC	White blood cell
NM-AIST	The Nelson Mandela African Institution of Science and Technology
TPRI	Tropical Pesticides Research Institute
CRBD	Completely Randomized Block Design

CHAPTER ONE

INTRODUCTION

1.1 Background

Parthenium hysterophorus (L.), commonly known as "Santa-Maria" or "Santa Maria feverfew" or "whitetop weed "or "famine weed" or "congress weed" or "carrot weed" is a flowering plant of the Asteraceae family and native to North and South America as well as West Indies (Picman *et al.,* 1984). It is considered to be one of the worst noxious weeds currently known worldwide (GISD, 2010; Holm *et al*., 1997). *Parthenium* is a weed 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 Evans, (1997). It has vigorous growth, high fecundity and can grow in semi-arid, subtropical, tropical and warmer temperate regions worldwide (Kohli *et al*., 2006; Adkins and Shabbir, 2014). It threatens biodiversity through degradation of natural ecosystems (Evans, 1997).

Though no documentation on its entry to Africa, there are possibilities that it was introduced into Ethiopia as a food grain contaminant in a food aid programme during 1976 (Adkins and Shabbir, 2014), after which subsequent introductions were reported in different areas of sub–Saharan and northern Africa (Nigatu *et al.,* 2010; Ayele *et al.,* 2013; CAB International, 2014).

In Tanzania, carrot weed was first reported in Arusha in 2010 and since then the weed has spread to Kilimanjaro, Manyara and Kyerwa (Kilewa, 2014) Management of this weed species as for other invasive plants is challenging due to its ability to adapt different habitats (Ngondya *et al.,* 2017). Several management approaches such as mechanical, chemical, competitive replacement and biological control have been tried to control this weed only herbicides approach seemed to be preferred (Kumar, 2009). Nevertheless, chemical herbicides are no longer reliable due to the cost and increasing weed resistance to polyphosphate, atrazines, 4-D, and Metribuzin (Vila-Aiub *et al*., 2008). Hence, the development of eco-friendly approaches including bio pesticides is currently receiving great attention as a vital pest control strategy in recent years (Marcías *et al*., 2004; Vasilakoglou *et al*., 2005; Dhima *et al*., 2006; Javaid *et al*., 2008).

This study therefore focused on developing eco-friendly weed management strategy involving but not limited to bio pesticides for managing *P.hysterophorus* using selected plants namely; *Azadirachta indica*, *Sorghum bicolar*, *Sorghum arundinaceum*, *Tagetes erictus* L Cassia *tora* and *Amaranthus spinous* L. In addition, the study will assess their bio herbicidal effects, competitive interaction and effectiveness of their extracts on the development of *P. hysterophorus* hence proposing feasible eco-friendly bio-pesticides management strategy in Arusha and other invaded areas in Tanzania

1.2 Problem Statement and Justification

Since its occurrence report, *P. hysterophorus* has become a serious threat to biodiversity through degradation of natural ecosystems in Tanzania (Msafiri *et al.,* 2013). The plant poses a threat of spreading to many broader habitats including agricultural lands, protected areas as well as pasture land (Tamado and Milberg, 2000). It has a potential to suppress crops and pasture growth and therefore reduce crops and forage productions (APFISN, 2007; Mahadevappa *et al.* (2001). Due to its allelopathic effects, the plant has ability to colonize soils and inhibit growth of most plant/crop species and cause injuries to humans and animals (Evans, 1997; Levine *et al.*, 2000; Zavaleta, 2000; Belnap and Philips, 2001; Maharjan, 2007). Currently, *P. hysterophorus* has spread to Kyerwa, Kilimanjaro and Manyara (Kilewa, 2014). This weed is a potential threat firstly, as it spreads very fast due to ability to produce larger number of seed (Javaids and Adrees, 2009). Secondly, the weed is aggressive and destructive that very little and sometimes no other plant species are seen in areas where it has dominated (Adkin, 1996; Kohli, 2004; Prasanta *et al*., 2005; Shabbir and Swhsana, 2005).

Management of *P. hysterophorus* as other invasive plants has been very challenging (Ngondya *et al.,* 2017). Chemical-based management has been reported to be effective, but *P. hysterophorus* has been reported to develop resistance to the chemicals making them less effective (Tranel and Wright, 2002; De Prado and Franco, 2004). On the other hand the use of biological management of *P. hysterophorus* has been practiced in different countries in the world. For example, in Australia the use of insects and rust pathogen to control the weed have been practiced for 30 years ago (McFadyen, 1992; Dhileepan and McFadyen, 2012). It has been reported that, the use of Epiblema *stenuana* Walker and *Zygogramma bicolorata* Pallister in the war against *P. hysterophorus* has shown success, though with some limitations. The organisms do not induce full suppression of the weed (Dhileepan, 2003). Similar observation on *Parthenium* control using the same organisms was recently reported in

Tanzania. *Zygogramma* has emerged as an alternative biological control of the weed, the approach deals only with parts of the plant such as leaves. Despite of all the efforts applied in the management of *P. hysterophorus* in Tanzania, the weed is still spreading rapidly. Due to its harmful effects, there is a need to investigate other management strategies such as suppressive allelochemicals from different plants. The use of suppressive plants have been done in countries such as India using guinea grass (*Panicum maximum* Jacq.) tanner's cassia (*Cassia auriculata* L.) and Fedogoso (*Cassia occidentalis* L) (Yaduraju *et al*., 2005), Ethiopia using; Sorghum (*Sorghum bicolor* L, Moench); Tamado and Milberg, (2004) and in South Africa using African Lovegrass (*Eragrostis curvula Nox*) (Van der Laan *et al*., 2008). Therefore the aim of this study was to identify possible eco-friendly bio-pesticides approaches that suppress the growth of *P. hysterophorus* by testing the reported competitive and allelopathic effects of *T. erectus* and *A. spinous* against *P. hysterophorus* as reported by (Shazia *et al.,* 2011), and bio-herbicidal effects of extracts from *A. indica* and Sorghum *sp* (Manpreet *et al.,* 2014). The current findings from this study can help researchers to propose feasible mitigation/management measures for P. *hysterophorous* not only in Arusha but also in other regions affected by *P. hysterophorus* in Tanzania.

1.3 Objectives

1.3.1 General objective

To develop an eco-friendly and bio-management strategy that can be used to suppress *Parthenium hysterophorous* L. in Arusha and other infested locations in Tanzania.

1.3.2 Specific objectives

(i) To evaluate the suppressive effects of *Tagetes erectus Sorghum bicolor*, *Sorghum arundinaceum Cassi*a *tora* L and *Amaranthus spinous* on seed germination and seedling growth of *Parthenium hysterophorus* in Arusha Tanzania.

(ii) To evaluate the effects of extracts of *Azadirachta indica*, *Sorghum bicolor*, *Sorghum arundinaceum Tagetes erectus* and *Amaranthus spinous* L. on *Parthenium hysterophorus* seed germination and development.

1.4 Research Questions

(i) Does extracts frm *Targetes erectus* and *Amaranthus spinous, Azadirachta indica, Sorghum bicolor* and *Sorghum arundinaceum have* effects *on Parthenium hysterophorus*?

(ii) Are there any effects when *Parthenium hysterophorus* is grown in association with the *T. erectus, S. bicolor, S. arundinaceum A. spinous.* and *C. tora*

1.5 Significance of the study

This study will avail farmers with simple and low costly technology for management of invasive weed especially *parthenium hysterophorus*. The materials will then help to reduce health impacts associated with the use of chemicals and physical methods in the control of invasive species. It will also lead to protection of the environment by reducing the amount of chemicals deposition in the soil and in the air as the results of chemical control, methods. This study aims to provide baseline information for future research on the use of botanical to control invasive weed species.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biology of *Parthenium hysterophorus* (carrot-weed)

Parthenium hysterophorus, Carrot-weed is an annual, erect herb with the height of 1.0 to more than 2.0 m. It has a taproot system with a number of secondary and tertiary roots (Dogra and Sharma, 2011). The plant is fast maturing and has dark green leaves which are rhomboidal, dissected and alternately arranged on the stem (Javaid and Adrees, 2009). Parthenium has ability to grow and reproduce itself any period of the year. It has white or yellow flowers based on race type each of which produces four to five black wedge-shaped seeds that are 2 mm long with thin white scales and difficult to see by the naked eye (Javaid and Adrees, 2009). The leaves and stems have small hair-like outgrowths called trichomes. Its inflorescence is capitulum with cypsela fruits and they produce thousands of seeds which are dark brown and very light in weight (Javaid and Adrees, 2009). *Parthenium hysterophorus* has two races namely south race and north race. The south race occurs in Southern America while north race occurs in North America and distributed worldwide (Dale, 1981). These races differ in morphology and biochemical properties where the South America race has hymenin as a dominant sesquiterpene lactone and pathenin for North America race. The North America race produces white flowers while that of South American race are yellow (Annapurna and Singh, 2003). Generally, the life cycle of this weed is completed within 180–240 days (Gnanavel and Natarajan, 2013).

The study conducted by Pandey *et al*. (2003) reported that the photosynthetic characteristics of parthenium leaf is mostly related to C3 type pathway and exhibits a photosynthesis rate of 25-35 ^{O}C and a high CO2 level. Low temperature considerably reduces plant growth, mainly flowering and seed production by reducing leaf area index, comparative growth rate, net assimilation rate, and leaf area duration (Navie *et al*., 1996; Pandey *et al.*, 2003).

Once the weed dominates an area, it becomes aggressive, destructive and oppressive to other plant species (Bhowmik and Sarkar, 2005; Batish and Singh, 2004; Shabbir and Bajwa, 2005). The weed spreads very fast due to its ability to produce a greater amount of seeds up to 25 000 seeds/plant which results into a significant amount of seed bank in the soil (Javaid and Adrees, 2009). The favourable soil conditions which the weed can grow fast is on

alkaline to neutral clay soils (Dale, 1981). Nonetheless, its growth is slow and less prolific on a wide range of other soil types (Adkins *et al.,* 2005; Rezene *et al*., 2005).

Parthenium germination process involves several steps that is to change the quiescent embryo to metabolically active embryo (Buhler and Hoofman, 2000). It also requires adequate water, suitable temperature and composition of gases (O2/CO2 ratio) in the atmosphere, and light for the seeds to germinate. The germination of *Parthenium* as other plants is prevented by both internal and external factors. Among the internal factor is the presence of biochemical inhibitor in the seed and immature embryo and the common known external factor is the soil moisture content and temperature (Fernandez-Qviatanilla *et al.,* 1991). The seeds of this weed take a long time in the soil which signifies the survival of the weed species. However, the longevity of seed in soil varies according to the characteristics, burial depth, and climatic conditions of seeds (Carmona, 1992). The studies of longevity of *P.hysterophorus* have made unpredictable results, but Bulter (1984) came up with finding that the viability of seed was 60% after one week after burial to 29% two years. Nevertheless, Naivie *et al*. (1998) and Tamado *et al*. (2002) reported that the viability of the seeds was greater than 74% after two years and showed 50% viability after 26months of burial in the soil correspondingly. This suggests that a potential buildup considerable persistence in the soil seed bank makes it difficult to eradicate the population of *Parthenium* in the short period of time.

Unlike other weed seeds *Parthenium* seeds do not possess dormancy mechanism (McFadyen, 1994). However, the study by Picman and Picman (1984) confirmed the presence of water soluble germination inhibitors (*i.e:* Parthenin and phenolic acid) in the accessory structure and the seed coat of parthenium seeds. Also the weed has viability greater than 85% (Pandey and Dubey, 1988). Further the study conducted by Williams and Groves (1980) reported that maximum germination of *Pathenium* was (88%) of the seed in dark, under a day/night temperature regime of 21/16 ^{0}C. They also noted that the percentage of the germination decreased as the day/night temperature differential was increased. Tamado *et al*. (2002) reported that germination of parthenium seed occurred at the mean minimum (10^{0}C) and maximum (25 ^{O}C) temperatures as well as over a widely range of fluctuating (12/2^{0}C-35/25^{0}C) temperatures.

2.2 Seed Dispersal mechanism of *Parthenium hysterophorus*

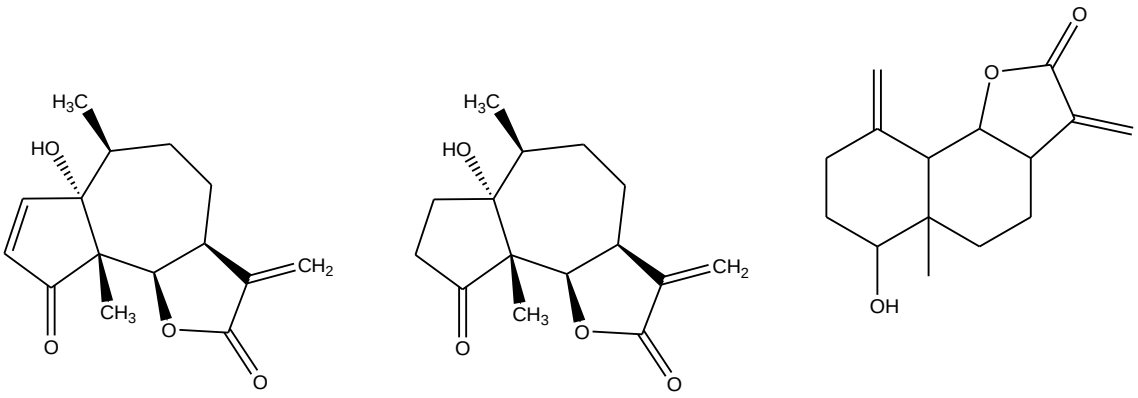
The spread of *Parthenium* seeds and its ability to remain viable in the soil for many years makes most complex problems for control. This fact makes eradication difficult for many seed Producing weeds (Monaco *et al.,* 2001). The dispersal of this weed occur in multiple ways including short distance wind dispersal, or water surface, runoff in natural streams and rivers, in irrigation and drainage channels and irrigation water from the ponds (Monaco *et al.,* 2002; Nigatu *et al*., 2010; Riaz and Javaid, 2010). Weed seeds have special adaptation that helps them spread. Parthenium weed seeds are very small and with short wing like structures (Navie *et al*., 1996). This morphological features helps them to float in wind. Transportation by wind usually is few meters, but whirl winds can carry a large number of light achenes to considerable distance. The dispersal of parthenium achenes by water is possible as indicated by large populations of the weed spreading along water ways in central Queensland (Auld *et al.,* 1983). 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). In addition to that it has been reported by Auld (1983) that the seed of Parthenium achenes are scattered by humans and animals. They may carry the seeds on their feet, cling to their fur or clothes, or internally (ingested seed). Parthenium seed achenes are capable of being transported to long distance in mud and debris. In general, parthenium, like any other weeds, can be dispersed easily by water, farm machinery, vehicles, movement of livestock, animal dung and grain seeds. Appropriate handling of the farm equipment after use, sowing of uncontaminated seed and a short-term quarantine of livestock in parthenium infested area will reduce the risk of spreading the weed (Tamado, 2001). Therefore, seed dispersal mechanism of *Parthenium hysterophorous* via various agents needs special attention in new areas of invansion.

2.3 Allelopathic effects of *Parthenium hysterophorus* on plants

Msafiri *et al.* (2013) defined allelopathy as a biological occurrence where one plant inhibits the growth of another plant through the release of allelochemicals. The idea of allelopathy was studied broadly for the first time in the forestry ecosystems, where initially it was revealed that most of the forestry species surveyed had unwanted allelopathic effects on food and fodder crops (Jalali *et al.,* 2013; Msafiri *et al.,* 2013) pondered both beneficial and harmful allelochemicals influences by defining allelopathy as the capability of the plant to hinder or stimulate growth of other plants in the surrounding by exuding chemicals. Based on

this definition, it is apparent that the oppressive nature of *P. hysterophorus* carrot weed is associated with it is allelopathic effects caused by sesquiterpene lactones, parthenin, and coronopilin (Singh and Arora, 2002) as presented in Fig. 1. These allelochemical groups act synergistically and significantly reduces seed germination and delayed growth of other crops (Singh and Kohli, 2003). Also, it was reported that allelochemicals such as tannis, saponins, cardiac glycosides, terpenoids, and steroids are founder on the upper parts of *Parthenium* (Neeraja and Vikas, 2010). All these chemicals have an effects on crops and animals. The leaves and inflorescence contain a higher level of allelochemicals than the stem and roots. These allelochemicals affects other plants either directly by leaching, root exudation, and residue decay (Chippendale and Panetta, 1994) or indirectly leading to the loss of native flora.

Kumar (2014) reported that the weed can degrade the natural ecosystem due to its high capacity of invasiveness and its potential allelopathic properties which disrupt any natural ecosystem. Nevertheless, the weed was reported to cause a decline undesirably the herbaceous components of vegetation up to 90% due to its destructive nature of competition and allelopathic effect (Kapoor, 2012; Mahadevappa and Kumar, 2001) It is reported to cause great change of native habitat in grassland, open woodland, floodplains and rivers (Riaz and Javaid, 2011; Shabbir *et al*., 2012; Adkins, 2012; Wakjira and Tulu, 2009). Therefore, studies on plant species with allelopathic effects to this noxious weed are urgently needed. Further, studies on the chemistry of the plant to elucidate information on chemical composition from different parts of the plant are required for proper management of the weed in Africa.



Parthenin Coronopilin sesquiterpene lactones

Figure 1: Structures of allelochemical groups of P. hysterophorous

2.4 Impacts of *P. hysterophorous* on growth and yield of crops

Parthenium hysterophorus has been reported to result in food insecurity (Fig. 2) due to decline in agricultural yields of crops and domestic animals to levels of up to 40% to 90% (Maharjan and Jha, 2007; Tamado and Milberg, 2002). It is also reported to reduce the carrying capacity of pasture crops of up to 90% (Khosla and Sobti, 1981; Fessehaie *et al.*, 2005; Hailegeorgis, 2005; Nath, 1988). The laboratory experiment and field studies by Wakjira *et al.* (2009) shows that all plant parts of the carrot weed (shoot, root, inflorescence, and seed) are toxic to other plants. This brings changes in the physical and chemical characteristics of the soil such as soil pH, soil organic matter, phosphorus, and others (Bhowmik *et al.*, 2007; Yaduraju, 2007). Although numerous information exists on the effects of this noxious weed, still there is lack of information on how it affects and induces changes to soil pH and structure. This calls further urgent investigation.

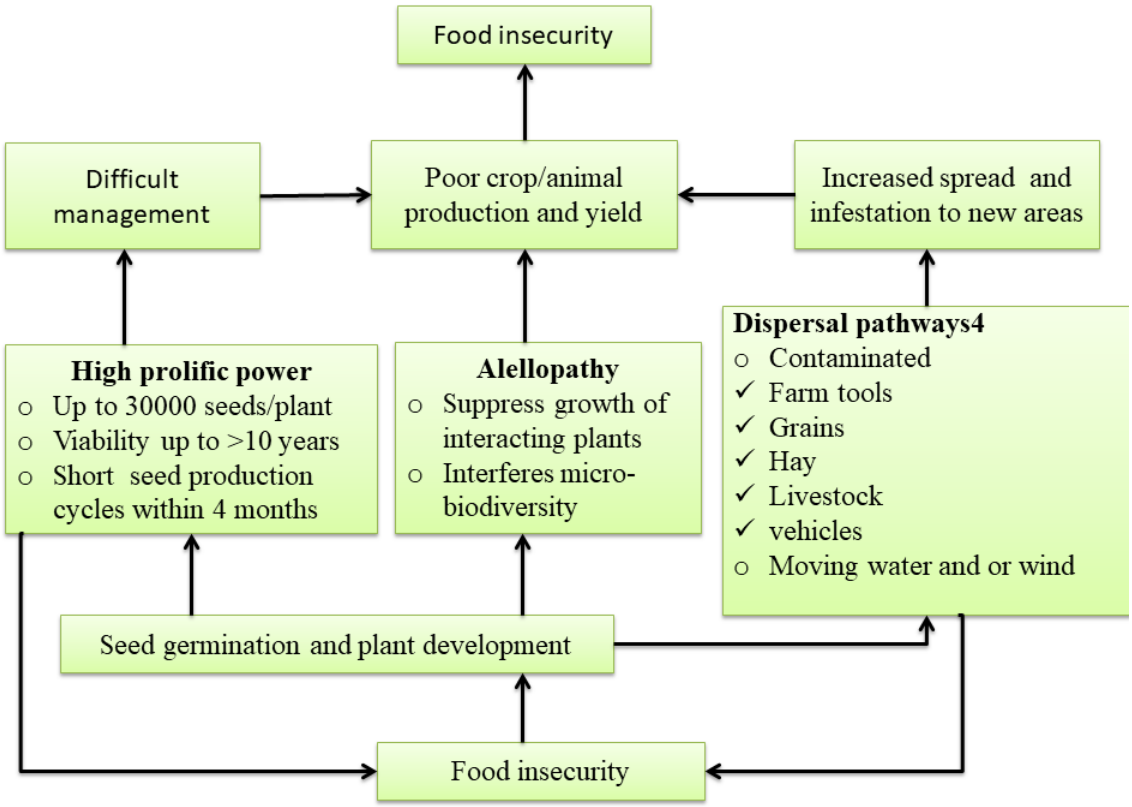


Figure 2: Relationship between carrot-weed and food insecurity

2.5 Impacts of *Parthenium hysterophorus* on Animals

Parthenium hysterophorus produces toxic substance such as parthenin as described earlier which is harmful to animals when feed on it or coming into contact, causing both dermatitis with distinct skin lesions on various animals including horses and cattle's (Singh *et al*., 2003). Once eaten by animals, it can cause mouth ulcers with excessive starvation (Aneja, and Sharma, 1991; Narasimhan, 1977) reported that carrot –weed causes anorexia, pruritus, alopecia, diarrhea, and eye irritation in animals such as dogs and acute illness, bitter milk and tainted meat in animals such as buffaloes, goat, and cows (Yadav *et al*., 2010). Also, experimental work reported that the plant weakens the immune system by reducing the number of white blood cells (WBC) in rats (Yadav *et al*., 2010). Further, the weed lowers forage productivity by 90%, reduce land fertility weakens the land and make it infertile and hence lowers the quality weakens the quality of the grazing land. All these cause poor animal health both domesticated and the wildlife since most of them feed on the grasses (Fessehaie *et al*., 2005). Regardless of the information provided on the impacts of this weed on animals,

still there is a need for more research on how this weed exactly affect the animals once feed on them.

