ENHANCING RANGELAND PRODUCTIVITY THROUGH INTEGRATED MANAGEMENT OF KONGWA WEED (*Astripomoea hyoscyamoides* Vatke Verdc.): A CASE STUDY OF KONGWA RANCH

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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

Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) is noxious weed species in Tanzania which is defined as an unusual species that pose harmful effect to other species and ecosystems hence causing significant economic damage in grassland and cropland as well as natural areas. Recently, there is a decline of livestock production due to insufficient animal feeds resulting from diminishing of pasture in range land caused by weeds infestation. This study aimed to develop integrated management strategies and technologies for management of Kongwa weed so as to increase livestock production by improving the natural pasture in grazing land. Specifically, the study sought: (1) To determine efficacy of selected plant species for allelopathic effects against Kongwa weed, (2) To evaluate the effectiveness of selected cultural, biological and chemical methods singly or in combination as management options against Kongwa weed and (3) To establish the most economical integrated weed management option(s) for controlling the Kongwa weed. The first chapter contains general introduction, the second, third and fourth chapter in the dissertation comprise manuscripts in the form of publishable papers which cover the first, second and third specific objectives while chapter five covers general conclusion and recommendation.

Methods

With respect to specific objective 1, the study was conducted in a screen house in two phases. The experiment was laid out in factorial experiment; the pots were

arranged in a randomized complete block design with 12 treatment combinations replicated four times. Factor A contained three types of plant extracts (*M. azedarach*, *R. communis* and *N. tabacum*) and factor B contained four concentration levels (0.0, 2.5, 5.0 and 10 g l^{-1}). Data were collected for plant growth parameters14 to 60 days after sowing in seven days intervals. Data was analyzed using GenStat software (version 16). Turkey's significant test at 5% level of significance. The study was conducted in two sites located in Sejeli ward, Kongwa district. Site A and B contained five and 12 treatments as weed management options applied in paddocks occupied with *Cenchrus ciliaris and Cynodon dactylon*, respectively. The experimental layout in site A and B followed a randomized complete block design with four replications. Data were collected for plant growth parameters 7 to 35 days after treatment application at seven days interval. Data was analyzed using GenStat software (version 16). Turkey's significant test at 5% level of significance. The economic analysis of natural pasture production and weed management package were carried out based on benefit cost ratio using partial budget analysis per objective 3. The variable costs for purchasing inputs, acquiring of plant materials and labour cost calculated by working out expenditure using prevailing price on different aspects of weed management and gross income under different treatments. The net return and cost-benefit ratio were also calculated to determine the feasibility of the treatments. Data collected from two sites were used to estimate the profitability of pasture yield under different weed management options. The return produced from each treatment was found by multiplying the pasture yield by the market price.

Findings

Results revealed that, the allelopathic effect of *M. azedarach, R. communis* at 10 g l^{-1}concentration showed significant effect at ($P \leq 0.05$) on weed height, girth, leaves, leaf area and chlorophyll contents in phase I and II. Significant effect at ($P \leq 0.05$) were recorded for treatments applied at concentration level of 10 g l^{-1} followed by 5 g l^{-1}. Similar effects were observed on chlorophyll contents and number of survived weed at the same concentration in phase I and II. Results showed that, at site A treatment *M. azedarach* significantly affected the number of Kongwa weed survivors (5) and number of weed leaves (7). Similar effect was observed on pasture DM yield of (8.9 ton ha^{-1}) in the same treatments at $P<0.001$. However results on site B showed that, number of weed leaves (14), height (37.55 cm) and girth (3 mm) were significantly affected at $P<0.001$ by 2,4-D treatment, while cutting + *M. azedarach* treatment significantly affected weed survivor (10) at $P<0.001$ compared to other applied treatments. Further, hand pulling + *M. azedratch* and cutting + 2, 4-D had significant influence on pasture DM yield of 14.02 ton ha^{-1} at $P<0.001$ compared to other treatments. However, the highest profits of controlling Kongwa weed was obtained from *M. azedarach* (TSh. 435 555.00 ha^{-1}) and 2, 4-D (TSh. 232 053.00 ha^{-1}) treatments resulted from the mean pasture MD yield of 8.94 t ha^{-1} and 6.58 respectively. While at site B, the highest net profit were recorded from treatments on hand pulling + *M. azedarach* TSh.928 328.00 ha^{-1} followed by cutting + 2, 4-D TSh. 749 577 ha^{-1}), 2, 4-D (TSh.682 949.00 ha^{-1}) and hand pulling + 2, 4-D (TSh. 648 281.00 ha^{-1}) with the average pasture DM yield of 14.02 t ha^{-1}, 14.02 t ha^{-1}, 12.76 t ha^{-1} and 12.10 t ha^{-1} table 4.3 and 4.4 respectively.

Conclusion

The study concludes that *M. azedarach* is an important plant species in controlling Kongwa weed due to its allelopathic effect and thus it can be used as a bio-herbicidal plant for controlling the weed compared to *R. communis* and *N. tabacum.* However, all allelochemicals activities depend on the level of concentration applied. Therefore, appropriate weed control provided a favourable environment for the pasture growth and development. Integrated weed management option was more effective than single treatment when applied in high weed infestation. Where single treatment was applied, lower yield and marginal return was consistently achieved compared to where supplemented by a combination of treatments.

Recommendations

For sustainable ecosystems, *M. azedarach* and *R. communis* should be used as bio-herbicides in managing Kongwa weed in rangelands as an alternative to industrial herbicides. Concentration (10 g l^{-1}) of *M. azedarach* and *R. communis* should be used in open field particularly grazing lands. Integrated weed management option applied in high weeds infestation and herbicides or plant extracts applied singly in low weeds infested range lands are recommended. The study suggests weeds management practices; cutting + 2, 4-D, Hand pulling + *M. azedarach* and hand pulling + 2, 4-D to reduce Kongwa weed in grazing lands consequently minimising the cost of production required for forage optimum yield and increased profitability.

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DECLARATION

I, Notkery Andrew Mwalongo, declare to the Senate Postgraduate Studies Committee that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted in any other institution.

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DEDICATION

This treasurable work is dedicated to my beloved father Andrew Ananidze Mwalongo (deceased) and mother Modester Christian Mkalawa, for their tireless encouragement and support during the course of my studies.

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LIST OF ABBREVIATIONS AND SYMBOLS

2, 4-D	2, 4 Dichlorophenoxyacetic acid
ANOVA	Analysis of Variance
APX	Ascorbate peroxidase
B:C	Cost benefit ratio
COSTECH	Tanzania Commission for Science and Technology
CV%	Coefficient of variation
DAARS	Department of Animal, Aquaculture and Range Sciences
DAS	Days after sowing
DM	Dry matter
Fig.	Figure
GPX	Guaiacol peroxidase
GR	Gross revenue
i. e.	That is
IAA	Indole Acetic Acid
masl	Meters Above the Sea Level
MR	Marginal returns
NARCO	National Ranching Company
NS	Not significance different
PORA	President's office regional administration and local government
RCBD	Randomized Complete Block Design
SD	Standard deviation

S.E	Standard error of means
SUA	Sokoine University of Agriculture
TALIRI	Tanzania Livestock Research Institute
TSh	Tanzania shilling
TVC	Total Variable Cost
UNIDO	United Nations Industrial Development Organization

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background Information

Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) recognized as noxious weed species in Tanzania (Nkombe *et al.,* 2018). Noxious plants defined as unusual species that pose harmful effects to native species and ecosystems hence causing significant economic damage in grassland and cropland as well as natural areas (Rai *et al.,* 2012). These invasive weeds species are found in all taxonomic clusters and are accountable for a major reduction of both food for humans and feed for animals due to their ecological and economic consequences (Nkombe *et al.,* 2018). It has been reported by Nkombe *et al.* (2018) that in Tanzania the weed has moved beyond the open areas and often is found in many land uses such as grazing land, cropping land and protected areas. The weed are widely spread in both grazing and cropping lands with potential negative effects in terms of decline of both crop harvest and pasture productivity (Nkombe *et al.,* 2018). The invasion of rangelands by the weed particularly in grazing lands (Kongwa district) causes deterioration in livestock production due to shortage of pasture (Bosco *et al.,* 2015). The semi-arid region of central Tanzania, mostly Kongwa district has been extremely infested by the weed.

Invasive weed species such as Lantana (*Lantana camara*), Guava tree (*Psidium guajava*), Mesquite (*Prosopis juliflora*), Prickly pear cactus (*Opuntia ficus indica)* and *Astripomea lachnospermaare* are capable for competing with native species for nutrients, light and space making necessary forages to be in competitive disadvantage (Obiri, 2011 and Rija *et al*., 2013). Kongwa weed is noxious annual native weed which has invaded grazing and cropping lands and is dominant in Kongwa district (Nkombe *et al.,* 2018). These invasive weed species indirectly affect other plants and change ecosystems by altering soil stability, promoting erosion, colonizing open substrates, affecting the accumulation of litter, salt, or other soil resources and promoting or suppressing fire (Richardson *et al.,*2000). Noxious and invasive weeds reduce the potential yields of row crops and pasture and result in an estimated annual cost of US $ 99.2 billion per year in the United States of America, United Kingdom, Australia, India, South Africa and Brazil (Pimentel *et al.,* 2001; Hailu *et al.,* 2003). In South Africa alone over US $ 60 million is spent annually to control invasive and noxious weeds (Duncan, 2005). Kongwa weed negatively affected the livelihoods of farmers (75%) in Central Tanzania particularly Kongwa district (Nkombe *et al.,* 2018). This noxious weed reported to reduce both crop yield and the amount of forage available to livestock on public and private grazing lands. Although Kongwa weed covers increases more than 57% in Kongwa district and has a notable negative impact on pasture growth, development and yield, to date there is only one synchronized research results reported in the area by Nkombe *et al.* (2018).

1.1.1 Botanical Description

Kongwa weed is a dry land annual weed, enclosed with greyish hairs attaining a height of 1.8 m with alternate simple leaves and showy, white and purple flowers characterized by rapid growth rates, extensive dispersal capabilities, large and rapid reproductive and wide range of environmental adaptability (Nkombe *et al.,* 2018).

1.1.2 Kongwa weeds under the family of Convolvulaceae

Kongwa weed belongs to Convolvulaceae family commonly known as morning glory family under Astripomoea genus (Ogunwenmo, 2006). The successive emergence and spread of Kongwa weed on its environment is intimately associated with the seed production, seed dispersal and accumulation of seeds reserves in the soil, germination of seeds, establishment and growth of seedlings maturation of the plant to produce seeds (Hailu *et al.,* 2003).

1.1.2.1 Morphological features of the Convolvulaceae

Convolvulaceae family is distinguishable by its plicate corolla, axile placentation with few ovule, bi-collateral vascular bundles and latex usually present (Okereke, 2015). It is recognized by funnel shaped, radially symmetrical corolla, the floral formula for the family has five sepals, five fused petals, five epipetalous stamens and two parts of syncarpous and superior gynoecium. The gynoecium is composed of two united carpels, unlobed, forming a two locular, superior ovary, with 2-4 ovules (Okereke, 2015).The convolvulaceae family showed the major morphological difference basically on the leaf size and arrangement, nature of stem and internodes and floral color and morphology (Heine, 1963).

1.1.2.2 Seed germination of the Convolvulaceae

Seed germination varies among of genera of the Convolvulaceae family in the soil. Some genera of the Convolvulaceae family take fifth to twelfth day of cotyledon emergence from the soil (Ogunwenmo, 2006). The dormancy of the seed may cause delay in seed germination of some species; the seed coat have been known to delay germination in many Convolvulaceous seeds, (Ugborogho *et al.*, 1999)

1.1.2.3 Flowers and Seed production of the Convolvulaceae

Flowers of the Convolvulaceae family is in umbel-like cymes; peduncle up to 7 cm long; pedicels 4–17 mm long; bracts elliptic lanceolate to ovate cordate, 12–20 mm long. Corolla white with purple centre: 1.8–3.8 cm long. Capsule sub globose 5–9 mm in diameter glabrous, Seeds 3.5 mm long and brown pubescent (Okereke, 2015), flowers are divided by 2 or more planes into roughly equal halves usually refers to the perianth of a flower with petals that form a funnel or tube that , as bud, is twisted longitudinally so that to parts overlap one another. The flowers have both pollen bearing and ovule bearing parts with 5 stamens and 1 style that may be forked **(**Stefanovic *et al.*, 2002).

1.1.2.4 Fruit morphology of Convolvulaceae

The variation of fruit morphology of the Convolvulaceae family often results from diversification in the structure of flowers (Ogunwenmo, 1998). Even fruits derived from the same type of flowers may undergo distinctive on genic pathways leading to variation in morphology (Esau, 1965).

1.2 Problem Statement and Justification

1.2.1 Problem statements

Agricultural losses caused by invasive weed species are increasing all over the world particularly in rangelands and cropping land (Rai *et al.*, 2012). In the last 10 years

Kongwa weed has been reported to course negative effects on rangeland, which subsequently affects livestock production in ranch (Nkombe *et al.,* 2018). Kongwa ranch, the biggest in Tanzania has an area of 38 200 ha with a carrying capacity of 14 400 cattle excluding feedlots (NARCO, 2012). However the stocking density of the area is only 57% with potential to support 2000 beef sold per annum, at 1.2 billion Tanzanian shillings. About 10% decrease of stocking density in Kongwa ranch has been attributed to insufficient animal feed mainly due to pasture displacement caused by the Kongwa weeds (Nkullo, 2013; UNIDO, 2012).

High rainfall and animals such as cattle are among the potential sources of spreading the Kongwa weed out of the ranch and it persists due to its rapid growth rates, extensive dispersal capabilities, large and rapid reproductive and wide range of environmental adaptability (Nkombe *et al.*, 2018). Direct and indirect losses of agricultural produce due to invasive weed species have been recognized in various parts of the World. Economic losses due to invasive weeds have been estimated for about US$ 4 billion per year of the total damages in cropland and pastures combined. Since 60% of these weeds are alien, they account for about US$ 2.4 billion per year in losses to agriculture (Borokini and Babalola 2012). Pimentel *et al.* (2001) described the costs related with the negative effects of invasive weeds at a global scale to be US$ 1.4 trillion per year. However, there are limited studies conducted in tropical Africa mainly in Tanzania on invasive plant species and their impact (Pyšek, *et al.*, 2008). Surveillance data for the direction of spread and abundance in order to control further invasions and appropriate management options including sustainable land management strategies or integrated weed management approaches in the already affected areas are needed (Nkombe *et al.,* 2018).

1.2.2 Justification of the study

Managing the invasive species in grazing land is a key important aspect in reducing their adverse impact on desirable pasture species. Several economic losses associated with Kongwa weed to farmers have been documented by Nkombe *et al.* (2018). There was limited information on the control method to avoid further spreading. Testing different integrated weed management practices consisting of cultural practices, synthetic and bio-herbicide tactics in managing Kongwa weed could enhance the biological diversity and improve pasture quality and productivity. In the long run, this would increase the stocking density in Kongwa ranch due to presence of sufficient animal feed.

