IMPACT OF PARTHENIUM WEED (*Parthenium hysterophorus* L.) ON PRODUCTION OF MAIZE AND COMMON BEANS IN ARUSHA, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE, MOROGORO, TANZANIA

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EXTENDED ABSTRACT

Introduction and spread of *Parthenium hysterophorus* is affecting crop production and farmer's health. Impacts of this weed on crop production need be assessed and effective management measures be developed in order to reduce or prevent its effects. A study was therefore carried out in Arusha and Meru districts, to (i) describe the farmer's perceptions about parthenium weed (ii) establish distribution and abundance of parthenium weed (iii) assess effective methods for parthenium weed control in maize fields. To achieve the above mentioned objectives, a field survey was conducted during the long rain season of 2017 in the study areas where 120 farmers growing maize and common beans were interviewed. List of villages and farmers were obtained from the district agricultural officers in the two districts. Three villages from Meru district (Mbuguni, Nasholi and Mareu) were selected randomly while Ilkerini, Losikito and Olorieni were randomly selected from Arusha district. Selection of 20 farmers from each village was also done randomly. On distribution and abundance of the weed, latitudes, longitudes and altitudes were recorded for every 10km intervals along the main arterial roads leading out of Arusha to Namanga, Kilimanjaro Airport, Mbuguni and Ilkerini using a hand-held GPS and simultaneously absence or presence and abundance were recorded. In order to identify effective methods to control the parthenium weed, a field experiment was carried out in a randomized complete block design (CRBD) with four replications at the Tropical Pesticides Research Institute (TPRI) in Arusha. The treatments included hand hoeing twice, dry grass mulch, cover crop (cowpeas) mulch, application of 2, 4-D twice, weed free and un-weed plot. Results showed that only 60% of the respondents in Arusha district were aware of the parthenium weed problem. Forty percent of farmers in Meru district reported to have

known the weed. Overall, occurrence of parthenium weed in both maize and common bean fields was noted as non-significant. Although farmers reported to have managed other weeds effectively by hand hoeing, mulching and herbicides application, they were not actively managing parthenium weed. Few farmers (5.8) reported to have heard some farmers getting itchiness of hands, arms and legs as they come into contact with parthenium weed. Habitats, such as roadsides, arable lands, villages and towns are highly vulnerable to invasion by parthenium weed in Arusha and Meru districts. It was observed that parthenium weed was highly concentrated on roadsides and along water tunnels. For instance most (83.08%) farmers in Ilkerini village in Arusha District confirmed parthenium weed had infested their village. Additionally, 74% of farmers in Mbuguni village in Meru District also reported the weed to infest their fields. However few (39.15%) farmers in Olorieni village in Arusha District noticed the weed to infest their fields. Therefore Arusha municipality was highly infested with the weed considering its villages and the conducted survey routes being highly infested with the weed compared with Meru district. For example Ilkerini village and a road from Arusha Municipal to Namanga had 81% and 79% parthenium weed coverage respectively. Frequent observation of the weed was observed only in few areas, for instance along the road from Arusha municipal to Kilimanjaro International Airport 46% weed coverage was observed after 10km car driving and 42% after 40km car driving. Water drainage caused 50% weed coverage to be observed in Mbuguni village in Meru District. In addition, it was noted that road construction works and drainage water were main agents of disseminating seeds of parthenium weed. Before the first hand weeding, 2, 4-D application, dry grass mulch and cover crop (cowpea) hindered parthenium weed growth. Low populations and minimum parthenium heights

were recorded in mulch treated plots. Dry grass and cover crop (cowpeas) mulches were the best parthenium weed control methods as they reduced parthenium weed height and population at maize maturity. The control methods did not significantly affect Maize grain yield ($p>0.05$). It is concluded that farmers were not aware of the health hazard caused by parthenium weed in the study areas. Thus proper and targeted control methods should be employed, especially on roadsides to mitigate the spread of the weed. Mulching was observed to reduce parthenium weed population; hence farmers should integrate such method with other control techniques like hand weeding, biological and chemical control in order to maximize maize and common beans yields.

DECLARATION

I, **Hamis Daniel Wambura,** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been nor concurrently being submitted for a higher degree awards in any other institution.

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This dissertation is dedicated to my son Godwin Hamis Daniel whom I regard as the leaven of my education, also to my mother Aziza Said Juma who shaped my career with love and sacrificed much for value of my life. Not forgetting my late brother Simion Daniel who fought hard for my education.

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ABBREVIATIONS AND SYMBOLS

2, 4-D	2, 4-Dimethylamine
cm	Centimeter
C RCAW	Cooperative Research Center for Australian Weed Management
CV	Coefficient of variation
GPS	Global Positioning System
KIA	Kilimanjaro International Airport
km	Kilometer
m	Meter
RCBD	Randomized Complete Block Design
SE	Standard error
t/ha	Tons per hectare
TPRI	Tropical Pesticides Research Institute
TZS	Tanzania Shillings
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Carrot weed (*Parthenium hysterophorus* L.) is native to Mexico and parts of South America and the Caribbean. It is also regarded as the world's most serious invasive plants (McConnachie *et al*., 2010). The weed first was detected in Asia, Africa and Oceania during the 1950's and probably introduced as a contaminant of cereals and grass seed shipments from America, but has now become a problematic weed in many parts of the world (Cooperative Research Center for Australia Weed Management, 2003). Masum *et al*. (2009) reported that *Parthenium hysterophorus* spreads easily by water, farm and industrial machinery, feral animals, humans, vehicles and movement of stock, grain and seed.

Parthenium weed has an allelopathic effect on neighboring flora through which is capable of replacing most of the associated herbaceous species (Singh *et al*., 2004). Devi and Dutta (2012) reported that parthenium weed suppresses crops such as maize, sorghum and sunflower through the release of allelochemicals called parthenin and coronopilin from decomposing biomass and root exudates. The authors concluded that the weed competes directly with crop species, reducing crop vigour and seed set, leading to reduced yield. Studies by Anil (2014) showed that all parthenium plant parts namely, shoot, root, inflorescence and seeds are toxic to crop plants. Similarly, Devi and Dutta (2012) noted that the aqueous extracts of parthenium inhibited seed germination and seedling vigor in maize.

In eastern Ethiopia, areas with heavy infestation of parthenium weed, sorghum grain yield reductions ranged from 40-97% and 18.5-86.4% in common bean (Lisanework *et al*., 2010). Seed germination and root length of *Cicer aeritinum* were affected by the allelopathic effect of leaf extract of parthenium weed (Raj and Jha, 2016). Manpreet *et al*. (2014) argued that parthenium weed produces enormous numbers of pollens (on average of 624 million/plant), which are carried away at least to short distance in clusters of 600-800 grains and settle on the vegetative and floral parts, including stigmatic surfaces, inhibiting fruit setting in crops like tomato, beans and maize. They also reported that the weed acts as an alternative host for many diseases, notable being the diseases in sunflower and tomato. If parthenium weed was left uncontrolled in sorghum field throughout the season, grain yield losses could vary between 40 and 97% (Tomado and Milberg, 2004)

All parts of the parthenium plant at any stage of growth are toxic to humans and animals (Masum *et al*., 2009). It can taint sheep meat and make dairy products unpalatable to human beings (Masum *et al*., 2009). Cooperative Research Center for Australian Weed Management (2003) reported that parthenium weed can cause dermatitis with pronounced skin lesions and eye irritation on all animals including cattle, horses and goats. Parthenium weed has been shown to be related to health problems for some people living or working in close proximity to it (Anil, 2014). Individuals in contact with any part of the weed can develop sensitivity to the plant, which may then be manifested as an allergy-type response (Boniface *et al*., 2014). Consumption of milk from livestock grazed around parthenium invaded grazing land could be hazardous to man. Reactions to parthenium include severe contact dermatitis, asthma and itching (Gnanavel, 2013).

A recent survey on the importance and distribution of parthenium weed in eastern Ethiopia showed the weed to be serious problem not only in grazing lands, but also in crop fields in lowland and intermediate altitudes of up to 1900m (Lisanework *et al*., 2010). They observed the weed to grow on roadsides, gardens, waterways and in grasslands and crop fields both during the cropping season and after harvest so long as moisture is available. Study conducted by Niguse *et al*. (2016) revealed that the parthenium weed is widely distributed in East Shewa and is spreading in alarming rates to West Arsi district following main road from Modjo town to Hawassa town in Ethiopia.

In Tanzania, parthenium weed was first reported in 2010 and was observed to be widespread along roadsides, croplands, residential areas and grazing lands of Njiro-suburb, Arusha-Kilimanjaro border and Arusha Airport in Arusha Region (Clark and Lotter, 2011). The weed observed to be highly distributed in Kilimanjaro airport, Arusha airport and in-and around Arusha town. Unfortunately, parthenium weed has also been recorded in the Ngorongoro conservation area, since Clark and Lotter (2011) observed parthenium seedlings just outside the headquarters of the protected area.

In Africa, parthenium weed is currently controlled by hand weeding and the task is primarily conducted by women and school age children and uses much time and labor at the same time it reduces crop yield (McConnachie *et al*, 2011). The same observation was given by Tomado *et al*. (2004) in eastern Ethiopia that repeated hand hoeing before flowering was the most effective method for controlling the weed. Mulching with a smoother crop such as cowpea (*Vigna unguiculata*) reduced parthenium biomass, but the reduction was only substantial when combined with hoeing (Abebe and Chemeda, 2016). Cooperative Research Center for Australian Weed Management (2003) reported that timing of chemical control is critical. Therefore, parthenium weed should be treated when plants are small and have not produced seed. However, the use of herbicides to control parthenium weed is currently not economically feasible under the condition of small scale farmers in Tanzania. Overall, there is no single management option that would be adequate to manage parthenium weed across all habitats and there is a need to integrate various management options such as herbicide application, cultural practices with biological control as a core management option (Manpreet *et al.*, 2009).

1.2 Justification

Weeds are among the biotic factors that hinder crop production especially in developing countries. A noxious weed such as *Parthenium hysterophorus* intimidates farmers to use available land for crop production due to its allelopathic effects on crops once it invades. Various methods have been developed to reduce the impact of parthenium weed on crop production in countries like Australia, Sri-Lanka, India, Pakistan and Ethiopia. For example, herbicides have proved effective for control of parthenium weed. Singh *et al*. (2004) found that atrazine and 2, 4-D caused 45% mortality to parthenium weed when applied to young plants. Methods such as manual weeding and use of atrazine, hexazinone and biological control using a moth (*Epiblema strenuana*) have been used to manage parthenium weed in Bangladesh (Masum *et al*., 2009).

Despite the presence of some effective control measures, these technologies have not been used widely in Tanzania. Furthermore, from a wide range of available technologies, selecting appropriate combination suitable for the area based on existing cropping systems is yet to be established. Most farmers in Tanzania still depend on hand weeding mainly using family labour force, but in the near future labour will become scarce and expensive as the drift from rural to urban areas increases. On the other hand, a single method cannot manage weeds to the point of maximizing crop yield, therefore this study was carried out in order to come up with weeding methods in which once integrated will minimize or prevent those impacts of *Parthenium hysterophorus* on maize and common bean production in Arusha, Tanzania. Furthermore, there is a scarcity of information regarding the distribution and abundance of parthenium weed in Arusha and Tanzania in general.

1.3 Objectives

1.3.1 Overall objective

Assessment of impacts of *Parthenium hysterophorus* on crop fields to develop management strategies to improve productivity.