2.6 Impact of *Parthenium hysterophorus* on Human

Parthenium hysterophorus has been reported to cause human health problem such as asthma, bronchitis, dermatitis, hay fever when exposed to it (Kololgi, 1997; Sriramarao e*t al.*, 1991; Rao, 1991), and allergic eczematous and mental depression (Sharma *et al.*, 2005). Furthermore, carrot-weed lead to general illness, annoyances of skin and pustules on handballs, extending and furious of skin and stomach pains on humans (Wiesner *et al*., 2007). Human contact with carrot-weed followed with exposure to sun results to health effects such as violaceous papulae, as well as a plaque on exposed parts such ears, forehead, cheek and upper chest. Nevertheless, health effects like hyperkeratotic papule and prurigo nodules have been associated with exposure to carrot-weed (Jayaramiah *et al*., 2017). On other hands, Patel (2011) further showed that dermatitis health effects are due to the presence of a cytotoxic compound sesquiterpene lactone Parthenin. Apart from that, exposure to carrot-weed was further correlated with diarrhea, breathlessness, and chocking as well as erythematous eruptions (Patel, 2011). Allergic bronchitis was also associated with exposure to carrot-weed, however, no signs of mutagenicity and genotoxicity have been observed. In addition, exposure to carrot weed has shown positive reactions to mAb-2 as well as cytokines (Patel, 2011). In general, these effects are classified into four categories: airborne contact dermatitis (ABCD), chronic actinic dermatitis (CAD) and the combination of ABCD and CAD and lastly exposure to the sun (photosensitive lichenoid) (Jayaramiah *et al*., 2017). Therefore there is a need of more research to know exactly the compounds present in the pollen of this weed which is responsible for the health problems to a human being to make easy management with precaution during physical control practice.

2.7 Impacts on Biodiversity

According to McConnachie *et al*. (2011) *Parthenium* is among of harmful invasive species in the World and an increasing problem in Africa. Its invasion results into the degradation of the natural ecosystem and biodiversity due to its high invasion capacity (Kapoor, 2012). Further, it has been reported that the allelopathic properties of this weed are potential for disrupting the growth and distribution of natural vegetation which in turn affect the diversity of animals (Ayele, 2007). Also, the weed is capable of causing the decline of the species

richness and abundance in the natural system as it inhibits the physiological processes of other weed species (Nguyen and Adkins, 2010).

In some countries such as Australia, the weed is reported to cause changes in the entire habitat in Australia grassland, open and woodlands, and river banks (Chippendale and Panetta, 1994; McFadyen, 1992). Furthermore, Kohli *et al*. (2004) reported that *Parthenium* weed has a negative impact on the structural composition on dynamic and diversity of the plant and animals in India. It also affects not only the species diversity of native areas but also their ecological integrity. It has been shown that *Parthenium* residues are toxic to aquatic flora and fauna (Kanchan and Chandra, 1980). Table 1 Summarizes the general impacts of carrot-weed on crops, animals, and biodiversity in general.

Table 1: Some of the reported impacts of carrot-weed (*P. hysterophorus*)

Categories	Mode of action	Effects	References
Crops (legumes &cereals).	The release of phytotoxic compounds	Reduced crop yield as well as carrying capacity of pastures.	Khosla and Sobti, (1981); Tamado *et al.* (2002); Fessehaie *et al*. (2005) and Aneja *et al.* (1991)
Wild animals/ livestock	Weakens the immune system by reducing the number of WBC	Skin lesions, mouth ulcers, anorexia, pruritus, alopecia, diarrhea, eye irritation.	Narasimhan, 1977; Patel, 2011; Singh *et al*. (2003) and Yadav *et al.* (2010)
Human health	Induction of cytotoxicity also reacts with cytokines.	Allergic, bronchitis, skin inflammation, asthma, blisters, hay fever, erythematous eruption	Sharma *et al. (*2005) and Sriramarao *et al*. (1991).
Soil	Utilizing soil nutrients	Soil infertility	(Fessehaie *et a*l. (2005) and Yadav *et al*. (2010).
Vegetation/landscape composition	Disrupt the structure of the natural ecosystem and displace numerous native plant species. Shrinking of biodiversity	Degradation of natural ecosystem and biodiversity, allelopathic effects, toxic to flora and fauna, reduced species richness.	Kanchan and Chandra (1980) and Nguyen *et al*. (2010)

2.8 Management and or Control

The use of biocontrol agents such as (Insects and fungal pathogens) and use of competitive plants (allelopathy) is suggested as the greatest cost-effective and practical way of managing *Parthenium* (Kohli *et al.*, 1997; Kumar, 1997). However, the management of the weed has not been well developed below the edge level and the weed continues to threaten biodiversity

by posing ill problems to humans and animals. Therefore several methods, for example, physical, mechanical, chemical and use of allelopathic plants are being practiced to manage this weed around the globe.

2.8.1 Physical and mechanical methods

These are the most common methods used in the management of carrot-weed in many countries. The methods are widely used as they are cheaper, easy to apply and are cost effective. Farmers manage the weed by hand uprooting or using a hoe in their fields, collect and burn before flowering time. Despite, the success of this method, it is faced with many challenges including the frequent growth of the weed (Gnanavel and Natarajan, 2013).

2.8.2 Chemical control

Management of *Parthenium hysterophorus* by using chemical method seems to be popular in most developed countries such as India where the weed has spread in large areas**.** This method mostly used to remove the weed from the area in time, therefore the issue of time is very important for this type of management. Application of the chemicals should be done at the early stages to prevent flowering and seed setting. The spraying of the herbicides which are not harmful to other plants which are growing nearby the weed is mostly recommended to reduce the infestation. Despite the fact that chemical control is the most common method employed, it is reported to be less effective due to the development of resistance (Culliney, 2005). Although the use of chemical seems to be most applicable in many countries in the management of *Parthenium*, yet the method has been reported to have many negative impacts in the environment (Commare *et al.*, 2002).

2.8.3 Biological control.

The bio-control strategy is the most applicable way used in managing the weed by manipulating natural enemies to control others. The biological control method is less cost, environmentally friendly and ecologically practicable method. Several insects and pathogens have been used in the control of this weed. For instance, leaf feeding (*Zygogramma bicolorata*) and stem-galling moth (*Epiblema strenuana*) have been used to control this weed and have shown efficacy in reducing the number of seeds and leaves especially at the young stage (Ray and Gour, 2012; Stamps, 2011). Also, the use of fungus is now regarded as a bio-control strategy of *Parthenium* among others, example; *Fusarium pallidoroseum*, *Puccinia*

melampodii and *Oidium parthenii* (Florentine and Dhileepan, 2002). Studies conducted by Alavanja and Kamel (2004) shows that the use of microorganisms as a biological agent as a strategy for controlling this weed control it has many advantages such as higher selectivity, their capacity to inhibit plant growth, the lower potential to resist, lower production costs.

Therefore, there is a need of using botanicals and microorganisms in controlling this weed because they are environmentally friendly, easy to apply and such resources are readily available in our environment.

2.8.4 Use of suppressive plants as a Management Strategy

Competition is one of the several types of interference among species or population. When competition occurs among the population means one must interfere the performance of the other. Interference can be positive or negative interactions between species. Within the population the interference can involve physical factors like space, light, moisture, nutrients, and atmosphere. It may also be a type of chemical interaction (Monaco *et al*., 2001). Competition between weeds and crops are generally associated with negative interference. Such a competition involves physical factors that decrease growth in both type of plant due to the absence of an insufficient supply of a necessary growth factor. Competition can be either within the same species (intra), that is when two or more plants of the same species co-exist in time and space or between different species (inter), that is when two or more different species co-exist. For example, allelopathy is a negative type of interference between plants that occurs in the form of chemical influence (Monaco *et al*., 2001).

Biological control methods, such as use of plants with allelopathic effect is an important component of biological control of *Parthenium*. In this method it involves two approaches which are control of parthenium using Bio-agent and the other one is through planting of the selected plants species in a target areas (Wahab, 2005). A study of botanical survey across India has shown that species such as *Cassia sericea, Cassia tora, Cassia auriculata, Croton bonplandianum, Amaranthus spinosus, Tephrosia purpurea, Hyptis suaveolens, Sida spinosa, and Mirabilis jalapa* are capable in reducing the *Parthenium* weed infestation in natural habitats (Wahab, 2005). Another study in India revealed that *Cassia sericea* reduces the accumulation of *Parthenium* by 70% and its population by 52.5% (Kandasamy and Sankaran, 1997). Aqueous extracts from *Imperata cylindrical, Desmastachya bipinnata, Otcantium*

annulatum, and *Sorghum halepense* markedly suppressed seedling growth and germination of *Parthenium* (Anjum and Bajwa, 2005).

Furthermore in USA, there are a large number of plants that compete with *Parthenuim* for resource and space. Studies confirmed that parthenium could be a weak competitor in the face of othernative and non-native plants such as Johnson grass (*Sorghu*m *halepense*), Congongrass (*Imperata cylindrica*), barnyardgrass (*Echinochloa crus*galli), *Senna obtusifolia, etc (*Bryson, 2003). The occurrence of allelopathy has been widely reported in grasses like *Desmostachy*a *bipinnata, Imperata cylindrica, Eragrostis poaioides, Cenchrus ciliaris, Panicum antidotale* (Bajwa *et al*., 1998; Hussain and Abidi, 1991). Many other grasses have also been reported toexhibit allelloapathic to preclude the associated species through reducing their regeneration growth and yield. A survey in Pakistan revealed that in *Parthenium* infested areas there was a marked reduction in the density of *Parthenium,* particularly at *Imperata cylindrical* and Desmostachya *bipinnata* dominated localities, when compared to the infested nearby grasses. The conclusion drawn from the study was that this low density of parthenium could be due to allelopathic nature of these grasses (Anjum and Bajwa, 2005). In similar manner, agreenhouse study in Australia indicated that grasses like Bothriochloa *insculpta*, *Dichanthium aristatum* and *Cenchrus ciliaris* out compete parthenium and that among the legumes that were tested butterfly pea (*Clitoria ternatea*) competed strongly with parthenium (O'Donnel and Adkins, 2005).

Table 2: Summarizing the Management approaches for *P. hysterophorus*

Methods	How was applied	Items used	Results	References
Physical control	the burning of the surface part and seeds near the surface and crop rotation	Tagetes sp and Fire	Reduce infestation and spreads.	McConnachie *et al.* (2011) and Stamps, (2011)
Chemical control	Many chemical pesticides applied both in cropped and non-cropped condition	Glyphosate (1 to 1.5 kg/ha) diquat 0.5 kg/ha in 500 liters,	Control Parthenium in all stages. But only kills the target population	Dhanaraj and Mittra (1976) and Kumar, (2015).
Biological control	Through the introduction of control agents in the affected fields. Spraying of foliar extracts	Microbial pathogens (like Fusarium pallidoroseum, Puccinia melampodii and Oidiumparthenii), Insects: (Zyogramma bicolorata, Bucculatrix parthenica (leaf-mining moth), Smicronyx lutulentus,) Fungil (Fusarium pallidoroseum, Puccinia melampodii and Oidium parthenii)	Reduce flowers and seed production, Inhibit germination	Ray and Gour, (2012), Stamps, (2011), Dhileepan, (2003), Dhileepan, (2001), Dhileepan and Wilmot Senaratne, (2009)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental sites

The experiments were conducted at the Nelson Mandela African Institution of Science and Technology (NM- AIST) and Tropical Pesticides Research Institution (TPRI) in Arusha, Tanzania from March to November 2018. The seed-seed interaction experiment was conducted in the laboratory at NM-AIST and the plant–plant interaction was hosted by TPRI. Experiments were conducted to determine the suppressive/bio-herbicidal effects of leaf and (*Tagetes* flowers) aqueous extracts of *A. indica, T. erictus S. bicolor and A. spinous* on seed germination, fresh biomass, dry biomass and shoot and root elongation *Parthenium hysterophorus*. Extracts preparation was conducted at NM-AIST while screen house experiments and part of laboratory work was conducted at (TPRI). The experiments were conducted in two different seasons, the first in May-August 2018 and the second in September-November 2018 following complete randomized block design (CRBD).

3.2 Plant species and plant materials used in the interaction experiments

Five plants species namely *Tagetes erictus, Amaranthus* s*pinous, Cassia tora, Sorghum bicolor* and *Sorghum arundinaceum* were used as suppressive plants. Seeds from mature plants were collected from different fields at Nambala village in Arusha, region, Tanzania due to their availability in this site. For each plant, 0.25 kg of seeds was collected and properly labelled and stored at -4 ºC at NM-AIST, laboratory until used. For each plant about 0.25 kg of seeds were collected viability test was done and properly labeled and stored at -4 degrees at Nelson Mandela Laboratory until used. Materials used were seeds, leafs for *T. erictus, A. spinous,* and *A. Indica,* flower for *T. erictus,* Distilled water, Petri dish, ruler, weight balance, envelopes, pencil, pen, pots, screen house nets, nails wood, coolant, plastic bottles , makers, cloves sprayer and Masks.

3.4 Seed-seed and plant–plant interaction experimental design

The experimental design for both laboratory and pot were established using a randomized block design. The treatments included seeds of a) *P. hysterophorous* grown alone; b) *T. erictus* + *P. hysterophorous*; c) *A. spinosus* + *P. hysterophorous*; d) *C. tora* + *P.*

hysterophorous; e) *S. bicolor* + *P. hysterophorous*, and f) *S. arundinaceum* + *P. hysterophorous*. In petri dish experiment, germination was performed based on international seed testing standards (IST2014) in which seed subsamples were placed on blotters in petri dish. For *P. hysterophorous* grown alone, 200 seeds were planted in the petri dishes (20 seeds/petri dish). For treatments including a combination of species (*A. spinosus*, *C. tora*, *S. bicolor*, and *S. arundinaceum*) with *P. hysterophorous*, each petri dish was planted with 20 seeds of each species and 20 seeds of *P. hysterophorous*. These treatments were replicated four times. Before starting germination test all seeds were sterilized using sodium hypochlorite (5%) to remove any possible contaminations and then the seeds were washed thoroughly 4 times with distilled water. After planting, each treatment in petri dishes were irrigated with 3 mL of distilled water equally in the interval of four days to maintain moisture. The same treatments above were also planted in plastic pots containing six kilograms of sterile soils with a ratio of 1:3 sand and forest soils. These were replicated eight times. The pots were exposed to direct rain, and no fertilizer neither watering was used. All other plants/weeds that germinated other than those selected species sown and *P. hysterophorus* were removed manually. The petri dish (Laboratory experiment) and four replications of the pot experiments were kept for 21 days. Other four replications of the pot experiments were evaluated for three months to determine the suppressive effects between plants.

During the 21 days of germination test, the percentage germination was rated as normal, subnormal and dead seeds. In this experiment, only percentage of normal seeds was considered. Percentages of inhibition/stimulation effect on seed germination over control (T1) were calculated using the formula proposed by Singh and Chaudhary (2011). Inhibition (-) or stimulation (+) = [(Germinated seeds in association - Germinated seed in control)/Geminated seeds in control] x 100.

For pot experiments that were evaluated for three months to determine the suppressive effects between plants, the growth parameters such as plant height and root length were determined by selecting five plants randomly, uprooting them from each of the replicated pots. All samples were separated from *P. hysterophorus* or test species, then dried for 72 h at 70 ºC, and weighed for dry plant biomass.

3.5 Preparation of plant extracts

Leaves of *A. indica, A. spinous, T. erictus* and flowers from *T. erictus* plants were collected from the fields in Kikwe village, Arusha (3^{o}426345N 36 ^{o}827934E) and air-dried at room temperature (25^{o}C) for 20 days. The dried leaves and flowers were grinded separately to powder using laboratory blender. Distilled water was used as extraction solvent whereby 100 g of powdered flowers/leaves were prepared and soaked in 1000 mL of distilled water. The mixture was kept in a conical flask with its top closed and stored in dark room for 72 hours at room temperature and, thereafter, filtered using muslin cloth to obtain a stock solution of 0.1 g/mL concentration (Shafique, 2011). The stock solution was diluted in three different concentrations of 25, 50 and 100% and named as T2, T3, and T4, respectively. Distilled water was used as a control (T1).

3.5.1 Laboratory bioassays

Extracts were evaluated on *Parthenium* seeds germination using concentrations of 25%, 50% and 100%. Twenty seeds of *Parthenium* were placed in a 7 cm diameter Petri dish plate lined with Whatman No. 1 filter papers moistened with 3 mL of separate concentration of each extract. The control treatments received the same quantities of distilled water. Each treatment was replicated three times. Plates were incubated in the growth chamber under 12 hours light periods daily. Germinated seeds were counted manually for 14 days with an interval of 2 days and the experiment last for 21 days.

3.5.2 Foliar spray bioassays

Seeds of *P. hysterophorus* were sown in pots of 10 cm diameter and 30 cm deep each containing 400 g of soil. Initially 20 seeds were sown in each pot which was thinned to 5 uniform seedlings at the time of harvest. The freshly prepared extracts of *A. spinous, A. indica, S. bicolor and T. erictus* (leaf and flower) were sprayed on the surface of 4 and 8 weeks old *P. hysterophorus* plants. Two consecutive sprays were carried out with 5 days intervals each. Control plants were similarly sprayed with distilled water. Plants were harvested 20 days after spraying.

3.5.3 Determination of shoot length, root length, fresh biomass and Dry Biomass for the extracts

Measurements of parameters were taken at the tenth week of growth of species in the pot experiment. Roots and shoots for *Parthenium* in each replicate were measured using a ruler. Fresh biomass was measured using weighing balance thereafter the plants were placed in a labeled envelop and oven dried at 70°C for 3 days. The dry biomass of plants were recorded and the data obtained were analyzed using statistica Software.

3.6 Germination inhibition/stimulation

Percentages of inhibition/stimulation effect on seed germination over control (T1) were calculated using the formula proposed by Singh and Chaudhary (2011).

$$\text{Inhibition } (-) \text{or stimulation } (+) = \frac{\text{Germinated seeds in intercroped} - \text{Germinated seeds in control}}{\text{Germinated seeds in control.}} \text{x100}$$

This for the seed-seed and plant-plant interaction.