1.3 OBJECTIVE

1.3.1 Overall Objective

To develop integrated management strategies and technologies for management of Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.)

1.3.2 Specific Objectives

i. To determine efficacy of selected plant species Melia (*Melia azedarach*), Castrol plant (*Ricinus communis*) and Tobacco plant *Nicotiana tabacum*) for allelopathic effects against Kongwa weed.

ii. To evaluate the effectiveness of selected cultural, biological and chemical methods singly or in integration as management options against Kongwa weed.
iii. To establish the most economical integrated weed management option(s) to control of Kongwa weed.

1.4 Organization of the dissertation

This dissertation is developed in the format of publishable manuscripts comprising five main chapters. Chapter one is a general introduction, chapter two, three and four consist of the publishable manuscripts and chapter five is a general conclusion and recommendations.

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CHAPTER TWO

2.0 EFFICACY OF SELECTED PLANT SPECIES (*Melia azedarach, Ricinus communis* and *Nicotiana tabacum*) FOR ALLELOPATHIC EFFECTS AGAINST KONGWA WEED (*Astripomoea hyoscyamoides* Vatke Verdc.)

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2.1 Abstract

Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) is a noxious weed species in Tanzania; currently the weed rapidly spread the central zone of the country particularly in rangelands. The experiment was conducted to determine allelopathic effects of *M. azedarach, R. communis* and *N. tabacum* in suppressing Kongwa weed. This study was carried in screen houses from November 2019 to January 2020 and repeated from January to March 2020. A factorial experiment was used, laid down in a randomized complete block design with 12 treatment-combinations replicated four times. Factor A contained three types of plant extracts (*M. azedarach, R. communis* and *N. tabacum*), factor B contained four concentrations 0.0, 2.5 5.0 and 10 g l^{-1} respectively. Data were collected for plant growth parameters 14 to 60 days after sowing at a seven days interval. Analysis of variance was used at ($P \leq 0.05$), Turkey's test was used to compare the means at 5% level. Results revealed that, the allelopathic effect of *M. azedarach*, *R. communis* at 10 g l^{-1}concentration showed significant effect at ($P \leq 0.05$) on weed height, girth, leaves, leaf area and chlorophyll contents in phase I and II. Significant effects at ($P \leq 0.05$) were recorded for treatments applied at concentration level of 10 g l^{-1} followed by 5 g l^{-1}. Similar effects were observed on chlorophyll contents and number of survived weeds at the same concentration in phase I and II.

These results proved the ability of *M. azedarach* and *R. communis* to be effective in suppressing Kongwa weed growth when applied at 10 g l^{-1} during both phases I and II experimentation. The study recommended that plant extract from *M. azedarach* and *R. communis* applied at 10 g l^{-1} concentration is effective in controlling the Kongwa weed.

Keywords: Kongwa weed, Allelopathy, Plant extract.

2.2 Introduction

Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) is troublesome weed species in central Tanzania that pose harmful effects to native species and ecosystems hence causing significant economic damage in grassland and cropland as well as natural areas (Rai *et al.*, 2012). Kongwa weed invaded grazing and cropping lands and is dominant in Kongwa district (Nkombe *et al.*, 2018). The invasion of rangelands by the weed particularly in grazing lands (Kongwa ranch) causes deterioration in livestock production due to shortage of pasture (Bosco *et al.*, 2015).

Kongwa weed negatively affected the livelihoods of farmers (75%) in central parts of Tanzania particularly Kongwa district due to reduce both crop yield and the amount of forage available to livestock on both public and private grazing lands resulting to low per-capital income (Nkombe *et al.*, 2018).

Despite its effect, Kongwa weed control is still a challenge though the majority of farmers use traditional methods such as uprooting or slashing the weed before flowering to control the weed. However, this method is not cost effective and needs enough labor if control has to be at a large scale. Labour cost is among the factors that hinder the control of the weed (Bosco *et al.*, 2015). Some farmers use herbicides applications to control weeds (Nkombe *et al.*, 2018). The improper usage of herbicides has contributed to the accumulation of active compounds in the soil, and in weed species leading to evolution of resistant biotypes (Rola *et al.*, 2007). The misuse include; application of incorrect herbicide dosage, weed development stage and unsuitable weather conditions

Eco-friendly trend in weed management was developed as a new solution and tool to control weeds while maintaining the ecosystem. The natural compounds from plant species successively contributed for the discovery of new environmentally safe herbicides, the so called “bio-herbicides” (Dayan *et al.*, 2009). Application of bio-herbicides, is an emerging technique for weed control in sustainable agriculture. The use of plant extracts, allelochemicals, allelopathy and some microbes are utilized as bio-herbicides to control weed populations (Gniazdowska and Bogatek, 2005; Radhakrishnan *at el.*, 2018). Some of these compounds involved in allelopathic interactions and prove to suppress the growth of some plant species. The discovery of the allelopathic potential of some plant species allows the introduction of alternative techniques for weed management, which is environmentally eco-friendly. Thus the plant extracts from allelopathic plants species developed specific concentration, which can be applied as foliar sprays to suppress the weed growth (Soltys *et al.,* 2013). The development of weeds resistant to herbicides requires innovative solutions to deal with troublesome weed as economic losses posed by weeds increased than those caused by other pests (Vencill *et al*., 2011). The current agricultural practices of abandoning chemical weed control only is quite impossible, it is necessary to create new classes of herbicides with new mechanisms of action as an alternative to chemicals (Dayan *et al.,* 2012). Generally the use of bio-herbicides is cost effective compared to other weed management options/systems. Apart from minimizing the costs of herbicide application, this method also is much contributing to the agro ecological aspect.

2.3 Materials and Methods

2.3.1 Description of the study site

The experiment was conducted in a screen house at Sokoine University of Agriculture (SUA), Department of Crop Science and Horticulture (DCSH) located at 6°51'06.1"S 37°39'25.6"E and an altitude of 564m above sea level, from November 2019 to January of 2020 and repeated from January to March 2020.

2.3.2 Collection and preparation of plant extract

Standard method of Nekonam *et al.* (2013) for preparation of aqueous plant extracts (*N. tabacum, R. communis* and *M. azedarach*) was followed. Three composite during short rain season of 2019 (October – December) and long rain season of 2020 (January to May), aerial plant parts (leaves+ flower+ stem) samples of *R. communis* and *N. tabacum,* were collected from Morogoro Municipal, while *M. azedarach* plants samples were collected from Songea Municipal during flowering stage. The samples were air dried and ground using mortar and pestle to get fine powder. The fine powder was used to generate three concentrations of (2.5, 5.0 and 10 g l^{-1}) for each plant. The powder weighing 100g, 50 g and 25 g each were added into 1000 ml of distilled water to prepare aqueous extract with, 10 g l^{-1}, 5.0 g l^{-1} and 2.5 g l^{-1} concentration levels, respectively. Each mixture was left at ambient condition for 24 hrs, then filtered through filter paper and used as a source of phytotoxin compounds. The supernatant solution of each plant extract after filtration was applied to Kongwa weed to test allopathic potential.

2.3.3 Experimental design and treatment allocation

The study was laid out as a factorial experiment; pots were arranged in a randomized complete block design (RCBD) with 12 treatment-combinations replicated four times. Factor A consists of three types of plant extracts (*M. azedarach, R. communis* and *N. tabacum*) and factor B consists of four concentration levels (0.0 g l^{-1} 2.5 g l^{-1}, 5.0 g $^{-1}$ and 10 g l^{-1}). The experimental area was 24m^2, a table with a carrying capacity of 48 plastic pots with a radius of 8.51cm and height of 17.6cm making a capacity of 4004.25cm^3. The pots were placed in raised bench.

2.3.4 Screen house experiment

This study was conducted in a screen house at DCSH. Forest soil sample mixed with humus was collected near a horticultural unit at SUA and sterilized by heating to kill insect pests and other weeds seed then left overnight to cool. Six seeds of Kongwa weed were sown at one cm depth in plastic pots of (17.6 cm deep, 17.02 cm wide) containing approximately four kilogram of soil. Tap water was used to keep the soil moist during the whole period of the experiment. After seven days, when the weeds complete germination was accomplished, the number of seedling per pot was reduced to four and maintained healthy one, by careful manual thinning. Fourteen days after sowing three plants extracts (*M. azedarach*, *R. communis* and *N. tabacum*) with four levels of concentrations were applied in each pot.

Figure 2.1: Experiment layout in screen house

2.4 Data collection

2.4.1 Weed emergence

The numbers of seeds germinated and emerged are counted on a daily basis (Zohaib *et al.,* 2017). The number of weeds that emerged was counted seven days after sowing, and then used to calculate weed emergence percentage (%) in Equation 1 as described by Farooq *et al*. (2006).

$$Weeds\,emergence\,(\,)=\left(\frac{No.\,of\,seeds\,emerged\,7\,day\,s\,after\,sowing}{Total\,number\,seeds\,tested}\right)X\,100 \quad \text{………. …… (1)}$$

2.4.2 Growth characteristics

After treatments application, the data of all growth variables were collected in seven days intervals from 14, 21, 28 and 35 days after sowing (DAS) as indicated below

2.4.2.1 Number of leaves plant^{-1}

Data on the number of leaves per plant was obtained by counting leaves of two plants in each pot and their averages were recorded.

2.4.2.2 Leaf area count (cm^2 plat $^{-1}$)

Data on leaf area (cm^2) was measured by using graph papers without distracting the plant. Two leaves from two plants in a pot were measured by fitting the leaves on a graph paper, then the margin where leaves end were marked. Finally all half squares were counted and its summation divided by two then sum-up with all full squares to obtain leaf area and its average were recorded.

2.4.2.3 Plant height cm plant^{-1}

Data on plant height (cm) was obtained by measuring plant height from ground to the tip of plant using meter rule. Two plants were taken from each pot and their averages were recorded

2.4.2.4 Plant girth (mm) plant^{-1}

Data on plant girth (mm) was obtained by measuring plant girth using vernier caliper, at the center of the plant shoot. Two plants were taken from each pot and their averages were recorded.

2.4.2.5 Chlorophyll contents (%)

Chlorophyll content (%) was determined using chlorophyll meter (atLEAF CHL PLUS). Four leaves were selected from two plants in each experimental unit then placed in a chlorophyll meter to read chlorophyll content (%) available in the plant and the average recorded as described by Novichonok *et al*. (2016)

2.4.2.6 Number of survived weeds per experimental unit

Number of surviving weeds was collected following the procedure described by Farooq *et al*. (2006), where the number of surviving weeds per pot was obtained by counting the number of weeds existing after treatment application.

2.4.2.7 Root length (cm) plant^{-1}

Sixty days after sowing, the weeds were carefully uprooted and stretched to measure the root length from shoot to the end-root tip using a meter rule.

2.4.3 Weed biomass per experimental unit

Data on fresh and dry weight was collected 60 days after sowing as follows;

2.4.3.1 Fresh weight (g)

All weeds remaining in each pot after treatments application were uprooted, cleaned using tape water and keep under shade for 24hrs to remove excess moisture content. Using a digital weighing balance, fresh weight (g) of weeds was measured and recorded

2.4.3.2 Dry weight (g)

After measuring the fresh weight as indicated in section 2.7.3.1 the weeds were dried in an oven at 70ºC for 24hrs. Using a digital weighing balance, dry weight (g) of weed was measured and recorded.

2.5 Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) at ($P \leq 0.05$) using GenStat 16th Edition statistical package. Treatment means were separated using Turkey's, significant

2.6 RESULTS

2.6.1 Effect of plant extract on Kongwa weed growth and developments 35 days after sowing

Results on the effect of plant extract on Kongwa weed growth and development are shown in Table 2.1. Treatment Melia (*M. azedarach*) indicated that there were significantly low plant heights of 12.3 cm, 14.17 cm at P = 0.01 and 0.004 in phase I and II respectively. However this treatment resulted in a non- significant effect on plant girth at P=0.803 in phase one and significant at P= 0.01 in phase two. For phase I results show that, number of leaves were not significantly affected at P= 0.19 but in phase II there was significant influence of melia at P<0.001. Leaf area was not significantly affected at P= 0.43 during phase I while in phase II there was significant effect at P<0.001. Kongwa weed chlorophyll contents was significantly affected by M.azedarach application at P= 0.08 in phase I (29.96%) and at P<.001 in phase II (21.72(%) as compared with other treatments.

Table 2.1: Effect of plant extract on Kongwa weed growth and developments 35 days after sowing

Factor A (Type of plant extract)	Plant height(cm)		Plant girth(mm)		Number of leaves plant^{-1}		Leaf area(cm^2)		Chlorophyll Contents (%)		Number of survived weeds	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
M.azedarach	12.30a*	14.17a	1.55	1.71a	5.61	6.75a	5.4	7.02a	29.96	21.72a	2.78	1.69a
R. communis	15.19b	15.22a	1.62	2.03ab	6.41	7.70a	5.86	7.64a	35.47	28.17a	3.00	2.81b
N. tabacum	14.28ab	19.67b	1.59	2.46b	5.97	9.57b	5.53	11.28b	34.20	38.58b	2.92	1.67a
Mean	13.90	16.35	1.60	2.07	6.00	8.01	5.60	8.65	33.20	29.50	2.90	2.06
SD	2.64	4.61	0.29	0.62	1.21	1.82	1.02	2.00	6.94	8.26	0.67	0.45
CV%	19.00	28.20	18.30	30.10	20.10	22.7	18.20	23.10	20.90	28.00	23.00	21.70
P-Value	0.01	0.01	0.80	0.007	0.19	0.001	0.43	0.001	0.08	0.001	0.65	0.001

*Means in the same column followed by the same letter(s) do not differ significantly at P≤0.05 according to Tukey's honestly significance test. CV (%) = coefficient of variation and SD = Standard deviation. Phase I experiment conducted from November 2019. January of 2020. Phase II experiment conducted from January to March 2020.