1.3.2 Specific objectives

i. To document the perceptions of farmers on parthenium weed on maize and common beans.

ii. To establish the distribution and abundance of parthenium in Arusha and Meru Districts, Tanzania.

iii. To assess the effective control method(s) for parthenium weed in maize fields

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CHAPTER TWO

2.0 FARMER'S PERCEPTIONSON PARTHENIUM WEED (*Parthenium hysterophorus* L.) ON MAIZE AND COMMON BEANSPRODUCTION

Abstract

Damages caused by parthenium weed in Arusha and Meru Districts and farmers' perceptions about the weed are not yet documented. The study was thus conducted with the purpose of describing farmer's perception on parthenium weed and infestation levels in maize and common bean. Diagnostic survey was conducted during the long rain season of 2017 in Arusha and Meru districts, Tanzania. The research was conducted by interviewing 120 farmers who grow maize and common beans using simple random sampling technique. Descriptive statistical analysis was conducted to analyse data. Mean separation in some variables was done using Krustal-Wallis H-Test while to some variables analysis was done using Independent t-test or Chi-square test. The study revealed that 60% of farmers in Arusha were aware of parthenium weed, while only 40% of farmers in Meru district knew about the weed. Farmers' fields were not highly invaded by the weed. It was only 18.3% of farmers confirmed to have the weed in their fields. Common bean fields were more infested compared to maize fields. Few farmers (3.3%) had *Parthenium hysterophorus* as the major weed. The research confirmed parthenium weed to be highly concentrated on roadsides and its intensity of infestation increased with increases in time. Most farmers reported that the weed caused no effect on crop seed germination and yield, while others were not actively managing the weed. Hand weeding, mulching and herbicides were reported as weed management techniques. It was observed farmers were not

aware of the health hazard caused by parthenium weed. Only 5.8% reported to have heard about people getting itchiness on hands, arms and legs after coming into contact with parthenium weed. It is suggested that awareness of the effects of parthenium weed on crop production, health problems associated with it and its management should be increased among farmers.

Key words: *Parthenium weed, Farmers' perceptions, Maize, Common beans and Cropping systems.*

2.1 Introduction

Although parthenium weed was first reported in India in 1880, it was not recognized as a threat until the 1950s. In 2005, the weed was estimated to infest over five million acres of the Indian subcontinent (Robert, 2011). However, recently parthenium weed is considered as a weed of global significance occurring as an alien invader in over 20 countries in Africa, Asia and Australia (McConnachie *et al*., 2011). Several studies to document farmers' perceptions on parthenium weed have been conducted in several countries. For example in India it was revealed that most of farmers in Handia and Phulpur tehsils were aware about the characteristic features of parthenium weed but they got the knowledge about the weed from their own analysis or fellow farmers (Riti, 2016). However, most farmers observed not to be aware of the parthenium weed spreading methods. It was only 20% of the Handia tehsil farmers reported that parthenium weed has been introduced in their fields through wind, water and animals.

High infestation level of parthenium weed in Dilla-Ethiopia was reported by 73% farmers (Talemos *et al*., 2013). Additionally, those farmers had some information about the impact of the weed on their surrounding but they did not have any information about the effect of the weed on animals, human health and bio-diversity (Talemos *et al*., 2013). Authors reported 88% of the respondents that heard and knew about the parthenium weed, were able to identify parthenium from other weeds by its morphology or physical form and believed that the first appearance of the weed was observed particularly in Dilla town at the beginning of 2001 where donated food grain is stored and temporary station for grain trucks. Niguse *et al*. (2016) claimed that areas with high infestation of parthenium weed, all respondents became aware about the weed. Despite their awareness the rate of infestation increased from time to time. The authors suggested the increase in infestation could be due to proper action was not carried out by different stakeholders and generally communities were not mobilized to take action on the parthenium weed. In areas with medium and high parthenium weed infestation, the weed observed to grow throughout the year and farmers in these areas perceived the weed as highly invasive (Niguse and Kifle, 2016).

Parthenium weed was first appeared on roadside in East Shewa and West Arsi Zones of Ethiopia and later on it propagated to other habitats especially in soils that are disturbed constantly for purposes of construction of roads, buildings and waterways for irrigation channels (Niguse and Kifle, 2016). In South Africa, parthenium weed has invaded particularly KwaZulu-Natal and Mpumalanga as well as North-West and Lim-popo provinces and continues to spread. Dense and extensive infestations occur along roadside, watercourses, grazing, cultivated fields and protected areas for the conservation of biodiversity (Lorraine, 2015)

It has been established by Boniface *et al*. (2014) that the majority of farmers controlled parthenium weed using physical control methods such as uprooting, hand weeding and slushing. However, when a person comes into contact with the weed frequently it may lead into health problems such as allergies, dermatitis, eczema, black spots and blisters around eyes, burning rings and blisters over skin, redness of skin and asthma (Anil, 2014). Level of awareness in Africa on the adverse effects of parthenium weed on agricultural production is low. This causes the weed to spread rapidly and extensively negatively impacting on agricultural production (Boniface *et al*., 2014). Efforts to facilitate the biological control of parthenium weed further North in Africa (Ethiopia and Tanzania) have been undertaken so that to come up with integrated management package which will reduce weeding burden to women and school aged children (Lorraine, 2015).

Eradication of isolated infestations can be achieved by early detection and monitoring procedures. Once weed outbreaks are detected, timely coordinated action and the ability to enforce control requires declaration of parthenium weed throughout all states and territories (Agriculture and Resource Management Council of Australia and New Zealand, 2001). New South wales legislation in Queensland gives the government the power to require inspection and cleaning of vehicles that should decrease the rate of spread but the primary emphasis of the strategy is to encourage landholders through involvement in weed management to have ownership of the issues and consequent outcomes and to coordinate collective action where the problem surpasses the capacity of the individual (Agriculture and Resource Management Council of Australia and New Zealand, 2001).

2.2 Materials and Methods

2.2.1 Description of the study areas

The study areas were Arusha and Meru districts in Arusha Region, Tanzania. The sites were selected following parthenium weed distribution in Arusha region as reported by Clark and Lotter (2011). Arusha district is located south of the equator between latitudes 3º10'- 4º00' and longitudes 34º47'-35º56'east. The district is characterized by two rainy seasons, long and short rains. It receives rainfall ranging between 800 and 1000mm per annum while temperatures range from 16to 33ºC throughout the year (URT, 2017). Meru district lies between 3.5 and 3.7ºS and 35 to 37ºE of the equator. It also belongs to the Northern Highlands Zone with bimodal rainfall pattern that ranges from 1000 to 2000mm per annum (Erasto, 2012).

2.2.2 Methods

A field survey was conducted to determine crop damage as a result of parthenium weed infestation in two districts in Arusha Region, Tanzania, namely Arusha and Meru. Interview method of data collection was used in which twenty seven (27) interview questions relevant to impact of parthenium weed on crop production were prepared. A total of 60 maize and common bean fields were surveyed per district, thus a total of 120 farmers from the two districts were interviewed using simple random sampling technique. List of villages as well as farmers that grew those crops were obtained from the district council. Three villages from each district were selected randomly. A total of 20 farmers per village were interviewed, gender balance was given priority whereby 10 farmers were women while the remained 10 selected farmers were men.

2.2.3 Data collection and analysis

Data collection was done based on the prepared close-ended survey questionnaire as described in Appendix 1. It included size of the surveyed fields, cropping system used, common insect pests and diseases affecting farmer's crop fields with their management methods, common weeds found in farmers' fields with their common control methods, awareness of farmers to parthenium weed, number of fields infested with parthenium weed and non-infested fields per village, parthenium control methods used by farmers, number of farmers who abandoned fields due to parthenium weed infestation, ill-effects due to parthenium weed, effect of parthenium weed on crop yields and demographic characteristics such as age, education, other trainings, gender, marital status and age of the farmer were recorded. Descriptive statistical analysis of collected data was done using Statistical Package for Social Science (SPSS, version 16) software, in which frequencies and percentiles of each variable were derived. Mean separation in some variables was done using Krustal-Wallis H-test while there were some variables in which their analysis was done using Independent Sample t-test and Chi-square test in order to determine whether there was statistical evidence that the associated population means were significantly different.

2.3 Results and Discussions

2.3.1 Results

2.3.1.1 Demographic characteristics of farmers

Characteristics of respondents have important implications towards impacts of parthenium weed on production of maize and common beans in the study areas.

Therefore this section describes the characteristics of the farmers, focusing on marital status, age, gender, education level and other training

2.3.1.1.1 Age of respondents

The age range of respondents was from 18 to a maximum of 67 years with the mean age of 45 years (Table 2.1). Majority of the farmers were in the 29 to 39 age group while 30.8% belonged to 40-50 age groups. Furthermore few farmers were aged above 61 years and age group of 51 to 61 years. The data showed that young farmers within 18 to 28 years group, constituted only 10% of the respondents. Gender of the respondents was nearly balanced. A little difference was observed due to some cultural inhibitions that denied women access to interview. A good example was in Losikito village when women were not allowed to be interviewed on anything except their husbands or any man in the household (Table 2.1).

2.3.1.1.2 Marital status of the respondents

Most of the respondents were married while few of them were single and only 0.8% were divorced (Table 2.1). Widow and widower were 5.8 and 2.5%, respectively (Table 2.1).

2.3.1.1.3 Education level and other training

Most of the respondents had attained primary education while only few attained college and university education (Table 2.1). On the other hand, 12.5% of the interviewed farmers had not gone to school. The results showed that many respondents did not attend other trainings. However, there were government employees with different carriers such as livestock officer, policemen, accountant and agricultural officers.

Table 2.1 Demographic characteristics of respondents in percentages (n=120)

Characteristics	Frequency	Percent (%)
Age group		
18 to 28 years	12	10
29 to 39 years	54	45
40 to 50 years	37	30.8
51 to 61 years	13	10.8
Above 61 years	4	3.3
Total	**120**	**100**
Gender		
Male	61	50.8
Female	59	49.2
Total	**120**	**100**
Marital status		
Single	32	26.7
Married	77	64.2
Widow	7	5.8
Widower	3	2.5
Divorced	1	0.8
Total	**120**	**100**
Education level		
None	15	12.5
Primary	58	48.3
Secondary	35	29.2
College	9	7.5
University	3	2.5
Total	**120**	**100**
Other trainings		
None	71	59.2
Carpentry	8	6.7
Welding/Metal works	8	6.7
Mechanics	4	3.3
Shoe Making	2	1.7
Tailoring	4	3.3
Driver	3	2.5
Government Employees	20	16.7
Total	**120**	**100**

2.3.1.2 Cropping system and types of crops grown

It was observed that most farmers in the study area were practicing mixed intercropping while few practiced sole cropping system. The main crops intercropped were maize and common beans. In case of sole cropping, most farmers were growing maize crops and few grew common beans (Table 2.2).

Table 2.2 Cropping systems and type of crops grown in the study areas (n=120)

Cropping system	Frequency	Percent (%)
Sole cropping	36	30
Mixed intercropping	84	70
Total	**120**	**100**
Crops grown		
Maize	22	18.3
Common beans	14	11.7
Intercropped	84	70
Total	**120**	**100**

2.3.1.3 Farmers' perceptions on parthenium weed (*Parthenium hysterophorus* L.)

Overall 50% of farmers were aware of existence of the parthenium weed (Table 2.3). This overview was mainly from farmers (60%) in Arusha district. Only 40% of farmers in Meru district were aware of the weed. Despite knowing parthenium weed, most farmers did not know its local name (Table 2.3). They have only seen it on roadsides while others called it '*gugu karoti*' (Carrot weed) while others called it '*karoti pori*' (Wild carrot). Only few farmers called the weed by the name '*wild rose flower*'. The name arose from comparing it with rose flower and they were mixing it with rose flowers for sale. Although farmers were aware of parthenium weed, only 18.3% indicated to have the weed in their crop fields. Majority of farmers did not have the weed in their crop fields. On the other hand, some farmers were not sure of its presence or absence in their crop fields. Regardless of whether farmers were aware of parthenium weed or not, most of them could not remember the time of appearance in their farms. Some mentioned that the weed was introduced in 2015 while others said it arrived in 2016, 2007-11 and 2012-14. There were farmers reported to be unsure if the weed affected their farm operations as shown on Table 2.3. It was only few farmers who considered parthenium weeds as a major weed problem in their fields (Table 2.4). On the contrary, farmers considered major weeds in their farms to be *Cyperus rotundus*, *Argemone mexicana* and *Dactyloctenium aegyptium*. Nearly everyone (50.8%) reported that parthenium weed was conspicuous on roadsides and some did not know where the weed appeared. Very few reported to have observed the weed on pastures. These data indicate that, farmers in the study area were not aware when the weed was introduced in Arusha. Despite presence of parthenium weed in farmer's fields many farmers (70%) noted that the weed was not affecting farm operations while few (17%) noted effects of the weed on their farm operations.