Inhibition (-) or stimulation (+) = [(Germinated seeds in extracts - Germinated seed in control)/Geminated seeds in control] x 100. This for the evaluation of efficacy of plant extracts on seed germination and seedling development of *P. hysterophorus*

3.7 Statistical analysis

The effects of treatments on different parameters such as percent germination, plant height, root length and dry biomass were assessed using one way Analysis of Variance (ANOVA). The analysis were done using STATISTICA package Version 8. The significant means were compared at p=0.05 according to Fischer's least significant different test.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

Results on suppressive effects of the tested plant species on seed germination and seedling growth of Parthenium are presented below

4.1.1 Suppressive effects of selected plant species on seed germination and seedling growth of *Parthenium*

(i) Seed-seed interaction

The results indicate that *P. hysterophorus* germination was significantly decreased when grown in association with *S. bicolor, T. erictus, S. arundinaceum* and *A. spinous* (Table 3). The highest germination percentage was 97.5% in the control treatment as compared with other treatments. The germination percentage was lowered from 97.5% to 22.8, 21.3, 17.5, 11.3 and 10 for *C. tora, S. arundinaceum, A. spinous, T. erictus* and *S. bicolor*, respectively (Table 3). Furthermore, numerically, *S. bicolor* showed highest inhibition effects on germination of *P. hysterophorus.* Seeds to seeds interaction showed highest inhibition percentage value -89.5%, (equivalent to 10.0% germination) for *S. bicolor* compared with lowest inhibition percentage of -74.9% (equivalent to 22.8% germination) for *C. tora.*

Table 3: Effects of seed-seed interaction

Plant Name	**% Germination**	**% Inhibition**
P. hysterophorus	97.5 ± 4.33a	
P. hysterophorus+A. spinous	17.5 ± 2.50b	-81.8 ± 4.76a
P. hysterophorus+T. erictus	11.3 ± 1.25b	-88.5 ± 2.37a
P. hysterophorus +S. bicolor	10.0 ± 2.04b	-89.5 ± 2.39a
P. hysterophorus+S. arundinaceum	21.3 ± 7.18b	- 78.2 ± 7.17a
P. hysterophorus+ C. tora	22.8 ± 8.98b	-74.9 ± 9.43a
F- STATISTICS	41.8***	

Values presented are means± SE. Values with the same letter in the column are not statistical different (p=0.05).

(ii) Plant –Plant interaction

The pot experiments from all the plant species showed a significant suppressive effects on germination of *P. hysterophorus* expect *Cassia tora* (Table 4). The highest germination percentage was 91.3% in the control as compared with other treatments. The germination was lowered from 91.3% to 62.5%, 18.8% 16.3%, 16.3% and 12.5% for *C. tora, S. arundinaceum, T. erictus, A. spinous* and *S. bicolor* respectively. Numerically, *S. bicolor* showed stronger inhibition effect compared with other treatments. Inhibition percentage increased significantly ($p<0.001$) from -37.5%, -81.5%, -82.4%, -83.8% and -87.5% for *C. tora, S. arundinaceum, T. erictus, A. spinous* and *S. bicolor* respectively. Furthermore, this study showed that plant height, root length and dry biomass were significantly lowered when *P. hysterophorus* was grown in association with *S. bicolor, T. erictus, S. arundinaceum, A. spinous* (Table 4). However, sowing *P. hysterophorus* with *C. tora* had no significant effects on plant height, root length and dry biomass yield.

Table 4: Suppressive effect of selected plants on growth of *Parthenium hysterophorus* in pots

Plant Name	Germination (%)	Inhibition %	Plant height (cm)	Root Length (cm)	Biomass (g)
P. hysterophorus	91.3± 8.75c	-	4.25±0.51b	2.50 ± 0.11b	4.05 ± 0.21b
P. hysreophorus + A. spinous	16.3 ± 6.88a	-83.8 ± 6.88a	1.09 ±0.26a	1.02 ± 0.49a	1.50 ± 0.29a
P. hysterophorus+ T. erictus	16.3 ± 4.73a	-82.4 ± 4.31a	1.10 ±0.34a	0.86 ± 0.15a	1.50 ±0.29a
P. hysterophorus + S. bicolar	12.5 ± 1.44a	-87.5 ± 1.44a	1.05 ±0.19a	0.89 ± 0.09a	1.03± 0.39a
P. hysterophorus + S. arundinaceum	18.8 ± 54.27a	-81.3 ± 4.27a	1.42±0.03a	1.24 ± 0.34a	1.13 ± 0.13a
P. hysterophorus + C. tora	62.5 ± 13.62b	-37.5 ± 13.62b	3.63±0.70b	2.69 ± 0.41b	3.45± 0.33b
F-Statistic	**18.35*** **		**11.95*** **	**7.38*** **	**16.56*** **

Values presented are means ± SE. Values with the same letter in the column are not statistical different (p=0.05).

4.1.2 Effects of aqueous extracts of different plant species used in this study on germination and seedling growth of *P. hysterophorus*

The results show that plant extracts from different plant species used in this study significantly ($p \leq 0.001$) inhibited germination and seedling growth of *P. hysterophorus*. Root and shoot length, fresh and dry biomass as well as percentage germination of *P. hysterophorous* in control were significantly higher than in the plant extracts treatments.

Results presented in Table 5-7 indicate that seed germination of *P.hysterophorus* was significantly inhibited by the aqueous extracts of *A. spinous, A. indica, T. erictus* (leaf and flower) and *S. bicolor*. The inhibitory effect on seed germination trends of *P. hysterophorus* was concentration reliant whereby, increased plant aqueous extracts concentration led to increased inhibitory effect on the germination of *P. hysterophorus*. The highest germination percentages were 95.5% and 93.33% in control treatment for T. *erictus* flower extracts and the leaf extracts respectively. Inhibition percentage increased significantly ($p \leq 0.001$) from -30%, -38%,-40%, -44.25% to -80.% at 25% concentration and from -66.67, -70%, -80%, -83.33% to -95.0% at 100% concentration for *A. indica, T. erictus* leafs, *T. erictus* flower, *A. spinous*, and *S. bicol*or extracts respectively (Table 5-7). Among the plant extracts used, maximum inhibition was observed with *S. bicolor* where 5.0% seeds germinated followed by *A.spinous* (16.67%). Comparatively, *T. erictus* (flower), *T. erictus* and *A. indica* leaves, also significantly reduced the germination percentage by 20%, 30% and 33.33% respectively compared with the control treatment Table 5-7.

Results presented in Table 5 and 8 revealed that aqueous leaf extract of *A. spinous* significantly ($p \leq 0.001$) reduced dry and fresh biomass of the *P. hysterophorus.* The highest values of fresh and dry biomass were 19.17 g and 9.50 g and 87.33g and 24.67 g for measurements taken at four and eight weeks of growth respectively. In the control treatment, the lowest values of fresh and dry biomass of *P. hysterophorus* were 0.83 g, 0.012 g, and 20.33 g and 0.43 g for four and eight weeks respectively recorded at the100% concentration. These results suggest that fresh biomass of *P. hysterophorus* decreases significantly ($p \leq 0.001$) as the concentration level were increased (Table 5, 6, 7, 8 and 9). Further, the results revealed that the control (0%) concentration was observed to have high root and shoot length (9.67 cm, 10.73 cm, 8.36 cm and 8.82 cm, respectively) when compared with high concentration 100%. Moreover, high inhibition rate was observed on *A. indica* extracts on root and shoot length, fresh biomass and dry biomass with values of 2.64

cm, 3.48 cm, 2.94 cm, 2.95 cm, 1.33 g, 28.00 g and 0.25 g and 2.50 g, respectively and eight weeks respectively, as compared with control which had the values 9.68 cm, 11.40 cm, and 7.93 cm 8.32 cm, 84.6 g, 24 g, 19.67 g and 9.50 g for root, shoot, fresh biomass and dry biomass, respectively (Table 5 and 8).

Results presented in Table 6 and 9 show significant ($p \leq 0.001$) bio herbicidal effects of *T. erictus* leaf aqueous extract on roots and shoot length of *P. hysterophorus.* The effect on root and shoot length reduction was observed for both four and eight weeks for *Parthenium* treated with plant extracts, whereby the highest values were recorded in the control, which were 9.67 cm and 6.68 cm in roots and 11.00 cm 8.71 cm in shoots, respectively. The lowest root and shoot length were 2.03 cm and 2.94 cm and 2.17 cm and 2.38 cm, respectively (Tables 6 and 9). Additionally, results also showed significant reduction in both fresh and dry biomass (Tables 6 and 9). Furthermore the effects of aqueous flower extracts of *T. erictus* on the, root, shoot length and fresh and dry biomass on *P. hysterophorus was* also studied and the results are as presented on Table 4 and 7. Both fresh and dry biomass of *P. hysterophorus* were reduced compared with the control treatment. The highest fresh biomass values observed in control treatments were 19.67 g and 74.67 g for the four and eight weeks respectively, while the lowest values were 2.17 g and 18.67 g observed for four and eight weeks, respectively, recorded at 100% concentration. The similar inhibition effects was observed in dry biomass whereby the highest biomass values were 9.50 g and 27.67 g in the control treatment while the lowest values were 0.27 g and 0.37 g recorded in a treatment with 100% concentration of aqueous flower extracts of *T. erictus.* The lowest root length (1.63 cm and 3.50 cm) and shoot length (1.80 cm and 3.40 cm) of *P. hysterophorus* were in found in pots treated with 100% (Tables 6 and 9).

Results in Table 7 also showed that *Sorghum bicolor* extracts exhibited strong inhibition on root length, shoot length, fresh biomass and dry biomass of *Parthenium* (Table 7).The highest root and shoot length values were observed in the control treatments which were 7.93 cm and 11.00 cm respectively while the lowest values were observed at the concentration of 100%. The same observations were recorded on the fresh and dry biomass where the highest values were observed in the control treatments and the lowest in 100% concentration

Table 5: The effects of aqueous extracts of the of *A. spinous* and *A. indica* on germination and growth of *P. hysterophorus* sprayed at 4th week of growth and harvested 20 days after spraying

	***A. spinous* (Leaves)**						***A. indica* (Leaves)**					
Treatments	**% Germ++.**	**% Inh**	**Root**	**Shoot**	**FBM**	**DBM**	**%Germ++**	**%Inh**	**Root**	**Shoot**	**FBM**	**DBM**
T1 (0%)	93.33.3.33a		9.67 ± 0.63a	10.73±0.78a	19.17 ±3.84a	9.50 ±2.08a	93.33 ±3.33a		9.68 ±0.63a	11.40 ±0.77a	19.67 ±3.35a	9.50 ±2.08a
T2 (25%)	51.67 ±4.41a	-44.25±6.26a	4.33 ±0.37b	3.67 ±0.03b	5.50 ±1.25b	2.00 ±0.29b	70.00 ±10.00a	-30.00 ±1.67a	4.32 ±0.12b	4.16 ±0.22b	4.83 ±0.60b	2.17 ±0.33b
T3 (50%)	40.00 ±5.00a	-57.41±3.70a	2.97 ±0.12c	3.43 ±0.21bc	2.33 ±0.44b	0.60 ±0.45b	36.33 ±1.67a	-36.67 ±1.67a	3.03 ±0.20b	3.28 ±0.07b	2.00 ±0.29b	1.17 ±0.33b
T4 (100%)	16.67 ±1.67b	-83.33±1.67b	2.10 ±0.15c	2.50 ±0.17c	0.83 ±0.17b	0.12 ±0.07b	33.33 ±6.01b	-66.67 ±6.01b	2.64 ±0.11c	2.94 ±0.17b	1.33 ±0.17b	0.25 ±0.14b
F	**70.65*** **		**79.88*** **	**86.44*** **	**16.89*** **	**16.52*** **	**91.97*** **	**94.08*** **	**91.97*** **	**94.08*** **	**25.39*** **	**15.62*** **

Values presented are means ± SE. *** = significance at P = 0.001 T1, T2, T3, and T4 are levels of concentrations. Means followed by different letters in the same column are significantly different from each other at P = 0.05 based on Fishers Least Significant Difference test. Germ=%Germination, Inh=%Inhibition, FBM=Fresh biomass and DBM=Dry biomass represent fresh biomass, dry biomass, and germination rate and inhibition percent respectively. ++ = Germination test conducted in petri dishes in the laboratory

Table 6: The effects of aqueous leaf and flower extracts of *T. erictus* on germination and seedling growth of *P. hysterophorus* sprayed at 4th week of growth and harvested 20 days after spraying

	T. erictus (leaves)						*T. erictus* (Flower)					
Treatments	**% Germ++.**	**% Inh**	**Root**	**Shoot**	**FBM**	**DBM**	**%Germ++**	**%Inh**	**Root**	**Shoot**	**FBM**	**DBM**
T1 (0%)	93.33±3.33a		9.67 ±0.63a	11.40 ±0.75a	19.67 ±3.35a	9.50 ±2.08a	95.00 ±2.89a		9.67 ±0.63a	11.40 ±0.75a	19.67 ±3.84a	9.50 ±2.08a
T2 (25%)	61.67±11.67a	-38 ±11.67b	3.00 ±0.29b	3.70 ±0.26b	4.53 ±0.29b	2.33 ±0.17b	60.00 ±5.77b	-40 ±5.77c	3.73 ±0.22b	3.75 ±0.22b	5.17 ±0.73b	2.00 ±0.29b
T3 (50%)	35.00 ±2.89a	-65 ±2.89a	2.88 ±0.23b	2.93 ±0.09bc	2.17 ±0.17b	0.83 ±0.33b	40.00 ±5.00b	-60 ±8.66b	2.70±0.06bc	2.67 ±0.03bc	3.67 ±0.17b	1.67 ±0.17b
T4 (100%)	30.00 ±10.00b	-70 ±17.32a	2.03 ±0.34b	2.17 ±0.13c	1.33 ±0.44b	0.28 ± 012b	20.00 ±2.88c	-80 ±2.89a	1.63 ±0.17c	1.80 ±0.10c	2.17 ±0.80b	0.27 ±0.13b
F	**13.24*** **		**77.04*** **	**110.06*** **	**25.73*** **	**16.21*** **	**54.68*** **		**106.56*** **	**125.44*** **	**1*** **	**15.54*** **

Values presented are means ± SE. *** = significance at P = 0.001. T1, T2, T3, and T4 are levels of concentrations. Means followed by different letters in the same column are significantly different from each other at P = 0.05 based on Fishers Least Significant Difference test. Germ=%Germination, Inh=%Inhibition, FBM=Fresh biomass and DBM=Dry biomass represent fresh biomass, dry biomass, and germination rate and inhibition percent respectively. ++ = Germination test conducted in petri dishes in the laboratory

Table 7: The effects of aqueous extracts of the of *S. bicolor* on germination and growth of *P. hysterophorus* sprayed at 4th week of growth and harvested 20 days after spraying

			***Sorghum bicolor* (Leaves)**			
Treatments	**% Germ++.**	**% Inh**	**Root**	**Shoot**	**FBM**	**DBM**
T1 (0%)	93.33± 3.33a		7.93± 0.29a	11.00 ± 1.37a	14.67 ± 2.80a	7.17 ± 1.76a
T2 (25%)	20.00± 2.88b	-80± 2.88b	4.90 ± 0.35 b	4.57 ± 0.35b	6.00 ± 0.58b	1.83 ± 0.33b
T3 (50%)	11.67± 1.67bc	-88 ± 1.67b	3.07 ± 0.27c	3.23± 0.12bc	3.33 ± 0.44b	0.72 ± 0.40b
T4 (100%)	5.00± 2.89c	-95± 2.89c	2.03 ± 0.23c	1.77 ± 0.09c	1.83 ± 0.88b	0.21 ± 0.14b
F-Statistics	**220.24*** **		**79.55*** **	**32.35*** **	**14.36*** **	**11.99*** **

Values presented are means ± SE. *** = significance at P = 0.001. T1, T2, T3, and T4 are levels of concentrations. Means followed by different letters in the same column are significantly different from each other at P = 0.05 based on Fishers Least Significant Difference test. Germ= %Germination, Inh =%Inhibition, FBM=Fresh biomass and DBM =Dry biomass represent fresh respectively. ++ = Germination test conducted in petri dishes in the laboratory

Table 8: The effects of aqueous leafs of *A. spinous* and *A. indica* on seedling growth of *P. hysterophorus* sprayed at 8th week of growth and harvested 20 days after spraying

	A .spinous (Leaves)				*A. Indica* (Leaves)			
Treatments	**Root**	**Shoot**	**FBM**	**DBM**	**Root**	**Shoot**	**FBM**	**DBM**
T1 (0%)	8.36 ±0.80a	8.82 ±0.76a	87.33 ±7.75a	24.67 ±4.91a	7.93±0.87a	8.31±0.86a	84.67±7.69a	24.08±5.86a
T2 (25%)	5.20 ±0.23b	5.03 ±0.34ab	39.67 ±1.33ab	4.30 ±0.57b	5.12±0.36b	4.60±0.44b	52.67±9.17b	10.67±2.19b
T3 (50%)	4.37 ±0.13bc	5.40 ±0.06b	34.67 ±4.37b	1.83 ±0.44b	4.28±0.11bc	3.82±0.28b	43.67±1.85bc	5.67±0.42b
T4 (100%)	3.53 ±0.23c	3.93 ±0.28c	20.33 ±1.20b	0.43 ±0.03b	3.48±0.19c	2.95±0.24c	28.00±6.11c	2.50±0.29b
F	**23.21*** **	**22.77*** **	**40.99*** **	**20.93*** **	**15.88*** **	**20.75*** **	**13.70*** **	**9.13*** **

Values presented are means ± SE. *** = significance at P = 0.001. T1, T2, T3, and T4 are levels of concentrations. Means followed by different letters in the same column are significantly different from each other at P = 0.05 based on Fishers Least Significant Difference test. FBM=Fresh biomass and DBM=Dry biomass and represent fresh biomass and dry biomass, respectively

Table 9: The effects of aqueous leaf and flower extracts of *T. erictus* on seedling growth of *P. hysterophorus* sprayed at 8th week of growth and harvested 20 days after spraying

	***T. erictus* (leaves)**				***T. erictus* (Flower)**			
Treatments	**Root**	**Shoot**	**FBM**	**DBM**	**Root**	**Shoot**	**FBM**	**DBM**
T1 (0%)	6.68± 0.46a	8.71± 0.47a	75.33±2.90a	26.33±4.48b	6.55±0.41a	7.83±0.87a	74.67±394a	27.67±5.04b
T2 (25%)	4.25± 0.40b	3.26±0.38b	47.00±4.56b	7.73±0.54a	5.10±0.51b	4.33±0.17b	29.67±3.94b	1.83±0.73a
T3 (50%)	3.53± 0.42bc	3.22±0.35b	38.33±5.04bc	3.23±0.65a	4.07±0.32bc	4.20±0.15b	27.00±3.94b	1.20±0.90a
T4 (100%)	2.94± 0.21c	2.38±0.38b	26.00±4.04c	1.17±0.44a	3.50±0.06c	3.40±0.11b	18.67±3.94b	0.37±0.09a
F	**17.87*** **	**54.54*** **	**24.68*** **	**25.07*** **	**19.01*** **	**41.02*** **	**26.33*** **	**26.33*** **

Values presented are means ± SE. *** = significance at P = 0.001 respectively. T1, T2, T3, and T4 are levels of concentrations. Means followed by different letters in the same column are significantly different from each other at P = 0.05 based on Fishers Least Significant Difference test. FBM=Fresh biomass and DBM=Dry biomass and represent fresh biomass and dry biomass, respectively

4.2 Discussion

This study aimed at assessing seed to seed interaction of different plant in the management of *P. hysterophorous*. Detailed discussion is given below.

4.2.1 Seed-seed interaction

Plants are known to produce metabolites which can affect the growth and development of other plants (Kim, 2005). The extracts of plants have been considered in the past for management of *P. hysterophorous* due to their inhibition potentials (Javid and Adrees, 2009; Yarnia *et al*., 2015), the same trend was observed in this experiment. Herein, we have assessed the seed to seed interaction of different plant to manage the growth of *P. hysterophorous.* We found that different seeds (*S. bicolor, T. erictus, S. arundinaceum* and *A. spinous*) showed suppressive effect on the measured growth parameters. Other studies have also reported the use of biological agents to manage weeds. For example, the use of phytopathogenic fungi extracts were reported to strongly supress the growth of *P.hysterophorus* and hence manage its spread in Pakistan (Javaid and Adrees, 2009). Furthermore, Yarnia *et al*. (2015) reported that extracts of different parts of *Sorghum* showed significance reduction on the germination of *Amaranthus refroflexus* weed. In a similar way, our findings on the tested plants showed suppressive inhibition on *P. hysterophorus* seed germination. This suggests that allelochemicals present in *S. bicolor, T. erictus, S. arundinaceum* and *A. spinous* have suppression effects to the germination of other crops. Findings from this study suggest that both tested plants could be used in management of *Parthenium* weed as they exhibited growth and germination inhibition. These results, indicate that the suppressive effects contributed is by allelochemicals present in the tested plant species which have strong inhibition property and competes with the *P. hysterophorus* for nutrition and growth.