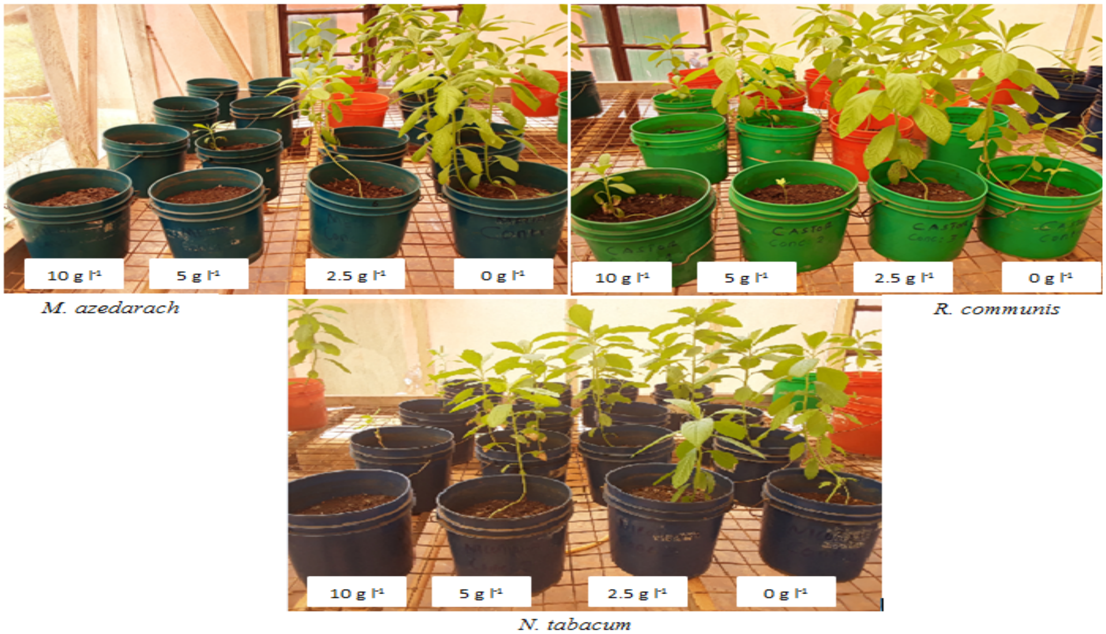

Plate 2.1: Effect of plant extract on Kongwa weed growth and developments in Phase I

Plate 2.2: Effect of plant extract on Kongwa weed growth and developments in Phase II

2.6.2 Influence of plant extract concentration levels on Kongwa weed growth and development 35 days after sowing

Results on effects of plant extract concentration on Kongwa weed growth and development in phase I and II. are shown in Fig 2.2 indicates Application of 10 g l^{-1}. plant extract concentration resulted into the shortest plant height of 8.67 in phase I and 5.91 cm in phase II at P<0.001 compared to the control (0 g l^{-1}). Followed by 5 g l^{-1} and 2.5 g l^{-1} concentration where significantly result on plant height were recorded at P<0.001. Similar effects were observed on plant girth, number of leaves per plant, leaf area (cm), chlorophyll contents (%) and number of survived weeds.

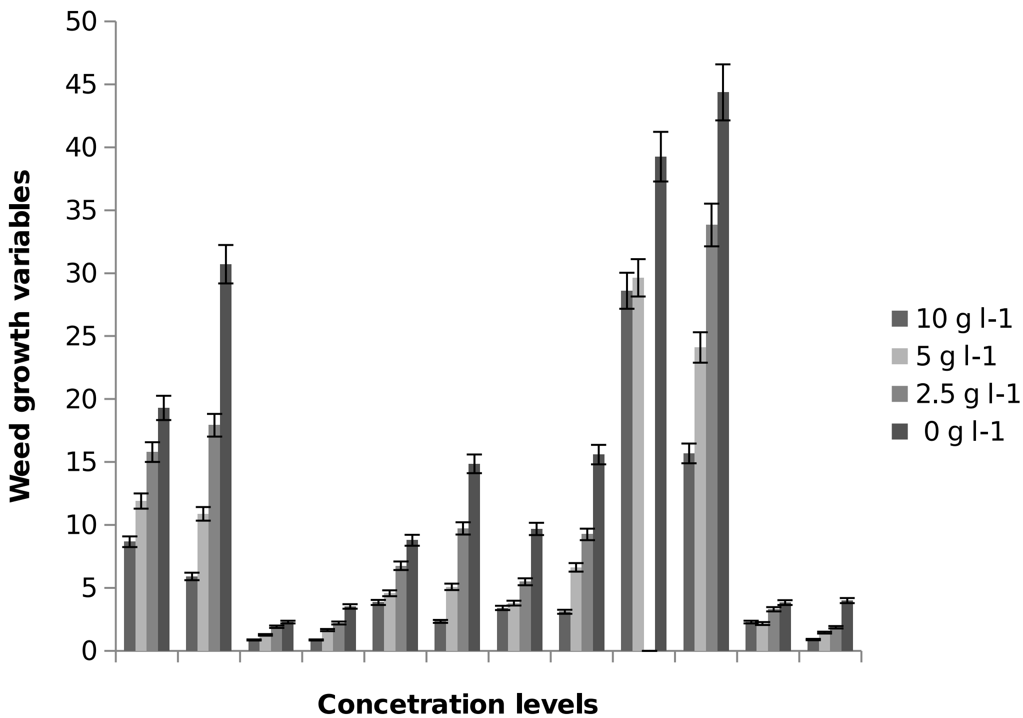

Figure 2.2: Influence of plant extract concentration levels on grow and development of Kongwa weed 35 days after sowing

2.6.3 Interaction effects of plant extract and concentration levels in Kongwa weed growth and development 35 days after sowing

Results on interaction effect of plant extract and plant extract concentration on Kongwa weed growth and developments are shown in Table 2.3. Combination of plant extract and concentration had significant effects on plant growth and development. A combination of *M. azedarach* extract and 10g l^{-1} showed significant reduction at P = 0.05 in Kongwa weed height to 5.41 cm per plant in phase I and no growth (0.00) cm in phase I compared to plant height of 30.94 cm when melia was applied with 0 g l^{-1} concentration level. Further, results on plant girth of 0.53 mm indicate that, there was significant effect at P = 0.052 in phase I but no significant effect at P = 0.066 in phase II. However, number of leaves were significantly influenced at P = 0.05 and 0.042 in phase I and II. The leaf area of 2.83cm^2 was significantly reduced at P = 0.052 in phase I experiment while in phase II leaf area was significantly affected at P = 0.002 as compared to leaf area of 14.50 and 10.02 cm^2 in control 0 g l^{-1}. Results of chlorophyll contents ranging from 23.98 to 40.29 % in phase I were not significantly influenced at P = 0.99, but was significantly affected at P = 0.038 in phase II, Chlorophyll contents ranged from 0.00 to 46.86 % when applied with *M.azedarach* x 10g l^{-1} and control 0 gl^{-1} respectively. Moreover treatment combination of *M. azedarach* extract and 10 g l^{-1} concentration had significant affect at P = 0.043 and <.001in number of survived weed 2, 0 for phase I and no growth in phase II experiment as compared to the control 0 g l^{-1} was average of 4 weeds were recorded per pot.

Table 2.2: Interaction effects of plant extract and concentration levels in Kongwa weed growth and developments35 days after sowing

Factor (a) X Factor(b)	Plant height(cm)		Plant girth(cm)		No of leaves		Leaf area(cm^2)		Chlorophyll contents		No of survived	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
M.azedarach x 10g l^{-1}	5.41a*	0.00a	0.53a	0.00a	3.50a	0.00a	2.83a	0.00a	23.98	0.00a	2.25ab	0.00a
N. tabacum x10g l^{-1}	9.36ab	11.22abc	0.97ab	1.72bc	3.44a	4.56bc	3.62ab	6.44bcd	29.28	32.02bcde	2.06ab	2.19cd
M.azedarach x5g l^{-1}	9.51ab	6.75ab	1.18abc	0.95abc	3.63a	2.50ab	3.24ab	3.38ab	25.79	12.93ab	1.63a	0.75ab
R. communis x10g l^{-1}	11.25abc	6.50ab	1.09abc	0.85ab	4.63ab	2.50ab	3.81ab	2.90ab	32.52	15.03abc	2.56abc	0.50ab
R. communis x5g l^{-1}	12.15bc	11.56bc	1.21abc	1.94bcd	4.75ab	7.39cd	4.36ab	5.60bc	32.69	24.10bcd	2.50abc	0.88ab
N. tabacum x5g l^{-1}	14.18bcd	14.33bc	1.46bcd	2.10bcde	5.37ab	5.38bc	3.78ab	10.92def	30.42	35.27cde	2.38abc	2.72d
N. tabacum x2.5g l^{-1}	14.77bcd	22.12cde	1.77cde	2.42cde	6.63bc	11.31def	5.61b	12.46efg	36.81	40.66de	3.25abc	2.31cd
M.azedarach x2.5g l^{-1}	15.52bcd	19.00cd	2.04de	2.28bcde	6.38abc	10.00de	5.32ab	8.55cde	32.91	31.10bcde	3.25abc	2.00cd
R. communis x2.5g l^{-1}	17.06cd	12.62bc	1.94de	1.93bcd	7.25bc	7.88cd	5.53b	6.73bcd	36.36	29.69bcde	3.44bc	1.31bc
M.azedarach x0g l^{-1}	18.77d	30.94e	2.46e	3.61e	8.94c	14.50ef	10.20c	16.13g	37.18	42.86de	4.00c	4.00e
N. tabacum x0g l^{-1}	18.81d	31.00e	2.18de	3.60e	8.44c	15.00f	9.10c	15.31fg	40.29	46.36e	4.00c	4.00e
R. communis x0g l^{-1}	20.29d	30.19de	2.23e	3.38ce	9.00c	15.06f	9.73c	15.32fg	40.29	43.86de	3.50bc	4.00e
Mean	13.90	16.35	1.60	2.07	6.00	8.01	5.60	8.65	33.2	29.50	2.90	2.06
SD	2.64	4.61	0.29	0.62	1.21	1.82	1.02	2.00	6.94	8.26	0.67	0.45
CV%	19.00	28.20	18.30	30.10	20.10	22.70	18.20	23.10	20.90	28.00	23.00	21.70
P-Value	0.053	0.051	0.052	0.05	0.05	0.042	0.52	0.002	0.987	0.038	0.043	<.001

*Means in the same column followed by the same letter(s) do not differ significantly at $P \leq 0.05$ according to Tukey's honestly significance test. CV (%) = coefficient of variation and SD = Standard deviation. Phase I experiment conducted from November 2019. January of 2020. Phase II experiment conducted from January to March 2020

2.6.4 Effect of plant extract on weed suppression, growth and biomass of Kongwa weed 60 days after sowing

Results on the effect of type plant extract on Kongwa weed survivors were not significantly affected at P = 0.918 between the treatment. *M. azedarach* influenced at P<0.001 while. *M. azedarach* and *R.communis* recorded 25% of survived weeds; *N. tabacum* had the highest population of survived weeds (56.25%). There were highly significant (P< 0.001) influences of extract on plant height and root growth. For *M. azedarach* extract plant height of weeds in phase I was 26.16 cm and 14.75 in phase II whereas root growth was 5.48 cm in phase I and 3.44 cm in phase II as indicated in Table 2.4

Table 2.3: Effect of plant extract on weed suppression, growth and biomass of Kongwa weed 60 days after sowing

Factor A (Plant Extracts)	Survived weeds (%)		Plant Height (cm)		Root length (cm)		Dry weight (g)	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
M. azedarach	42.19*	25.00a	26.16a	14.75a	5.48a	3.44a	2.24a	1.92a
R. communis	40.62	25.00a	41.22b	15.12a	9.70b	3.38a	3.34b	1.55a
N. tabacum	40.62	56.25b	41.25b	40.67b	10.46b	10.13b	2.54a	4.04b
Mean	41.10	35.40	36.20	23.51	8.50	5.65	2.70	2.50
SD	12.33	7.75	11.48	4.30	2.62	1.32	0.89	0.62
CV (%)	30.00	21.90	31.70	18.30	30.80	23.40	32.80	24.70
P-value	0.918	<.001	<.001	<.001	<.001	<.001	0.004	<.001

*Means in the same column followed by the same letter(s) do not differ significantly at P≤0.05 according to Tukey's honestly significance test. CV (%) = coefficient of variation and SD = Standard deviation. Phase I experiment conducted from November 2019. January of 2020. Phase II experiment conducted from January to March 2020

2.6.5 Performance of plant extract concentration on weed suppression, growth and biomass of Kongwa weed 60 days after sowing

Fig 2.3 present results on plant extract concentration effect on weed suppression, growth and biomass of Kongwa weed. Concentration 10 g l^{-1} had highly significant influence at P<.001 on weed survivor percentage 12.50, 10.4 in phase I and II respectively. Similar effect was observed on plant height (13.88 cm, 5.42cm), root length (3.51 cm, 1.67 cm) fresh weight (1.52 g, 4.9 g) and dry weight of (0.21 g, 0.43 g) compared to untreated (control) 0.0 g l^{-1} which recorded higher values

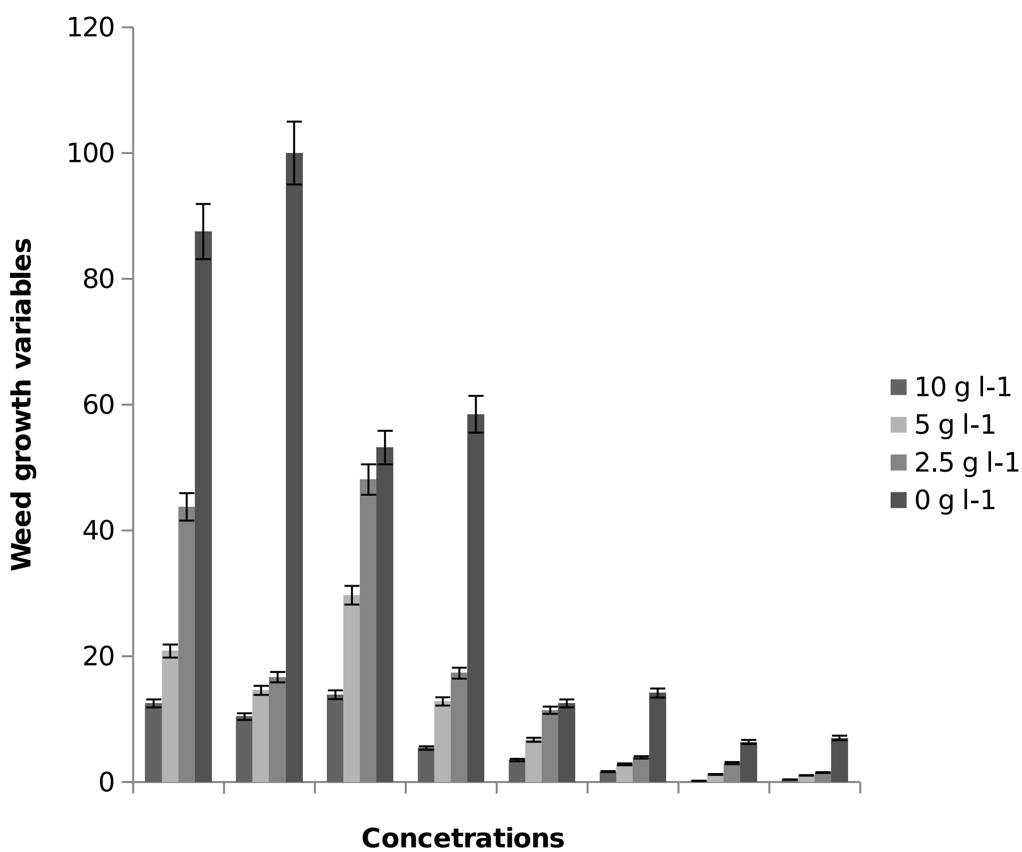

Figure 2.3: Performance extract effect concentration on weed suppression, growth and biomass of Kongwa weed 60 days after sowing

2.6.6 Interaction effects of plant extract and concentration on Kongwa weed suppression and biomass 60 days after sowing

Treatments combinations of *M.azedarach* and 10 g l^{-1}, *M.azedarach* and 5 g l^{-1} and *R. communis* with 10 g l^{-1} resulted into significant reduction at P = 0.028 and <.001 of plant height in phase I and II. A similar trend was observed on plant height, root length at P = 0.046 and <.001, fresh weight and dry weight (g) at P = 0.026, <.001 and P = 0.016 <.001 in phase I and II respectively compared to other treatments as indicated in Table 2.6