Results on Fig. 2.1 indicated that occurrence of parthenium weed in fields of maize, common beans and in mixed cropping (Maize and common beans) is similar while there was statistically significant difference in infestation score between the different crops ($p<0.05$). Common bean fields were more infested than maize fields. Therefore, light infestations were observed in maize fields while mixed cropping had moderate infestation as reported by sampled farmers.

Table 2.3 Farmers perception on parthenium weed (n=120)

Knowing parthenium weed	**Frequency**	**Percent (%)**
Meru (yes)	24	40
Meru (no)	36	60
Total	60	100
Arusha (Yes)	36	60
Arusha (No)	24	40
Total	**60**	**100**
All districts (yes)	60	50
All districts (no)	60	50
Total	**120**	**100**
Local name of parthenium weed		
Don't know	60	50
Gugu Karoti (Carrot weed)	44	36.7
Karoti pori (Wild carrot)	13	10.8
Wild rose flower	3	2.5
Total	**120**	**100**
Presence of parthenium weed in crop fields		
Yes	22	18.3
No	59	49.2
Unsure	39	32.5
Total	**120**	**100**
First place parthenium weed appeared		
Pasture	2	1.7
Roadside	61	50.8
Don’t know	57	47.5
Total	**120**	**100**
Duration of parthenium weed in fields		
Don’t know	60	50
2017	2	1.7
2016	5	4.2
2015	10	8.3
2012-2014	3	2.5
2007-2011	3	2.5
No parthenium weed	37	30.8
Total	**120**	**100**
Effect of parthenium weed on farm operations		
Yes	17	14.2
No	70	58.3
Unsure	33	27.5
Total	**120**	**100**

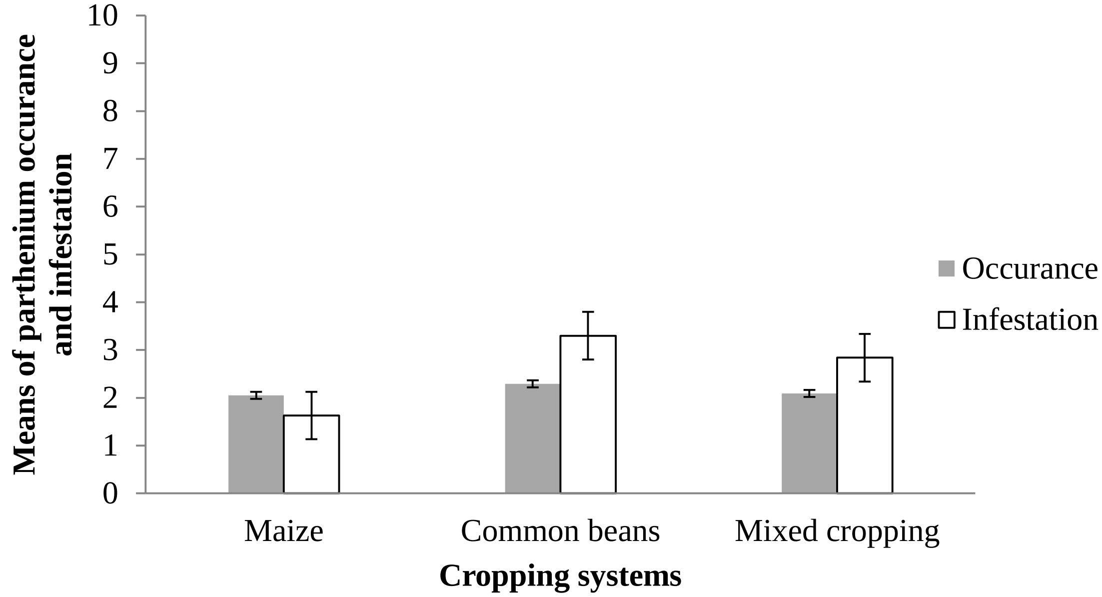

Figure 2.1 Occurrence and infestation level of parthenium weeds in crop fields

Table 2.4 Major weeds found in farmer's fields (n=120)

Name of the weed	Frequency	Percent (%)
Cyperus tenuispica	11	9.2
Datura stamonium	8	6.7
Dactyloctenium aegyptium	14	11.7
Altanthera pungens	3	2.5
Cyperus rotundus	32	26.7
Datura ferox	4	3.3
Eleusine indica	4	3.3
Imperata cylindrica	2	1.7
Argemone mexicana	22	18.3
Echinocloa colona	3	2.5
Elymus repens (Quack grass)	1	0.8
Parthenium hysterophorus	4	3.3
Amaranthus spp	5	4.2
Rottboellia cochinchinensis	1	0.8
Argemone albiflora	6	5
Total	**120**	**100**

2.3.1.4 Estimated farm size and other common insect pest and diseases

Relatively high percentages of farmers in the study areas owned 1.2ha of farmland, while low percentages had 0.4 to 0.8ha and 1.62 to 2.02ha farmland, respectively (Table 2.5). Respondents that owned less than 0.4ha farm size constituted 10%. Few sampled farmers owned more than 2.02 ha of farmland.

Three common insect pests reported by most farmers were cutworm (*Agrotis segetum*), pod borers (*Maruca vitrata*) and stem borers (*Scirpophaga incertulas*) (Table 2.5). On the other hand, three common diseases noted by farmers were anthracnose (*Colletotricum spp*), head smut (*Sphacelothera reilina*) and maize streak virus.

2.3.1.5 Other insect pests and diseases management methods

The chemical method was highly used by farmers in the study area to control insect pests and diseases. Nearly every farmer reported to have used chemicals to manage common insect pests and diseases (Table 2.6). Different diseases control methods such as chemical, crop rotation, rogueing and planting resistant varieties were used by farmers. There were some farmers that were neither managed insect pests (15%) nor diseases (14.2%) throughout the growing season.

2.3.1.6 Effect of *Parthenium hysterophorus* on crop yields

Krustal-Wallis H test showed that there was a statistically significant difference ($p<0.05$) on effects of parthenium weed on seed germination between the two crops (Table 2.7). The Krustal Wallis H test showed that parthenium weed did not cause any crop loss regardless of its presence in maize and common bean fields (Table 2.8).

Table 2.5 Estimated farm size and other common pests and diseases (n=120)

Farm size	Frequency	Percent (%)
Less than 0.4ha	12	10
0.4 to 0.8ha	35	29.2
1.2ha	38	31.7
1.6 to 2.02ha	22	18.3
More than 2.02ha	13	10.8
Total	**120**	**100**
Insect pests		
None	3	2.5
Cutworms	43	35.8
Pod bores	27	22.5
Stem bores	19	15.8
Bruchids	4	3.3
Leaves cutworms	2	1.7
Ear maggot	10	8.5
Leaf beetles	2	1.7
Aphids	3	2.5
Mole rat	7	5.8
Total	**120**	**100**
Diseases		
None	5	4.2
Root rot	9	7.5
Leaf spots	3	2.5
Maize streak virus	14	11.5
Rust	17	14.2
Anthracnose	6	5
Brown spots	4	3.3
Bean rust	6	5
Head smut	16	13.3
Bacterial wilt	12	10
Maize lethal necrosis	13	10.8
Bean common mosaic virus	10	8.3
Ear rot	5	4.2
Total	**120**	**100**

Table 2.6 Crop pest and management methods adopted by farmers (n=120)

Insect pests	**Frequency**	**Percent (%)**
None	18	15
Chemical method	75	62.5
Crop rotation	1	0.8
Planting resistant crop varieties	1	0.8
Chemical methods, crop rotation and planting resistant crop varieties	1	0.8
Field clearance, crop rotation and chemical method	22	18.3
Chemical method and planting resistant varieties	2	1.7
Total	**120**	**100**
Crop diseases		
None	17	14.2
Crop rotation	9	7.5
Rouging diseased plants	3	2.5
Chemical method	54	45
Chemical method, crop rotation, rouging diseased plants and planting resistant plants	23	19.2
Chemical method, rouging diseased plants, chemical method and crop rotation	12	10
Chemical method and crop rotation	2	1.7
Total	**120**	**100**

Table 2.7 Effect of parthenium weed on crop seed germination

Crop	Sample Mean rank
Maize	16.2
Common beans	22.11
P-value	0.064

Results show that there was no statistical difference on yield loss between common bean and maize.

Table 2.8 Influence of parthenium weed on crop yield

Crop	Sample Mean rank
Maize	16.93
Common beans	20.96
P-value	0.166

2.3.1.7 Parthenium weed in farmers' fields

Infestation level of parthenium weed was observed to be highly significant across the villages in the study areas ($p<0.05$). Ilkerini village had high level infestation followed by Mbuguni and Mareu while low infestations were reported in Losikito village (Table 2.9).

2.3.1.8 Parthenium weed management strategies

Overall, most farmers controlled weeds twice in a growing season while some managed weeds once during the growing season and, only 0.8% controlled weeds once per month. The largest part of the sampled farmers was not actively controlling

Table 2.9 Infestation level of Parthenium weed in different villages

Village	Sample mean rank of infestation
Mareu	64.88
Mbuguni	74.95
Nasholi	63.95
Ilkerini	83.08
Olorieni	39.15
Losikito	37
P-value	<0.0001

Parthenium weed, while few managed it. They consider parthenium weed as a normal weed, without realizing its negative impacts. Farmers use hand weeding and organic mulch (crop mulch) as the main weed control methods (Table 2.10).In the case of herbicides, many farmers are not using them solely as a weed management tool. There were farmers who used round up to manage weeds and others used 2, 4-D and Gramaxone herbicides. Few reported use of Gramaxone and 2, 4-D while other farmers were using round up and 2, 4-D in combination. Farmers used round up and Gramaxone (non-selective herbicides) before planting while 2,4-D (selective herbicides) was used in the presence of crops. Results on Table 11 indicated that among the respondents, only few admitted to have used herbicides as an effective method for weed management. It was only 13.3% of farmers in the study area used more than 4 workers in the weeding process (Table 2.11).

Table 2.10 Parthenium weed management strategies (n=120)

Actively controlling parthenium weed	**Frequency**	**Percent (%)**
Yes	19	15.8
No	71	59.2
Unsure	30	25
Total	**120**	**100**
Weeds control time interval		
Once per month	1	0.8
Twice per season	100	83.3
Once per season	19	15.8
Total	**120**	**100**
Weeds control methods used		
No control	28	23.3
Hand weeding	2	1.7
Hand weeding, herbicides and mulching	26	21.6
Hand weeding, herbicides, mulching and burning	2	1.7
Hand weeding, mulching and burning	5	4.2
Hand weeding and mulching	54	45
Hand weeding, burning and mulching	3	2.5
Total	**120**	**100**

Table 2.11 Parthenium weed management strategies (n=120)

Herbicides used	Frequency	Percent
None	87	72.5
Round up	11	9.2
2,4-D	1	0.8
Gramaxone	6	5
Gramaxone and 2,4-D	4	3.3
Round up and 2,4-D	11	9.2
Total	**120**	**100**
Herbicides effectiveness		
Yes	33	27.5
Unsure	87	72.5
Total	**120**	**100**
Number of people involved in weeding		
1 person	16	13.3
2 people	39	32.5
3 people	33	27.5
4 people	16	13.3
More than 4 people	16	13.3
Total	**120**	**100**
Estimated amount (TZS/0.4 ha) spent on weed management		
0	58	48.3
<10,000	1	0.8
10001 to 20,000	13	10.8
20001 to 30,000	33	27.5
30001 to 40,000	14	11.7
>40,000	1	0.8
Total	**120**	**100**

2.3.1.9 Health hazards due to presence of parthenium weed

The data showed that all farmers (100%) were not aware of the health hazards caused by parthenium weed (Table 2.12). Likewise, most (90.8%) farmers said that they had not heard of others getting ill as a result of parthenium weed infestation. However, there were few (5.8) respondents who confirmed to hear some people saying that they had itchiness of hands, arms and legs that resulted from getting into contact with the parthenium weed. Few farmers (1.7%) noted that some fellow farmers suffered from tight chest problem when they were in contact with the weed. However, it was only 0.8% of the farmers reported problem of struggling to breathe when managing or coming into contact with parthenium weed (Table 2.12).