4.2.2 Plant-plant interaction of S. bicolor, T. erictus, S. arundinaceum, A. spinous on the growth of P. hysterophorus

These findings suggest that, *S. bicolor, T. erictus, S. arundinaceum, A. spinous* had significant suppressive effects on the growth of *P. hysterophorus*, whereas, *C. tora* was not effective in inhibiting the growth of *P. hysterophorus*. The effectiveness of *S. bicolor, T. erictus, S. arundinaceum* and *A. spinous* in reducing growth of *P. hysterophorus* could be attributed by the presence of active metabolites/allelochemicals which resulted in the

suppression effects. For instance, it has been shown that, compounds such as organic and amino acids, phenolics, cyanogenic glycosite, sorgoleone, benzoquinone, alpha-terthienyl produced by *A. spinous*, *S. bicolor, S. arundinaceum* and *T. erictus* affects the growth of other plants by suppressing growth (Ali and Khan, 2017).

Furthermore, *Sorghum almun* was previously reported to suppress *P. hysterophorus* by Khan *et al*. (2013) in Australia and Pakstani. In their study, they found that *S. almun* reduced the height of *P. hysterophorus* up to 73%. Such findings are similar to our present study where *S. bicolor*, reduced the height of *P. hysterophorus* by 4-folds. Our finding suggests that different species of sorghum can be used to reduce infestation of *P. hysterophorus* in the ecosystems. In a study by Ali and Khan (2017), it is reported that sorghum species reduced biomass of *P. hysterophorus* up to 84%. Likewise, in our present study we observed that *S. bicolor* reduce *P. hysterophorus* biomass by nearly 4-folds. Furthermore, in our study we have found that *A. spinous* inhibited shoot height of *P. hysterophorus*. Our findings are similar to those reported by Thapar and Singh (2005) who found that leaves of *A. spinous* produces metabolites such as amino acids and organic acids which accumulates in the leaves of *P. hysterophorus and* hence affects its respiration. Similarly, it is possible that inhibition of *A. spinous* in our study could have resulted from the accumulation of the amino and organic acid metabolites which eventually affected the respiration system of the plant and impaired its growth. It has also been reported that, *T. erictus* extracts inhibited growth of *P. hysterophorus,* reduced shoots, root length and biomass (Shafique 2011). Aerial leaf extracts of *T. erictus* are known to reduce the growth of shoot and root length and biomass of *P. hysterophorous* due to allelochemicals which is in agreements with the present study. Such compounds could have contributed to the suppression effects on the growth *P. hysterophorus* observed in our study. This plant could be further tested in large scale and for other weeds.

4.2.3 Effects of Aqueous extracts on seed germination and seedling growth of *P. hysterophorus*

The aim of this study was to evaluate the bio herbicidal effects of selected plant extracts on the growth of *P. hysterophorus.* All plant extracts applied showed significance suppression of *P. hysterophorus* seedling growth in pot trials. Four weeks seedling were found to be more susceptible compared with eight weeks seedlings. Results showed that the aqueous leaf extracts of *A. indica, T. erictus, S. bicolor, A. spinous* and *T. erictus* as well as flower extracts of *T. erictus* showed significant effects on seeds germination, reduction in shoot and root

length as well as reduced dry and fresh biomass production. Findings obtained in our study are similar with those of Ngodya *et al.* (2016) who reported that germination inhibition, root and shoot length reduction and fresh and dry biomass were decreasing with the increase of concentration of *Desmodium* species extracts. Furthermore, Gholami (2011) report that inhibitory effects in roots and shoots were contributed by reduction in cell division. This suggests that bioactive (bio-herbicidal) obtained from aqueous extracts of the investigated plants has a negative effects cell division of *P. hysterophorus.*

Plant extracts have been reported to have inhibitory effects on the growth and development of other plants. For example Siddiqui *et al.* (2009) reported that the aqueous leaf extract of mesquite (*Prosiposis julifora*) at different concentrations cause pronounced inhibitory effects on seed germination and root length on wheat (*Triticum aestivum*). Similarly, Elisante *et al*. (2013) reported the inhibitory effects of *Datura stramonium* extracts on *Cenchrus ciliaris* and *Neonotania wightii* with their increasing concentration. Generally, germination is the results of continuation of metabolic activities and growth of seed tissues which start with absorption of water through diffusion and osmosis hence cause activation of enzymes and increase metabolic activities. In our experiments, seeds of P. *hysterophorus* supplied with aqueous extracts of *A. indica, T. erictus, A. spinous* and *S. bicolor* affected their germination compared with those supplied with water. This might be to the reasons that plant extracts had metabolic compounds with inhibition effects. This findings are similar to the recently study conducted by Ramachandran (2018) who reported that the germination of *P. hysterophorus* was inhibited due to imbalance of enzymes due to application of aqueous extracts of *Datural metel, Mangifera indica, A. indica, T. erictus* and *S. bicolor* and *Heliantus annuus* which all showed inhibitory effects on the germination.

In this study, we have found strong reduction of *P. hysterophorus* biomass by 33.33% using extracts from A. *indica*. This reduction is due to the bioactive compounds found in *A. indica* which has bio-herbicides that suppress the growth of *P. hysterophorus*. Behl *et al*. (2004) reported the presence of bioactive compound such as Nimbin, Azadirone, Azadirachtins and Salanin in *A. indica*. These bioactive compounds have strong bio-herbicidal properties and might have caused the suppressive effects in the *Parthenium* growth parameters. This findings suggests that aqueous extracts of *A. indica* could be effective in controlling and managing *P. hysterophorous*.

Extracts from *A. spinous* showed significant effects on the growth of *P. hysterophorus* parameters (Table 1). For example, at 50 percent concentration of *A. spinous*, the root length was reduced by nearly 2-folds, while the dry biomass was reduced nearly by 20-folds (Table 2). This could be contributed by the bio-herbicidal present in *A. spinous*. Our results are in agreements with a similar study by Thapar and Singh (2005) who reported that the leaf extracts of *A. spinous* reduced the growth of *P. hysterophorus*. In their study, the suppressive effects of growth were associated with the presences of organic compounds such as amino acids. Another study Thapar (2005) has reported that the bio-herbicidal present in the leaves of *A. spinous* stimulated lignin biosynthesis which increased the rigidity of the cell wall and limited the cell growth.

The effects of aqueous leaf and flower extracts of *T. erictus* on seeds germination and growth of *P. hysterophorus* was investigated. Our findings showed that both extracts inhibited the growth of *P. hysterophorus* nearly by 3-folds at the 100% concentration. These findings are in agreements with the study conducted by Shafique (2011) whose results revealed that the increase of concentration of aqueous extracts of *T. erictus* reduced the root length, shoot length, fresh and dry biomass of *P. hysterophorus* and this was attributed to the concentration of the extract and presence of herbicidal properties found in *T. erictus*. Furthermore, Guzman (1988) revealed that intensity of inhibitory effects of different parts of plants may be due to presence of different phytotoxic compounds such as phenolics, sesquiterpenes and lactones from plant parts. In this study more inhibition on roots, shoots, and germination, fresh and dry biomass was observed when the flower extracts were applied as compared with the leaf extracts. This suggests that flowers of *T. erictus* released stronger bioactive compounds which inhibited the growth parameters compared with leaves.

Sorghum bicolor plant extracts also significantly inhibited the germination and the growth of *P. hysterophorus* root, shoot, fresh and dry biomass and germination as a function of concentration increase. Our findings suggests that, *S. bicolor* has a great potential to control and manage *P. hysterophorus*. The present results are in agreement with findings of Randhawa *et al.* (2002) who reported that sorghum water extracts at high concentration significantly reduced the germination, root, and shoot length of *Trianthema portulacastrum*.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, management of *Parthenium hysterophorous* by using suppressive plants species has been studied and their effects established. Growth parameters of *P. hysterophorous* such as germination rate, root length, shoot length, fresh and dry biomass were obtained as discussed in chapter four. The growth parameters (germination rate, root length, shoot length, fresh and dry biomass) were decreased as when they were interfered with the plant extracts and competition experiment. The effects of plant extracts were seen when *P. hysterophorus* grown in association with the selected plant species. Further the effects also was seen when the plant extracts were used in both germination and foliar spray. Tested plant species showed suppression effects on seed germination, growth, root length, and dry biomass on *Parthenium*. Degree of suppression differed significantly with *C. tora* showing minimum suppressive effects. This study provide basis for parthenium management. Further we conclude from this study that aqueous leaf and flower extracts of *S. bicolor, A. spinous, T. erictus* (leafs and flower) and *A. indica* have bio-herbicidal effects on root and shoot length, fresh and dry weight and germination of *P. hysterophorus* in the laboratory and pot experiments. The results shows that all the applied plant extracts have potential in the management of *P. hysterophorus* when applied at higher concentrations.

5.2 Recommendations

Although this study has fulfilled its objectives, there are limitations encountered. These should be utilized as a new areas for further research opportunities.

(i) The promising plants are recommended for large scale testing in areas where the weed is increasingly becoming a problem.

(ii) Further studies should be conducted under field conditions to ascertain the effectiveness of *S. bicolor, A. spinous, T. erictus* and *A. indica* in controlling *P. hysterophorus*.

(iii) Further research on biological management by using other botanicals are needed to come up with proper solution for this noxious weed.

(iv) Molecular characterization of plant species used in this study in order to come up with best way of managing Parthenium at molecular level.

(v) Soil analysis is also needed especially in the place where *P. hysterophorus* are grown so that to know the amount of seeds present in the seed bank to assist the effort of managing this weed.

(vi) Similar study could be conducted on extracts preparation by using other solvents instead of water to see if the suppression will be more effective.

(vii) Further study of the effects of plant extracts on the parthenium metabolism such as compositions of sugar, amino acids, lipids and organic acid is needed in order to know how the effective of the extracts are and to recommend the appropriate plants since alteration of the plant metabolism can lead to suppression effects.

(viii) More work is recommended to come up with the bioactive compounds to know which one work best especially for the species found in Tanzania.

REFERENCES

Adkins, S. and Shabbir, A. (2014). Biology, ecology and management of the invasive *Parthenium* weed (*Parthenium hysterophorus* L.). *Pest Management Science.* **70**(7): 1023-1029.

Alavanja, M. C., Hoppin, J. A. and Kamel, F. (2004). Health effects of chronic pesticide exposure: cancer and neurotoxicity. *Annual Review Public Health.* **25**: 155-197.

Ali, S. and Khan, I. A. (2017). Management *of Parthenium hysterophorus* using suppressive plants. *Malaysian Journal of Science*. **36**(2): pp.75

Aneja, K., Dhawan, S. and Sharma, A. B. (1991). Deadly weed, parthenium hysterophorus and its distribution. *Indian Journal of Weed Science.* **23**(3and4): 14-18.

Annapurna, C. and Singh, J. (2003). Variation of Parthenium hysterophorus in response to soil quality: implications for invasiveness. *Weed Research.* **43:**(3): 190-198.

APFISN/Asian-Pacific Forest Invasive Species Network/ (2007) Invasive, *Newsletter of the Asian-Pacific Forest Invasive Species Network,* Volume 9. Kerala, India.

Auld, B., Hosking, J. and McFadyen, R. (1982). Analysis of the spread of tiger pear and parthenium weed in Australia. *Australian Weeds.* **2**(2): 56-60.

Ayele, S. (2007). The impact of *Parthenium* (*Parthenium hysterophorus* L.) on the range ecosystem dynamics of the Jijiga rangeland, Ethiopia. *Department of Animal Sciences, School of Graduate Studies, Haramaya University*. 134.

Ayele, S., Nigatu, L., Tana, T. and Adkins, S. W. (2013). Impact of *Parthenium* weed (*Parthenium hysterophorus* L.) on the above-ground and soil seed bank communities of rangelands in Southeast Ethiopia. *International Research Journal of Agricultural Science and Soil Science.* **3**(7): 262-274.

Belnap, S. L. (2001). Phillips Soil biota in ungrazed grassland. Response to annual grass (Bromustectorum) invasion *Ecological Applications.* **11**:1261-1275

Bhawmilk, C. P. and Sarkar, D. (2005.). *Parthenium hysterophorus* L: Its world status and potential management. Pp.1-6. In: Proceeding of the Second International Conference on *Parthenium* Management 5-7 December 2005. University of Agricultural Science Bangolore, India.

Bhowmik, P. and Sarkar, D. (2005). *Parthenium hysterophorus: its world status and potential management.* Paper presented at the Proceedings of the Second International Conference on Parthenium Management.

Bhowmik, P., Sarkar, D. and Yaduraju, N. (2007). The status of Parthenium hysterophorus and its potential management. *Ecoprint: An International Journal of Ecology*. **14**: 1-17.

Bryson, C. T. (2003). Weed Science. In: Encyclopedia of Agrochemicals, Volume 3, Plimmer, J. (Ed.). John Wiley and Sons, New York, USA. ISBN-13: 9780471238690, pp: 1571-1588.

Buhler, D. D. and Hoofman, M. L. (2000). Andersen's Guide to practical methods of propagating weeds and other plants. Weed Science society of America, Lawrence, USA. Pp.115-135

CAB International. (2014). *Parthenium hysterophorus L* (parthenium weed). In: Invasive Species Compendium lliney, T. W. (2005).

Chamberlain, J. and Gittens, A. (2004). Parthenium weed management: challenges, opportunities and strategies. Parthenium action group. *The State of Queensland (Department of Natural Resources, Mines and Energy), Brisbane, Australia*, 82. *Chemistry and mode of action of allelochemicals*. CRC Press, New York

Chippendale, J. and Panetta, F. (1994). The cost of parthenium weed to the Queensland cattle industry. *Plant Protection Quarterly*. **9**(2): 73-76. hileepan, K. (2001). Effectiveness of introduced biocontrol insects on the weed Parthenium hysterophorus (Asteraceae) in

Commare, R. R., Nandakumar, R., Kandan, A., Suresh, S., Bharathi, M., Raguchander, T. and Samiyappan, R. (2002). Pseudomonas fluorescens based bio-formulation for the management of sheath blight disease and leaf folder insect in rice. *Crop Protection.* **21***(*8): 671-677.

Culliney, T. W. (2005). Benefits of classical biological control for managing invasive plants. *Critical Reviews in Plant Sciences.* **24**(2): 131-150.

Dale, I. (1981). *Parthenium* weed in the Americas. *Australian weeds.* **1**(1):8-14.

De Prado, R. A. and Franco, A. R. (2004). Cross-resistance and herbicide metabolism in grass weeds in Europe: Biochemical and physiological aspects. *Weed Science* 52: 441-447.

Dhanaraj, R. and Mittra, M. (1976). Control of *Parthenium hysterophorus* L. with diquat. *PANS,* **22**(2): 269-272.

Dhileepan, K. (2001). Effectiveness of introduced biocontrol insects on the weed *Parthenium hysterophorus* (Asteraceae) in Australia. *Bulletin of Entomological research.* **91**(3) :167-176.

Dhileepan, K. (2003). Current status of the stem-boring weevil Listronotus setosipennis (Coleoptera: Curculionidae) introduced against the weed Parthenium hysterophorus (Asteraceae) in Australia. *Biocontrol Science and Technology,* **13**(1):3-12.

Dhileepan, K. and McFadyen, R. C. (2012). *Parthenium hysterophorus* L. *Parthenium*. In: Biological Control of Weeds in Australia. CSIRO Publishing, Melbourne, pp.448–462

Dhileepan, K. and Wilmot Senaratne, K. (2009). How widespread is Parthenium hysterophorus and its biological control agent Zygogramma bicolorata in South Asia? *Weed Research,* **49** (6): 557-562.

Dhima, K.V., Vasilakoglou, I. B., Eleftherohorinos I. G. and Lithourgidis, A. S. (2006). Allelopathic potential of winter cereals and their cover crop mulch effect on grass weed suppression and seedling growth.

Dogra, K. S., Sood, S. K. and Sharma, R. (2011). Distribution, biology and ecology of *Parthenium hysterophorus* L.(*Congress grass*) an invasive species in the North-Western Indian Himalaya (Himachal Pradesh). *African Journal of Plant Science*, **5**(11): 682-687.

.

Evans, H. C. (1997). *Parthenium hysterophoru*s: A review of its weed status and the possibilities for biological control. Biocontrol: *News and Information.* 18*(3): 89-98*

Fessehaie, R., Chichayibelu, M. and Hailegeorgis, M. (2005). Spread and ecological consequences of *Parthenium hysterophorus* in Ethiopia. *Arem.*

Filemon, E., Mokiti, T. T. and Ndakidemi, A. P. (2013) Allelopathic Effect of Seed and Leaf Aqueous Extracts of *Datura stramonium* on Leaf Chlorophyll Content, Shoot and Root Elongation of *Cenchrus ciliaris* and *Neonotonia wightii*

Florentine, S. K., Raman, A. and Dhileepan, K. (2002). Responses of the weed *Parthenium hysterophorus* (Asteraceae) to the stem gall-inducing weevil Conotrachelus albocinereus (Coleoptera: Curculionidae). *Entomologia Generalis.* **26**(3): 195-206.

Gholami, B. A., Faravani, M. and Kashki, M. T. (2011) "Allelo-pathic Effects of Aqueous Extract from Artemisia Kopet- daghensis and Satureja Hortensison Growth and Seed Germination of Weeds," *Journal of Applied Environ- mental and Biological Sciences*, Vol. 1, No. 9, pp. 283-290

Gnanavel, I. and Natarajan, S. (2013). *Parthenium hysterophorus* L.: a major threat to natural and agro eco-systems in India. *International Journal of Agriculture, Environment and Biotechnology.* **6**(2:, 261-269.

Gommers, F. J. and Bakker, J. (1988). Physiological diseases induced by plant responses or products In: *Diseases of nematodes*. (Eds.): G. O. Poinar, Jr. and H.-B. Jansson. Vol. I. CRC Press, Inc. Incorporation on *Parthenium hysterophorus* management. *Allelopath Journal.* **22**(2): 353-362.

Holm, L., Doll, J., Holm, E., Pancho, J. V. and Herberger, J. P. (1997). World Weeds: Natural Histories and Distribution, John Wiley & Sons, New York, NY, USA.

Issakwisa, B. N., Treydte, A. C., Ndakidem, A. P. and Linus, K. M. (2017). Invasive plants: ecological effects, status, management Challenges in Tanzania and the way forward.

Issakwisa, B. N., Munishi, L., Treydte, C. A. and Ndakidemi, A. P. (2016). "Demonstrative effects of crude extracts of *Desmodium* spp. to fight against the invasive weed species Tagetes minuta." *Acta Ecologica Sinica* **36**(2): 113-11

Jalali, M., Gheysari, H., Azizi, M., Zahedi, S. and Moosavi, S. (2013). Allelopathic potential of common mallow (Malva sylvestris) on the germination and the initial growth of blanket flower, plumed cockscomb and sweet William. *International Journal of Agriculture and Crop Sciences.* **5** (15):1638.

Javaid, A. and Adrees, H. (2009). *Parthenium* management by cultural filtrates of phytopathogenic fungi. *Natural Product Research.* **23** (16):1541-1551.

Javaid, A. and Anjum, T. (2006). Control of *Parthenium hysterophorus* L., by aqueous extracts of allelopathic grasses. *Pakistan Journal of Botany.* **38** (1): 139.

Javaid, A., Anjum, T. and Bajwa, R. (2005.) "Biological control of *Parthenium* II: allelopathic effect of *Desmostachya bipinnata* on distribution and early seedling growth of *Parthenium hysterophorus* L.," *International Journal of Biology and Biotechnology.* **2**(2*)*:459–463.

Javaid, A., Shafique, S. and Riaz, T. (2008). Effects of rice extracts and residue incorporation on Parthenium hysterophorus management. *Allelopath. Journal.* **22**(2): 353-362.

Jayaramiah, R., Krishnaprasad, B., Kumar, S., Pramodh, G., Ramkumar, C. and Sheshadri, T. (2017). Harmful effects of *Parthenium hysterophorus* and management through different approaches-A review. *Annals of Plant Sciences.* **6**(05): 1614-1621.

Jong-Bum, K. (2005). Pathogen, Insect and Weed Control Effects **o**f Secondary Metabolites from Plants.

Kanchan, S. and Chandra, J. (1980). Pollen allelopathy—a new phenomenon. *New Phytologist.* **84** (4): 739-746.