Table2.4: Interaction effects of plant extract and concentration on weed suppression and biomass of Kongwa weed 60 days after sowing

Factor (a) x Factor (b)	Survived weeds %)		Plant Height (cm)		Root length (cm)		Dry weight (g)	
	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II	Phase I	Phase II
M. azedarach x 10 g l^{-1}	0.00 a*	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a	0.00a
M. azedarach x 5 g l^{-1}	6.25ab	0.00a	7.50ab	0.00a	2.00ab	0.00a	0.18a	0.00a
M. azedarach x 2.5 g l^{-1}	62.50de	0.00a	44.75cde	0.00a	9.30cd	0.00a	2.43b	0.00a
Control (0 g l^{-1})	100.00f	100.00c	52.38e	59.00d	10.60cd	13.8de	6.35c	7.68c
R. communis x 10g l^{-1}	18.75abc	0.00a	23.4abcd	0.00a	5.28abc	0.00a	0.53ab	0.00a
R. communis x 5 g l^{-1}	25.00abc	0.00a	35.3bcde	0.00a	7.8bcd	0.00a	1.78ab	0.00a
R. communis x2.5g l^{-1}	31.25bc	0.00a	49.50de	0.00a	12.30d	0.00a	4.70c	0.00a
Control (0 g l^{-1})	87.50ef	43.75b	56.75e	60.5d	13.45d	13.5de	6.35c	6.20c
N. tabacum x10g l^{-1}	18.75abc	50.00b	18.2abc	16.25b	5.25abc	5.00b	0.10a	1.28a
N. tabacum x 5g l^{-1}	31.25bc	31.25b	46.38cde	38.50c	10.4cd	8.50c	1.73ab	3.20b
N. tabacum x 2.5g l^{-1}	37.50cd	100.00c	50.00de	52.00d	12.70d	11.8cd	1.92ab	4.53b
Control (0 g l^{-1})	75.00ef	100.00c	50.38de	55.93d	13.45d	15.25e	6.43c	7.18c
Mean	41.10	35.40	36.20	23.51	8.50	5.65	2.70	2.50
SD	20.53	17.67	11.48	4.30	2.62	1.32	0.89	0.62
CV (%)	30.00	21.90	31.70	18.30	30.80	23.40	32.80	24.70
P-Value	<.001	<.001	0.028	<.001	0.046	<.001	0.016	<.001

*Means in the same column followed by the same letter(s) do not differ significantly at P≤0.05 according to Tukey's honestly significance test. CV (%) = coefficient of variation and SD = Standard deviation. Phase I experiment conducted from November 2019. January of 2020. Phase II experiment conducted from January to March 2020

2.7 Discussion

The current study findings revealed that, aqueous extract of *M. azedarach* and *R. communis* have an ability to reduce Kongwa weed growth by reducing its plant height, girth, leaf area and number of leaves. This reduction in growth might be due to allelopathic effects caused by *M. azedarach* and *R. communis* extract applied to the tested plant species. These results are in agreement with Zohaib *et al.* (2017) who reported that allelopathic compound found in those plant species interrupts some physiological processes such as photosynthesis, respiration, hormonal action and cell division and elongation, which interferes with normal plant growth partially or completely. Further Nekonam *at el.* (2013) also observed allelopathic effects of *R. communis* on reduction of field bindweed growth that are similar to Kongwa weed growth when treated with similar plant species.

The reduction in total chlorophyll was probably due to presence of allelochemicals released by aqueous extracts from *M. azedarach* and *R. communis.* It was noticed that the inhibitory effects in tested plant species (Kongwa weed) increased as the concentration of extracts increased from 2.5 g l^{-1}, 5 g l^{-1} up to 10 g l^{-1}. These results also supported by Peng *et al.* 2004; Stupnicka-Rodzynkiewicz *et al.* 2006; Hussain and Reigosa 2011; Elisante *et al.* 2013. The authors pointed out that, the allelochemicals produced by invasive species interfere the photosynthesis and plant growth by destroying the chlorophyll hence disrupting photosynthesis process resulting to reduced plant growth and total plant biomass.

Previous studies revealed that, aqueous extract of *M. azedarach,* and *Casuarina cunninghamiana* prove to inhibit plant growth of some plant species like *Lactuca sativa* and *Raphanus sativus* by reducing root length as results of allelochemicals interference which prevent seedlings root growth (Lungu *at el.*, 2011; Shapla *et al.*, 2011; Akacha *et al.*, 2013; Sheded and Jahang, 2017). Stress due to allelopathic effects may be the reason for reducing plant height, leaf area, and number of Kongwa weed leaves which are important factors for plant growth and development.

The reductions in Kongwa weed biomass is possibly due to the presence of phenolic compounds in different weed tissues which decompose plant structure (Shapla *et al.*, 2011). P-coumaric acid, 4-hydroxy-3-methoxybenzoic acid, chlorogenic acid, vanilic acid, caffeic acid, ferulic acid and, gallic acid often occurring plant phenolic compounds and have been noticed in many weed plants which inhibit the germination and decrease seedling growth (Muzaffar *et al*., 2012; Zohaib *et al*., 2014; Zohaib *et al.,* 2016).

The study by Jalageri *et al.* (2010) and Zohaib *et al.* (2017) reported that, residues of *Commelina benghalensis, Parthenium hysterophorus, Cyperus rotundus* and *Prosopis juliflora* applied at 2.5% (w/v) and 5% (w/v) concentrations showed weed biomass suppression in production of wheat crop, soybean, ground nut and sorghum. According to the authors, the inhibition increase of weed biomass was due to release and accumulation of allelochemicals in the soil and within the plant species itself which caused perturbation in water relations and photosynthetic activity of tasted plant species.

Based on this observation the findings revealed that plant extracts from *M. azedarach and R. communis* applied at different concentrations levels with different time intervals inhibited the growth and biomass accumulation of Kongwa weed. The highest plant extracts concentration of 10g l^{-1} caused the most inhibition effect than lower concentrations of (5 g l^{-1} and 2.5 g l^{-1}) on weed growth and biomass production

The results indicated that Kongwa weed was highly suppressed during phase II experiment as compared to phase I experiment this could be due to seasonal variation and growth stages of the plant. Plant extract from plant species collected in October of 2019 had slightly less influence on Kongwa weed growth compared to plant extract from plant species collected in January of 2020. Observation made in this study may have resulted from concentration differences caused by growth stage of the plant species and seasonal variations. During phase I experimentation period, plant materials used may have been sampled prematurely due to seasonal variations probably this could be the reason for low weed suppression efficiencies effects. In phase II experimentation the plant materials may have been sampled at an advanced stage of maturity hence the reason for high efficiency in weed suppression observed in study. These results are in line with Silva, *et al*., 2014 and Holopainen, *et al*., 2018) who pointed out that high temperature particularly during drought season had a negative effect on phytotoxic compound accumulation in plant species. According to Gatti *et al*. (2014) and Kobayashi and Kato-Noguchi (2015) inhibition effect of plant extract varies depend on the season of collection plant extract from *B. brizantha* obtained in June, October and January inhibited the root and shoot growth of cress, lettuce, *Phleum pretense* and *Lolium multiflorum* in a concentration and season dependent. The inhibitory activity of *B. brizantha* of June and October was greater than that of *B. brizantha* of January.

2.8 Conclusions and Recommendations

2.8.1 Conclusions

This study played an important role in determining plant species with allelopathic potential against Kongwa weed with appropriate concentration to be applied in managing the weed.

i. Results proved the ability of *M. azedarach* and *R. communis* to be effective in suppressing the Kongwa weed growth when applied at 10 g l^{-1} during both phases I and II experimentation, first week of November 2019 to third week of January 2020 and Fourth week of January to last week of March 2020, respectively.

ii. The extract of *M. azedarach* and *R. communis* at 10 g l^{-1} concentration was found to be the best in controlling the Kongwa weed followed by 5 g l^{-1}. Furthermore, *N. tabacum* applied at 10 g l^{-1} was also found to be effective in weed suppression.

2.8.2 Recommendations

Therefore this study suggests plant extract from *M. azedarach* and *R. communis* applied at 10 g l^{-1} concentration is effective in controlling the Kongwa weed. Further studies are needed to determine the extraction method (s) of plant extract, chemical composition of the extract, mechanism and mode of action of *M. azedarach* and *R. communis* extract to suppress the weed.

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CHAPTER THREE

3.0 EFFECTIVENESS OF SELECTED CULTURAL, BIOLOGICAL AND CHEMICAL METHODS SINGLY OR IN INTEGRATION AS MANAGEMENT OPTIONS AGAINST KONGWA WEED (*Astripomoea hyoscyamoides* Vatke Verdc.)

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3.1 Abstract

Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) cause's damage on pasture productivity. This study was carried-out to evaluate the effectiveness of cultural, biological and chemical methods singly or in integration as management options. The experiment was conducted at two sites 2.2 km apart within Kongwa District, Dodoma region in Tanzania. Site A located at 06.06225S, 36.34204E and 992 masl, characterized with low weed population, and site B located at 06.07862S, 36.32756E and 962 masl, characterized with high weed population, both with sandy loam texture. A randomized complete block designs with four replicates were used at both sites. Site A contained five treatments while site B had 12 treatments as weed management techniques applied in paddocks occupied with buffel grass (*Cenchrus ciliaris*) and star grass (*Cynodon dactylon*), respectively. Results showed that, at site A treatment *M. azedarach* significantly affected the number of Kongwa weed survivor (5) and number of weed leaves (7), similar effect observed on pasture DM yield of (8.9 ton ha^{-1}) in the same treatments at $P<0.001$. However results on site B showed that, number of weed leaves (14), height (37.55 cm) and girth (3 mm) were significantly affected at $P<0.001$ by 2,4-D treatment, while cutting + *M. azedarach* treatment significantly affected number of survivor weed at $P<0.001$ compared to other applied treatments. Further hand pulling + *M. azedratch* and cutting + 2, 4-D had significant influence on pasture DM yield of 14.02 ton ha^{-1} at $P<0.001$ compared to other treatments. Integrated weed management (cutting + *M. azedarach*, hand pulling + *M. azedarach* and cutting + 2, 4-D) were more effective than single treatment when applied in high weed infestation. It is recommended that, integrated weed management could be applied in high weed infestation, whereas herbicides or plant extracts could be applied singly in low weeds infested rangelands.

Keywords: Kongwa weed, Allelopathy, Noxious, Invasive

3.2 Introduction

According to Rao and Nagamani (2010), weed management is a science based on decision making process that directs the use of ecology, weed biology and environment information and all available technologies to control weeds by the most economical and ecologically viable methods. But it is encountered with a daunting set of challenges such as weed resistance to herbicides, environmental damage caused by control practices, greater weed impacts due to changes in climate and land use and accelerated rates of weed dispersal through global trade (Liebman *et al*., 2016). However managing invasive weeds species in rangelands has several challenges including remoteness (massive roadless areas) that limit access for weed control, and lands of low economic value that make chemical and mechanical control impractical (Frost and Launchbaugh, 2003). The Kongwa weed has been reported to be dominated in various land use types especially in lands used for crop production and grazing, while the species is not observed in the bush. The weed has ability to overcome wide barriers from individual level to population level in the new habitat and affects the native plant species particularly the desirable forages in rangelands and crops in the cropping lands (Nkombe *et al.*, 2018). Moreover, Yassin, (2019) reported that the increase in weed population as ecological process may change after invading and spreading the weed plant species in the rangelands, these may result in the disappearance native species and increasing the vulnerability of the desirable forages. These challenges support the use of various weed control methods such as cultural and biological methods applied in integration.

Manipulating the pasture ecosystem, focusing on plant competition and allelopathy could facilitate sustainable management of broadleaf weeds in perennial pasture (Huwer *et al*., 2002). Using weeds control method alone would be unsuccessful with weeds challenges. Rather, their user will need to be integrated with a range of other weed management strategies and the practical use of herbicides (Andrew *et al.*, 2015). These studies indicate that broadleaf weeds like Kongwa weed in perennial pasture are amenable to mitigation using available weed control methods. Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) is among obstacles to rangeland productivity through their ability of competing for resources and causing negative impact on forage quality (Nkombe *et al.,* 2018). Kongwa weeds have been reported to cause pasture losses up to 100% if not managed (Hejda *et al.,* 2009; Nkombe *et al.,* 2018). From Kongwa the weed has spread beyond the open areas and continued to invade a wide range of agro–ecosystems. The weeds reported to reduce both crop yield and the amount of forage available to livestock on both public and private grazing lands (Hailu *et al.,* 2003; Duncan and Clark, 2005). Although Kongwa weed covers more than 70% (Lutege, R. personal communication, 2020) of the Kongwa Ranch and had a notable negative impact on pasture production, to date there is only one consistent research result reported in the area (Nkombe *et al.,* 2018). Farmers have experienced heavily infested grazing and crop land when the weeds reach unmanageable levels, resulting in food insecurity and increased loss of household income.

Recently, stocking density in Kongwa ranch declined by 10% annually due to insufficient animal feed resulting from pasture displacement caused by the weeds infestation (UNIDO, 2012; Nkullo, 2013). The study was conducted to evaluate the effectiveness of selected cultural, biological and chemical methods singly or in integration as management options against Kongwa weed.

3.3 Materials and Methods

3.3.1 Description of the study sites

The study was conducted at two sites in Kongwa district of Dodoma region with different weeds population and growth stage. Site A located at 06.06225S, 36.34204E and 992 m above the sea levels was occupied with low weed population in vegetative growth stage. Site B located at 06.07862S, 36.32756E and 962 m above the sea levels, the field occupied with high weed population during flowering stage (Figure1). The study area is semi-arid zone, with an average annual rainfall of 500 – 800 mm, which falls between December and April. Rainfall is unimodal, unpredictable, and poorly distributed with high variation within and between seasons (Nkombe, *at el*., 2018). The mean temperature is 26.5°C, but sometimes gradually changes up to 11°C. The cool weather occurs between January and June when temperature ranges between 20 – 33°C and the highest temperature recorded is 31°C while the lowest temperature is 18° C (PORA and LGOVT, 2016). The dominant soil types are classified as Chromic Luvisols with a sandy loam texture (Mkonda and He, 2017).