Table 2.12 Health hazards due to parthenium weed (n=120)

Ill-effect to farmer her/himself	**Frequency**	**Percent (%)**
No	120	100
Heard of Ill-effects to other farmers		
No	109	90.8
Itchiness of hands, arms or legs	7	5.8
Struggling to breathe	1	0.8
Tight chest	2	1.7
Itchiness of hands, arms or legs and struggle to breathe	1	0.8
Total	**120**	**100**

2.3.2 Discussions

The data imply that many married couples concentrated more on crop production since it was only farmers that grow either maize or common beans were interviewed. They had to do so to insure food security among their families. In addition, these results show clearly that the farm labour force in Arusha and Meru Districts is within the working age. Adebayo (2012) reported that married couples have additional responsibilities to their spouses and children, hence have better chances of venturing into on-farm activities than people who are not married.

The mean age indicates that most of the farmers belong to the productive group. This implies that production activities are not mainly carried out by old people in the study area. The study conducted by Ngeywo *et al*. (2015) highlighted that age was a key factor in adoption rate of technologies and performance of the farmer as she/he engaged in farming or retiring from farming. The productive age of labour force ranges between 15 and 40 years (Echibiri and Mbanasor, 2003)

Although farmers had low level of education, majority had better access to information and resources since they could be able to read and write and the presence of literate people in a community. Each village had personnel in agricultural related field and hence farmers had a place to address problems related to crop production. The presence of literate people in the household means better access to information and resources and better social networking (Dessalegn, 2008).

Most farmers in the study area could be categorized as small holder farmers because they owned small plots of land and were aware of the importance of practicing intercropping system. They intercropped maize with common beans so that the latter crop acts as a source of nitrogen for the maize crop as well as managing weeds through mulching. In addition to have advantage of getting yields of both maize and beans at once. Intercropping and sole cropping are among the cropping systems found in the study areas as explained by Nafziger (2009). Information on parthenium weed introduction being not known to farmers in the study area may lead to further spread of the weed. Therefore, awareness about the weed should be created so that the weed it becomes familiar among farmers which will make management processes easy.

In the case of diseases, farmers were aware of integrated pest management methods that helped them in controlling diseases. However, farmers knew that the most effective method to manage diseases and insect pests was the use of chemicals. Their motive is how to obtain high crop yields regardless of possible chemical hazards. This implies that most farmers do not care about side effects of pesticides as reported by Ivan, (2015).

Parthenium weed causes crop yield losses of 40-97% if a field is left uncontrolled (Lorraine, 2015). However farmers in Arusha and Meru Districts reported not to experience yield loss in maize and common bean fields due to parthenium weed infestation. This implies that crop yield losses that farmers encounter are due to factors other than the presence of *Parthenium hysterophorus* in their fields. This does not mean that farmers in Meru and Arusha districts should stop managing parthenium weed, although there were few farmers who reported presence of the weed in their farms and at low levels of infestation. It should be noted that the weed produces many seeds, spreads easily and hence it can cover large area within a short time (Boniface *et al*., 2014).

According to the results, most farmers in Ilkerini (Arusha district) and Mbuguni (Meru district) reported high parthenium weed infestation in their crop fields. The weed is spreading at a high rate in the Arusha municipality, and it is predicted that the weed will soon invade all villages in Arusha district and later in Meru district, if no any control measures will be taken. The findings also show that the sampled farmers in the study area owned small farms and hence few workers were involved in weed management. Most farmers paid nothing for weeding because of using family members and friends. Since farmers were not actively managing parthenium weed, it provides some insight that the weed will probably spread at a higher rate. Intercropping was highly adopted as a cropping system among farmers and it was used as a weed management method. Maize was mostly intercropped with common beans and hence the latter was used as a cover crop to suppress weed growth by preventing light from reaching the weeds. It has been observed by Parviz *et al*. (2009) that intercropping could be used to reduce weed density since it reduces open niches that the weeds occupied.

Farmers in the study area were not experiencing any health-effects due to parthenium weed because they had not come into contact with it. The majority did not feel any effects when they came into contact with parthenium weed for the first time or several times. This could be due to the fact that the parthenium infestation in farmer's fields is at its initial stages. These results concur well with those of Boniface *et al*. (2014) that confirmed that the ill-effects of parthenium weed on agricultural production were not directly associated to parthenium invasion in Nyando-Kenya. Chances of getting some effects of the weed are high when exposed on regular basis for periods ranging from 4 to 15 months (Anil, 2014).

2.4 Conclusions and Recommendations

2.4.1 Conclusions

i. Parthenium weed was considered as a normal weed in Arusha and Meru Districts despite its hazardous effects on human health and crops.

ii. Although there were some villages with heavy infestation of parthenium weed such as Ilkerini and Mbuguni in Arusha and Meru Districts respectively, farmers' awareness on the weed and its control was still low.

iii. It was observed that mixed intercropping was more adopted by farmers in Meru and Arusha districts than sole cropping system. These helped farmers in parthenium weed management and hence reduced weeding intervals because the short intercrop component (common bean) smothered weed growth.

iv. Herbicides were also used by some farmers on parthenium weed management.

v. Additionally, most farmers were not familiar with health hazards associated with parthenium weed although there were some villages with heavy infestation by the weed.

2.4.2 Recommendations

i. Awareness about the effects of the weed on human health and crops should be further emphasized in order to be able to manage the weed effectively.

ii. Parthenium weed should be managed before it flowers so as to reduce its seed bank.

iii. Efforts should be made by the Arusha Regional Administration through its local government to manage the weed along the roadsides where it is mostly concentrated.

iv. Based on these findings, it is recommended that similar studies should be extended to other districts in Arusha Region and beyond, such as Kagera and Geita Regions where the weed has been reported.

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CHAPTER THREE

3.0 DISTRIBUTION AND ABUNDANCE OF *Parthenium hysterophorus* L. IN ARUSHA AND MERU DISTRICTS IN TANZANIA.

Abstract

The current threats posed by parthenium weed are significant and are growing at an alarming rate. As a result, habitats such as roadsides, arable lands, villages and towns are in danger of being invaded by the weed in Northern Tanzania. There is scarce information regarding the distribution and abundance of parthenium weed in Arusha and Tanzania in general. Thus, the study on generating information on this weed for a better understanding of its distribution and abundance in Arusha and Meru districts, Tanzania was conducted. Field survey was conducted, latitudes, longitudes and altitudes were recorded at 10 km intervals using a hand-held GPS and simultaneously noting the absence or presence and abundance on a data sheet. The distribution and abundance of parthenium weed was recorded at 10 km intervals along the main arterial roads leading out of Arusha to Namanga, Mwandeti village, Kilimanjaro Airport, Mbuguni and Ilkerini Village. Results indicated that parthenium weed was highly concentrated on roadsides and in water ways. Arusha municipality was highly infested with parthenium weed (81%) than Meru district with 46% as the highest weed coverage. The weed was very abundant in Ilkerini (81%) and Olorieni (79%) villages in Arusha District, while in Meru District the weed occurred occasionally (20%) in Mbuguni village and frequently around Kilimanjaro Airport (50%). The findings also indicated that when moving away from the main roads, parthenium weed infestation

decreases and sometimes in the interior villages such as Mareu and Losikito, the weed was not apparent (0%). It was noted that road construction activities and water in canals were the main agents of dispersing parthenium weed seeds. Therefore, proper and targeted control methods should be employed especially on roadsides to control further spread of the weed into crop lands.

Key words**:** *Parthenium hysterophorus, Distribution, Abundance and Parthenium weed*

3.1 Introduction

The parthenium weed (*Parthenium hysterophorus* L.) became one of the world's seven most devastating and hazardous weeds in more than 20 countries worldwide (Ramadhan and Amzath, 2012). On the African continent, *Parthenium hysterophorus* has been reported in South Africa, Swaziland, Mozambique, Zimbabwe, Kenya, Ethiopia, Eritrea, Somalia, Uganda, Tanzania, Rwanda and Egypt (CABI International, 2007). The weed has been reported from all states of India and in general, the overall spread of density and infestation level is that it is highest in Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Haryana, Kamataka, Maharashtra, Madhya Pradesh, Punjab, Tamil Nadu and Uttar Pradesh (Sushilkumar, 2012). The author confirmed that the weed was present in high abundance which might reflect its future potential for spread and its presence is increasing in the coastal regions of Tamil Nadu, Orissa and Gujarat. In a recently undertaken survey and collection of information from various sources from around India, the current spread of parthenium weed has been estimated to be around 35 million ha of land which includes wastelands, crop lands and forested lands (Sushilkumar, 2012).

Bharat, (2012) reported that there were small to large patches of parthenium weed found inside the Chitwan National park along the elephant ride routes, vehicle tracks and trails. The area around elephant breeding center, which lies in the buffer zone was the most heavily infested site and also reported that the abundance of the weed was not yet at a damaging level inside the park. The weed is also thought to have been introduced into the Khyber Pakhtunkhwa Province from Islamabad, mainly through heavy public and goods vehicles and infested mainly roadsides and cropping areas, the weed was expected to have a good chance to become a major problem in those cropping areas (Naeem, 2012).

From America, parthenium weed was accidentally imported into Ethiopia as a contaminant of grain during the 1988 famine (Murphy and Cheesman, 2006). High abundance of parthenium weed along roadsides in the different Districts in Ethiopia was reported. This was attributed to continuous disturbance and transportation of sands and soil for construction and maintenance of roads (*Niguse et al*., 2016). Additionally, the extensive dense stands along roadsides in Ethiopia might be due to the routine disturbance and upgrading of road verges (Taye, 2002).In Tanzania, parthenium weed was first reported in 2010 and observed to be widespread alongside roads, croplands, residential areas and grazing lands of Njiro-suburb, Arusha-Kilimanjaro border and Arusha Airport in Arusha Region (Clark and Lotter, 2011). They further reported that parthenium weed is found in Kilimanjaro airport, Arusha airport and in and around Arusha town. The highest parthenium weed density in Arusha was observed in grazing land, crop land and alongside road at Rubwera sub-village (Ramadhan and Amzath, 2012).

There is inadequate information about distribution and abundance of *Parthenium hysterophorus* in Arusha region, especially in agricultural fields. Therefore this study was conducted to fill in the information gap by mapping the distribution and abundance of parthenium weed in Arusha and Meru District. Generated information will help in planning for parthenium weed management, assisting researchers where to release bio agents (*Zygograma bicolorora*) in case of biological control and creating awareness to researchers and farmers on level of infestation of parthenium weed in the study areas.

3.2 Materials and Methods

3.2.1 Description of the study area

The study area is located in the northern part of Tanzania; Arusha region is one among the regions in northern agro-ecological zone as described by ministry of agriculture food security and cooperatives (2011). The region comprises of five districts namely Arusha, Meru, Karatu, Ngorongoro and Monduli. Arusha and Meru were selected based on the parthenium weed survey carried in 2011 by Clark and Lotter (2011). The districts are characterized by high rainfall, general cool climates and fertile highlands soils (United Republic of Tanzania, 2005).

3.2.2 Methods

A field survey of parthenium weed was carried out during the long rain season of 2017 in Arusha and Meru districts at 10 km interval. Using the border between the two districts (Fig. 1) as a starting point, the presence of parthenium weed was recorded at 10 km intervals along all of the main arterial roads leading out of Arusha to Namanga, Kilimanjaro Airport, Mbuguni and Ilkerini Village. The coordinates at each interval were recorded using a hand-held and then mapped using the software GPS Arc View GIS 3.2. The absence or presence and abundance of parthenium weed at each 10 km intervals were recorded based on percentage cover estimation method as developed by Booth *et al*, (2003). Abundance was rated on the basis of coverage with 5% or less being rare, 6-25% occasional, 26-50% frequent, 51-75% abundant and 76-100% very abundant (Booth *et al*., 2003).

3.2.3 Data collection and analysis

Coordinates (latitudes, longitudes and altitudes) were recorded using a hand-held GPS and simultaneously the presence or absence and abundance of parthenium weed were observed and noted on the data collection sheet based on percentage cover estimation with the modification developed by Booth *et al*. (2003). . Finally the data collected were imported into Arc View GIS 3.2 software to develop point distribution and abundance map of the two districts (Arusha and Meru) in Arusha, Tanzania.