Kandasamy, O. S. and Sankaran, S. (1997). Biological suppression of *Parthenium* weed using competitive crops and plants. pp. 33-36 In: Proceeding of the First International Conference on Parthenium Management, 6-8 October 1997, University of Agricultural Sciences, Dahrwad, India

Kapoor, R. (2012). Awareness related survey of an invasive alien weed, *Parthenium hysterophorus* L. in Gautam Budh Nagar district, Uttar Pradesh, India. *Journal of Agricultural Technology.* **8**(3): 1129-1140.

Kaur, M., Aggarwal, N. K., Kumar, V. and Dhiman, R. (2014). Effects and management of *Parthenium hysterophorus*: A weed of global significance. *International scholarly research notices.*

Kebede, A. (2008). The distributions of *Parthenium* weed (*Parthenium hysterophorus* L. Asteraceae) and some of its socio-economic and ecological impacts in the Central Rift Valley, Adami Tulu-Jido Kombolcha Woreda; Ethiopia. Addis Ababa University.

Khosla, S. and Sobti, S. (1981). Effective control of *Parthenium hysterophoru*s Linn. *Pesticides*

Kilewa, A. R. (2014). Distribution of Invasive Weed *Parthenium hysterophorus* in Natural and Agro-Ecosystems in Arusha Tanzania. *International Journal of Science and Research (IJSR).* **3**(12):1724-1727.

Kohli, R. K. and Rani, D. (1994). *Parthenium hysterophorus* – a review. *Research Bulletin (Science) Punjab University*. 44: 105-149.

Kohli, R. K., Batish, D. R., Singh, H. and Dogra, K. S. (2006). "Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., Ageratum conyzoides L., Lantana camara L.) In India. "*Biological Invasions.* **8**(7): 1501–1510.

Kohli, R. K., Dogra, K. S., Batish, D. R. and Singh, H. P. (2004). Impact of invasive plants on the structure and composition of natural vegetation of northwestern Indian Himalayas. *Weed Technology*. **18** (sp1): 1296-1300.

Kohli, R., Rani, D., Singh, H. and Kumar, S. (1997). Response of Crop Seeds Towards the Leaf Leachates of *Parthenium hysterophorus* L. *Indian Journal of Weed Science.* **28** (1and2):104-106.

Kohlil, F., Batish, D., Singh, J., Singh, H. and Bhatt, J. F. (2011). *Invasive Alien Plants An Ecological Appraisal for the Indian Subcontinent.* **1**, 1.

Kololgi, P., Kololgi, S. and Kololgi, N. (1997). *Dermatologic hazards of parthenium in human beings.* Paper presented at the Proceedings of the First International Conference on *Parthenium* Management, Dharwad, India.

Kumar, A. (2014). *Parthenium hysterophorus* L. and its impact on living world. *Indian Journal Science Research.* **4**(1): 8-14.

Kumar, S. (2015). History, progress and prospects of classical biological control in India. *Indian Journal of Weed Science.* **47:**306-320.

Kumar, S. (2009). "Biological control of *Parthenium* in India: status and prospects," Indian *Journal of Weed Science.* vol. 41, no. 1-2, pp. 1–18.

Levine, J. M., Vila, M., D' Antonio, C. M., Dukes, J. S., Grigulis, K. and Lavorel, S. (2003). Mechanisms underlying the impacts of exotic plant invasions Protection. *Proceedings of Royal Society of London. ,* **270**: 775-781 *Ecosystems, 503-523.*

Macias, F. A., Oliveros-Bastidas, A., Marin, D., Castellano, D., Simonet A. M. and Molinillo, J. M. G. (2004). Degradation studies on benzoxazinoids. Soil degradation dynamics of 2, 4-Dihydroxy-7-methoxy-(2*H*)-1, 4-benzoxazin-3(4*H*)-one (DIMBOA) and its degradation products, phytotoxic allelochemicals from gramineae. *Journal of Agriculture and Food Chemistry*, **52**: 6402-6413.

Mahadevappa, M., Das, T. and Kumar, A. (2001). *Parthenium: a curse for natural herbs.* Paper presented at the Proceedings of the National Research Seminar on Herbal Conservation, Culture, Marketing and Utilization with Special Emphasis on Chhatisgarh, The Herbal State.

Maharjan, S., Shrestha, B. and Jha, P. (2007). Allelopathic effects of aqueous extract of leaves germination and seedling growth of some of *Parthenium hysterophorus* L. on seed cultivated and wild herbaceous species. *Scientific World,* **5** (5): 33-39.

McConnachie, A., Strathie, L., Mersie, W., Gebrehiwot, L., Zewdie, K., Abdurehim, A. and Assefa, F. (2011). Current and potential geographical distribution of the invasive plant *Parthenium hysterophorus* (Asteraceae) in eastern and southern Africa. *Weed Research,* **51** (1): 71-84.

McFadyen, R. C. (1992). Biological control against *Parthenium* weed in Australia. *Crop protection.* **11**(5): 400-407.

Monaco, T. J., Weller, S. C. and Ashton, F. M. (2002). *Weed science: principles and practices*: John Wiley and Sons.

Msafiri, C. J., Tarimo, M. T. and Ndakidemi, P. (2013). Allelopathic effects of *Parthenium hysterophorus* on seed germination, seedling growth, fresh and dry mass production of Alysicurpus glumaceae and Chloris gayana. *American Journal of Research Communication.* **1**(11): 190-205.

Narasimhan, T. R. M., Annath, M. N. and Rao, P. V. S. (1977). Toxicity of *Parthenium hysterophorus* L. *Current Science.* **46**:15-16.

Nath, R. (1988). *Parthenium hysterophorus* L.-a review. *Agricultural Reviews.* **9**(4): 171-179.

Navie, S., McFadyen, R., Panetta, F. and Adkins, S. (1996). The biology of Australian weeds. 27. *Parthenium hysterophorus* L. *Plant Protection Quarterly.* **11**(2): 76-88.

Neeraja, A. and Vikas, G. (2010). Phytochemical analysis of Lantana camara and Parthenium

Nguyen, T. L., Navie, S. C. and Adkins, S. W. (2010). *The effect of parthenium weed (Parthenium hysterophorus L.) on plant diversity in pastures in Queensland, Australia.* Paper presented at the 17th Australasian weeds conference. New frontiers in New Zealand: together we can beat the weeds. Christchurch, New Zealand. 26-30 September, 2010.

Nigatu, L., Hassen, A., Sharma, J. and Adkins, S. W. (2010). Impact of *Parthenium hysterophorus* on grazing land communities in north-eastern Ethiopia. *Weed Biology and Management.* **10** (3): 143-152.

Pandy D. K., Palni, L. M. S. and Joshi, S. C. (2003). Growth production and photosynthesis of ragweed parthenium (*Parthenium hysterophorus* L.). Weed Sci. **51**:191-201

Parsons, W. T., Parsons, W. T. and Cuthbertson, E. (2001). *Noxious weeds of Australia*: CSIRO Publishing.

Patel, S. (2011). Harmful and beneficial aspects of *Parthenium hysterophorus*: an update. *3 Biotech,* **1** (1): 1-9.

Picman, J. and Picman, A. K. (1984). Autotoxicity in *Parthenium hysterophorus* and its possible role in control of germination. *Biochemical Systematics and Ecology,* **12**(3): 287-292.

Rajiv, P., Rajeshwari, S. and Venckatesh, R. (2013). Bio-fabrication of zinc oxide nanoparticles using leaf extract of *Parthenium hysterophorus* L. and its size-dependent antifungal activity against plant fungal pathogens. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy.* **112**: 384-387.

Ray, P. and Gour, H. (2012). Integrated management of *Parthenium hysterophorus* L.(Asteraceae): a weed of worldwide significance. *Indian Society of Mycology and Plant Pathology.* **5:** 605-632.

Rezene, F., Chichayibelu, M. and Giorgi, M. H. (2005). Spread and ecological consequences of *Parthenium hysterophorus* L. in Ethiopia. Arem. **6**:11-21

Riaz, T. and Javaid, A. (2010). Prevalence of invasive *Parthenium* weed in district Hafizabad, Pakistan. *Journal of Animal and Plant Science.* **20** (2): 90-93.

Riaz, T. and Javaid, A. (2011). Prevalence of alien weed *Parthenium hysterophorus* L. in grazing and wastelands of District Attock, Pakistan. *Journal of Animal and Plant Science.* **21:** 542-545.

Roy, D. and Shaik, M. M. (2013). Toxicology, phytochemistry, bioactive compounds and pharmacology of *Parthenium hysterophorus*. *Journal of Medicinal Plants Studies.* **1**(3): 126-141.

Sad, A. S. and Swhsana, R. B. (2005). *Parthenium hyterophorus* L spread and status on its management in Pakistan. pp. 28-35. In: Proceeding of the Second International Conference on *Parthenium* Management. 5-7 December. 2005. University of Agricultural Science Bangolore, India.

Shabbir, A., Dhileepan, K. and Adkins, S. W. (2012). Spread of *Parthenium* weed and its biological control agent in the Punjab, Pakistan. *Pakistan Journal of Weed Science Research.* **18**(Special Issue):581-588.

Shafique, S., Bajwa, R. and Shafique, S. (2011). *Tagetes erectus* L.-a potential resolution for management of Parthenium hysterophorus L. *Pakistan Journal of Botany.* **43**:885-894

Sharma, V. K., Sethuraman, G. and Bhat, R. (2005). Evolution of clinical pattern of *Parthenium* dermatitis: a study of 74 cases. *Contact Dermatitis.* **53**(2): 84-88.

Shazia, S., Rukhsana, B. and Sobiya, S. (2011). A potential Resolution for Management of *Parthenium hysterophorous* L.

Siddiqui, Z. S. and Zaman, A. U. (2005). "Effects of Capsicum Leachates on Germination, Seedling Growth and Chloro- phyll Accumulation in *Vigna radiata* (L.) Wilczek Seedlings," *Pakistan Journal of Botany*. Vol. 37, No. 4, pp. 941-947.

Singh, H. P., Batish, D. R., Kohli, R., Saxena, D. B. and Arora, V. (2002). Effect of parthenin a sesquiterpene lactone from *Parthenium hysterophorus* on early growth and physiology of Ageratum conyzoides. *Journal of Chemical Ecology*. **28**(11): 2169-2179.

Singh, H., Batish, D., Pandher, J. and Kohli, R. (2003). Assessment of allelopathic properties of *Parthenium hysterophorus* Bresidues. *Agriculture, Ecosystems and Environment*, **95**(2-3):537-541.

Singh, H., Batish, D., Pandher, J. and Kohli, R. (2003). Assessment of allelopathic properties of *Parthenium hysterophorus* residues. *Agriculture, Ecosystems and environment*, **95***(*2-3): 537-541

Sriramarao, P., Nagpal, S., Rao, B. S., Prakash, O. and Rao, P. S. (1991). Immediate hypersensitivity to *Parthenium hysterophorus*. II. Clinical studies on the prevalence of Parthenium rhinitis. *Clinical and Experimental Allergy.* **21**(1): 55-62.

Stamps, R. H. (2011). Identification, Impacts, and Control of Ragweed *Parthenium (Parthenium hysterophorus* L.). *University of Florida IFAS Extension*, 10.

Sunday, A. and Afolayan, A. J. (2012). "Assessment of Al- lelopathic Properties of *Aloe Ferox* Mill. On Turnip, Beet- root and Carrot," *Biological Research*, Vol. 45, No. 4, pp. 363-368. http://dx.doi.org/10.4067/S0716-97602012000400006

Tamado, T. and Milberg, P. (2000).Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of *Parthenium hysterophorus*. L Weed Research. **40**:507–521.

Tamado, T. and Milberg, P. (2004). Control of *Parthenium* (*Parthenium hysterophorus*) grain sorghum (*Sorghum bicolor* L.) in the smallholder farming system in eastern Ethiopia. Weed Technology **18**: 100–105.

Tamado, T., Ohlander, L. and Milberg, P. (2002). Interference by the weed *Parthenium hysterophorus* L. with grain sorghum: influence of weed density and duration of competition. *International Journal of Pest Management.* **48**(3): 183-188.

Taye, T., Gossmann, M., Einhorn, G., Büttner, C., Metz, R. and Abate, D. (2002). The potential of pathogens as biological control of *Parthenium* weed (*Parthenium hysterophorus* L.) in Ethiopia. *Mededelingen (Rijksuniversiteit te Gent. Fakulteit van de Landbouwkundige en Toegepaste Biologische Wetenschappen).* **67**(3): 409-420.

Thapar, R. and Singh, N. (2005). Allelopathic influence of leaf residue of *Amaranthus spinosus* on growth and metabolism of *Parthenium hysterophorus* L. *Ecoprint: An International Journal of Ecology.* **12**: 77-84.

Timsina, B., Shrestha, B. B., Rokaya, M. B. and Münzbergová, Z. (2011). Impact of *Parthenium hysterophorus* L. invasion on plant species composition and soil properties of grassland communities in Nepal. *Flora-Morphology, Distribution, Functional Ecology of Plants.* **206**(3): 233-240.

Valuing, E. Z. (2000). Ecosystem services lost to Tamarix invasion in the United States.

Van der Laan, M., Reinhardt, C. F., Belz, R. G., Truter, W. F. Foxcroft, L. C. and Hurle, K. (2008) Interference potential of the perennial grasses Eragrostis curvula, Panicum maximum and Digitaria eriantha with *Parthenium hysterophorus*. Trop. Grassland. **42**: 88–95.

Vasilakoglou, I., Dhima, K. and Eleftherohorinos, I. (2005). Allelopathic potential of *bermudagrass* and *Johnsongrass* and their interference with cotton and corn. *Agronomy J*ournal. **97**: 303-313.

Vila-Aiub, M. M., Vidal, R. A., Balbi, M. C., Gundel, P. E., Trucco, F. and Ghersa, C. M. (2008). "Glyphosate-resistant weeds of South American cropping systems: an overview," Pest Management Science. **64**(4):366–371,

Wakjira, M., Berecha, G. and Tulu, S. (2009). Allelopathic effects of an invasive alien weed *Parthenium hysterophorus* L. compost on lettuce germination and growth. *African Journal of Agricultural Research.* **4**(11): 1325-1330.

Wiesner, M., Tessema, T., Hoffmann, A., Wilfried, P., Buettner, C., Mewis, I. and Ulrichs, C. (2007). Impact of the Pan-Tropical weed *Parthenium hysterophor*us L. on human health in Ethiopia. *Institute of Horticultural Science, Urban Horticulture, Berlin, Germany*.

Worku, M. (2010). Prevalence and distribution survey of an invasive alien weed (*Parthenium hysterophorus* L.) in Sheka zone, Southwestern Ethiopia. *African Journal of Agricultural Research.* **5**(9): 922-927.

Yadav, N., Saha, P., Jabeen, S., Kumari, S., Verma, S., Singh, B. and Sinha, M. (2010). Effect of methanolic extract of *Parthenium hysterophorus* on haematological parameters in Wistar albino rat. *The Bioscan—International Journal of Life Sciences.* **2**: 357-363. Patel, S. (2011). Harmful and beneficial aspects of Parthenium hysterophorus: an update. *3 Biotech.* **1** (1):1-9.

Yaduraju, N. T., Sushilkumar, M. B. B., Prasad, B. and Gogoi, A. K. (2005). *Parthenium hysterophorus* H.-B. Jansson. Vol. I. CRC Press, Inc., Boca Raton, FL. 3-22

Yarnia, M., Benam, M. B. and Tabrizi, E. M. F. (2015). Allelopathic effects of sorghum extracts on *Amaranthus retroflexus* seed:

RESEARCH OUTPUTS

- Review Manuscript Titled “Carrot-weed: A noxious plant that threatens biodiversity in Africa” *Submitted in Journal of American Plant science. (Accepted 11/10/2018)*

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To
Neema Mtenga*, Thadeo Mokiti, Patrick Ndakidemi and Ernest Mbega

Department of Sustainable Agriculture and Biodiversity and Ecosystem Management, School of Life Sciences and Bioengineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania
*Corresponding author

Subject: Acceptance letter for manuscript (2018/IJPSS/45691) submitted for IJPSS

Dear Dr. Neema Mtenga,

We are pleased to inform that your manuscript (MS no. 2018/IJPSS/45691) entitled "**The suppressive effects of selected plants species for the management of P. hysterophorus**" is ACCEPTED for publication in International Journal of Plant & Soil Science (IJPSS).

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The Suppressive Effects of Selected Plants Species for the Management of *P. hysterophorus*

Neema Mtenga[1*], Thadeo Mokiti[1], Patrick Ndakidemi[1] and Ernest Mbega[1]

[1]Department of Sustainable Agriculture and Biodiversity and Ecosystem Management, School of Life Sciences and Bioengineering, The Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present study investigated the suppressive effects of *Sorghum bicolor, Sorghum arundinaceum, Amaranthus spinous, Tagetes erictus* and *Cassia tora* on the management of *P. hysterophorus*.

Study Design: A randomized block design was used to assess the suppressive effects of Sorghum *bicolor, Tagetes erictus, Amaranthas spinous, Sorghum arundinaceum and C tora* in laboratory and pot experiments. The treatments were replicated four times.

Place and Duration of Study: Experiments were conducted at the Tropical Pesticides Research Institute (TPRI) and Nelson Mandela Institution of Science and Technology (NM-AIST) for three months from March to June, 2018.

Methodology: Plant to plant and seed to seed interactions were used to study the growth parameters behavior of tested plants both in pots and in laboratory settings. The germination of each plants in both laboratory and screen house was recorded soon after germination for 14 days at the interval of two days. Additionally, for pot studies, plant height, root length and biomass yield were assessed after a period of 3 months during the termination of the study

**Corresponding author: E-mail: mtengan@nm-aist.ac.tz;*

Results: Results showed that *Sorghum bicolor, Tagetes erictus, Amaranthus spinous* and *Sorghum arundinaceum* demonstrated strong suppression on germination inhibition and plant height and root length as well as reduced biomass of *P.hysterophorus*. However, *Cassia tora* exhibited weak suppression effects in both laboratory and pot experiments.
Conclusion: Findings from this study suggest that *Sorghum bicolor, Tagetes erictus, Amaranthus spinous, Sorghum arundinaceum* were effective in affecting *P.hysterophorus*. Our finding provides bases towards developing an effective alternative to manage *P. hysterophorous*.

Keywords: Parthenium; management; suppression; allelloapathic.

1. INTRODUCTION

Parthenium hysterophorus L. (Carrot-weed) is a noxious herbaceous plant originating from the subtropical region of North and South America [1]. In Africa, the weed is recently reported to invade different countries such as Ethiopia, Somalia, Kenya, Madagascar, Mozambique, South Africa, Swaziland, Zimbabwe and Tanzania [2] & [3];[4]. *Parthenium* is considered as a weed of global significance because of its negative impacts including skin dermatitis, asthma, and bronchitis to human and animals and, effect on agricultural crops incited by its allelopathic dominance [1]; [5]L; [6]; [7]; [8]; [9]; [10]; [11]. *P. hysterophorus* is characterized by strong tolerance to a wide range of soil and environmental conditions, high seed production and seed persistence in soil banks, rapid germination, seedling growth and short life cycle [12]: [13]. Furthermore this weed produces phytotoxic substance/chemicals which inhibit germination of other plant species around it [14]: [15]. Different control methods for the weed have been reported so far. One of the mostly reported methods is the use of other organisms (biological management) to control the weed. Biological management of *P. hysterophorus* has been practiced in different countries in the world. For example, in Australia the use of insects and rust pathogen to control the weed have been practiced [16]; [17]. It has been shown that, the use of Epiblema *stenuana* Walker and *Zygogramma bicolorata* Pallister in the war against *P. hysterophorus* has shown success, though with some limitations. The organisms do not induce full suppression of the weed [18]. Similar observation on *Parthenium* control using the same organisms was recently reported in Tanzania. *Zygogramma* has emerged as an alternative biological control of the weed, the approach deals only with parts of the plant such as leaves. Moreover, number of chemical methods have been used in the management of this weed but the results shows that the chemicals kill only the existing *P.hysterophorus* weed population found in the area, but cannot prevent the entry of new seeds that are brought in by wind, water or other dissemination agents [19].

Despite of all the efforts applied in the management of *P. hysterophorus*in in Tanzania, the weed is still spreading rapidly. Due to its harmful effects, there is a need to investigate other management strategies such as suppressive potential from different plants. The use of suppressive plants have been done in countries such as India using guinea grass (*Panicum maximum* Jacq.) tanner's cassia (*Cassia auriculata* L.) and Fedogoso (*Cassia occidentalis* L) [20], Ethiopia using; Sorghum (*Sorghum bicolor* L, Moench); [21] and in South Africa using African Lovegrass (*Eragrostis curvula Nox*; [22].