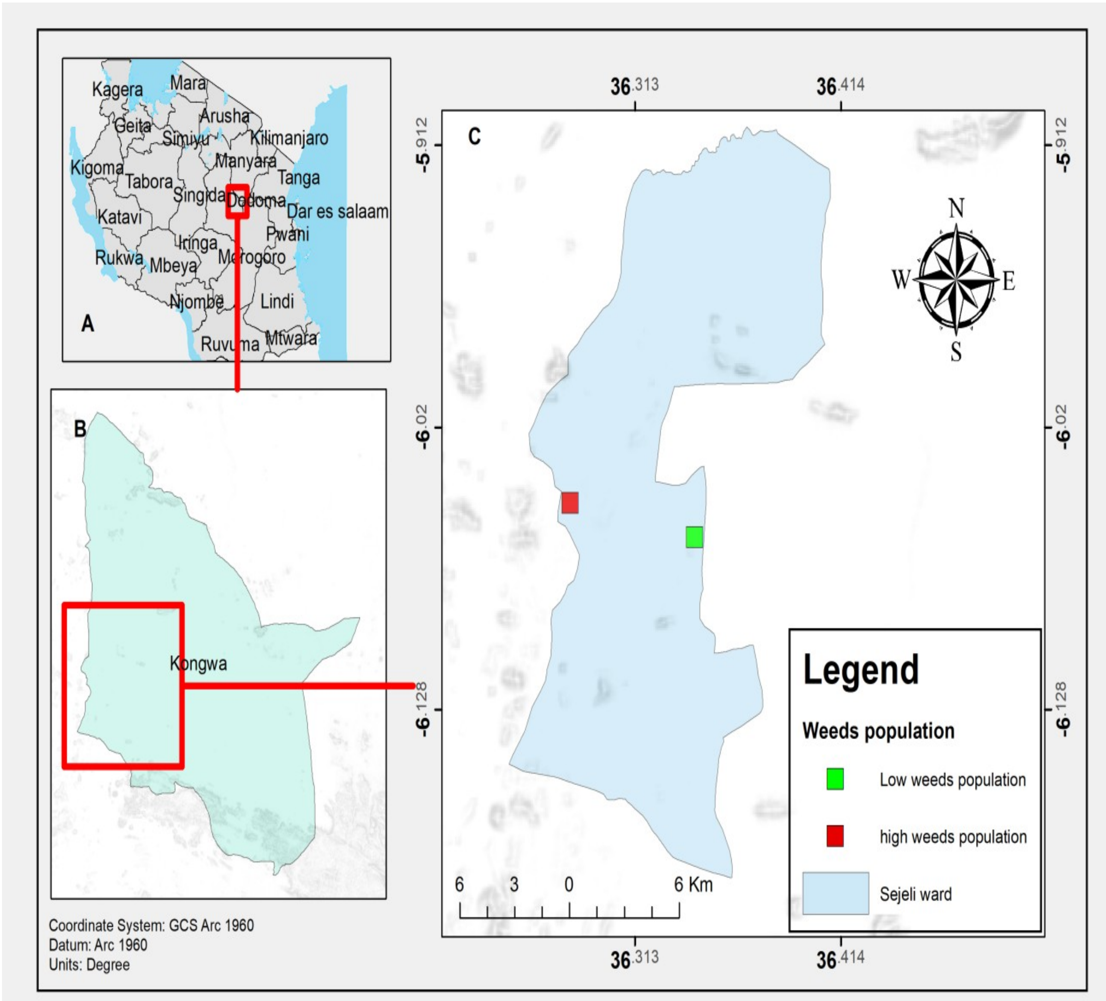

Figure 3.1: A represents Tanzania, B represents Kongwa District and C represent experimental site

3.3.2 Description of experimental material

Table 3.1: Materials used as weed management practices evaluated in site A

S/No.	Treatments	Descriptions
1	*M.azedarach*	Aqueous plant extract from *M. azedarach* applied at a rate of 10 g l^{-1} sprayed once using a knapsack sprayer in natural established pasture.
2	*R.communis*	Aqueous plant extract from castor *R. communis* applied at a rate of 10 g l^{-1} sprayed once using a knapsack sprayer in natural established pasture.
3	2,4-D	Application of 2, 4-Dichlorophenoxyacetic acid (2, 4-D) at application rate of 2 L ha^{-1} in 150 litres of water (267ml 20 l^{-1} of water) sprayed once using a knapsack sprayer in natural established pasture.
4	Hand-pulling	Pulling done once, only Kongwa weed were uprooted in the plot
5	Control	No weed management practices applied.

Table 3.2: Materials used as weed management practices evaluated in site B

S/No.	Treatments	Descriptions
For treatment description step number 1 to 5 were as already described for site A table 3.1 of this study.		
6	Hand-pulling + *M. azedarach*	Pulling done once, only Kongwa weed were uprooted in the plot flowed by application of *M. azedarach* applied at a rate of 10 g l-1 sprayed once using knapsack sprayer in natural established pasture.
7	Hand-pulling + *R. communis*	Pulling done once, only Kongwa weed were uprooted in the plot flowed by application of *R. communis* applied at a rate of 10 g l-1 sprayed once using knapsack sprayer in natural established pasture.
8	Cutting + *M. azedarach*	Cutting done once by using machete only Kongwa weed were slashed, flowed by application of *M. azedarach* applied at rate of 10 g l-1 sprayed once using knapsack sprayer in natural established pasture.
9	Cutting + *R. communis*	Cutting done once by using machete only Kongwa weed were slashed, flowed by application of *R. communis* applied at rate of 10 g l^{-1} sprayed once using knapsack sprayer in natural established pasture.
10	Cutting + 2,4-D	Cutting done once by using machete only Kongwa weed were slashed flowed by application of 2, 4-Dichlorophenoxyacetic acid (2, 4-D) at application rate of 2 L ha^{-1} in 150 litres of sprayed once using knapsack sprayer in natural established pasture.
11	Hand-pulling + 2,4-D	Pulling done once, only Kongwa weed was uprooted in the plot flowed by application of 2, 4-Dichlorophenoxyacetic acid (2, 4-D) at application rate of 2 l ha-1 in 150 litres of water sprayed once in natural established pasture.
12	Cutting	Cutting done once by using machete only Kongwa weed were slashed

3.3.3 Preparation of plant extract as bio-herbicides

Standard procedures of Nekonam *et al.* (2013) for preparation of aqueous plant extracts *R. communis* and *M. azedarach* were followed. The aerial plant parts (mixture of old and young leaves) samples of *R. communis* and *M. azedarach* were collected from Kongwa District. The samples were air dried and ground to get fine powder. Extracts were prepared for each plant species using the fine powder at concentrations of 10 g l^{-1}, 100g of the powder was added into 1000 ml of distilled water to prepare aqueous extract with, 10 g l^{-1}concentration. Then the mixture was left at ambient condition for 24 hrs, thereafter was filtered through filter paper and used as a source of bio-herbicides. The supernatant solution of each plant extract after filtration was applied in a field as bio-herbicides. However 2, 4-Dichlorophenoxyacetic acid (2, 4-D) at application rate of 2 l ha^{-1} in 150 litres of water (267ml 20 l^{-1} of water) was purchased from the nearby Agro dealers at Kongwa.

3.3.4 Experimental design

The experiment at site A was laid out in randomized complete block design (RCBD) with five treatments replicated four times. Each replication contained five treatments: *M. azedarach, R. communis,* 2, 4-D, Hand pulling and Control as weed management practices. Treatments were applied in a selected paddock occupied with *Cenchrus ciliaris,* the paddock were covered with low Kongwa weed infestation at vegetative stage of growth. The dimension of each plot was 5m x 5m and the distance between the plots was 1m. The distance between one replication and another was 1m. All treatments were applied to existing natural vegetation in grassland. The experiment was carried from 13, January to 13 March 2020.

The study at site B was laid out in a randomized complete block design (RCBD) with

12 treatments replicated four times. Each replication contained 12 treatments. *M. azedarach*, hand pulling + *M. azedarach*, cutting + *M. azedarach*, *R. communis*, cutting + *R. communis*, 2,4-D, hand pulling+2,4-D, cutting+2,4-D, cutting, hand pulling and control treatments was applied in a selected paddock occupied with *Cynodon dactylon* and highly infested with Kongwa weed during flowering stage. The dimension of each plot, distance between plots, distance between replication and treatments allocation were as described in site A. The experiment was carried out from 17, February to 17 April 2020.

3.3.5 Data collection

Kongwa weed and pasture species (*Cenchrus ciliaris* in site A and *Cynodon dactylon* in site B) were sampled from two quadrants of 1 m x 1 m in each plot using zigzag method of Thomas, (1985) at seven days intervals (7, 14, 21 and 28 days) after treatment application). The number of survived weed, number of weed leaves, number of pasture leaves and pasture tillers were counted and recorded. Weed plants and pasture height was measured from the ground to the top of the growing tip by stretching its leaves upwards using a measuring tape. Weed plants and pasture girth was measured using a vernier caliper. Measurements of girth were taken from the center of the stem (a point between the rhizosphere and the canopy).

Sixty (60) days after treatment's application, pasture and weed were harvested using a sickle. Pasture species were separated from Kongwa weed and other plant species, and then sun dried for three days to biomass. Dried pasture were prepared in bundles per harvested plot. Kongwa weed and other plant species were also prepared in different bundles. Using portable electronic weighing scale, the weight of pasture species, Kongwa weed and weight of other weeds were determined and recorded. Finally the recorded weights were converted into kilogram per hectare (ha).

3.3.6 Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) at ($P \leq 0.05$) using GenStat 16th Edition statistical package. Treatment means were separated using Turkey's, significant test at 5% level

3.4 Results

3.4.1 Treatments effect on weed and pasture performance at site A

Weed management practices had a very high significant effect on the number of Kongwa weed survived, number of weed leaves and weed height at $P<0.001$. *M. azedarach* treatment resulted in the lowest number of weeds surviving, number of weed leaves 7 per plant, while control resulted in the highest values. Further weed girth was significantly influenced by the weed management practices applied at $P<0.01$ as indicated in Table 3.3.

Table 3.3: Treatment effects on weed and pasture performance at site A

Treatments	No. of Survived weeds m²	No. of leaves weed⁻¹	Weed height (cm)	Weed girth (mm)	Pasture height (cm)	Pasture girth (mm)	No of leaves plant⁻¹	No. of tillers⁻¹ (m²)
M.azedratch	4.53a*	6.65a	26.35a	1.73a	115.7	2.51	17.88	21.13
2,4-D	4.80a	8.05a	24.88a	1.57a	112.6	2.65	16.8	19.08
R.communis	6.80a	9.50a	43.38a	2.53ab	108.7	2.6	17.18	19.1
H. pulling	8.45a	17.62a	51.00a	2.81ab	110.4	2.63	16.58	18.5
Control	27.30b	38.42b	84.10b	4.98b	112.5	2.31	16.8	21.25
Mean	10.40	16.00	45.90	2.70	112.00	2.50	17.00	19.80
SD	1.71	2.94	12.48	0.38	7.50	0.26	2.64	2.32
CV%	16.40	18.40	27.20	13.90	6.70	10.20	15.50	11.70
P- Value	0.001	0.001	0.001	0.01	0.74	0.38	0.96	0.34

*Means in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly test. CV = coefficient of variation. SD = Standard deviation

3.4.2 Treatments effect on pasture yield and weed weight at site A

Results on treatments effect on weed weight and pasture DM yield at site A. are shown in Figure 3.2. Kongwa weed weight, was significantly affected at P<0.001 when treatment *M. azedarach* was applied (0.2 ton ha^{-1}) likewise pasture yield was very significantly influenced at P<0.001 by the same treatment (8.9 ton ha^{-1}). Other weeds weigh (0.4 ton ha^{-1}) were significantly affected at P = 0.03 by 2, 4-D treatment. However untreated plots (control) had the highest Kongwa weed (8.0 ton ha^{-1}), other weeds (2.1 ton ha^{-1}) and lowest pasture yield (2.9 ton ha^{-1}) than the other applied treatments.

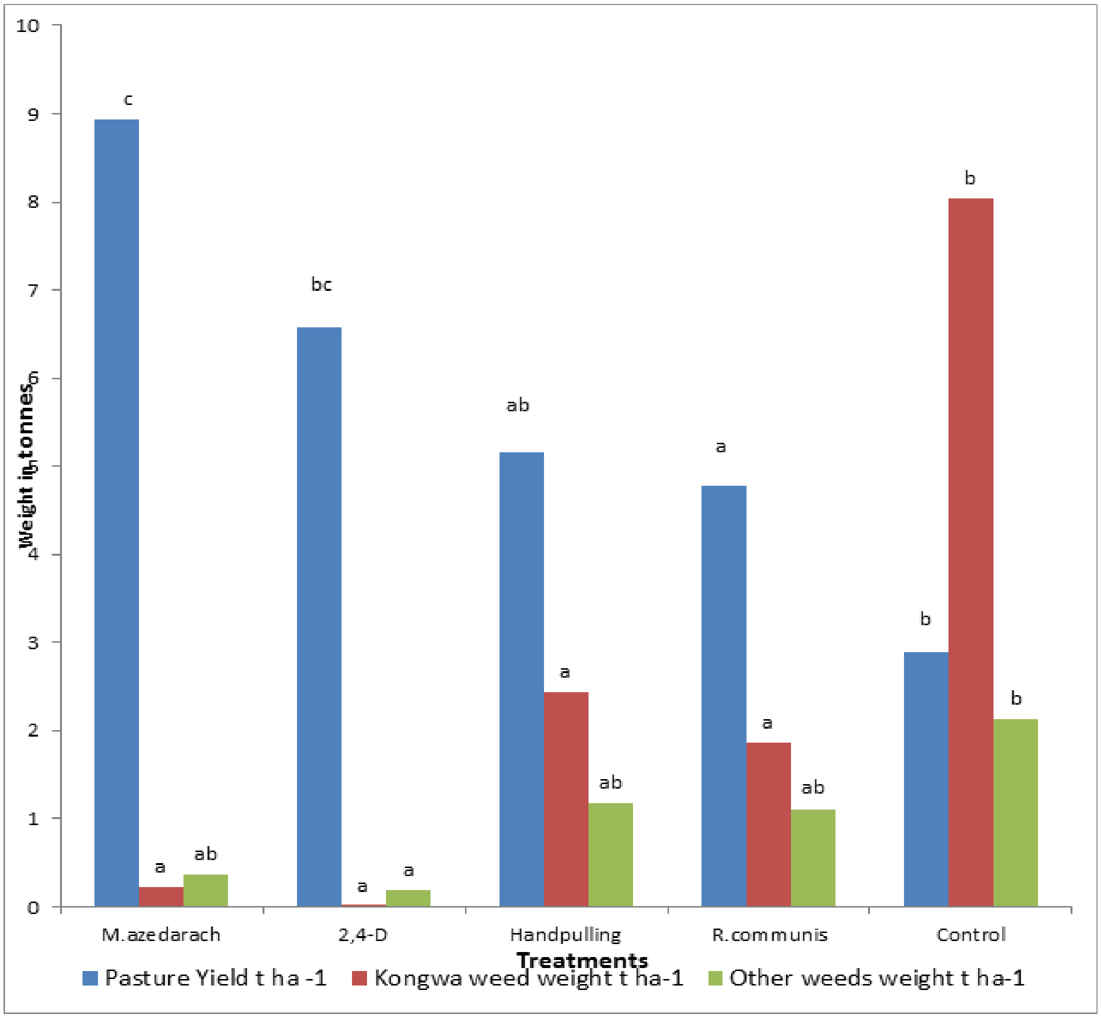

Figure 3.2: Treatments effect on weed weight and pasture yield at site A

3.4.3 Relationship between weed survival and pasture performance at site A

The regression analysis showed that the number of leaves per plant were significantly positive correlated to pasture girth with r = 0.44 at P <0.05 and as expected number of survived weed had a significant negative correlated (r = -0.64) at P<0.01 to pasture yield (*Cenchrus ciliaris*). The remaining variables were not significantly correlated at P <0.05. as indicated in Table 3.4.