3.3 Results and Discussion

3.3.1 Results

On the starting point (A border between Arusha and Meru districts), parthenium weed was observed to cover half of the area (Table 3.1 and Fig. 3.1). Dense stands of parthenium weed were seen on roadsides leading from Arusha municipal to Namanga, with no plants seen within farmers' fields. Parthenium weed was not seen after 30 km survey point along this road (Table 3.1 and Fig. 3.1).

Around Arusha Airport which is located in Ilkerini village, parthenium weed was very abundant (81%) along roadsides and farmers' fields (Fig. 3.1, Plate 3.1). Crop fields near main road parthenium weed observed to be dominant weed, but parthenium weed abundance was observed to decrease as you move away from the main road to Ilkerini village (Fig. 3.1).

Moving from Arusha municipal to Kilimanjaro airport, parthenium weed reported to cover small areas (5%) in some parts while frequent observations were made in various coordinates headed to Kilimanjaro Airport (Table 3.1). Around Kilimanjaro International Airport (KIA), parthenium weed was frequently observed, with 46% of the land invaded with parthenium weed (Table 3.1). Along the road to Ilkerini village the weed was very abundant (79%) in areas where soils had been dumped during road construction activities (Table 3.1 and Plate 3.2). Water was most likely responsible for dispersing parthenium wee seeds into Mbuguni village which caused half of the surveyed area to be covered by the weed (Plate 3.3).

Table 3.1 Distribution and abundance of the mapped routes

Mapped route	Distance (km)	Cordinates reading		Coverage (%)	Abundance
Road from Arusha Municipal to Ilkerini village	0	Latitude	3°22.025'S	81	Very abundant
		Longitude	36°38.167'E		
	10	Latitude	3°23.072'S	59	Abundant
		Longitude	36°32.998'E		
	20	Latitude	3°21.503'S	0	Absent
		Longitude	36°31.618'S		
	30	Latitude	3°22.552'S	79	Very abundant
		Longitude	36°33.571'E		
	40	Latitude	3°25.070'S	0	Absent
		Longitude	36°27.545'E		
Road from Arusha Municipal to Namanga	0 Km	Latitude	3°22.464'S	5	Rare
		Longitude	36°45.120'E		
	10Km	Latitude	3°21.643'S	20	Occasional
		Longitude	36°41.766'E		
	20Km	Latitude	3°18.257'S	75	Very abundant
		Longitude	36°37.995'E		
	30Km	Latitude	3°13.150'S	0	Absent
		Longitude	36°36.388'E		
Road from Arusha Municipal to Kilimanjaro International Airport	0 Km	Latitude	3°22.464'S	3	Rare
		Longitude	36°45.120'E		
	10Km	Latitude	3°22.49'S	46	Frequent
		Longitude	36°50.237'E		
	20Km	Latitude	3°22.885'S	0	Absent
		Longitude	36°54.719E		
	30Km	Latitude	3°22.960'S	23	Occasional
		Longitude	36°59.871'E		
	40Km	Latitude	3°22.060'S	42	Frequent
		Longitude	37°04.073'E		
Mwandeti village	0 Km	Latitude	3°16.352'S	0	Absent
		Longitude	36°36.941'E		
	10Km	Latitude	3°16.320'S	0	Absent
		Longitude	36°35.667'E		
Road from Meru District office to Mbuguni Village	0 Km	Latitude	3°33'S	50	Frequent
		Longitude	36°54'E		
	10Km	Latitude	3°28'S	20	Occasional
		Longitude	36°51'E		
	20Km	Latitude	3°24'S	0	Absent
		Longitude	36°49'E		

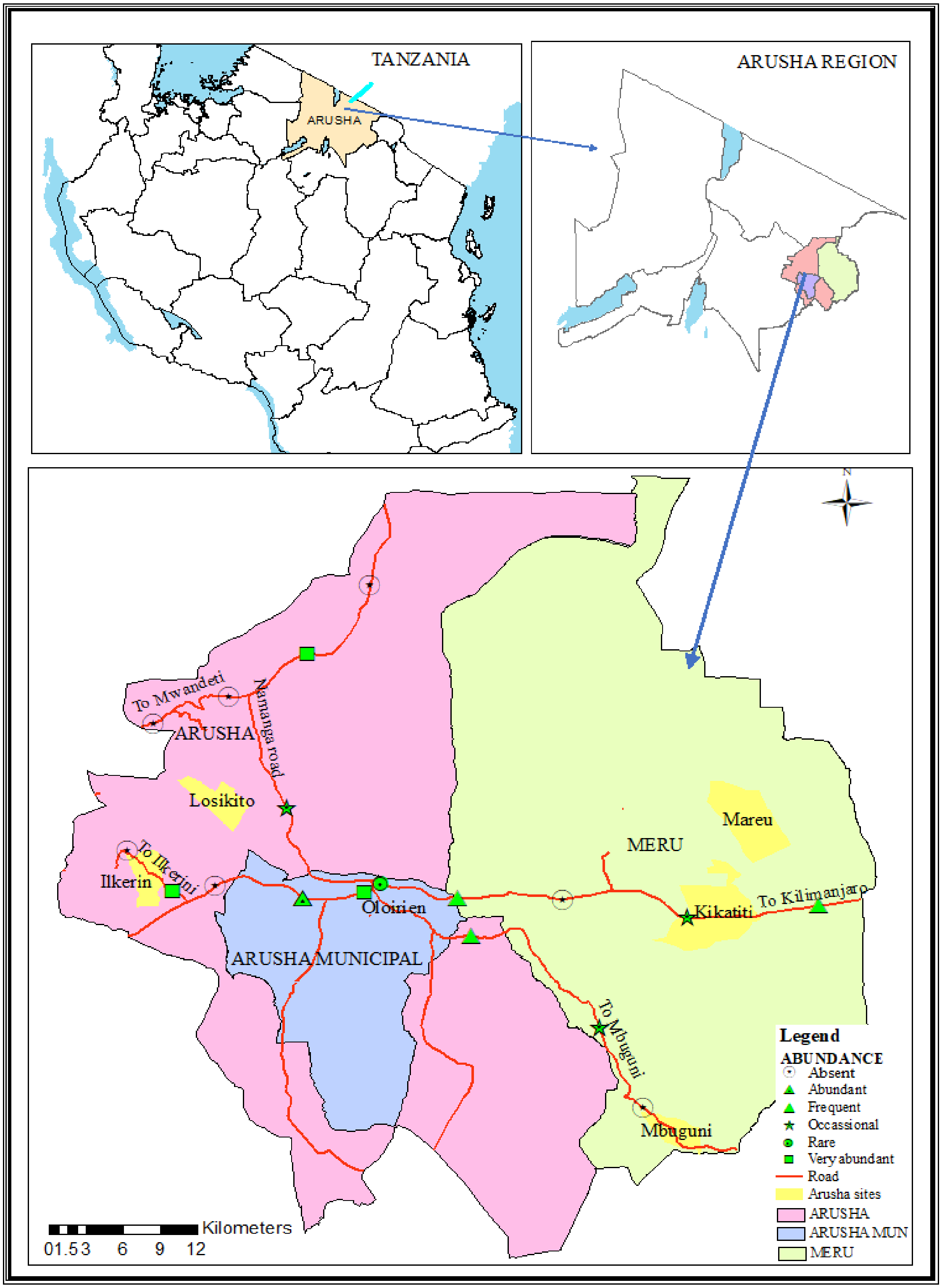

Figure 3.1 Distribution and abundance of *Parthenium hysterophorus* in Arusha and Meru districts in Tanzania

Plate 3.1 Parthenium weed in farmer’s fields near Arusha airport

Plate 3.2 Parthenium weed in sandwich with soil heaps carried by road construction tracks at Ilkerini village

Plate 3.3 Parthenium weed surrounding water canal in Mbuguni village

3.3.2 Discussions

According to the results, parthenium weed is still in its initial stage of infestation. The weed has observed to infest more on roadsides than in farmers' fields. However, the infestation was in patches in many surveyed areas, except to some areas, especially in Ilkerini and Olorieni villages in Arusha District, where the weed infested large area. Looking to distributions and abundances of parthenium weed being very high in and around Kilimanjaro International Airport (KIA) and Arusha Airport, it could be predicted that, the weed was first introduced through these airports and later on started to infest along roadsides heading from Airports to Arusha Municipal offices and Namanga road. The weed along roadsides and close to constructed water tunnels, shaded their seeds into water then got drained to lowland areas such as Mbuguni and hence caused new infestation.

3.4 Conclusions and Recommendations

3.4.1 Conclusions

i. The Sketch map and plates showed a clear indication of the spread of the parthenium weed along roadsides and water ways. This could be due to road construction activities, vehicles and animal movements and water drainage channels.

ii. Parthenium weed was very abundantly (81% and 79%) in Ilkerini village after 10km and 30km car driving respectively from Arusha municipality.

iii. Coverage of the weed was observed to be very abundantly (75%) after 20km car driving from Arusha Municipal to Namanga but moving to 30km the weed was not farther observed (0%).

iv. The weed observed to occur frequently on the road from Arusha municipal to Kilimanjaro International Airport and in Mbuguni village.

v. Additionally, the weed was observed to infest some of the farmers' fields especially those farms around Kilimanjaro International Airport and Arusha Airport. Having seen soil heaps sandwiched with parthenium weed, it indicated that road construction trucks do collect soils from infested area and deposit it into un-infested area and hence causing new parthenium weed infestation.

3.4.2 Recommendations

i. Parthenium weed being more concentrated around Kilimanjaro and Arusha Airports, responsible authorities should establish strict quarantine services in the airports and all entry points along the borders of Tanzania.

ii. Since the weed was observed to concentrate much along roadsides and water ways and somehow in crop fields, a quick action to manage parthenium weed on roadsides to stop further spread should be undertaken by relevant authorities. Farmers should control the weed in or near their fields before it flowered so as to reduce its seed bank and hence preventing further spread.

iii. It is further suggested that maps showing the distribution and abundance of the weed be developed to cover the whole of Tanzania, particularly in national parks and conservation areas in order to minimize impacts of parthenium weed.

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CHAPTER FOUR

4.0 ASSESSMENT OF EFFECTIVE CONTROL METHODS FOR PARTHENIUM WEED IN MAIZE FIELDS

Abstract

In the near future, labour to assist in weed management in the villages will become scarce and expensive, because of population drift from villages to cities. It is necessary to develop cheaper methods of weed management that will reduce weed impact on maize yield. A field experiment was conducted at the Tropical Pesticides Research Institute (TPRI), Arusha-Tanzania during the long rain season of 2017, to identify control methods for parthenium weed (*Parthenium hysterophorus* L.). The experiment was laid out in a randomized complete block design (RCBD) with four replications. Treatments were hand hoeing (twice), mulches (dry grass and cowpeas), application of 2, 4-D (twice), weed free plots and un-weeded plots. Data collected include plant height at flowering (m), leaf length and width (m), number of leaves at flowering, number of days to (tasseling, silking and milking), tassel length (m), number of days to maize maturity, plant height at maturity (m), number of plants harvested, ear length and diameter (m), number of kernel rows/ear, number of kernels/row and grain yield (t/ha) at 12% moisture content, parthenium weed plant height (m), canopy width (m), and number of parthenium plants before weeding, weed canopy width (m), height (m) and number of parthenium plants at maize maturity. Statistical analysis was performed using Genstat software (16^{th} edition) and means were separated by Tukey's mean separation test at $p \leq 0.05$. The results show that, mulches significantly reduced parthenium height and population in the maize crop at maturity ($p < 0.05$). Plant height at flowering, leaf length and width, number of days to tasseling, tassel length, number of days to silking, milking, maturity, plant height at maturity and number of plants harvested were not significantly affected by any of the weed management methods. Thus mulching and 2, 4-D were found to be the best methods for controlling parthenium weed growth and population.