Although several reports have shown suppressive effect from plants such as *A. spinous*, *T. erictus* and *C. tora* on the management of *P. hysterophorus* in different parts of the world, the suppressive effects of the same plants in the management of *P. hysterophorus* in Tanzania is not documented. Therefore, this study aimed at investigating the suppressive effects of the selected plants species on the management of *P. hysterophorus*. Seed to seed and plant to plant interaction approaches were used in the management of weed.

2. MATERIALS AND METHODS

2.1 Experimental Sites

The experiments were conducted at The Nelson Mandela African Institution of Science and Technology (NM-AIST) Laboratory and at the Tanzania Pesticides Research Institute (TPRI) Arusha-Tanzania.

2.2 Plant Material Used in the Study

Five plants species namely *Tagetes erictus, Amaranthus spinous, Cassia tora, Sorghum bicolor* and *Sorghum arundinaceum* were used as

suppressive plants. Seeds from mature plants were collected from different fields at Nambala village in Arusha, region, Tanzania. For each plant, 0.25 kg of seeds was collected and properly labeled and stored at -4 °C at NM-AIST, laboratory until used.

2.3 Seed-seed and Plant–plant Interaction Experiments

The experimental design for both laboratory and pot were established using a randomized block design. The treatments included seeds of 1) *P. hysterophorous* grown alone; 2) *T. erictus* + *P; hysterophorous*; 3) *A. spinosus* + *P. hysterophorous*; 4) *C. tora* + *P. hysterophorous*; 5) *S. bicolor* + *P. hysterophorous*, and 6) *S. arundinaceum* + *P. hysterophorous*. In petri dish experiment, germination was performed based on international seed testing standards (IST2014) in which seed subsamples were placed on blotters in petri dish. For *P. hysterophorous* grown alone, 200 seeds were planted in the petri dishes (20 seeds/petri dish). For treatments including a combination of species (*A. spinosus*, *C. tora*, *S. bicolor*, and *S. arundinaceum*) with *P. hysterophorous*, each petri dish was planted with 20 seeds of each species and 20 seeds of *P. hysterophorous*. These treatments were replicated four times. Before starting germination test all seeds were sterilized using sodium hypochlorite (5%) to remove any possible contaminations and then the seeds were washed thoroughly 4 times with distilled water. After planting, each treatment in petri dishes were irrigated with 3 mL of distilled water equally in the interval of four days to maintain moisture. The same treatments above were also planted in plastic pots containing six kilograms of sterile soils with a ratio of 1:3 sand and forest soils. These were replicated eight times. The plots were exposed to direct rain, and no fertilizer neither watering was used. All plants that germinated other than those selected species sown and *P. hysterophorus* were removed manually. The petri dish (Laboratory experiment) and four replications of the pot experiments were kept for 21 days. Other four replications of the pot experiments were evaluated for three months to determine the suppressive effects between plants.

During the 21 days of germination test, the percentage germination was rated as normal, subnormal and dead seeds. In this experiment, only percentage of normal seeds was considered. Percentages of inhibition/stimulation effect on seed germination over control (T1) were calculated using the formula proposed by [23] Inhibition (-) or stimulation (+) = [(Germinated seeds in association - Germinated seed in control)/Germinated seeds in control] x 100.

For pot experiments that were evaluated for three months to determine the suppressive effects between plants, the growth parameters such as plant height and root length were determined by selecting five plants randomly, uprooting them from each of the replicated pots. All samples were separated from *P. hysterophorus* or test species, then dried for 72 h at 70 °C, and weighed for dry plant biomass.

2.4 Statistical Analysis

The effects of treatments on different parameters such as percent germination, plant height, root length and dry biomass were assessed using one way Analysis of Variance (ANOVA). The analysis were done using STATISTICA package Version 8. The significant means were compared at p=0.05 according to Fischer's least significant different test.

3. RESULTS AND DISCUSSION

3.1 Laboratory Tests to Evaluate Effect of Seeds of *A. spinous*, *S. bicolor, S. arundinaceum*, *T. erictus* and *C. tora* on Germination of *Parthenium hysterophorus*

Laboratory germination results indicate *that P. hysterophorus* germination was significantly decreased when grown in association with *S. bicolor, T.erictus, S. arundinaceum* and *A. spinous* (Table 1). The highest germination percentage was 97.5% in the control treatment as compared with other treatments. The germination percentage was lowered from 97.5% to 22.8, 21.3, 17.5, 11.3 and 10 for *C. tora, S. arundinaceum, A. spinous, T. erictus* and *S. bicolor*, respectively (Table 1). Furthermore, numerically, *S. bicolor* showed highest inhibition effects on germination of *P.hysterophorus*. Seeds to seeds interaction showed highest inhibition percentage value -89.5%, (equivalent to 10.0% germination) for *S. bicolor* compared with lowest inhibition percentage of -74.9% (equivalent to 22.8% germination) for *C. tora*.

Plants are known to produce metabolites which can affect the growth and development of other plants [24]. The extracts of plants have been considered in the past for management of *P.*

hysterophorous due to their inhibition potentials [25]; [26], the trend also observed in this experiment. Herein, we have assessed the seed to seed interaction of different plant to manage the growth of *P. hysterophorous*. We found that different seeds (*S. bicolor, T. erictus, S. arundinaceum* and *A. spinous*) showed suppressive effect on the measured growth parameters. Other studies have also reported the use of biological agents to manage weeds. For example, the use of phytopathogenic fungi extracts were reported to strongly suppress the growth of *P. hysterophorous* and hence manage its spread in Pakistan [25]. Furthermore, [26] reported that extracts of different parts of Sorghum showed significance reduction on the germination of *Amaranthus refroflexus* weed. In a similar way, our findings on the tested plants showed suppressive inhibition on *P. hysterophorus* seed germination. This suggests that allelochemicals present in *S. bicolor, T. erictus, S. arundinaceum* and *A.spinous* have suppression effects to the germination of other crops. Findings from this study suggest that both tested plants could be used in management of the weed as they exhibited growth and germination inhibition. From these results, we conclude that the suppressive effects contributed by allelochemicals present in the tested plant species which have strong inhibition property and competes with the *P. hysterophorus* for nutrition and growth.

3.2 Suppressive Effects of Selected Plant Species on the Growth of *Parthenium*

The pot experiments from all the plant species showed a significant suppressive effects on germination of *P.hysterophorus* expect *Cassia tora* (Table 2). The highest germination percentage was 91.3% in the control as compared with other treatments. The germination was lowered from 91.3% to 62.5%, 18.8% 16.3%, 16.3% and 12.5% for *C. tora, S arundinaceum, T. erictus, A. spinous* and *S. bicolor* respectively .Numerically, *S. bicolor* showed stronger inhibition effect compared with other treatments. Inhibition percentage increased significantly ($p<0.001$) from -37.5%, -81.5%, -82.4%, -83.8% and -87.5% for *C. tora, S. arundinaceum, T. erictus, A. spinous* and *S. bicolor* respectively. Furthermore, this study showed that plant height, root length and dry biomass were significantly lowered when *P. hysterophorus* was grown in association with *S. bicolor, T. erictus, S. arundinaceum, A. spinous* (Table 2). However, sowing *P. hysterophorus* with *C. tora* had no significant effects on plant height, root length and dry biomass yield.

These findings suggest that, *S. bicolor, T. erictus, S. arundinaceum, A. spinous* had significant suppressive effects on the growth of *P. hysterophorus*, whereas *C. tora* was not effective in inhibiting the growth of *P. hysterophorus*. The effectiveness of *S. bicolor, T. erictus, S. arundinaceum* and A. *spinous* in reducing growth of *P. hysterophorus* could be attributed by the presence of active metabolites/allelochemicals which resulted in the suppression effects. For instance, it has been shown that, compounds such as organic and amino acids, phenolics, cyanogenic glycosite, sorgoleone, benzoquinone, alpha-terthienyl produced by *A. spinous, S. bicolor, S. arundinaceum*, and *T. erictus* affects the growth

Table 1. Effects of seed-seed interaction

Plant name	% Germination	% Inhibition
P. hysterophorous	97.5 ± 4.33a	
P. hysterophorus+ A. spinous	17.5 ± 2.50b	-81.8 ± 4.76a
P. hysterophorus+ T. erictus	11.3 ± 1.25b	-88.5 ± 2.37a
P. hysterophorus + S. bicolor	10.0 ± 2.04b	-89.5 ± 2.39a
P. hysterophorus + S. arundinaceum	21.3 ± 7.18b	- 78.2 ± 7.17a
P. hysterophorus+ C. tora	22.8 ± 8.98b	-74.9 ± 9.43a
F- STATISTICS	41.8****	

Values presented are means± SE. Values with the same letter in the column are not statistical different (p=0.05).

Table 2. Suppressive effect of different plants on growth of *Parthenium hysterophorus* in pots

Plant name	Germination (%)	Inhibition %	Plant height (cm)	Root length (cm)	Biomass (g)
P. hysterophorus	91.3± 8.75c	-	4.25±0.51b	2.50 ± 0.11b	4.05 ± 0.21b
P. hysreophorus + A. spinous	16.3 ± 6.88a	-83.8 ± 6.88a	1.09 ±0.26a	1.02 ± 0.49a	1.50 ± 0.29a

P. hysterophorus+ *T. erictus*	16.3 ± 4.73a	-82.4 ± 4.31a	1.10 ±0.34a	0.86 ± 0.15a	1.50 ±0.29a
P. hysterophorus + *S. bicolor*	12.5 ± 1.44a	-87.5 ± 1.44a	1.05 ±0.19a	0.89 ± 0.09a	1.03± 0.39a
P. hysterophorus + *S. arundinaceum*	18.8 ± 54.27a	-81.3 ± 4.27a	1.42±0.03a	1.24 ± 0.34a	1.13 ± 0.13a
P. hysterophorus + *C. tora*	62.5 ± 13.62b	-37.5 ± 13.62b	3.63±0.70b	2.69 ± 0.41b	3.45± 0.33b
F-Statistic	**18.35*****		**11.95*****	**7.38*****	**16.56*****

Values presented are means ± SE. Values with the same letter in the column are not statistical different (p=0.05)

of other plants by suppressing growth [27;[28];[29];[30]. Such compounds could have contributed to the suppression effects on the growth *P. hysterophorous* observed in our study. This plants could be further tested in large scale and for other weeds.

4. CONCLUSION

The motivation of the present study was to investigate the suppressive effects of effects of *S. bicolor, T. erictus, S. arundinaceum, A. spinous* and *C. tora* in the management of germination and growth of P. *hysterophorus*. Tested plant species showed suppression effects on seed germination, growth, root length, and dry biomass on parthenium. Degree of suppression differed significantly with *C. tora* showing minimum suppressive effects. The study provide basis for parthenium management. The promising plants are recommended for large scale testing in areas where the weed is increasingly becoming a problem.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Evans, H. C. *Parthenium hysterophorus*. A review of its weed status and the possibilities for biological control. *Biocontrol News and Information, 18*:89N-98N. In: Proceedings of the 2nd International Conference on Parthenium Management, 5–7 December 1997, Bangalore, India, and 1997; pp. 6–10.

2. Medhin, B., *Parthenium hysterophorus, new weed problem in Ethiopia.* In *Plant Protection Bulletin, FAO. 1992;* p. 40:49.

3. Clark, K. and W. Lotter. *What is Parthenium weed up to in Tanzania*, in *International Parthenium News*; 2011.

4 Ramadhan Kilewa, A. (2014). "Distribution of Invasive Weed *Parthenium hysterophorus* in Natural and Agro-Ecosystems in Arusha Tanzania." International Journal of Science and Research (IJSR) .2014; 3(12): 1724-1727.

5. Levine. J.M, M. Vila, C.M. D'Antonio, J.S. Dukes, K. Grigulis, S. Lavorel 2003.Mechanisms underlying the impacts of exotic plant invasions Protection. *R. Soc. Lond. B, 270, pp. 775-781 Ecosystems, pp. 503-523*

6.Zavaleta E. Valuing, 2000. Ecosystem services lost to Tamarix invasion in the United States.

7. Belnap and Philips, J. Belnap, S.L. Phillips Soil biota in ungrazed grassland. Response to annual grass (Bromustectorum) invasion Ecol.*Appl.*2001; *11, pp. 1261-1275 Plant Protect. Quart. 9 (1994), pp. 73-76*

8. Maharjan, S. Allelopathic effects of aqueous extract of leaves of *Parthenium hysterophorus* L. on seed germination and seedling growth of some cultivated and wild herbaceous species. *Sci.World, v. 5, n. 5.2007; p. 33-39.*

9. Tamado, T., Milberg, P. Control of parthenium (*Parthenium hysterophorus*) grain sorghum (Sorghum bicolor L.) in the smallholder farming system in eastern Ethiopia. Weed Technol.2004; 18, 100–105

10. Mahadevappa M, Das TK, Kumar A *Parthenium*: A Curse for Natural Herbs. Paper presented at National Research Seminar on Herbal Conservation, Cultivation, Marketing and Utilization with Special Emphasis on Chhattisgarh, "The Herbal State".2001; 13-14
11. APFISN/Asian-Pacific Forest Invasive Species Network Invasive, *Newsletter of the Asian-Pacific Forest Invasive Species Network*, Volume 9. Kerala, India. (2007
12. Nguyen, T.L., Navie, S.C. and Adkins, S.W. The effect of parthenium weed (*Parthenium hysterophorus* L.) on plant diversity in pastures in Queensland, Australia. In *17th* products. In: Diseases of nematodes. (Eds.): G. O. Poinar, Jr. and H.-B. Jansson. Vol. I. CRC Press, Inc., Boca Raton, FL. 1988; 3-22
13. Dhileepan K. Reproductive variation in naturally occurring populations of the weed Parthenium hysterophorus (Asteraceae) in Australia. Weed Science 2012; 60, 571–576
14. Mulatu W, Gezahegn B, Befkadu B. Allelopathic effects of *Parthenium hysterophorus* extracts on seed germination and seedlinggrowth of lettuce. Trop. Sci. 2005; 45(4): 159-162.
15. Mulatu W. Allelopathic effects of *Parthenium hysterophorous* L. on onion germination and growth. Allelo. J. 2009; 24: 351-362.
16. McFadyen, R.E. Biological control against Parthenium Weed in Australia. Crop Protection.1992; 11: 400-407
Plant Protection Quarterly, *11*(2).1996; pp.76-88.
17. Dhileepan, K., McFadyen, R.C. *Parthenium hysterophorus* L.—Parthenium. In: Biological Control of Weeds in Australia. CSIRO Publishing, Melbourne.2012; pp.448–462
18. Dhileepan, K. Current status of the stem-boring weevil Listronotus setosipennis (Coleoptera: Curculionidae) introduced against the weed Parthenium hysterophorus (Asteraceae) in Australia. *Biocontrol Science and Technology. 2003; 13* :(1), 3-12.
19. Sushilkumar Current spread, impact and management of *Parthenium* weed in India. *Internationa* Parthenium News 2012; 5: 1-6.
20. Yaduraju, N.T., Sushilkumar, M.B.B., Prasad, B., Gogoi, A.K. *Parthenium hysterophorus: 2005*
21. Tamado, T., Milberg, P., 2004. Control of parthenium (*Parthenium hysterophorus*) grain sorghum (Sorghum bicolor L.) in the smallholder farming system in eastern Ethiopia. Weed Technol. 18, 100–105
22. Van der Laan, M., Reinhardt, C.F., Belz, R.G., Truter, W.F., Foxcroft, L.C., Hurle, K. Interference potential of the perennial grasses Eragrostis curvula, Panicum maximum and Digitaria eriantha with *Parthenium hysterophorus*. Trop. Grassland. 2008; 42, 88–95
23. Singh, A.P. and Chaudhary, B.R. Allelopathic of algae weed pithophora aedogonia (Mont.) ittrock on the germination and seedling growth of Oryza sativa L. Botany Research International.2011;4(2):36-40
24. Jong –Bum Kim, Pathogen, Insect and Weed Control Effects of Secondary Metabolites from Plants; 2005
25. Arshad Javaid and Huma Adrees Parthenium management by cultural filtrates of phytopathogenic fungi germination and growth; 2009
26. Yarnia M, Khorshidi Benam M.B, Farajzadeh Memari Tabrizi E .Allelopathic effects of sorghum extracts on *Amaranthus retroflexus* seed: 2015
27. Ali, S. and Khan, I.A). Management *of Parthenium hysterophorus* using suppressive plants. *Malaysian Journal of Science*. 2017; 36(2), pp.75-84
28. Shafique, S., Bajwa, R. and Shafique, S. *Tagetes erectus* L.-a potential resolution for management of *Parthenium hysterophorus* L. *Pakistan Journal of Botany*, *43*.2011; pp.885-894
29. Thapar, R. and N. Singh. "Allelopathic influence of leaf residue of *Amaranthus spinosus* on growth and metabolism of *Parthenium hysterophorus* L." Ecoprint: An International Journal of Ecology. 2005; 12: 77-84
30. Gommers, F.J. and J. Bakker. 1988. Physiological diseases induced by plant responses or products. In: Diseases of nematodes. (Eds.): G. O. Poinar, Jr. and

H.-B. Jansson. Vol. I. CRC Press, Inc., Boca Raton, FL. 3-22

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Carrot-Weed: A Noxious Plant That Threatens Biodiversity in Africa

Neema C. Mtenga*, Thadeo Mokiti Tarimo, Patrick A. Ndakidemi, Ernest R. Mbega

Department of Sustainable Agriculture and Biodiversity Ecosystem Management, School of Life Science and Bioengineering, The Nelson Mandela African Institute of Science and Technology, Arusha, Tanzania
Email: *nmtenga@yahoo.com

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Abstract

Carrot-weed (*Parthenium hysterophorous* L.) is a flowering plant of the Asteraceae family (tribe: Heliantheae). The weed became famous due to its notorious invasive role in the environment and agricultural fields. The plant has arisen as the seventh most disturbing weed globally. In Africa, the weed is spreading very fast and information on its biology, impact, and management is scarce. Therefore, this review provides general information about the carrot weed's current distribution status and its impact on agricultural crops, animals and human health in Africa. The review also highlights areas for research in managing this noxious weed in the African habitats.

Keywords

Invasive Species, Biodiversity, *Parthenium hysterophorous*, Carrot-Weed, Allelopathy

1. Introduction

Carrot-weed (*Parthenium hysterophorous* L.), also known as "bitter weed" or "broom bush" or "congress grass" (in India) or "whitetop" or "feverfew" (in the Caribbean) or "false ragweed" or "ragweed parthenium" (in the USA) is a member of the family Asteraceae [1]. It is a noxious well-known weed that disrupts biodiversity in many parts of the world [2]. Carrot weed derived its Latin name *Parthenium hysterophorous* from three terms namely "parthenice" (Latin) and is the reference to the plant known as T*anacetum parthenium* (L.) and Greek word hystera (Womb) and phoros (bearing), referring to the prolific seeding habit of the plant [3] [4]. It originated from the region adjacent to the Gulf of Mexico, which includes Southern USA, or in central South America [5]. The plant grows in both humid and sub-humid tropics and is favored by weightier

fertile soil, such as black, alkaline clay loam, but has ability to grow on a wide variety of soil types from sea level up to 1800 m [6] [7]. The plant also grows mostly in places with summer rainfall greater than 500 mm per annum [8]. Carrot-weed seed germinates at temperatures between 8˚C and 30˚C [9]. The plant has the ability to colonize new habitats rapidly by producing a large number of seeds, which are eventually widely dispersed through vehicles, water, animals, farm machinery and wind, and grows in distressed areas around buildings and fallow agricultural land where inter-specific competition is very low [10]. Carrot-weed is recorded in the global invasive species database and has been reported to invade about 30 countries worldwide [11]. The weed is widespread in North and South America, Caribbean, Lesser Antilles, Australia, India, and Africa [12]. In Africa, the plant was first recorded in southern parts of Africa in 1880s [13]. There exists no clear documentation on how this weed entered Africa; however, some assumptions are that it was possibly introduced to Ethiopia through food grain contaminants in a food aid programme [14]. Currently, the plant is present in many countries of Africa (**Figure 1**) [15] [16] [17]. Carrot weed is known to compete with indigenous grasses and herbaceous plants used for grazing worldwide [18] thereby, reducing forage productivity by 90%. Furthermore, carrot weed is heavy feeder plant utilizing most of the soil nutrients which ultimately leads to soil infertility, hence resulting to poor crop and animal health [19] [20] [21]. In human, carrot weed has been reported to cause health problems such as asthma, bronchitis, dermatitis and hay fever once it comes into contact with the body [14].