Table 3.4: Relationship between weed survival and pasture performance at site A

	Pasture height (cm)	**Pasture girth (mm)**	**No. of leaves plant^{-1}**	**No. of tillers plant $^{-1}$**	**Pasture yield ton ha^{-1}**	**No. of Survived weeds**
Pasture height (cm)	1					
Pasture girth (mm)	0.08	1				
No. of leaves plant^{-1}	-0.13	0.44*	1			
No. of tillers m^2	-0.21	-0.27	0.26	1		
Yield plot^{-1}	0.05	-0.04	-0.05	0.23	1	
No. of Survived weed	0.05	-0.33	0.14	0.34	-0.64**	1

n = 20, df =n-2,*Significant liner correlation P = 0.05 and **Significant liner correlation P=0.01

3.4.4 Percentage pasture yield loss due to Kongwa weed in site A

The percentage yield loss derived by divide the total pasture yield in uncontrolled plot with total pasture yield from controlled plot multiplied by hundred to get pasture yield percentage. Results on pasture DM yield loss caused by Kongwa weed infestation are shown in figure 3.3. Yield losses ranged from 32% for *M. azedarach* treatment to 68% for the control treatments at site with low weed infestation.

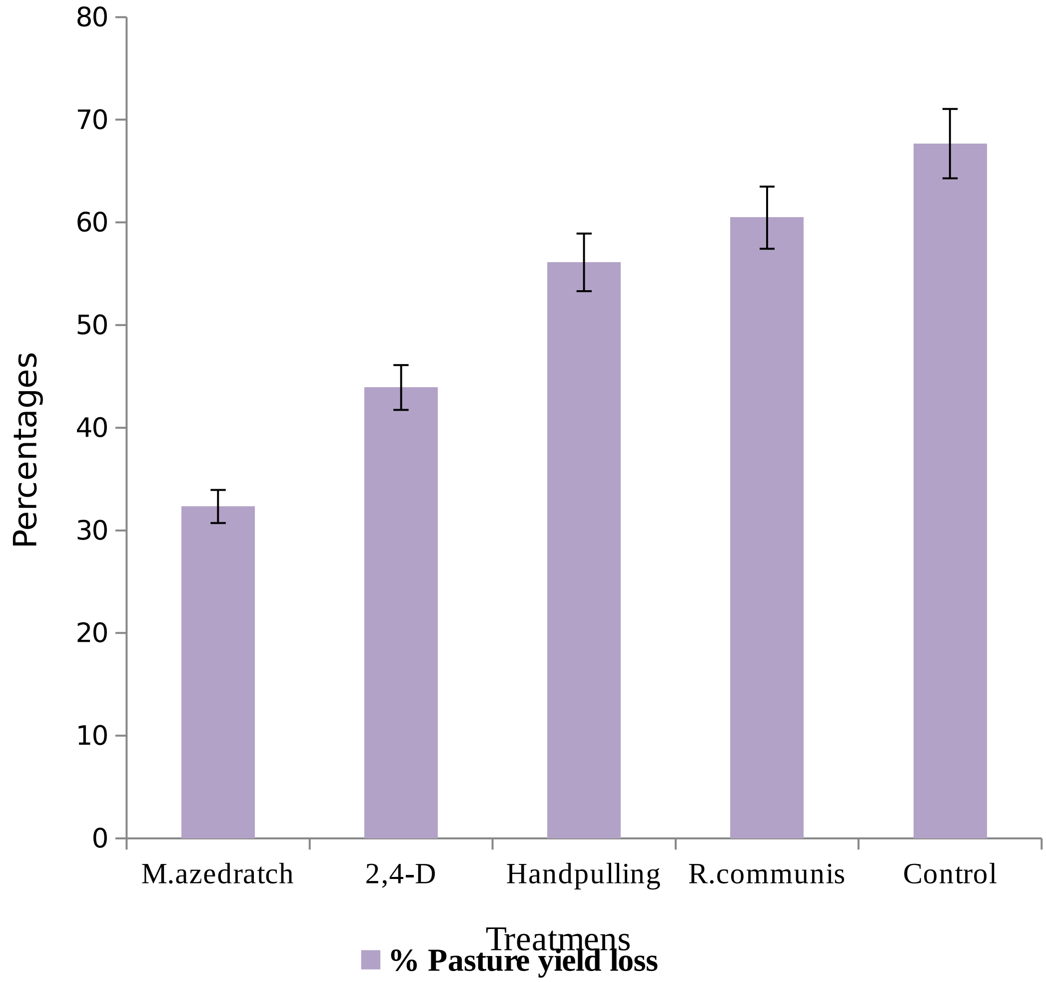

Figure 3.3: Percentage pasture yield loss at site A

3.4.5 Treatments effect on Kongwa weed and pasture performance at site B

Table 3.5 shows treatments' effects on Kongwa weed and pasture performance at site B. The results on number of weed leaves (14), weed height (37.55 cm) and weed girth (3 mm) were significantly affected at P<0.001 by 2,4-D treatment, while Cutting + *M. azedarach* treatment had a significant effect at P<0.001 on the number of survived weed 10 compared to other applied treatments.

Table 3.5: Treatments effect on weed and pasture performance at site B

Treatments	No. of Survived weeds (m^2)	No. of leaves weed $plant^{-1}$	Weed height (cm)	Weed girth (mm)	Pasture height (cm)	Pasture girth (mm)	No. of leaves $plant^{-1}$	No. of $tillers^{-1}$
Hand pulling+ *M.azedarach*	13.40ab*	18.55abc	62.17abc	4.67a-d	81.61	1.650	12.97	11.90
Cutting+ *M.azedarach*	9.92a	16.90ab	51.11abc	4.07abc	71.11	1.64	12.84	13.78
Cutting	22. 40c	25.97bcd	70.10bc	5.99bcd	72.76	1.75	13.04	13.50
Cutting+*R.communis*	16.32abc	25.82bcd	75.37c	6.65d	78.4	1.73	14.14	12.43
Hand pulling+2,4-D	12.00ab	16.35ab	42.86a	3.75ab	69.89	1.77	14.09	13.58
2,4-D	11.90ab	13.77a	37.55a	3.00a	69.76	1.77	13.62	13.35
Cutting+2,4-D	10.25a	16.25ab	46.79ab	4.04abc	71.56	1.72	13.24	14.18
M.azedarach	11.45ab	15.57a	47.60ab	3.98abc	80.76	1.79	13.77	14.30
Hand pulling	16.60abc	23.55a-d	74.32c	6.35cd	73.54	1.74	12.7	13.43
R.communis	21.87c	30.60d	75.95c	7.02d	68.39	1.66	14.04	14.25
Hand pulling+*R.communis*	18.20bc	28.02cd	69.75bc	6.22cd	72.31	1.73	13.97	14.45
Control	56.08d	86.45e	150.52d	10.76e	74.41	1.70	14.09	13.60
Mean	18.37	26.49	67.00	5.54	73.70	1.716	13.54	13.56
SD	2.76	4.11	10.12	0.98	7.59	0.12	1.15	1.33
CV%	15.00	15.50	15.10	17.60	10.30	7.00	8.50	9.80
P- Value	0.001	0.001	0.001	0.001	0.26	0.76	0.55	0.27

*Means in the same column, followed by the same letter(s) do not differ significantly ($P \leq 0.05$) according to Tukey's honestly test., CV = coefficient of variation. SD = Standard deviation.

3.4.6 Influence of treatments on pasture yield and weed weight in site B

Figure 3.4 shows the influence of treatments on pasture yield and weed weight in site B. Pasture yield (14.02 ton ha^{-1}) was significantly influenced at P<0.001 by treatments hand pulling + *M. azedarach* and cutting + 2, 4-D than other applied treatments. Kongwa weed weight was significantly affected at P<0.001 under hand pulling + 2, 4-D followed by cutting + 2, 4-D (0.14 ton ha^{-1}) and 2, 4-D. Further other weed weight were significant affected at P<0.001 by 2,4-D (0.12 ton ha^{-1}) followed by hand pulling + 2,4-D (0.43 ton ha^{-1}) and hand pulling + *M. azedarach*

(0.5 ton ha^{-1}), as expected the control treatment had the highest Kongwa weed weight (22.73 ton ha^{-1}), other weeds weight (1.09 ton ha^{-1}) and lowest pasture yield (1. ton ha^{-1}).

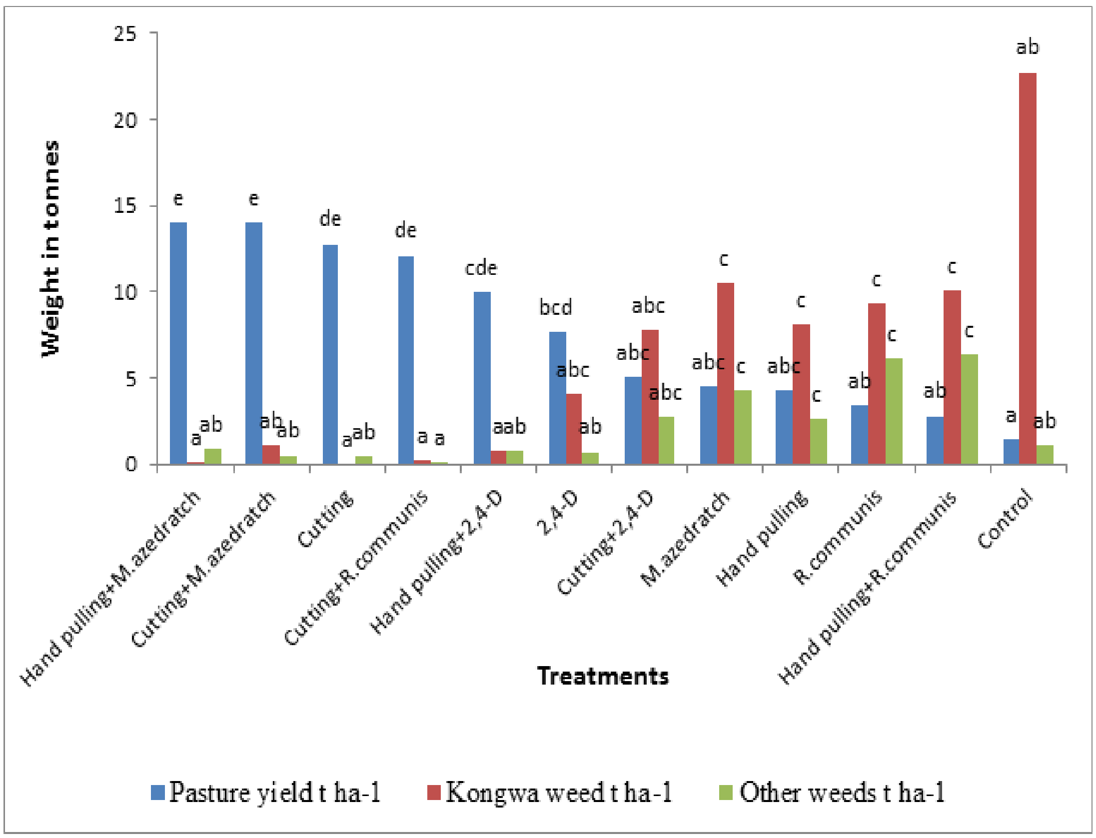

Figure 3.4: Treatments effect on weed weight and pasture yield at site B

3.4.7 Relationship between weed survival and pasture performance at site B

Table 3.6 shows the relationship between weed survivals and pasture performance at site B. The regression analysis showed that, the pasture (*Cynodon dactylon*) girth, number of leaves per plant, number of tillers were significantly positive correlated to pasture height r = 0.37, pasture girth r = 0.5 and number of leaves r= 0.44 respectively at P<0.01 while number of leaves per plant was significantly positive correlated to pasture height with $r = 0.27$ at $P < 0.05$. However, regression analysis showed significantly negative correlated between numbers of surviving weed and pasture yield $R = -0.54$ at $P < 0.01$. The remaining variables were not significantly correlated at $P < 0.05$.

Table 3.6: Relationship between weed survivals and pasture performance at site B

	Pasture height (cm)	**Pastur e girth (mm)**	**No. of leaves plant^{-1}**	**No. of tillers m^{2}**	**Yield plot^{-1}**	**No. of Survived weeds**
Pasture height	1					
Pasture girth	0.37**	1				
No. of leaves plant^{-1}	0.27*	0.50**	1			
No. of tillers	-0.24	0.32**	0.44**	1		
Yield plot^{-1}	0.07	0.23	0.01	0.02	1	
No. of Survived weeds	0.02	-0.07	0.14	0.00	-0.54**	1

n = 48, df =n-2,*Significant liner correlation P = 0.05 and **Significant liner correlation P=0.01

3.4.8 Percentage pasture yield loss due to Kongwa weed in site B

The percentage yield loss derived by divide the total pasture yield in uncontrolled plot with total pasture yield from controlled plot multiplied by hundred to get pasture yield percentage. Results on yield loss caused by Kongwa weed infection on pasture yield are shown in figure 3.5. Yield losses ranged from 10 for hand pulling + *M.azedarach* to 90% for the control treatments at site B which had high Kongwa weed infestation.