Key words*: *Parthenium weed, Control methods, Maize and Weeds

4.1 Introduction

Maize (*Zea mays*) is the world's widely cultivated highland cereal and primary staple food crop in many developing countries. Pradeep *et al*. (2017) ranked maize as the third in cereals world production after rice and wheat, but in productivity, it surpasses all cereals. In Tanzania maize is one of the dependable food and cash cereal crops but its production has been hindered by both biotic and abiotic factors. Among the biotic constraints, weeds are considered as an important category. Invasive weeds are considered to be among the biotic factors that hinder maize production. Parthenium weed is one of the threatening invasive weeds due to its allelopathic properties, as it produces parthenin compound that hinders germination of crop seeds and hence reducing crop establishment and yields (Tomado *et al*., 2002a; Singh *et al*., 2004).

Various methods have been tested to reduce the impact of parthenium on crop production in countries like Australia, Sri-Lanka, India, Pakistan and Ethiopia. For example, herbicides have proved effective for the control of parthenium weed. Singh *et al*. (2004) found that atrazine and 2, 4-D caused 45% mortality to parthenium weed in India when applied to young plants. Shabbir, (2014) discovered that, Glyphosate and Isoproturon are effective selective herbicides in controlling parthenium weed although Glyphosate was comparatively more effective as compared to Isoproturon. Methods such as manual weeding and use of atrazine, hexazinone and biological control, using a moth (*Epiblema strenuana*) have been suggested by Masum *et al*. (2009) and Abebe and Chemeda, (2016) to manage parthenium weed in Bangladesh.

Manual uprooting of parthenium weed before flowering and seed setting is the most effective method. This is due the fact that, uprooting the weed after seed setting will lead to weed seed dropping and hence increase the area of infestation (Manpreet *et al*., 2014). The author reported that, although there are some landholders that have achieved success in ploughing parthenium weed in the rosette stage before it seeds, but this must be followed up by sowing a crop or direct seeding the perennial pasture. Talemos *et al*. (2013) argued that, parthenium weed management practices like manual uprooting should be handled with care, which is, a person should make sure that protective gear such as gloves and masks are in place to prevent health hazards of the weed.

Serious inspection of parthenium weed seeds at border entry points and Airports could be a proper method in preventing and managing the weed. For example, In South Africa, the weed is regulated as well under the existing legislation (CARA 2002-Category 1 according to which invader plants must be removed and destroyed immediately. No trade in these plants and is also reported as a noxious weed by the government of Kenta and Puerto Rico (EPPO, 2014)

Despite the presence of some effective control measures, these technologies have not been used widely in Tanzania. Furthermore, from a wide range of available technologies, selecting appropriate combination suitable for the area based on existing cropping systems is yet to be established. Therefore, the present research work was carried out to evaluate different weed management practices with intension of obtaining the most effective and easily adoptable weeding technique in controlling parthenium weed in maize fields.

4.2 Materials and Methods

4.2.1 Description of the study area

A field experiment was conducted at the Tropical Pesticides Research Institute (TPRI) in Arusha, Tanzania, during the long rain season from February to July 2017. TPRI is located at 3º1953.265’’S latitude and 36º37.38.667’E longitude and at an elevation of 1451m above sea level. Selection of the experimental site was done following the presence of parthenium weed based on the survey report carried in March 2011 (Clark and Lotter, 2011).

4.2.2 Methods

Parthenium weed seeds were broadcasted in equal amounts in each plot of maize. The experimental site was ploughed and leveled before the field layout was made. The experiment consisted of six treatments namely weed free, hand hoeing, dry grass mulching, 2, 4-D application; cover crop mulching (cowpeas) and no weeding. Hand weeding and 2, 4-D applications were twice (4^{th} and 8^{th} week after planting). The herbicide, 2, 4-D was applied at the rate of 960g a.i/ha in a plot area of $9m^2$. The treatments were arranged in randomized complete block design (RCBD) with four replications. The distance between adjacent replications and plots were 1m each.

A maize variety SC 403 was used as a testing variety, which was sown by the dibbling method. Thus, space between one plant and another was 0.03m while rows were spaced at 0.75m. There were 4 rows per plot and 10 plants per row. Urea fertilizer was applied 16 days after sowing by banding method at the rate of 102kgN/ha. Other weeds were removed from the experimental plots by hand hoeing or hand pulling as soon as they emerged.

4.2.3 Data collection and analysis

Data were collected based on maize descriptor prepared by Badu-Apraku *et al*. (2012). The collection of maize data was done from ten (10) plants in the two middle rows with 3.6 m^2 as sampling area. Data collected were;

4.2.3.1 Plant height at flowering (m)

Heights of 10 plants were measured using a tape measure from the base of the plant to where tassel branching begun.

4.2.3.2 Leaf length at flowering (cm).

Six leaves in each plant for ten maize plants were selected and measured their length from point at which the lamina is attached to the petiole to the leaf tip.

4.2.3.3 Leaf width (cm)

Leaf width was obtained by measuring the widest part of the six leaves from each plant in ten selected plants using a tape measure.

4.2.3.4 Number of leaves at flowering

Total number of leaves per plant in 10 selected maize plants was obtained.

4.2.3.5 Number of days to tasseling

Days were counted from planting date to the date when 50% of the plants in a plot had emerged tassels.

4.2.3.6 Days to silking

Days to silking was obtained by counting number of days from planting to the date when 50% of the plants in a plot have emerged silks

4.2.3.7 Number of days to milking

The average number of days was obtained from sowing date to the day at least 50% of maize plants attained milking stage.

4.2.3.8 Tassel length (cm)

It was obtained by measuring tassel length using a tape measure from the peduncle to the longest part of the tassel.

4.2.3.8 Number of days to maize maturity

Days to maize maturity was counted from the date maize was sown to the date at least 50% of maize in a plot attained a physiological maturity.

4.2.3.9 Maize plant height at maturity (m)

It was obtained by taking an average plant height of 10 plants, measured by using tape measure from the base of the plant to where tassel branching begins.

4.2.3.10 Parthenium weed height (m)

Heights of ten selected parthenium weed plants were measured from the base of the plant to the longest part.

4.2.3.11 Canopy of parthenium weed (m)

The widest part of the canopy of the weed was measured and recorded.

4.2.3.12 Numbers of parthenium weed plants before weeding and after maturity

Parthenium weed plants were counted d by throwing 12 quadrants of 0.25 x 0.25 m in each plot and count the available parthenium plant in each quadrant and finally average counts were obtained.

4.2.3.13 Number of plants harvested

Total number of plants harvested were counted and recorded

4.2.3.14 Ear length and diameter (cm)

They were obtained by measuring a maize ear from peduncle to end of an ear and the diameter was measured by breaking a maize ear at the middle and measured a length at the middle using a ruler from one kernel to other kernel of the opposite side.

4.2.3.15 Number of kernel rows/ear and total number of kernels/row

They were obtained by counting number of kernels per ear for 10 selected maize ears and average number of kernels was calculated.

4.2.3.16 Grain yield (t/ha)

Grain yield was obtained by weighing dried maize kernels but after attaining not more than 12% moisture content.

Statistical analysis was performed using Genstat software (16th edition) and means were separated using the Tukey mean separation test ($p<0.05$). Analysis of variance was done based on the statistical model for randomized complete block design: $y_{ij} = \mu + \alpha_i + b_j + \varepsilon_{ij}$ whereby y_{ij} indicates random variable representing the response for treatment (i) observed in block j, μ is the constant (which may be thought of as the overall mean, α_i stand for the (additive) effect of the i^{th} treatment, b_j is the (additive) effect of the j^{th} block, ε_{ij} is the random error for the i^{th} treatment in the j^{th} block.

4.3 Results and Discussions

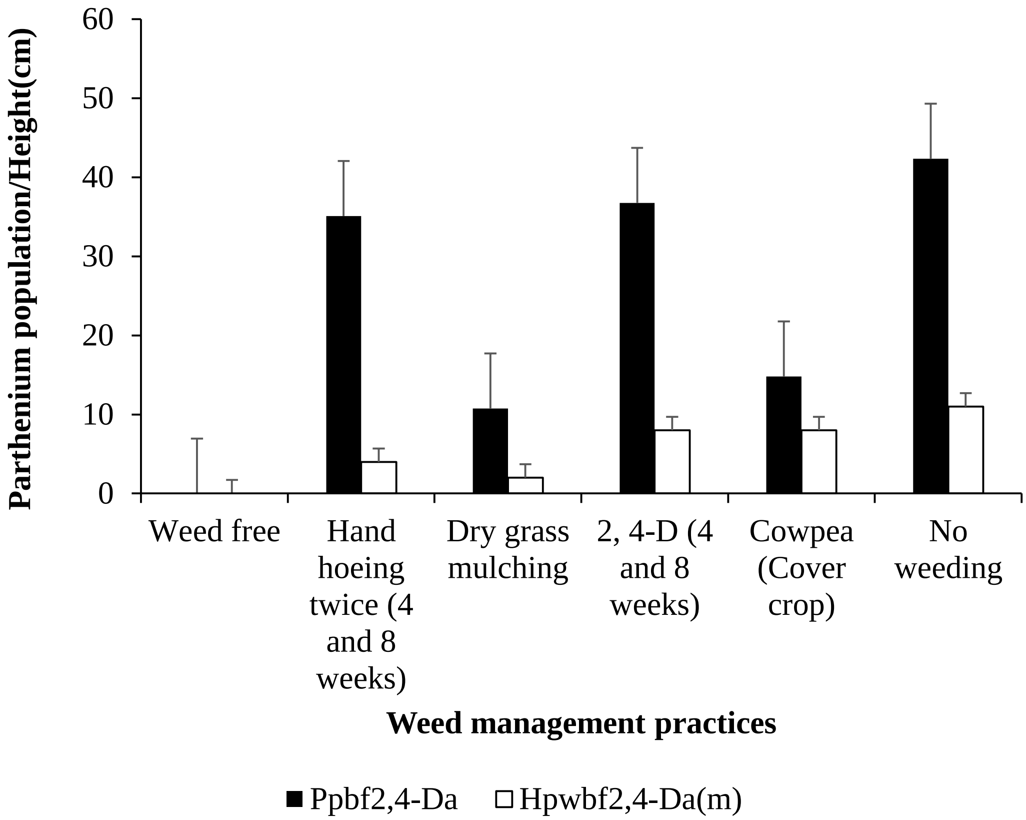
4.3.3 Results

4.3.3.8 Effect of control method on parthenium weed population and height before first weeding and 2, 4-D application

Population and height of parthenium weed was observed to be significantly different ($p<0.05$) among the applied treatments. Plots treated with dry grass mulches had lower parthenium weed population and height than cover crop treated plots while high parthenium weed population and height were observed from un-weeded plots (Fig. 4.1). Hand weeding observed to reduce height of the weed compared to when a plot was left un-weeded.