Despite the fact that this weed is very harmful, limited literature is available on the biology and impacts on the biodiversity in Africa. Thus this review provides general information of the carrot weed's current distribution status and its impact on agricultural crops, animals and human health in Africa.

2. Biology of Carrot-Weed

Carrot-weed is an annual, erect herb with the height of 1.0 to more than 2.0 m. It

Figure 1. Distribution of carrot-weed in Africa (CAB 2018).

has a taproot system with a number of secondary and tertiary roots [22]. The plant is fast maturing and has dark green leaves which are rhomboidal, dissected and alternately arranged on the stem [23]. It has white or yellow flowers based on race type each of which produces four to five black wedge-shaped seeds that are 2 mm long with thin white scales and difficult to see by the naked eye [23]. The leaves and stems have small hair-like outgrowths called trichomes. Its inflorescence is capitulum with cypsela fruits and they produce thousands of seeds which are dark brown and very light in weight [23].

Once the weed dominates an area becomes aggressive, destructive and oppressive to other plant species [20] [24] [25]. The weed spreads very fast due to its ability to produce a greater amount of seeds up to 25,000 seeds/plant which results into a significant amount of seed bank in the soil [23]. This morphological feature of the carrot weed seed enables it to be dispersed in multiple ways including short distance wind dispersal, or water surface, runoff in natural streams and rivers, in irrigation and drainage channels and irrigation water from the ponds. [15] [26] [27] Furthermore, seeds of this weed can be stored in fresh water for about five years and still can germinate [28]. Under favorable moist environment, the seeds can germinate within a week. Generally the life cycle of this weed completed within 180 - 240 days [29]. Carrot weed has two races namely south race and north race. The south race occurs in Southern America while north race occurs in North America and distributed worldwide [30]. These races differ in morphology and biochemical properties where the South America race has hymenin as a dominant sesquiterpene lactone and pathenin for North America race. The North America race produces white flowers while that of South American race are yellow [31].

Regardless of the available information, still there is a need to study the environmental factors which can affect the biology of this weed. This will be helpful since it will provide a way forward on how to control it by using the natural methods which are environmentally friendly that cannot affect the existence of other nearby plants hence improving the biodiversity.

Picture of carrot-weed

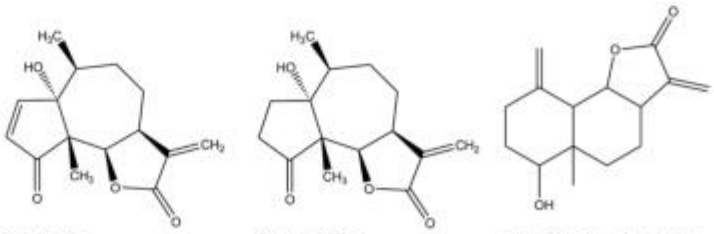
3. Allelopathic Effects of Carrot-Weed on Plants

[32] defined allelopathy as a biological occurrence where one plant inhibits the growth of another plant through the release of allelochemicals. The idea of allelopathy was studied broadly for the first time in the forestry ecosystems, where initially it was revealed that most of the forestry species surveyed had unwanted allelopathic effects on food and fodder crops [32] [33] pondered both beneficial and harmful allelochemicals influences by defining allelopathy as the capability of the plant to hinder or stimulate growth of other plants in the surrounding by exuding chemicals. Based on this definition, it's apparent that the oppressive nature of carrot weed is associated with its allelopathic effects caused by sesquiterpene lactones, parthenin, and coronopilin, [34] (**Figure 2**). These allelochemical groups act synergistically and significantly reduces seed germination and delayed growth of other crops [35]. Also, it was reported that allelochemicals such as tannis, saponins, cardiac glycosides, terpenoids, and steroids are founder on the upper parts of *Parthenium*, [36]. All these chemicals have an effects on crops and animals. The leaves and inflorescence contain a higher level of allelochemicals than the stem and roots. These allelochemicals affects other plants either directly by leaching, root exudation, and residue decay. [37] or indirectly leading to the loss of native flora.

According to [38], the weed can degrade the natural ecosystem due to its high capacity of invasiveness and its potential allelopathic properties which disrupt any natural ecosystem. Nevertheless, the weed was reported to cause a decline undesirably the herbaceous components of vegetation up to 90% due to its destructive nature of competition and allelopathic effect [39] [40]. It is reported to cause great change of native habitat in grassland, open woodland, floodplains and rivers [41] [42] [43]. Therefore, studies on plant species with allelopathic effects to this noxious weed are urgently needed. Further, studies on the chemistry of the plant to elucidate information on chemical composition from different parts of the plant are required for proper management of the weed in Africa.

4. Impacts on Growth and Yield of Crops

Carrot-weed has been reported to result in food insecurity (**Figure 3**) due to decline



Parthenin Coronopilin sesquiterpene lactones

Figure 2. Shows allelochemical groups found in Carrot-weed namely: parthenin, coronopoilin and sesquiterpene lactones.

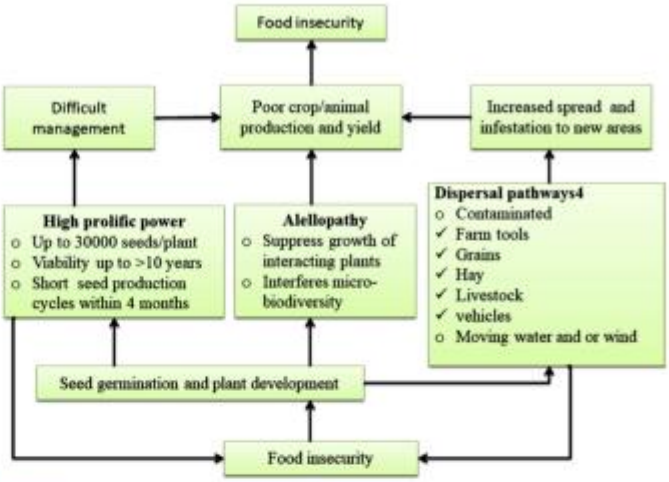


Figure 3. Relationship between carrot-weed and food insecurity.

in agricultural yields of crops and domestic animals to levels of up to 40% to 90% [44] [45]. It is also reported to reduce the carrying capacity of pasture crops of up to 90% [46] [47] [48]. The laboratory experiment and field studies by [43] shows that all plant parts of the carrot weed (shoot, root, inflorescence, and seed) are toxic to other plants. This brings changes in the physical and chemical characteristics of the soil such as soil pH, soil organic matter, phosphorus, and others. [49]. Although numerous information exists on the effects of this noxious weed, still there is lack of information on how it affects and induces changes to soil pH and structure. This calls further urgent investigation.

5. Impacts of Carrot-Weed on Animals

Carrot-weed produces toxic substance such as parthenin as described earlier which is harmful to animals when feed on it or coming into contact, causing both dermatitis with distinct skin lesions on various animals including horses and cattle's [35]. Once eaten by animals, it can cause mouth ulcers with excessive starvation [50] [51] reported that carrot –weed causes anorexia, pruritus, alopecia, diarrhea, and eye irritation in animals such as dogs and acute illness, bitter milk and tainted meat in animals such as buffaloes, goat, and cows [52]. Also, experimental work reported that the plant weakens the immune system by reducing the number of white blood cells (WBC) in rats [52]. Further, the weed lowers forage productivity by 90%, reduce land fertility weakens the land and make it infertile and hence lowers the quality weakens the quality of the grazing land. All these cause poor animal health both domesticated and the wildlife since most of them feed on the grasses [48]. Regardless of the information provided on the impacts of this weed on animals, still there is a need for more research on how this weed exactly affect the animals once feed on them.

6. Impact of Carrot-Weed on Human

Carrot-weed has been reported to cause human health problem such as asthma, bronchitis, dermatitis, hay fever when exposed to it [53] [54], allergic eczematous and mental depression [55]. Furthermore, carrot-weed lead to general illness, annoyances of skin and pustules on handballs, extending and furious of skin and stomach pains on humans [56]. Human contact with carrot-weed followed with exposure to sun results to health effects such as violaceous papulae, as well as a plaque on exposed parts such ears, forehead, cheek and upper chest. Nevertheless, health effects like hyperkeratotic papule and prurigo nodules have been associated with exposure to carrot-weed [57]. On other hands, [58] further showed that dermatitis health effects are due to the presence of a cytotoxic compound sesquiterpene lactone Parthenin. Apart from that, exposure to carrot-weed was further correlated with diarrhea, breathlessness, and chocking as well as erythematous eruptions [58]. Allergic bronchitis was also associated with exposure to carrot-weed, however, no signs of mutagenicity and genotoxicity have been observed [58]. In addition, exposure to carrot weed has shown positive reactions to mAb-2 as well as cytokines [58]. In general, these effects are classified into four categories: airborne contact dermatitis (ABCD), chronic actinic dermatitis (CAD) and the combination of ABCD and CAD and lastly exposure to the sun (photosensitive lichenoid) [57]. Therefore there is a need of more research to know exactly the compounds present in the pollen of this weed which is responsible for the health problems to a human being to make easy management with precaution during physical control practice.

7. Impacts of Carrot-Weed on Biodiversity

According to [13] carrot-weed is on of harmful invasive species in the World and an increasing problem in Africa. Its invasion results into the degradation of the natural ecosystem and biodiversity due to its high invasion capacity [39]. Further, it has been reported that the allelopathic properties of this weed are potential for disrupting the growth and distribution of natural vegetation which in turn affect the diversity of animal [19]. Also, the weed is capable of causing the decline of the species richness and abundance in the natural system as it inhibits the physiological processes of other weed species [59].

In some countries such as Australia, the weed is reported to cause changes in the entire habitat in Australia grassland, open and woodlands, and river banks [37] [60]. Furthermore, [24] reported that *Parthenium* weed has a negative impact on the structural composition on dynamic and diversity of the plant and animals in India. It also affects not only the species diversity of native areas but also their ecological integrity. It has been shown that *Parthenium* residues are toxic to aquatic flora and fauna [61]. **Table 1** summarizes the general impacts of carrot-weed on crops, animals, and biodiversity in general.

Table 1. Some of the reported impacts of carrot-weed (*P. hysterophorous*).

Categories	Mode of action	Effects	References
Crops (legumes &cereals).	The release of phytotoxic compounds	Reduced crop yield as well as carrying capacity of pastures.	[44] [46] [48]
Wild animals/livestock	Weakens the immune system by reducing the number of WBC	Skin lesions, mouth ulcers, anorexia, pruritus, alopecia, diarrhea, eye irritation.	[35] [50] [51] [52] [58]
Human health	Induction of cytotoxicity also reacts with cytokines.	Allergic, bronchitis, skin inflammation, asthma, blisters, hay fever, erythematous eruption	[53] [55].
Soil	Utilizing soil nutrients	Soil infertility	[48] [52].
Vegetation/landscape composition	Disrupt the structure of the natural ecosystem and displace numerous native plant species.	Degradation of natural ecosystem and biodiversity, allelopathic effects, toxic to flora and fauna, reduced species richness.	[59] [61]
	Shrinking of biodiversity		

8. Management and Control

The use of biocontrol agents such as (Insects and fungal pathogens) and use of competitive plants (allelopathy) is suggested as the greatest cost-effective and practical way of managing *Parthenium* [62]. However, the management of the weed has not been well developed below the edge level and the weed continues to threaten biodiversity by posing ill problems to humans and animals. Therefore several methods, for example, physical, mechanical, chemical and use of allelopathic plants are being practiced to manage this weed around the globe.

9. Physical and Mechanical Methods

These are the most common methods used in the management of carrot-weed in many countries. The methods are widely used as they are cheaper, easy to apply and are cost effective. Farmers manage the weed by hand uprooting or using a hoe in their fields, collect and burn before flowering time. Despite, the success of this method, it is faced with many challenges including the frequent growth of the weed [29].

10. Chemical Control

Management of carrot-weed by using chemical method seems to be popular in most developed countries such as India where the weed has spread in large areas. This method mostly used to remove the weed from the area in time, therefore the issue of time is very important for this type of management. Application of the chemicals should be done at the early stages to prevent flowering and seed setting. The spraying of the herbicides which are not harmful to other plants which are growing nearby the weed is mostly recommended to reduce the infestation. Despite the fact that chemical control is the most common method employed, it is reported to be less effective due to the development of resistance [63]. Therefore, there is a need for developing bio-management strategies for management of this weed rather than the use of chemicals which are no more

reliable and sometimes harmful to the environment.

11. Biological Control

Although the use of chemical seems to be most applicable in many countries in the management of *Parthenium*, yet the method has been reported to have many negative impacts in the environment [64]. The bio-control strategy is the most applicable way used in managing the weed by manipulating natural enemies to control others. The biological control method is less cost, environmentally friendly and ecologically practicable method. Several insects and pathogens have been used in the control of this weed. For instance, leaf feeding (*Zygogramma bicolorata*) and stem-galling moth (*Epiblema strenuana*) have been used to control this weed and have shown efficacy in reducing the number of seeds and leaves especially at the young stage [65] [66]. Also, the use of fungus is now regarded as a bio-control strategy of *Parthenium* among others, example; *Fusarium pallidoroseum*, *Puccinia melampodii* and *Oidium parthenii* [67]. Studies conducted by [68] shows that the use of microorganisms as a biological agent as a strategy for controlling this weed control has many advantages such as higher selectivity, their capacity to inhibit plant growth, the lower potential to resist, lower production costs.

Therefore, there is a need of using botanicals and microorganisms in controlling this weed because they are environmentally friendly, easy to apply and such resources are readily available in our environment.

12. Use of Suppressive Plants as a Management Strategy

Different literature shows that there are some plants/weeds which have been used to manage this weed and become successful. According to [69], the herbicidal extracts from *Tagetes erictus* obtained from roots, shoots, and flowers reduced root and shoot length of carrot-weed. Also, another study by [70] reported extracts from the roots and shoots of sorghum had significant impacts on the growth of the carrot-weed. Moreover [71] reported that the extracts and residues of *Amaranthus spinosus* significantly reduced the growth of carrot-weed by inhibiting the height of the plant, length of leaves and number of branches, capitula, and the seed of the plant.

Despite of the above research efforts of using suppressive plants which has impacts on growth and germination of Carrot-weed, yet more research is needed to know the chemical contents of the suppressive plants used so that to build a more scientific management approach of managing this weed by using suppressive plants.

13. Current Research Gaps

Several management approaches such as physical, chemical herbicide and biological control have been tried to control this weed only herbicides approach seem to be preferred by farmers in many parts of the world including Africa (Kumar; 2009) (**Table 2**). Nevertheless, chemical herbicides are no longer reliable

Table 2. Summarizing the management approaches for carrot-weed.

Methods	How was applied	Items used	Results	References
Physical control	the burning of the surface part and seeds near the surface and crop rotation	*Tagetes* sp. and Fire	Reduce infestation and spreads.	[13] [66]
Chemical control	Many chemical pesticides applied both in cropped and non-cropped condition	Glyphosate (1 to 1.5 kg/ha) diquat 0.5 kg/ha in 500 liters,	Control *Parthenium* in all stages. But only kills the target population	[72] [73]
Biological control	Through the introduction of control agents in the affected fields. Spraying of foliar extracts	Microbial pathogens (like Fusarium pallidoroseum, Puccinia melampodii and Oidiumparthenii), Insects: (Zyogramma bicolorata, Bucculatrix parthenica (leaf-mining moth), Smicronyx lutulentus,) Fungil (Fusarium pallidoroseum, Puccinia melampodii and Oidium parthenii)	Reduce flowers and seed production, Inhibit germination	[65] [66] [74] [75] [76]

Advantages and Disadvantages of different methods used in management of Carrot-weed

Methods	Advantages	Disadvantages
Mechanical Methods	Cheap, simple, easy to practice	Time consuming, high risk of being affected if the weed reaches flowering stage, Energy consuming methods. Also once involve burning it may kills some useful pants.
Chemical Method	Effective method in the absence of natural enemies, Prevent any emerging of weeds in the area where it sprayed, Cause complete kill of the weed.	-It is environmental hazards -Development of some resistance against herbicides - Damage flora and fauna -Ground water contamination -Reduce soil quality -Very costly in term of money
Suppressive plants	-Reduce seed germination -Suppress early seedling growth	-Time consuming -Difficult to measure its degree of suppression
Biological Method	-Less cost -It is environmental friendly -Lower production cost -High capacity of inhibiting the growth of the weed	-May cause damage to untargeted population -Need expertise -Time consuming.

due to the cost and increasing weed resistance to polyphosphate, atrazines, 4-D, and Metribuzin (Vila-Aiub *et al.*, 2008). Need for other options including development of eco-friendly approaches such as plant-based biopesticides and or agro-ecological principles based on weed-weed completion are currently receiving great attention as a vital pest control strategy worldwide (Marcias *et al.*, 2004; Vasilakoglou *et al.*, 2005; Dhima *et al.*, 2006; Javaid *et al.*, 2008). Thus and similarly for the African setting, there is need to develop eco-friendly weed management strategy involving but not limited to biopesticides for managing carrot weed. Plants such *Azadirachta indica, Eucalyptus tereticornis, Tagetes erictus, Sorghum spp, Cassia tora* and *Amaranthus spinous* can be targeted as potential competitors in weed-weed completion or in testing their extracts against carrot weed based on report by Kaur (2014).

14. Conclusion

Although many efforts have been exercised to reduce the spread of carrot weed in many countries, its colonization onto the African habitats is already noxious, impacting the Biodiversity. Of the preferred weed control options, chemical herbicides seem to be popular despite its harmful effects to the environment and human health. In addition, a chemical herbicide application is constrained by development of resistance by the weed. Therefore, beside showing how noxious carrot-weed is to the African Biodiversity, this review has also indicate the gaps of knowledge that needs to be addressed most of which besides knowledge of the weed biology highlights a need for exploration sustainable weed management techniques such use of botanical herbicides as these are believed to be environmentally friendly and cost-effective.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Picman, J. and Picman, A.K. (1984) Autotoxicity in *Parthenium hysterophorus* and Its Possible Role in Control of Germination. *Biochemical Systematics and Ecology*, **12**, 287-292. https://doi.org/10.1016/0305-1978(84)90051-6

[2] Timsina, B., *et al.* (2011) Impact of *Parthenium hysterophorus* L. Invasion on Plant Species Composition and Soil Properties of Grassland Communities in Nepal. *Flora-Morphology, Distribution, Functional Ecology of Plants*, **206**, 233-240. https://doi.org/10.1016/j.flora.2010.09.004

[3] Parsons, W.T., Parsons, W.T. and Cuthbertson, E. (2001) Noxious Weeds of Australia. CSIRO Publishing.

[4] Navie, S., *et al.* (1996) The Biology of Australian Weeds. 27. *Parthenium hysterophorus* L. *Plant Protection Quarterly*, **11**, 76-88.

[5] Kaur, M., *et al.* (2014) Effects and Management of *Parthenium hysterophorus*: A Weed of Global Significance. *International Scholarly Research Notices*, **2014**.

[6] Taye, T., *et al.* (2002) The Potential of Pathogens as Biological Control of *Parthenium* Weed (*Parthenium hysterophorus* L.) in Ethiopia. *Mededelingen (Rijksuniversiteit te Gent. Fakulteit van de Landbouwkundige en Toegepaste Biologische Wetenschappen)*, **67**, 409-420.

[7] Kebede, A. (2008) The Distributions of *Parthenium* Weed (*Parthenium hysterophorus* L. Asteraceae) and Some of Its Socio-Economic and Ecological Impacts in the Central Rift Valley, Adami Tulu-Jido Kombolcha Woreda. Addis Ababa University, Ethiopia.

[8] Chamberlain, J. and Gittens, A. (2004) *Parthenium* Weed Management: Challenges, Opportunities and Strategies. *Parthenium* Action Group. The State of Queensland (Department of Natural Resources, Mines and Energy), Brisbane, 82.

[9] Rajiv, P., Rajeshwari, S. and Venckatesh, R. (2013) Bio-Fabrication of Zinc Oxide Nanoparticles Using Leaf Extract of *Parthenium hysterophorus* L. and Its Size-Dependent Antifungal Activity against Plant Fungal Pathogens. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, **112**, 384-387.

https://doi.org/10.1016/j.saa.2013.04.072

[10] Auld, B., Hosking, J. and McFadyen, R. (1982) Analysis of the Spread of Tiger Pear and Parthenium Weed in Australia. *Australian Weeds*, **2**, 56-60.