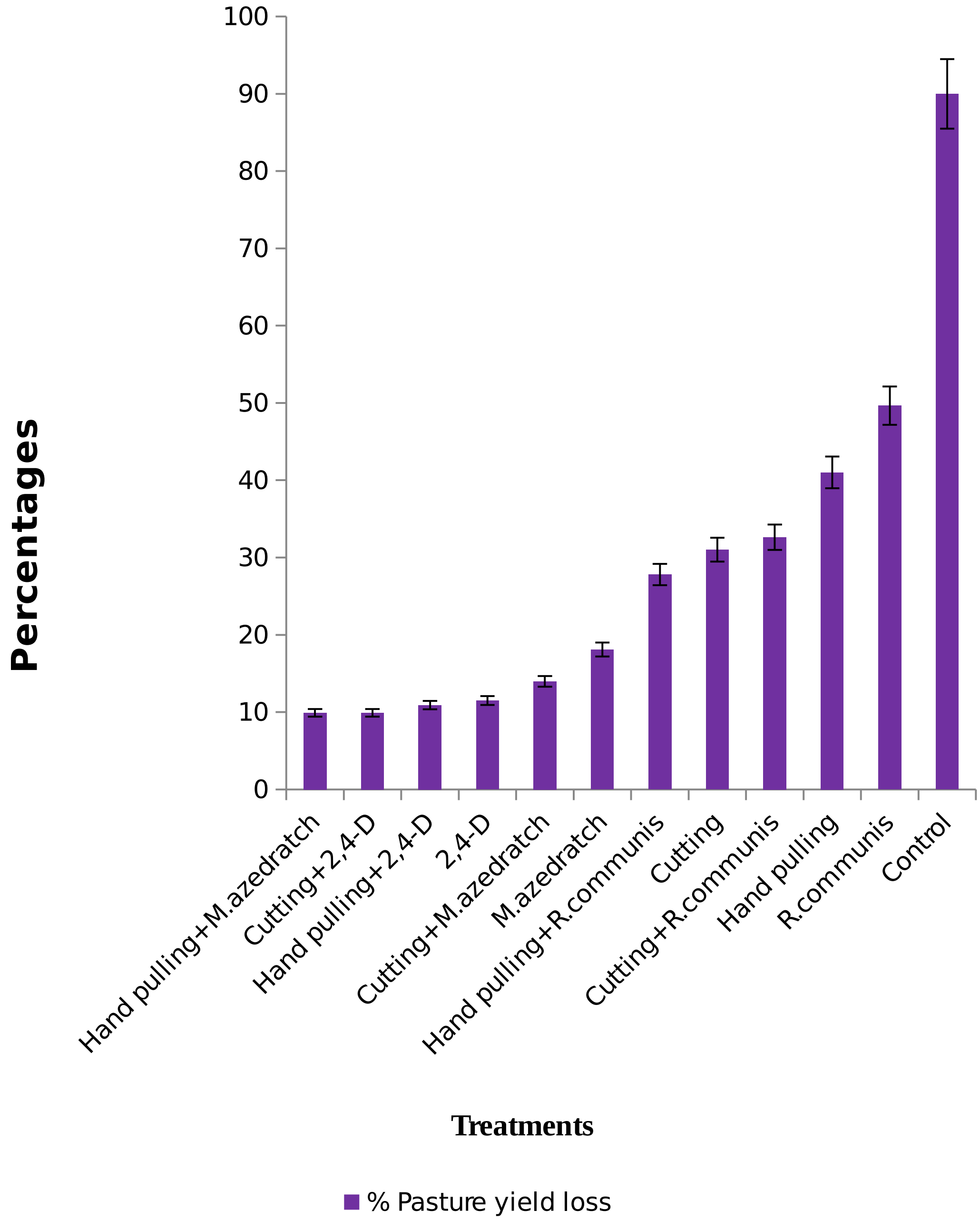

Figure 3.5: Percentage pasture yield loss at B

3.5 Discussion

The current study findings revealed that, in rangelands occupied with low Kongwa weed infestation during vegetative stage, herbicide 2, 4-D and plant extract *M. azedratch* applied singly at high concentration have the ability to suppress these weeds. Low Kongwa weed and other weeds growth could possibly be due to decrease in number of surviving Kongwa weed, number of weed leaves, weight of Kongwa and other weeds species. Shapla *et al.,* (2011) reported similar findings allelopathic effects of *M. azedarach* in mung bean and soybean crops whereby the number of leaves shoot length, leaf length and shoot biomass was significantly reduced. Several studies have shown that the phytotoxicity / inhibitory effect of *M. azedarach* extract was proportional to the concentration of the extract applied; whereby higher concentration has a stronger inhibitory effect which decreased root and shoot development of crops such as lettuce (Lungu *et al*., 2011) and radish (Akacha *et al.,* 2013). In their results it was indicated that, *M. azedarach* allelochemical produced an imbalance in the oxidative status of cells such as the change in activity of catalase (CAT), ascorbate peroxidase (APX), guaiacol peroxidase (GPX), membrane lipid peroxidation electrolytes leakage, the levels of hydrogen peroxide and assimilatory pigments in radish seedlings.

Herbicide 2, 4-D applied singly in rangelands with high Kongwa weed infestation and during flowering stage has high ability to suppress these weeds unlike plant extract *M. azedarach*. The decreased number of weed leaves, weed height, weed girth and weight of other weeds was likely due to de-regulation of the weed cell growth process by 2, 4-D herbicide. According to Hall *et al*. (1999) and Bhatla, (2018), herbicide 2, 4-D works by interfering with growth, either by blocking photosynthesis and protein synthesis or by inhibiting weeds root system and also interferes with the plant growth regulator such as Indole Acetic Acid (IAA) or Auxin that controls cell enlargement, division and plant development. 2, 4-D penetrates the stomata and is translocated to the meristems of the weed, resulting into uncontrolled and unsustainable growth consequently, weeds wilt and die.

Integrated weed management (IWM) involving cultural, chemical (2, 4-D) or biological (*M.azedarach*) decreased weight and number of survived Kongwa weed and resulted in increased pasture yield. As the weeds were either uprooted by hand pulling or cut to a large extent and later suppressed by the chemicals and/ or bio-herbicides that likely affect Kongwa weed chlorophyll content, leading to lower weed population and suppression of weed growth as also reported by Akacha *et al*., (2013).The minimum weed weight was probably due to higher suppression of weeds. These results are in agreement with Bari *et al*. (2020) who reported that cultural and herbicidal treatments suppressed the weed weight considerably than the untreated control. Although the current study does not show strong significant pasture-tiller correlated (r= 0.26). The increased pasture yield as a result of high number of tillers could be due to less number of weeds and reduced pasture-weed competition for the available resources such nutrient, moisture and light. Further, this study results indicated that, there was a negative correlated (r= -0.64*) between the number of surviving weeds and pasture yield. Such results are in line with Jabran *et al*., 2012;Khan *et al*.,2015; Moraes *et al*., 2015) who reported an increase in number of tillers due to better weed control and elimination of weed-crop competition for nutrients, moisture, light and better utilization of available resources by the crops such as wheat and pasture.

In totality, pasture yield loss caused by Kongwa weed that ranged from 32 to 68% at site A under low Kongwa weed infestation of this study was slightly lower (75%) than that reported by Nkombe *at el*. (2018) in the same ecological area. The difference between current results and those reported by Nkombe *at el*. (2018) could be due to fact that the early results were from farmer's perception. However results at site B are similar with those by Nkombe *at el*. (2018) and Rwomushana *at el*. (2019) who reported the highest value of 75 and 90 pasture yield loss respectively.

3.6 Conclusions and recommendation

Agronomically, the study concludes that integrated weed management (IWM) practices are more effective than single treatments applications such as hand pulling, cutting, 2, 4-D, *M. azedarach*, and *R. communis* when applied in infested rangelands. The results show that appropriate weed control provided a favourable environment for the pasture growth, development and yield. Therefore, a proper combination of cultural practices with plant extracts significantly reduces the frequent use of herbicides, and improves pasture productivity.

It is therefore recommended that, integrated weed management such hand pulling + *M. azedarach* at 10 g l^{-1} (cutting + 2, 4-D 2 L ha^{-1}) and hand pulling + 2, 4-D 2 L ha^{-1}) be applied in areas infested with Kongwa weed. Further studies are required to compare efficacy of *M. azedarach* extract from other plant parts of such as roots and shoots on management of Kongwa weed.

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CHAPTER FOUR

4.0 ESTABLISHMENT OF THE MOST ECONOMICAL INTEGRATED WEED MANAGEMENT OPTIONS TESTED TO MANAGE KONGWA WEED (*Astripomoea hyoscyamoides* Vatke Verdc.)

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4.1 Abstract

High cost of weed management in rangeland is a limiting factor to increasing livestock production and profit. Therefore, the importance of this study was to establish the most effective integrated weed management practices that enhance sustainability and profitability of pasture production in rangelands. Experiments were conducted at two sites 2.2 km apart within Kongwa District Dodoma region. Site A located at 06.06225S, 36.34204E and 992 masl, characterized with low weed population, and site B located at 06.07862S, 36.32756E and 962 masl, characterized with high weed population, both with sandy loam texture. A randomized complete block design with four replicates was used at both sites. Site A contained five treatments while site B had 12 treatments as weed management techniques applied in paddocks occupied with buffel grass (*Cenchrus ciliaris*) and star grass (*Cynodon dactylon*), respectively. The results at site A showed that, controlling Kongwa weed with *M. azedarach* treatment produced the mean pasture yield of 8.94 t ha^{-1} which was more profitable (TSh. 435 555.00 ha^{-1}) than other treatment. This was followed by 2, 4-D which gave an average pasture yield of 6.58 t ha^{-1} worth Tsh 232 053.00 ha^{-1}. While at site B, the highest net profit were recorded from treatments hand pulling + *M. azedarach* (TSh.928 328.00 ha^{-1}) followed by cutting + 2, 4-D (TSh. 749 577 ha^{-1}), 2, 4-D (TSh.682 949.00 ha^{-1}) and hand pulling + 2, 4-D (TSh. 648 281.00 ha^{-1}) treatment with average pasture yield of 14.02 t ha^{-1}, 14.02 t ha^{-1}, 12.76 t ha^{-1} and 12.10 t ha^{-1} respectively. Non-integrated weed management practices resulted in the lowest marginal return compared to application of integrated weed management practices. Consequently this study recommends integrated management package involving cutting + 2, 4-D, hand pulling + *M. azedarach* and hand pulling + 2, 4-D to control Kongwa weed in rangelands as they minimize the cost of production required for optimum yield and increased profitability.

Key words Kongwa weed, Marginal return, Cost benefit ratio

4.2 Introduction

Naturally-occurring pasture in Kongwa ranch found in Dodoma region, Tanzania offers over 90% of the feedstuff requirements of ruminant livestock (Sarwatt and Mollel, 2006). Kongwa ranch, being the biggest in the country has an area of 38 200 ha with a carrying capacity of 14 400 cattle (excluding feedlots) (NARCO, 2012). Recently the ranch was subjected to severe pasture depletion for a variety of reasons, including the infestation of noxious weeds particularly Kongwa weed (Nkombe *et al.,* 2018). According to Rai *et al,* (2012), noxious and an invasive weed species defined as an unusual species that pose harmful effects to native species and ecosystems hence causing significant economic damage in grassland and cropland as well as natural areas. Farmers' income and economic benefit, from livestock production is reduced due to weed infestation (Daramola *et al*., 2019). Even with improved and advanced technologies high losses are recorded by farmers as a result of weed interference. Economic losses due to weed infestation in pasture production vary with the cost of weed management used such as hand pulling, slashing, cultural, and chemical or bio herbicides (Sodangi *et al*., 2006).

Reduction in quality, interference with farm operations, reduce land use efficiency, reduced water use efficiency in water bodies and poison to humans and livestock and increase in the cost of production through direct yield losses associated with weed infestation (David, 2015). The management of rangelands has become complex due to increasingly invasion of noxious weed (Boyd and Svejcar 2009). Several weed management practices have been manipulated to improve the natural pasture in grazing lands including controlled burning, cutting and uprooting the weed but indigenous knowledge still challenges the farmers in controlling the weed in grazing and crop lands (Nkombe *et al.*, 2018). However, the adoption of integrated weed management options was economically viable in many land uses compared to singly techniques and that indigenous knowledge for weed managements.

4.3 Materials and Methods

4.3.1 Description of the study areas

The study was conducted at two sites in Kongwa district of Dodoma region in central Tanzania with different weeds population and growth stage. Site A located at 06.06225S, 36.34204E and 992 m above the sea level was occupied with low weed population in vegetative growth stage. Site B located at 06.07862S, 36.32756E and 962 m above the sea level, the field occupied with high weeds population during flowering stage (Figure1). The study area is semi-arid zone, with an average annual rainfall of 500 – 800 mm, which falls between December and April. Rainfall is unimodal, unpredictable, and poorly distributed with high variation within and between seasons (Nkombe, *at el*., 2018). The mean temperature is 26.5°C, but sometimes gradually changes up to 11°C. The cool weather occurs between January and June when temperature ranges between 20 – 33°C and the highest temperature recorded is 31°C while the lowest temperature is 18° C (PORA and LGOVT, 2016). The dominant soil types are classified as Chromic Luvisols with a sandy loam texture (Mkonda and He, 2017).

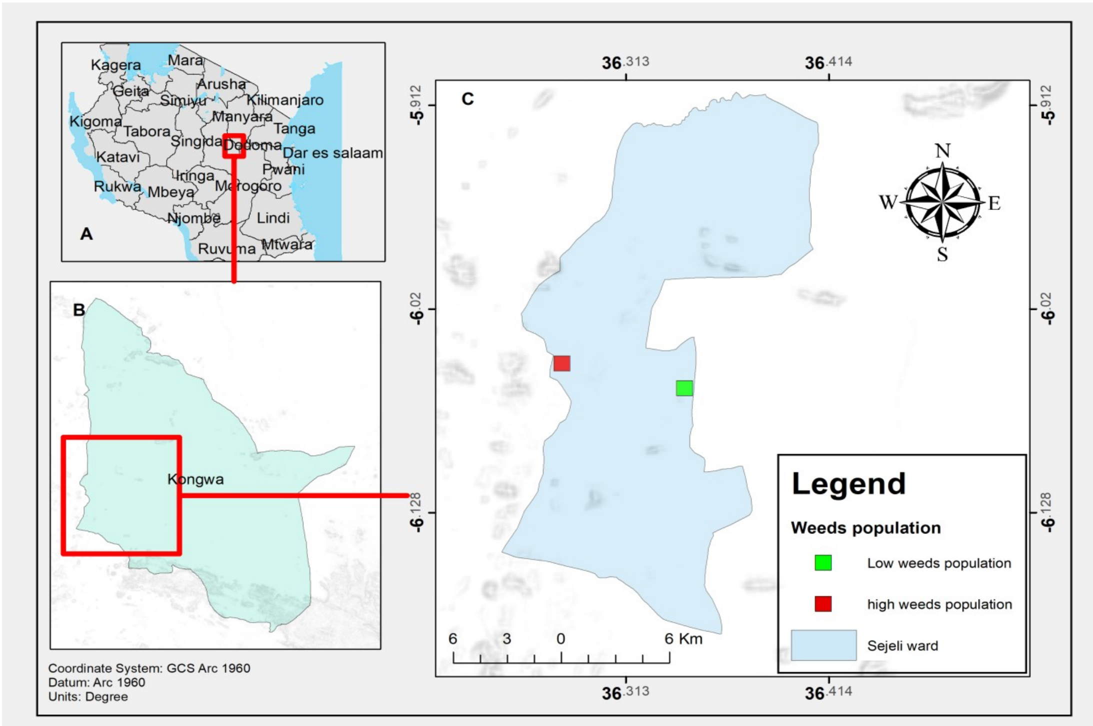

Figure 4.1: Study area. A represents Tanzania, B represents Kongwa District and C represents experimental sites

4.3.2 Experimental design

The experiment at site A was laid out in a randomized complete block design (RCBD) with five treatments replicated four times. Each replication contained five treatments: *M. azedarach, R. communis,* 2, 4-D, Hand pulling and Control as weed management practices. Treatments were applied in selected paddock occupied with *Cenchrus ciliaris.* The paddocks had low Kongwa weed infestation during vegetative stage of growth. The dimension of each plot was 5m x 5m and the distance between the plots was 1m. The distance between one replication and another was 1m. All treatments were applied to existing natural vegetation in grassland. The experiment was carried from 13, January to 13 March 2020.