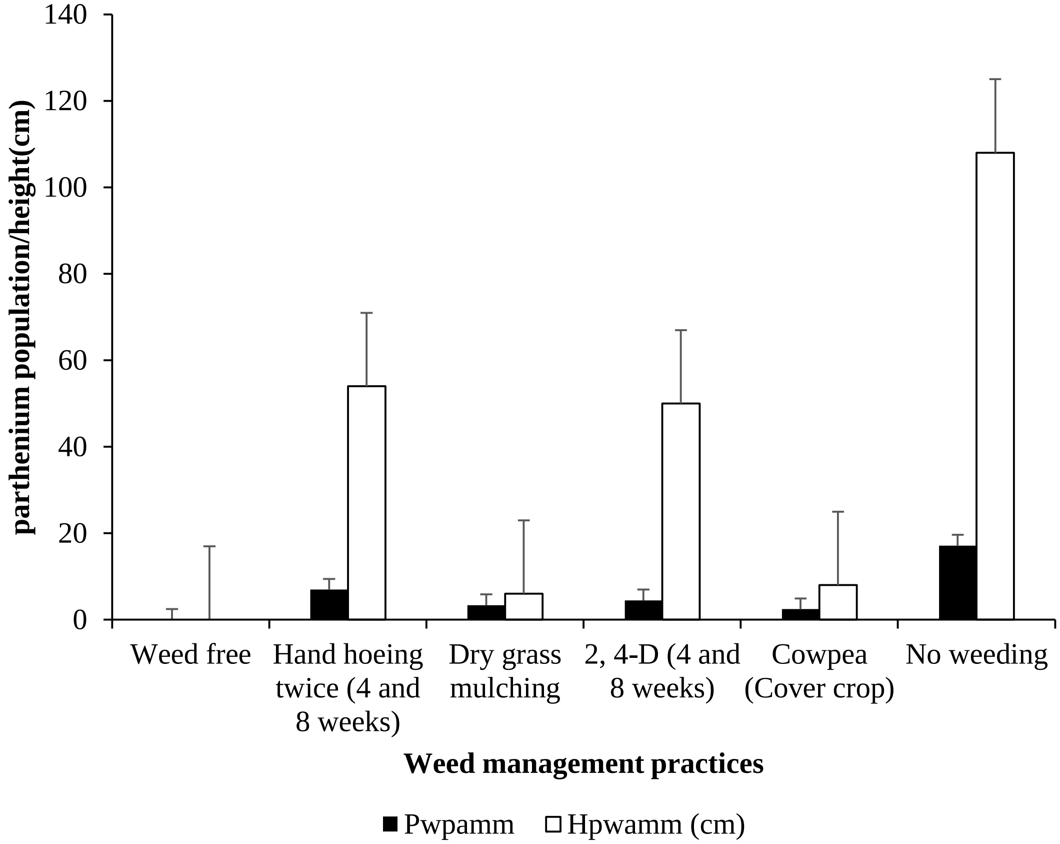
4.3.3.9 Effect of control method on population and height of parthenium weed after maize maturity

Statistical differences were observed to be significantly ($p<0.05$) among treatments in parthenium weed population and height at maize maturity (Fig. 4.2). A plot treated with cowpea as cover crop had lower parthenium weed population followed by cover crop plots and 2, 4-D plots while higher parthenium weed population was observed in the un-weeded plots (Fig. 4.2). Lowest parthenium weed height was recorded in dry grass mulched plots while the highest height was observed in the un-weeded plots.



(Ppbf2, 4-Da – Parthenium weed population before first weeding and 2, 4-D application, Hpwbf2, 4-Da – Height of Parthenium weed before first weeding or 2, 4-D application)

Figure 4.1 Effect of control method on parthenium weed population and height before first weeding or 2, 4-D application



(Pwpamm – Parthenium weed population after maize maturity, Hpwamm – Height of parthenium weed (cm) after maize maturity

Figure 4.2 Effect of control method on parthenium weeds population and height (cm) after maize maturity)

4.3.3.10 Effect of control method on plant height, number of leaves, leaf length and leaf width at flowering

Plant height was not significantly affected by the applied management practices of the parthenium weed in the maize field (Table 4.1). The tallest maize plants were observed in plots with 2, 4-D while the shortest were observed in control plots (no weeding and weed free). Not only on plant height but also leaf length, leaf width and number of leaves were not statistically affected by the weeding methods. However number of leaves was slightly higher with 2, 4-D (Table 4.1).

Table 4.1 Effect of control method on plant height, number of leaves, leaf length and leaf width at flowering

Treatments	Plant height at flowering (m)	Number of leaves at flowering	Leaf length/plant (cm)	Leaf width (cm)
Weed free	1.43[a]	11[a]	13.37[a]	7.37[a]
Hand hoeing twice (4 and 8 weeks)	1.43[a]	11[a]	13.27[a]	7.59[a]
Dry grass mulching	1.49[a]	11[a]	13.46[a]	7.94[a]
2, 4- D (4 and 8 weeks)	1.57[a]	12[a]	13.46[a]	7.61[a]
Cowpea (Cover crop)	1.50[a]	12[a]	13.46[a]	7.89[a]
No weeding	1.45[a]	12[a]	12.16[a]	7.67[a]
Grand mean	1.48	11	13.38	8
SE±	0.068	0.3	0.8	0.4
P-value	0.296	0.131	0.26	0.702
CV (%)	7.9	3.9	2.7	6.9

*Means that share a letter within a column are not significantly different by Tukey mean separation test ($P \leq 0.05$)

4.3.3.11 Influence of control method on number of days to 50% tasseling, tassel length, number of days to 50% silking and number of days to milking

The parthenium weed management practices did not significantly affect number of days to 50% tasseling, tassel length, number of days to silking and number of days to milking in maize (Table 4.2). Maximum number of days to tasseling, silking and milking was observed from weed free plots. The data also showed that the maize variety used (SC 403) took almost 18 days to milking stage after silking.

Table 4.2 Influence of control method in number of days to 50% tasseling, tassel length, number of days to silking and number of days to milking

Treatments	Days to 50% tasseling	Tassel length (cm)	Days to silking	Days to milking
Weed free	73.25[a]	27.93[a]	79.25[a]	94.75[a]
Hand hoeing twice (4 and 8 weeks)	71.25[a]	27.88[a]	78.00[a]	93.25[a]
Dry grass mulching	72.50[a]	27.98[a]	77.75[a]	93.75[a]
2, 4- D (4 and 8 weeks)	71.25[a]	27.50[a]	77.25[a]	93.00[a]
Cowpea (Cover crop)	71.25[a]	27.60[a]	77.75[a]	94.00[a]
No weeding	71.25[a]	26.85[a]	78.50[a]	93.75[a]
Grand mean	71.66	27.62	78.08	93.75
SE±	0.971	1.245	0.940	0.922
P-value	0.257	0.943	0.395	0.516
CV (%)	0.8	1.5	1.5	0.7

*Means that do not share a letter within a column are significantly different by Tukey mean separation test ($P \leq 0.05$)

4.3.3.12 Effect of control method on number of days to maturity and plant height

Results in Table 4.3 indicate that number of days to maize maturity was not significantly different among parthenium weed management practices. However, maximum number of days to maize maturity was recorded with dry grass mulch application while maize plants took relatively short days to mature when 2, 4-D was applied. The shortest maize plants at maturity were recorded in un-weeded plot while the tallest maize plants were noted in plots applied with dry grass mulch.

Table 4.3 Effect of control method on number of days to maturity and plant height at maturity

Treatments	Days to 50% maturity	Plant height at maturity (m)
Weed free	142.8[a]	1.89[a]
Hand hoeing twice (4 and 8 weeks)	143.2[a]	1.94[a]
Dry grass mulching	152.5[a]	1.99[a]
2, 4- D (4 and 8 weeks)	142[a]	1.98[a]
Cowpea (Cover crop)	143[a]	1.93[a]
No weeding	142.5[a]	1.85[a]
Grand mean	142.67	1.93
SE±	0.553	0.067
P-value	0.333	0.314
CV (%)	0.3	4.1

*Means that do not share a letter within a column are significantly different by Tukey mean separation test ($P \leq 0.05$)

4.3.3.13 Effect of control method on number of plants harvested, number of ears and ear length.

Despite of many maize plants being harvested when hand hoeing was practiced and few plants harvested in weed free treated plots, these practices did not affect significantly number of maize plants and ears harvested. Additionally, Ear length and ear diameter were also not significantly affected by the weeding methods (Table 4.4).

Table 4.4 Effect of control method on number of plants harvested, number of ears and ear length

Treatments	Number of plants harvested	Number of ears harvested	Ear length (cm)	Ear diameter(cm)
Weed free	25[a]	25[a]	13.37[a]	4.89[a]
Hand hoeing twice (4 and 8 weeks)	27[a]	27[a]	13.27[a]	4.86[a]
Dry grass mulching	26[a]	26[a]	13.86[a]	4.79[a]
2, 4- D (4 and 8 weeks)	26[a]	27[a]	14.17[a]	0.048[a]
Cowpea (Cover crop)	26[a]	26[a]	13.46[a]	4.96[a]
No weeding	26[a]	26[a]	12.16[a]	4.61[a]
Grand mean	25.88	26	13.38	4.82
SE±	3.057	3.038	0.806	0.14
P-value	0.999	0.997	0.49	0.262
CV (%)	8.3	8.7	2.7	3.6

*Means that do not share a letter within a column are significantly different by Tukey mean separation test ($P \leq 0.05$)

4.3.3.14 Effect of control method on number of kernel rows, number of kernels/ha and grain yield (t/ha)

Maize variety (SC 403), produced ears with almost the same number of kernel rows since significant differences was not found as shown in Table 4.5. Same number of plants and ear size was also harvested to every plot (Table 4.5). In addition pollination succeeded in the same rate to every plot.

Results in Table 4.5 show that there were similar number of kernels per cob that resulted into similar maize yield (t/ha).

Table 4.5 Effect of control method on number of kernels row, number of kernels/ha and total kernels weight (t/ha)

Treatments	Kernel rows/ha	Kernels/ha	Grain yield (t/ha)
Weed free	37500[a]	73264[a]	5.27[a]
Hand hoeing twice (4 and 8 weeks)	37639[a]	75278[a]	6.12[a]
Dry grass mulching	36528[a]	81042[a]	6.27[a]
2, 4- D (4 and 8 weeks)	37917[a]	81875[a]	5.69[a]
Cowpea (Cover crop)	37500[a]	78264[a]	6.86[a]
No weeding	35208[a]	68681[a]	5.41[a]
Grand mean	37049	76400	5.94
SE±	1029.8	5777.8	1.293
P-value	0.145	0.246	0.827
CV (%)	6.6	3.6	14.8

*Means that do not share a letter within a column are significantly different by Tukey mean separation test ($P \leq 0.05$).

4.3.4 Discussions

These results indicate that dry grass mulching and cover crop were the best management practices in reducing parthenium growth over the control (no weeding) plot. Thus, Dry grass and cowpea (cover crop) covered almost the whole plot, therefore they hindered parthenium weed to emerge by inhibiting light reaching the weed. Thus insufficient light hindered parthenium weed establishment and growth. The parthenium weed seeds were able to germinate and emerge easily only in spots which were not well covered by mulch. These results are similar to those reported by Nishanthan *et al*. (2013) in which high parthenium weed density was observed from un-weeded plots and mulching suppressed its growth. Parthenium weed germinated and emerged where there was insufficient cover by the mulch (Nishanthan *et al*., 2013). Parthenium weed in the un-weeded plots had higher population and taller plants since they were not disturbed with any weed management practices. Dry grass and cover crop mulches delayed parthenium weed emergence and even where they emerged maize crop was already full-established and provided shading effect to the weed which resulted into poor growth. Thus, grass mulch hinders parthenium weed growth and favors growth of maize plants by conserving soil moisture as well as suppressing growth of other weeds (Florence *et al*., 2015).

Additionally, application of 2, 4-D was the best management practices for reducing parthenium plant height over the control (no weeding). Thus, application of 2, 4-D two weeks after planting killed almost all parthenium weeds. New parthenium weeds that germinated were also killed when 2, 4-D was applied for the second time (8^{th} week after planting).

Cover crop mulch (cowpea plants) could be used by farmers to manage parthenium weed since it reduced parthenium weed growth and population by inhibiting its emergence through shading effect. Apart from reducing parthenium weed population, also cowpeas plants fixed nitrogen in the soil and hence became available to maize plants (Papa *et al.* 2015). Similar results were reported by Haroon *et al.* (2012) who reported that 71-80% of parthenium weed was controlled four weeks after 2, 4-D application while un-treated plot could not provide a mean mortality of over 80% to parthenium weed (Goodall *et al*.,2010).

Maize emerged earlier than parthenium weed and thus out-competed the weed resulting in greater plant height, leaf length and width. Wajeeh *et al*. (2016) reported similar results. They noted weeding methods were not affecting significantly on maize plant height. Although many leaves were counted when 2, 4-D, cowpeas and dry grass mulches were observed. These could be due to the effectiveness of the applied weed management methods that provided a chance for maize to explore all available nutrients for its growth. This is similar to Larbi *et al*. (2013) who observed the greatest number of leaves with 2, 4-D application.

Weed management methods such as dry grass mulch, cover crop and 2, 4-D affected parthenium weed growth. However, it did not reach a level to compete with maize plants. Maize, being the first to emerge and establish, it cause the weed not to affect maize growth parameters such as number of days to silking, days to tasseling and milking. This concurs with the results of Nleya *et al*. (2016) who reported that kernel milk stage occurred approximately 18 to 22 days after silking.