[11] Kohlil, F., *et al.* (2011) Invasive Alien Plants: An Ecological Appraisal for the Indian Subcontinent. *Journal of the Indian Botanical*, **1**, 1.

[12] Roy, D. and Shaik, M.M. (2013) Toxicology, Phytochemistry, Bioactive Compounds and Pharmacology of *Parthenium hysterophorus*. *Journal of Medicinal Plants Studies*, **1**, 126-141.

[13] McConnachie, A., *et al.* (2011) Current and Potential Geographical Distribution of the Invasive Plant *Parthenium hysterophorus* (Asteraceae) in Eastern and Southern Africa. *Weed Research*, **51**, 71-84. https://doi.org/10.1111/j.1365-3180.2010.00820.x

[14] Adkins, S. and Shabbir, A. (2014) Biology, Ecology and Management of the Invasive Parthenium Weed (*Parthenium hysterophorus* L.). *Pest Management Science*, **70**, 1023-1029. https://doi.org/10.1002/ps.3708

[15] Nigatu, L., *et al.* (2010) Impact of *Parthenium hysterophorus* on Grazing Land Communities in North-Eastern Ethiopia. *Weed Biology and Management*, **10**, 143-152. https://doi.org/10.1111/j.1445-6664.2010.00378.x

[16] Ayele, S., Nigatu, L., Tana, T. and Steve Adkins, W. (2013) Impact of *Parthenium* weed (*Parthenium hysterophorus* L.) on the Above-Ground and Soil Seed Bank Communities of Rangelands in Southeast Ethiopia. *International Research Journal of Agricultural Science and Soil Science*, **3**, 262-274.

[17] Ramadhan Kilewa, A. (2014) Distribution of Invasive Weed *Parthenium hysterophorus* in Natural and Agro-Ecosystems in Arusha Tanzania. *International Journal of Science and Research*, **3**, 1724-1727.

[18] Evans, H.C. (1997) *Parthenium hysterophorus*. A Review of Its Weed Status and the Possibilities for Biological Control. *Biocontrol News and Information*, **18**, 89N-98N.

[19] Ayele, S. (2007) The Impact of *Parthenium* (*Parthenium hysterophorus* L.) on the Range Ecosystem Dynamics of the Jijiga Rangeland, Ethiopia. Department of Animal Sciences, School of Graduate Studies, Haramaya University, Haramaya, 134.

[20] Bhowmik, P. and Sarkar, D. (2005) *Parthenium hysterophorus*: Its World Status and Potential Management. *Proceedings of the 2nd International Conference on Parthenium Management*, University of Agricultural Sciences, Bangalore, 5-7 December 2005, 1-6.

[21] Worku, M. (2010) Prevalence and Distribution Survey of an Invasive Alien Weed (*Parthenium hysterophorus* L.) in Sheka Zone, Southwestern Ethiopia. *African Journal of Agricultural Research*, **5**, 922-927.

[22] Dogra, K.S., Sood, S.K. and Sharma, R. (2011) Distribution, Biology and Ecology of *Parthenium hysterophorus* L. (Congress Grass) an Invasive Species in the North-Western Indian Himalaya (Himachal Pradesh). *African Journal of Plant Science*, **5**, 682-687.

[23] Javaid, A. and Adrees, H. (2009) *Parthenium* Management by Cultural Filtrates of Phytopathogenic Fungi. *Natural Product Research*, **23**, 1541-1551. https://doi.org/10.1080/14786410902726167

[24] Kohli, R.K., Dogra, K.S., Batish, D.R. and Singh, H.P. (2004) Impact of Invasive Plants on the Structure and Composition of Natural Vegetation of Northwestern Indian Himalayas. *Weed Technology*, **18**, 1296-1300. https://doi.org/10.1614/0890-037X(2004)018[1296:IOIPOT]2.0.CO;2

[25] Shabbir, A. and Bajwa, R. (2005) *Parthenium hysterophorus*-Spread and Status on

Its Management in Pakistan. *Proceedings of the 2nd International Conference on Parthenium Management*. University of Agricultural Sciences, Bangalore, 5-7 December 2005, 28-35.

[26] Monaco, T.J., Weller, S.C. and Ashton, F.M. (2002) Weed Science: Principles and Practices. John Wiley & Sons, New York.

[27] Riaz, T. and Javaid, A. (2010) Prevalence of Invasive *Parthenium* Weed in District Hafizabad. *Journal of Animal and Plant Sciences*, **20**, 90-93.

[28] Adnan, M., *et al.* (2015) Survey of District Sialkot for the Infestation of *Parthenium hysterophorus*. *Journal of Biology, Agriculture and Healthcare*, **5**, 111-119.

[29] Gnanavel, I. and Natarajan, S. (2013) *Parthenium hysterophorus* L.: A Major Threat to Natural and Agro Eco-Systems in India. *International Journal of Agriculture, Environment and Biotechnology*, **6**, 261-269.

[30] Dale, I. (1981) *Parthenium* Weed in the Americas. *Australian Weeds*, **1**, 8-14.

[31] Annapurna, C. and Singh, J. (2003) Variation of *Parthenium hysterophorus* in Response to Soil Quality: Implications for Invasiveness. *Weed Research*, **43**, 190-198. https://doi.org/10.1046/j.1365-3180.2003.00332.x

[32] Msafiri, C.J., Tarimo, M.T. and Ndakidemi, P. (2013) Allelopathic Effects of *Parthenium hysterophorus* on Seed Germination, Seedling Growth, Fresh and Dry Mass Production of *Alysicurpus glumaceae* and *Chloris gayana*. *American Journal of Research Communication*, **1**, 190-205.

[33] Jalali, M., *et al.* (2013) Allelopathic Potential of Common Mallow (*Malva sylvestris*) on the Germination and the Initial Growth of Blanket Flower, Plumed Cockscomb and Sweet William. *International Journal of Agriculture and Crop Sciences*, **5**, 1638.

[34] Singh, H.P., *et al.* (2002) Effect of Parthenin—A Sesquiterpene Lactone from *Parthenium hysterophorus*—On Early Growth and Physiology of *Ageratum conyzoides*. *Journal of Chemical Ecology*, **28**, 2169-2179. https://doi.org/10.1023/A:1021089013754

[35] Singh, H., Batish, D.R., Pandher, J.K. and Kohli, R.K. (2003) Assessment of Allelopathic Properties of *Parthenium hysterophorus* Residues. *Agriculture, Ecosystems & Environment*, **95**, 537-541. https://doi.org/10.1016/S0167-8809(02)00202-5

[36] Neeraja, A. and Vikas, G. (2010) Phytochemical Analysis of *Lantana camara* and *Parthenium hysterophorus*. *BIOINFOLET*, **7**, 135-136.

[37] Chippendale, J. and Panetta, F. (1994) The Cost of *Parthenium* Weed to the Queensland Cattle Industry. *Plant Protection Quarterly*, **9**, 73-76.

[38] Kumar, A. (2014) *Parthenium hysterophorus* L. and Its Impact on Living World. *Indian Journal of Scientific Research*, **4**, 8-14.

[39] Kapoor, R. (2012) Awareness Related Survey of an Invasive Alien Weed, *Parthenium hysterophorus* L. in Gautam Budh Nagar District, Uttar Pradesh, India. *Journal of Agricultural Technology*, **8**, 1129-1140.

[40] Mahadevappa, M., Das, T. and Kumar, A. (2001) *Parthenium*: A Curse for Natural Herbs. *Proceedings of the National Research Seminar on Herbal Conservation, Culture, Marketing and Utilization with Special Emphasis on Chhatisgarh—The Herbal State*, Raipur, 13-14 December 2001, 9-10.

[41] Riaz, T. and Javaid, A. (2011) Prevalence of Alien Weed *Parthenium hysterophorus* L. in Grazing and Wastelands of District Attock, Pakistan. *Journal of Animal and Plant Science*, **21**, 542-545.

[42] Shabbir, A., Dhileepan, K. and Adkins, S.W. (2012) Spread of *Parthenium* Weed and Its Biological Control Agent in the Punjab, Pakistan. *Pakistan Journal of Weed*

Science Research, **18**, 581-588.

[43] Wakjira, M., Berecha, G. and Tulu, S. (2009) Allelopathic Effects of an Invasive Alien Weed *Parthenium hysterophorus* L. Compost on Lettuce Germination and Growth. *African Journal of Agricultural Research*, **4**, 1325-1330.

[44] Tamado, T., Ohlander, L. and Milberg, P. (2002) Interference by the Weed *Parthenium hysterophorus* L. with Grain Sorghum: Influence of Weed Density and Duration of Competition. *International Journal of Pest Management*, **48**, 183-188. https://doi.org/10.1080/09670870110101739

[45] Maharjan, S., Shrestha, B. and Jha, P. (2007) Allelopathic Effects of Aqueous Extract of Leaves Germination and Seedling Growth of Some of *Parthenium hysterophorus* L. on Seed Cultivated and Wild Herbaceous Species. *Scientific World*, **5**, 33-39. https://doi.org/10.3126/sw.v5i5.2653

[46] Khosla, S. and Sobti, S. (1981) Effective Control of *Parthenium hysterophorus* Linn. *Pesticides*, **15**, 18-19.

[47] Nath, R. (1988) *Parthenium hysterophorus* L.—A Review. *Agricultural Reviews*, **9**, 171-179.

[48] Fessehaie, R., Chichayibelu, M. and Hailegeorgis, M. (2005) Spread and Ecological Consequences of *Parthenium hysterophorus* in Ethiopia. *Arem*, **6**, 1123.

[49] Bhowmik, P., Sarkar, D. and Yaduraju, N. (2007) The Status of *Parthenium hysterophorus* and Its Potential Management. *Ecoprint*, **14**, 1-17. https://doi.org/10.3126/eco.v14i0.4824

[50] Narasimhan, T. (1977) Toxicity of *Parthenium hysterophorus* L. *Current Science*, **46**, 15-16.

[51] Aneja, K., Dhawan, S. and Sharma, A.B. (1991) Deadly Weed, *parthenium hysterophorus* L. and Its Distribution. *Indian Journal of Weed Science*, **23**, 14-18.

[52] Yadav, N., *et al.* (2010) Effect of Methanolic Extract of *Parthenium hysterophorus* on Haematological Parameters in Wistar Albino Rat. *The Bioscan*, **2**, 357-363.

[53] Sriramarao, P., *et al.* (1991) Immediate Hypersensitivity to *Parthenium hysterophorus*. II. Clinical Studies on the Prevalence of *Parthenium rhinitis*. *Clinical & Experimental Allergy*, **21**, 55-62. https://doi.org/10.1111/j.1365-2222.1991.tb00804.x

[54] Kololgi, P., Kololgi, S. and Kololgi, N. (1997) Dermatologic Hazards of *Parthenium* in Human Beings. *Proceedings of the* 1*st International Conference on Parthenium Management*, Dharwad, 18-19.

[55] Sharma, V.K., Sethuraman, G. and Bhat, R. (2005) Evolution of Clinical Pattern of *Parthenium* Dermatitis: A Study of 74 Cases. *Contact Dermatitis*, **53**, 84-88. https://doi.org/10.1111/j.0105-1873.2005.00652.x

[56] Wiesner, M., *et al.* (2007) Impact of the Pan-Tropical Weed *Parthenium hysterophorus* L. on Human Health in Ethiopia. Institute of Horticultural Science, Urban Horticulture, Berlin.

[57] Jayaramiah, R., *et al.* (2017) Harmful Effects of *Parthenium hysterophorus* and Management through Different Approaches—A Review. *Annals of Plant Sciences*, **6**, 1614-1621. https://doi.org/10.21746/aps.2017.05.002

[58] Patel, S. (2011) Harmful and Beneficial Aspects of *Parthenium hysterophorus*: An Update. 3 *Biotech*, **1**, 1-9. https://doi.org/10.1007/s13205-011-0007-7

[59] Nguyen, T.L., Navie, S.C. and Adkins, S.W. (2010) The Effect of *Parthenium* Weed (*Parthenium hysterophorus* L.) on Plant Diversity in Pastures in Queensland, Australia. 17*th Australasian Weeds Conference, New Frontiers in New Zealand: Together We Can Beat the Weeds*, New Zealand Plant Protection Society, Christchurch, New Zealand, 26-30 September 2010, 138.

[60] McFadyen, R.C. (1992) Biological Control against *Parthenium* Weed in Australia. *Crop Protection*, **11**, 400-407. https://doi.org/10.1016/0261-2194(92)90021-V

[61] Kanchan, S. and Chandra, J. (1980) Pollen Allelopathy—A New Phenomenon. *New Phytologist*, **84**, 739-746. https://doi.org/10.1111/j.1469-8137.1980.tb04786.x

[62] Kohli, R., Rani, D., Singh, H.P. and Kumar, S. (1997) Response of Crop Seeds Towards the Leaf Leachates of *Parthenium hysterophorus* L. *Indian Journal of Weed Science*, **28**, 104-106.

[63] Culliney, T.W. (2005) Benefits of Classical Biological Control for Managing Invasive Plants. *Critical Reviews in Plant Sciences*, **24**, 131-150. https://doi.org/10.1080/07352680590961649

[64] Commare, R.R., *et al.* (2002) Pseudomonas Fluorescens Based Bio-Formulation for the Management of Sheath Blight Disease and Leaffolder Insect in Rice. *Crop Protection*, **21**, 671-677. https://doi.org/10.1016/S0261-2194(02)00020-0

[65] Ray, P. and Gour, H. (2012) Integrated Management of *Parthenium hysterophorus* L. (Asteraceae): A Weed of Worldwide Significance. *Indian Society of Mycology and Plant Pathology*, **5**, 605-632.

[66] Stamps, R.H. (2011) Identification, Impacts, and Control of Ragweed *Parthenium* (*Parthenium hysterophorus* L.). University of Florida IFAS Extension, 10.

[67] Florentine, S.K., Raman, A. and Dhileepan, K. (2002) Responses of the Weed *Parthenium hysterophorus* (Asteraceae) to the Stem Gall-Inducing Weevil *Conotrachelus albocinereus* (Coleoptera: Curculionidae). *Entomologia Generalis*, **26**, 195-206. https://doi.org/10.1127/entom.gen/26/2002/195

[68] Alavanja, M.C., Hoppin, J.A. and Kamel, F. (2004) Health Effects of Chronic Pesticide Exposure: Cancer and Neurotoxicity. *Annual Review of Public Health*, **25**, 155-197. https://doi.org/10.1146/annurev.publhealth.25.101802.123020

[69] Shafique, S., Bajwa, R. and Shafique, S. (2011) Tagetes Erectus L.—A Potential Resolution for Management of *Parthenium hysterophorus* L. *Pakistan Journal of Botany*, **43**, 885-894.

[70] Javaid, A. and Anjum, T. (2006) Control of *Parthenium hysterophorus* L., by Aqueous Extracts of Allelopathic Grasses. *Pakistan Journal of Botany*, **38**, 139.

[71] Thapar, R. and Singh, N. (2005) Allelopathic Influence of Leaf Residue of *Amaranthus spinosus* on Growth and Metabolism of *Parthenium hysterophorus* L. *Ecoprint*, **12**, 77-84. https://doi.org/10.3126/eco.v12i0.3203

[72] Kumar, S. (2015) History, Progress and Prospects of Classical Biological Control in India. *Indian Journal of Weed Science*, **47**, 306-320.

[73] Dhanaraj, R. and Mittra, M. (1976) Control of *Parthenium hysterophorus* L. with Diquat. *Proceedings of the National Academy of Sciences of the United States of America*, **22**, 269-272.

[74] Dhileepan, K. (2003) Current Status of the Stem-Boring Weevil *Listronotus setosipennis* (Coleoptera: Curculionidae) Introduced against the Weed *Parthenium hysterophorus* (Asteraceae) in Australia. *Biocontrol Science and Technology*, **13**, 3-12. https://doi.org/10.1080/0958315021000054340

[75] Dhileepan, K. (2001) Effectiveness of Introduced Biocontrol Insects on the Weed *Parthenium hysterophorus* (Asteraceae) in Australia. *Bulletin of Entomological Research*, **91**, 167-176.

[76] Dhileepan, K. and Wilmot Senaratne, K. (2009) How Widespread Is *Parthenium hysterophorus* and Its Biological Control Agent *Zygogramma bicolorata* in South Asia? *Weed Research*, **49**, 557-562. https://doi.org/10.1111/j.1365-3180.2009.00728.x

Output 2: Poster Presentation

DEVELOPING AN ECO-FRIENDLY AND BIO-MANAGMENT STRATERGY AGAINST *Parthenium hysterophorus* (L.) IN ARUSHA, TANZANIA

Neema C. Mtenga[1], **Thadeo T. Mokiti**[1], **Patrick A. Ndakidemi**[1], **Ernest R. Mbega**[1]

[1]School of Life Science and Bioengeering,NM-AIST, P.O.Box 447, Arusha, Tanzania.

e-mail: mtengan@nm-aist.ac.tz

Abstract

This study aimed at studying the suppressive effects of on Sorghum bicolor, Tagetes erictus Amaranthus spinous and Sorghum arundinaceum and Cassia tora on germination and development of carrot weed Parthenium hysteroporus L. under controlled experiments from March 2018 to November 2018 in Arusha Tanzania. Two experiments involving seed-seed interaction and effects of plant extract on carrot weed were established. Results showed that seeds of Sorghum bicolor, Tagetes erictus Amaranthus spinous and Sorghum arundinaceum showed strong inhibition effects (p_l0.001) on Parthenium seed germination, biomass, and plant height and root length. Similarly, the results from the plant extracts at 25% to 100% (v/v) concentration of A. Indica, T. erictus, A. spinous and S. bicolor inhibited germination rate, shoot and root length elongation, fresh and dry biomass of Parthenium weed. These finding provides bases towards developing an effective alternative bioherbicide for managing Parthenium weed in Tanzania.

1. Introduction

Parthenium hysterophorous (Carrot weed) is a flowering plant of the Asteraceae family, locally called gugu karoti is from tropical regions of Central America, Mexico and then spread to various part of Africa (Picmanet al 1984). In Tanzania, carrot weed was first reported in Arusha 2010. Since then the weed has spread to Kilimanjaro, Manyara and Kyerwa (Kilewa 2014). Parthenium has accidentally spread to many countries and become a major invasive pest. Since its occurrence report, carrot-weed has become a serious threat to biodiversity through degradation of natural ecosystems in Tanzania (Msafiri et al., 2013). Thus, findings from this study will help to identify possible eco-friendly biopesticides approaches that will suppress the growth of carrot weed.

2. Methods

Figure 1: *Methodology adopted in the study.*

Figure 2: *This study used a randomised experimental study design.*

3. Results & Discussion

Effects of plants extracts on Carrot weed.

Figure 3: *Parameters (root and shoot length measurement*

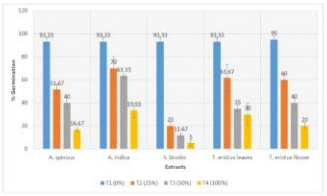


Figure 4: *Plant extracts significantly inhibited germination*

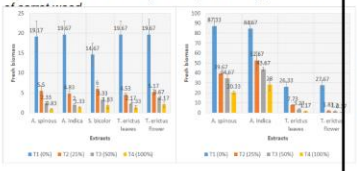


Figure 5: *Effects of extracts on fresh biomass*

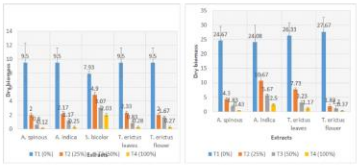


Figure 6: *Effects of extracts on dry biomass.*

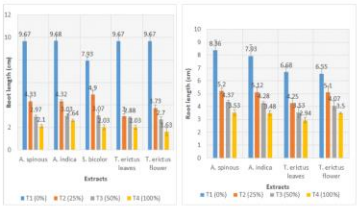


Figure 7: *Root growth inhibition by extracts*

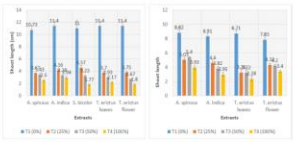


Figure 8: *Shoot growth inhibited by plant extracts*

4. Conclusion& future work

The promising plants are recommended for large scale testing in areas where the weed is increasingly becoming a problem. More research is needed to study the molecular characterization of plant species used in this study in order to come up with best way of managing Parthenium at molecular level.

5. Acknowledgement

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March, 2019, Mtenga et al.,