The study at site B was laid out in a randomized complete block design (RCBD) with 12 treatments replicated four times. Each replication contained 12 treatments. *M. azedarach*, hand pulling + *M. azedarach*, cutting + *M. azedarach*, *R. communis*, Cutting+*R. communis,* 2,4-D, hand pulling+2,4-D, cutting+2,4-D, cutting, hand pulling and Control were applied in a selected paddock occupied with *Cynodon dactylon* highly infested with Kongwa weed at flowering stage. The dimension of each plot, distance between plots, distance between replication and treatment allocation were as described in site A. The experiment was carried out from 17, February to 17 April 2020.

4.3.3 Data collection

An economic analysis of natural pasture production and weed management practices were carried out based on benefit cost ratio using partial budgeting (Daramola, *et al.*, 2019). The variable costs including purchasing herbicides, acquiring of plant materials and labour cost for land preparation, plant extracts application, physical weeding, herbicide application and harvesting was calculated by working out expenditure using prevailing price on different aspects of weed management and gross income under different treatments. The net return and cost-benefit ratio were also calculated to determine the feasibility of the treatments. Data collected from two sites were used to estimate the profitability of pasture yield under different weed management practices. The return produced from each treatment was found by multiplying the pasture yield by the market price which is Tsh 1600/= for 10kg bale. However weed population were obtained by sampling from two quadrants of 1 m x 1 m in each plot using zigzag method of Thomas, (1985) was used.

4.3.4 Data analysis

Data on cost of acquiring herbicide and plant materials; labour cost on land preparation, plant extract and herbicide application, hand pulling, and pasture harvesting were recorded and used to compute the benefit cost ratio according to (Daramola, *et al.*, 2019)

Where:

MR = GR – TVC…………………………………………………...…………. 1

MR Marginal revenue per hectare (TSH ha^{-1}) TVC is the Total Variable Cost of weed management's technics (TSH ha^{-1})

GR = Quantity × Price ……………………………………….………………. 2

GR is Gross Revenue per hectare (TSH ha^{-1}), Quantity is total pasture yield harvested in kilograms per hectare (t ha^{-1}), and Price is the market price of pasture

Total Variable Cost (TVC) = Summation of all variable cost

The benefit cost ratio (B: C) for each treatment was calculated by dividing gross profit by the total cost of weed control methods

Benefit Cost Ratio = $\frac{Marginal\ returns\left(MR\right)}{Total\ variable\ cost\left(TVC\right)}$ ……………………………...

………….3

If the B: C < 1 then the costs exceed the benefit, therefore the tested weed control package will be rejected. However, if the B: C≥ 1 then the benefits exceeds the costs, therefore the tested weed control package will be accepted.

4.4 Results and Discussion

4.4.1 Cost benefit assessment of Kongwa weed management option in site A

The results (Table 4.2) indicate that, the higher profits of controlling Kongwa weed in range lands were obtained from *M. azedarach* (TSh. 435 555.00 ha^{-1}) with mean pasture yield of 8.94 t ha^{-1} and 2, 4-D (TSh 232 053.00 ha^{-1}) which have mean pasture yield of 6.58 t ha^{-1}. Losses were recorded in control treatment TSh. -13 751.80 ha^{-1}, resulted from the mean pasture yield of 2.8 t ha^{-1}, respectively as indicated in Table 4.1.

The market price of pasture used for the budget estimation for *M. azedarach*, *R. communis*, hand pulling and 2, 4-D treatments was the same; thus, differences in revenue were largely due to variations in pasture yield levels of each treatment. The high yield level of pasture treated with *M. azedarach* was a major factor accounts for relatively high return and low variable cost compared to pasture treated with 2, 4-D. Also the increase in profit with application of *M. azedarach* could be attributed to effective weed suppression and reduced weed-pasture competition for resources, enhanced by allelochemicals released by *M. azedarach* (Akacha *et al.*, 2013; Kumar *et al.*, 2017; Alves *et al.*, 2019) compared to *R. communis*. These results are in line with findings by Hong *et al*. (2004) where *M. azedarach* suppressed weed growth, caused no injury and had higher yield in crops such as rice.

Table 4.1: Treatments effects on pasture yield in site A

Treatments	Weed Population (m^{2-1})	Yield ($t\ ha^{-1}$)	Weight of Kongwa weed ($t\ ha^{-1}$)	Weight of other weeds ($t\ ha^{-1}$)
M.azedratch	1.81a*	8.94c	0.23a	0.37ab
2,4-D	1.92a	6.58bc	0.002a	0.19a
Hand pulling	2.72a	5.15ab	2.40a	1.18ab
R.communis	3.38a	4.78ab	1.86a	1.11ab
Control	10.92b	2.89a	8.03b	2.13b
Mean	4.16	5.67	2.51	0.99
SD	0.77	0.50	0.45	0.31
CV%	18.52	8.80	18.00	31.32

*Mean in the same column, followed by the same letter(s) do not differ significantly (P≤0.05) according to Tukey's honestly significance test., CV = coefficient of variation. SD = Standard deviation.

Table 4.2: The cost of different weed management option in site A carried out from 13, January to 13 March 2020

VARIABLE COSTS	*M.azedarach*	2,4-D	*R.communis*	Handpulling	Control
A: Input cost					
Herbicides purchase	-	30,000.00	-	-	-
Acquire Botanicals	25,000.00	-	25,000.00		
Sub total 1	25,000.00	30,000.00	25,000.00		
B: Labour cost	-	-	-		
Land preparation and layout	20,000.00	66,667.00	20,000.00	20,000.00	66,667.00
Plant extracts application	66,667.00	-	66,667.00	66,667.00	-
Physical weeding	-	-	-	87,500.00	-
Herbicide application	-	66,667.00	-	-	-
Sub total 2	86,667.00	96,667.00	86,667.00	100,000.50	-
C: Harvesting cost	-	-	-	-	-
Slashing/Mowing	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00
Sorting	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00
Baling hay	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00
Sub total 3	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00
TOTAL VARIABLE COST (TVC)	279,667.00	294,667.00	279,667.00	342,167.00	234,667.00
REVENUE	-	-	-	-	
A: Hay Yield (t ha -1)	8.94	6.58	5.15	4.79	2.76
B: Price of Hay (Tshs/ Bale)	80000	80000	80000	80000	80000
GROSS REVENUE	715,200.00	526,720.00	411,959.81	383,078.40	220915.2
MARGINAL RETURN (MR) = GR – TVC	435,533.00	232,053.00	132,292.81	40,911.40	-13751.80
BENEFIT COST RATIO (BCR) = GR/TVC	**2.6**	**1.8**	**1.5**	**1.1**	**0.9**

*Exchange rate July 2020 was an average of Tshs 2318 to 1 USD.

4.4.2 Cost benefit assessment of Kongwa weed management option in site B

Table 4.4 showed a negative net return (loss) from untreated range land situations (TSh. – 76 892.00), which implies that weed management is an essential component of profitability in the grazing lands. On the other hand, highest net profit were recorded from treatments of hand pulling + *M. azedarach* (TSh.928 328.00 ha^{-1}) followed by cutting + 2, 4-D (TSh. 749 577 ha^{-1}), 2, 4-D (TSh.682 949.00 ha^{-1}) and hand pulling + 2, 4-D (TSh. 648 281.00 ha^{-1}) with the average pasture yield of 14.02 t ha^{-1}, 14.02 t ha^{-1}, 12.76 t ha^{-1} and 12.10 t ha^{-1} and 4.4 respectively (Table 4.3). The high pasture yield in plots applied with cutting + 2,4-D, hand pulling + *M. azedarach* and hand pulling + 2, 4-D was a major factor that accounts for their relatively high return and low variable cost compared to plots treated with *R. communis*, cutting, hand pulling and cutting + *R. communis*.

Thus, success of pasture production in grazing lands depends on effective integrated approaches in weed management. As a single weed control method may not be successful on rangeland occupied by a high population of noxious weeds (Kongwa weed); hence the weed problem needs to be solved by an integrated approach. Singh *et al*. (2018) reported that, effective weed management on long-term sustainable basis can be achieved by integrating physical and chemical herbicides or bio-herbicides with effective allelopathic properties. Application of herbicides in combination with physical weeding (Gare *et al*., 2015) proved to be effective and viable weed management practice even for other crops like chilli, *Capsicum annum*. Through use of cutting + 2, 4-D, hand pulling + *M. azedarach* and hand pulling + 2, 4-D strategies, control of this noxious weed species was greatly improved as compared to physical methods, synthetic herbicide and bio-herbicides applied singly. Thus integrated weed management potentially reduces the amount and frequency of synthetic herbicides application, minimising the possibility of injury to desirable pasture and increasing the stability of the ecological community in rangeland. Similar findings were reported by Soltani *et al*. (2012); Miller, (2016) and Osipitan, *et al*. (2018) whose results indicated that integrated weed management treatments provide higher gross and net returns, compared to non-integrated approaches. According to Malidza *et al.* (2016); Bajwa *et al.* (2017) such integrated strategies have shown to enhance control of many noxious weed species, while potentially reducing the amount of herbicide applied, lessening the possibility of injury to adjacent desirable vegetation and increasing the stability of the ecological community at the site. Therefore integrated weed management treatments increase the benefit-cost ratio that results in maximum economic benefit for pasture production.

Table 4.3: Treatments effects on pasture yield in site B

Treatments	**Weeds Population (m^{2-1})**	**Pasture Yield (t ha^{-1})**	**Weight of Kongwa weed (t ha^{-1})**	**Weight of other weeds (t ha^{-1})**
Hand pulling + *M.azedarach*	5.36ab*	14.02e	1.07ab	0.50ab
Cutting + *M. azedarach*	3.96a	9.95cde	0.76a	0.73ab
Cutting	8.96c	4.48abc	10.54c	4.30bc
Cutting+*R.communis*	6.53abc	4.26abc	8.08c	2.66abc
Hand pulling+2,4-D	4.80ab	12.76e	0.00a	0.43ab
2,4-D	4.76ab	12.10de	0.24a	0.12a
Cutting+2,4-D	4.10a	14.02e	0.14a	0.86ab
M.azedarach	4.58ab	7.68bcd	4.09abc	0.72ab
Hand pulling	6.64abc	3.39ab	9.29c	6.12c
R.communis	8.75c	2.80ab	10.04c	6.38c
Hand pulling+*R.communis*	7.28bc	5.00abc	7.78bc	2.75abc
Control	22.43d	1.39a	22.73d	1.09ab
Mean	7.35	7.64	6.24	2.22
SD	0.44	0.61	1.06	0.64
CV%	6.00	8.00	17.00	29.00

*Means in the same column followed by the same letter(s) do not differ significantly ($P \leq 0.05$) according to Tukey's honestly significance test. CV = coefficient of variation. SD = Standard deviation.

Table 4.4: The cost of different weed management option in site B carried out from 17, February to 17 April 2020.

VARIABLE COSTS	M.azedarach	R.communis	2,4-D	Handpulling	Cutting+2,4-D	Hand pulling+M.azedarach	Hand pulling+2,4-D	Cutting+M.azedarach	Hand pulling+R.communis	Cutting	Cutting+R.communis	Control
A: Input cost												
Herbicides purchase	-	-	30,000.00	-	30000					-		-
Acquire Botanicals	25,000.00	25,000.00	-		-	25,000.00	-	25,000.00	25,000.00		25,000.00	
Sub total 1	25,000.00	25,000.00	30,000.00		30000	25,000.00	30,000.00	25,000.00	25,000.00		25,000.00	
B: Labour cost	-	-	-		-	-	-	-	-		-	
Land preparation and layout	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00	20,000.00
Plant extracts application	66,667.00	66,667.00		-	-	66,667.00	-	66,667.00	66,667.00	-	66,667.00	-
Physical weeding	-	-	-	87,500.00	87,500.00	87,500.00	87,500.00	87,500.00	87,500.00	87,500.00	87,500.00	-
Herbicide application	-	-	66,667.00	-	66,667.00	-	66,667.00	-	0	-	0	-
Sub total 2	86,667.00	86,667.00	86,667.00	100,000.50	86,667.00		174,167.00	174,167.00	174167	100,000.50	174167	200000
C: Harvesting cost	-	-	-	-	-	-	-	-	-	-	-	-
Slashing	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00	48,000.00
Sorting	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00	64,000.00
Baling hay	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00	56,000.00
Sub total 3	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00	168,000.00
TOTAL VARIABLE COST (TVC)	279,667.00	279,667.00	284,667.00	275,500.00	372,167.00	193,000.00	372,167.00	367,167.00	367,167.00	275,500.00	367,167.00	188,000.00
REVENUE	-	-	-	-						-		
A: Hay Yield (t ha-1)	7.68	2.80	12.10	3.39	14.0218	14.0166	12.7556	9.9476	5.0024	4.48	4.26	1.38885
B: Price of Hay (Tshs/ Bale)	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000	80000
GROSS REVENUE	614,432.00	223,808.00	967,616.00	271,024.00	1121744	1121328	1020448	795808	400192	358,431.33	340,912.00	111108
MARGINAL RETURN (MR) = GR – TVC	334,765.00	(55,859.00)	682,949.00	-4476.00	749,577.00	928,328.00	648,281.00	428,641.00	33,025.00	82,931.33	-26255.00	-76892.00
BENEFIT COST RATIO (BCR) = GR/TVC	**2.2**	**0.8**	**3.4**	**1.0**	**3.0**	**5.8**	**2.7**	**2.2**	**1.1**	**1.3**	**0.9**	**0.6**

*Exchange rate July 2020 was an average of Tshs 2318 to 1 USD.

4.5 Conclusions and Recommendation

4.5.1 Conclusions

The total variable cost of pasture production was considerably influenced by the cost of weed management. Lowest cost of weed control resulted by using IWM that gave the highest benefit-cost ratio, while higher cost of weed control was corded for single treatments. The higher profits were due to increased yield at a relatively less cost in IWM. Where Kongwa weed was applied with single treatment, lower yield and marginal return were consistently achieved compared to where supplemented by a combination of treatments.

4.5.2 Recommendation

This study recommends cutting + 2, 4-D, hand pulling + *M. azedarach* and hand pulling + 2, 4-D weed management practices to reduce Kongwa weed in grazing lands and consequently minimising the cost of production required for optimum yield and increased profitability.

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CHAPTER FIVE

5.0 GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study concludes that, *M. azedarach* is an important plant species in controlling Kongwa weed due to its allelopathic effect and thus it can be used as a bio-herbicidal plant compared to *R. communis* and *N. tabacum*, but all allelochemicals activities depend on the level of concentration applied. Therefore, appropriate weed control provided a favourable environment for the pasture growth and development. Integrated weed management option was more effective than single treatment when applied in high weed infestation. Where single treatment was applied, lower yield and marginal return was consistently achieved compared to where supplemented by a combination of treatments.

5.2 Recommendations

For sustainable ecosystem results suggest that *M. azedarach* and *R. communis* should be used as bio-herbicides in managing Kongwa weed in rangelands rather than using industrial herbicide which is not environmentally eco-friendly. Therefore, appropriate concentration of *M. azedarach* and *R. communis* to be used in open fields particularly in grazing lands. Finally the study recommends integrated weed management option could be applied in high weed infestation, whereas herbicides or plant extracts could be applied singly in low weeds infested range lands, because minimising the cost of production required for optimum yield and increased profitability.