In order for a weed to suppress growth of a plant it must out-compete the grown plant. Late parthenium weed germination even in un-weeded plot favored maize plant growth and hence caused applied weed management methods not to have statistical differences in plant height and number of day to maize maturity. Additionally, the results provide the information that maize variety used (SC 403) had almost the same ear length and diameter. This could be due to maize crop being the first to emerge before the weed and hence managed to use effectively the available resources such as moisture, oxygen and nutrients. These results were similar to those of Tesfay *et al.* (2014) who observed longest ears (16.3, 19.2 cm) with hand weeding and hoeing respectively, but not significant.

Factors such as plant population, ear size and success at pollination were not affected by the parthenium weed, that’s why there was no significant difference in number of kernel rows and number of kernels per hectare. The number of kernel per hectare depends upon plant population, ear size and success at pollination (Jeff, 2010). These results may imply that, rate and duration of grain filling was unaffected by the parthenium weed. Parthenium weed did not out-compete the maize crop, thus not affecting grain yield. Maize emerged and well established before the weed from un-weeded plot hence dominated the cropped area and got all necessary requirements for its growth. Thus, they grew taller than parthenium weeds; hence maize had advantage of light over the weed. The weed should out-compete a respective crop in nutrients, moisture and air so that to alter its growth (Montserrat *et al*., (2004). Therefore, this made grain yield in the un-weeded plots to be similar to weeded ones. Grain yield is directly related to number of kernels per cob (Wajeeh *et al*., 2016). The number of rows per cob is genetically controlled factor but environmental and nutritional level may alter the number of rows per cob (Muhammad *et al*., 2008). Thus, the grain yield being not affected despite of applying weed management practices could be attributed by environment and/or nutritional level of the soil.

4.4 Conclusions and Recommendations

4.4.3 Conclusions

i. The study demonstrated that parthenium weed population can highly be reduced by applying 2, 4-D, dry grass mulches and cover crop mulching as weed management practices.
ii. Cowpea mulch and 2, 4-D treatments, dry grass mulch was noted to reduce height of parthenium weed.
iii. Additionally application of 2, 4-D reduced parthenium weed population as compared to hand hoeing.
iv. After maize maturity, height of parthenium weed was observed to be highly reduced in plots treated with dry grass and cowpea mulches.

4.4.4 Recommendations

i. Although, 2, 4-D reduced parthenium weed more than mulching, herbicides due to their health hazards, researchers and farmers should go for other weed control options.
ii. This research work suggest the use of cover crop mulching (cowpea plants) to be the best option for farmers to manage parthenium weed since it was among the best practices in reducing parthenium weed growth and population by inhibiting

its germination through shading effect provided by the large canopy of cowpea plants.

iii. These results were obtained from a single season experiment. Therefore, more research should be carried out in order to confirm current results and wok on economically viable and environmental friendly control method of parthenium weed in maize field.

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CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

On farmer's fields, *Cyperus rotundus, Argemone mexicana, Dactyloctenium aegyptium* and *Cyperus tenuispica* were noted to be the major weeds. Parthenium was not regarded as the major weed since it was yet to invade most (49.2%) farmer's fields. From 120 interviewed farmers, most of them (60% and 40% in Arusha and Meru Districts respectively) reported to be aware of parthenium weed regardless of it not having infested their crop fields. The weed was observed to be highly concentrated on roadsides and spread rapidly by road construction activities and water drainage. However, Arusha District observed to be highly infested with the weed compared to Meru District. Parthenium weed infested some of the farmers' fields especially in Ilkerini village which had 81% coverage of the weed. Frequent observation of the weed was made near and/or around Arusha and Kilimanjaro International airports. Overall, the study has revealed that among the sampled farmers, parthenium weed was considered as a normal weed and not as invasive weed specie. This made farmers not actively involved in managing the weed despite its impact on crop production as well as animal and human health hazards.

The field survey confirmed that farmers in the study areas used chemical methods as their major weed management method. However, maize experiment carried out at the Tropical Pesticides Research Institute noted that, cover crop (cowpea), dry grass mulches and 2, 4-D application were effective in reducing parthenium weed population compared to other weed management methods.

5.2 Recommendations

Farther spreading of parthenium weed can be prevented by devoting an effort on managing the weed on roadsides and along water channels before it flowers. Since most farmers were not aware of the health hazards of parthenium weed, relevant agents should take into consideration the issue of educating farmers on the impact of parthenium weed, especially on farmer's and animal health, its impact on crop production and how to manage it. Farmers should opt for cover crop mulching dry grass mulching as the effective methods for managing the weed. Farmers can also integrate chemical methods with other methods such as crop rotation, mulching, biological control, field clearance and planting resistant varieties to control insect pests and diseases.

Parthenium weed, being visibly observed on roadsides and along water canals, it may imply that its seeds are mainly disseminated by tracks and drainage water. Therefore the government through its plant protection unit in all borders should prevent entrance of cars and individuals carrying plant material into the country without quarantine clearance against parthenium weed seeds. In addition, care should be taken to ensure road construction tracks do not carry soil heaps sandwiched with parthenium weed seeds and deposit them into crop fields. By doing so, further spread of the weed may be minimized.

The field survey was carried out in only two Districts of Arusha region, Tanzania. Therefore this research suggests further research be conducted to assess impact of parthenium weed and its distribution and abundances in remained districts such as

Ngorongoro, Monduli and Karatu Districts. Additionally, an experiment to identify effective method to manage parthenium weed was conducted in a single season. Therefore, more research should be carried out in order to confirm current results and wok on economically viable and environmental friendly control method of parthenium weed in maize field.

APPENDICES

Appendix 1 List of 27open and closed ended questions in the questionnaires

Introduction

The aim of this survey is to generate information on parthenium weed (Carrot weed) and information collected will be useful in designing improved management and control of the weeds and hence increase yields in your crop fields.

Village………………..Ward………………….

District………………..Region………………..

Date of Interview………………….. Name of Respondent…………………………..

Age…… Gender………. Occupation………………………

Education level (a) none [ ] (b) Primary [ ] (c) Secondary [ ] (d) College [ ] (e) University [ ] (f) Others, specify……………………….

Other training (a) None [ ] (b) Carpentry [ ] (c) Welding/metal works [ ] (d) Mechanics [ ] (e) Shoe making [ ] (f) Plumbing (g) Tailoring [ ] (h) Others, Specify…………………

Marital status (a) Single [ ] (b) Married [ ] (c) Widow [ ] (d) Widower [ ]

(e) Divorced [ ]

Individuals in household………

1. What crop/crops do you grow?
    a. Mono crop, Yes [ ] No [ ], If yes specify……………..
    b. Mixed crops, Yes [ ] No [ ], If yes specify…………….and……………
2. What is the estimated size of your farm used to grow the above mentioned crop/crops? ……………..Acres
    a. Less than 1 acre
    b. 1 to 2 acres
    c. 2 to 3 acres
    d. 4 to 5 acres
    e. More than 5 acres

3. Are there any pests (e.g. insects, rodents, birds) or diseases that affect your farm during production?

   Yes [ ]

   No [ ]

4. If yes which are these pests and diseases? and rank them
   i. ……………………………………
   ii. ……………………..………….
   iii. …………………..……..………
   iv. ………………………..…..……
   v. ……………………………..…….

5. Which crop diseases/pests management methods did you use?
   i. ……………………………..……….
   ii. ………………………..……….
   iii. ………………………………….
   iv. ……………………..………..
   v. ………………………………….

6. What are the major weeds of your farm and rank them?
   i. …………………………………..
   ii. ………………..……………….
   iii. …………………..…………….
   iv. ………………..……………….

7. Do you know the parthenium weed Yes [ ] No [ ]
8. What is the local name of parthenium? ………………..
9. Do you currently have parthenium in your farm? Yes [ ] No [ ] Unsure [ ]
10. Where did it first appear? (a)Pasture [ ] (b) Roadside [ ] (c) Cropland [ ] (d) Wasteland [ ] (e) Others [ ] if others specify………………(f) Don't know [ ]
11. How long has parthenium weed been in your farm?
    a. Don't know [ ]
    b. This year(2017) [ ]
    c. 0ne year ago (2016) [ ]
    d. 2 years ago (2015) [ ]

e. 3-5 years ago (2012-2014) [ ]
f. 6-10 years ago (2007-2011) [ ]
g. more than 10 years ago [ ]
h. No parthenium weed

12. Does parthenium affect operation of your farm? Yes [ ] No [ ] Unsure [ ]
13. To what extent does the presence of parthenium weed affect seed germination?
    a. Highly reduced…………
    b. Slightly reduced………..
    c. No difference…………..
    d. Don't know
14. Do you experience any crop loss due to this weed? Yes [ ] No [ ] Unsure, if yes how much? (a) None [ ] (b) A little/some (<25%) (c) Moderate (26-50%) (d) Substantial (51-75%) (e) Most (>75)
15. By how much does parthenium reduced your yields
    a) Nil
    b) Some
    c) Moderate
    d) Substantial
    e) Most
    f) Don't know

	Maize	Common Bean
Nil		
Less than 25%		
26-50%		
51-75%		
More than 75%		
Don't know		

16. Has there been any change in the area infested and density of parthenium infestation over the past 5 years?
    a) Area infested (i) Stayed the same [ ] (ii) Increased [ ] (iii) Decreased [ ]

b) Density of infestation (i) Stayed the same [ ] (ii) Increased [ ] (iii) Decreased [ ]

c) Don’t know

17. In your estimate, what percentage of your farm land area is currently infested with parthenium?

(i) Zero/None (0%) [ ]

(ii) A little/some (<25%) [ ]

(iii) Moderate (26-50% [ ]

(iv) Substantial (51-75) [ ]

(v) Most (>75%) [ ]

(vi) Don’t know

18. Do you know farmers who have abandoned their farms because of the parthenium infestations?

a. None

b. Less than 5

c. Between 5 and 10

d. More than 10

19. Do you actively control parthenium in cropped areas? Yes [ ] No [ ] Unsure [ ]

20. How often do you control weeds on your farm for a growing season?

	Maize	Sunflower	Common beans	Other
a. Every day				
b. 3-4 days per week				
c. One day per week				
d. One day every 2 weeks (14 days)				
e. One day per month				
f. Twice per season				
g. Once per season				

21. What type of weed control methods do you use in your farm and rank them?

(i) Hand weeding: Yes [ ] No [ ]

(ii) Herbicides: Yes [ ] No [ ]

(iii) Burning: Yes [ ] No [ ]

(iv) Organic mulching: Yes [ ] No [ ]

(v) Others [ ]. Please specify…………………………………………………...

22. If you use herbicides which ones do you use to manage parthenium?

a) ....……………

b) ………………..…………………

c) ………………...……………….

d) ………………………………….

Are they effective? Yes [ ] No [ ] Unsure [ ]

23. How many people are involved in weeding/controlling parthenium each time?

a. 1 person
b. 2 people
c. 3 people
d. 4 people
e. More than 4 people? Specify……………

24. What is the estimated amount (TSH) do you spend on the control of weeds?

a. Nothing-family and friends [ ]
b. Food and/or beer [ ]
c. Less than 10,000TZS per acre [ ]
d. 10,0001 to 20,000TZS per acre [ ]
e. 20,001 to 30,000TZS per acre [ ]
f. 30,001 to 40,000TZS per acre [ ]
g. More than 40,000TZS per acre [ ]

25. If you manage parthenium on your cropland does it cause any ill health?

a. No….
b. Itchiness of hands arms or legs……
c. Tight chest……

d. Runny nose…..
e. Others please specify……

26. Have you heard of others getting ill as a result of parthenium?
    a. No
    b. Itchiness of hands, arms or legs?
    c. Struggle to breathe
    d. Tight chest
    e. Sneezing
    f. Other, please specify…………..

27. Are there any other issues that you would like to tell us regarding the control of parthenium weed or its impact?

…………………………………………………………………………………………
…………………………..……………………………..…………………………………
………………………..…….………………………..……………………………………
…………………………………………………………………………………………

THANK YOU VERY MUCH FOR YOUR TIME