CHARACTERIZATION OF BIOLOGICAL FEATURES OF THE KONGWA WEED (*Astripomoea hyoscyamoides* Vatke verdc) IN KONGWA DISTRICT, CENTRAL TANZANIA

YACOB MANYABULUBA LUSAMILA

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ABSTRACT

A study was carried out in Kongwa ranch and surrounding villages to evaluate the biological characteristics of kongwa weed. The study site was stratified into three land use types namely; Grazing Land (GL), Crop Land (CL) and Bush Land (BL). The study used split-split-plot design, whereas study areas (Kongwa Ranch, Sejeli and Ngomai villages) were considered as main factor while land use types and soil textural compositions were treated as minor factors within the split plots. Range inventory techniques were used to determine species composition. Soil samples were taken from each land use types for laboratory analysis. Three textural soil types (Clay, Loamy-Sand, and Sand-Clay-Loamy) were determined from each land use type. Kongwa weed seeds were randomly planted in different soil texture sampled from grazing, crop and bush land. A total of forty one plant species were identified during range inventory of which the Kongwa weed was significantly higher in terms of coverage, occurrence and density in grazing land in the grazing land of Kongwa Ranch. The soil pH from grazing (5.35) and crop land (5.72) was relatively acidic than in the bush land (7.11) it seemed to favour the growth of kongwa weed. The highest mean soil bulk density values (1.57 g/100 cm^{-3}) recorded in the grazing land and crop lands (1.49 g/100 cm^{-3}). The relatively lowest soil bulk density in the bush land (1.42 g/100 cm^{-3}) was attributed to litter decomposition available in the bushland soil. Moreover, the poor performance of Kongwa weed was observed in the bush land ^{x} clay interaction, crop land ^{x} clay interaction and grazing land ^{x} clay interaction rather than the two land use type ^{x} sandy clay loam and land-use type ^{x} loamy sand. By understanding appropriate biological characteristic of the weed in different land use types and soil textural soils may be useful in developing effective integrated control measures and increasing awareness among a wider range of stockholders such as agro-pastoralists, pastoralists, researchers and policy makers.

Keywords: Growth**,** Characteristics, Kongwa weed, Land use type, Plant species

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DECLARATION

I, Yacob Manyabuluba Lusamila, declare to the Senate Postgraduate Student Committee that this dissertation is my original work and that it has either been submitted or concurrently submitted in any other institution.

……………………………………… ....…...…………

Yacob Manyabuluba Lusamila Date

(MSc. Tropical Animal Production Candidate)

The above declaration is confirmed

…………………………………… …….………….…………

Dr. Ismail S. Selemani Date

(Supervisor)

…………………………………… …………......…..………

Prof. Anthony Z. Sangeda Date

(Supervisor)

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DEDICATION

This treasurable work is dedicated to my beloved mother Lucia Mchele Henye and young brother Elias Lusamila for their tireless encouragement and support during the course of my studies.

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LIST OF ABREVIASSIONS AND SYMBOLS

BL	Bush land
cm	Centimeter
CL	Crop land
COSTECH	Tanzania Commission for Science and Technology
COVID	Corona virus disease
DAS	Days after sowing
DAARS	Department of Animal, Aquaculture and Range sciences
Fig	Figure
G	gram
GL	Grazing land
GPS	Global positioning system
H′	Shannon Wiener diversity index
KDC	Kongwa District Council
K^+	Potassium
LL	Leaf length
LW	Leaf width
Ln	Natural logarithm
LGVT	Local Government
M	Meter
N	Total number of individual species for the sites
Ni	Number of individual of each species
NoL	Number of leaves
NoB	Number of branches
NARCO	National Ranching Company

MM	Millimeter
P	Phosphorus
PORA	President's office regional administration and local government
RL	Root length
S	Species richness
SE±	Standard error of means
SE	Seedling emergence
SOM	Soil organic matter
SOC	Soil organic carbon
%	Percentage
TALIRI	Tanzania Livestock Research Institute
TN	Total nitrogen
UNIDO	United Nations Industrial Development Organization
WG	Weed stem girth

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Kongwa weed (*Astripomoea hyoscyamoides* Vatke verdc) is one of the noxious species in the Convolvulaceae family commonly known as the morning glory family under the genus of *Astripomoea.* The noxious and invasive weeds are described as plant species growing where they are not wanted and cause negative impacts on native species and ecosystems (Zahid *et al.* 2004; Olson. 2006). They can directly affect other native plants by becoming either monopolisers or suppressors of palatable vegetation resources (Richardson *et al.* 2000). Globally, the weed invasions have been reported to disrupt nutrient cycling and availability (Ehrenfeld, 2003; Weidenhamer and Callaway. 2010), displace native plant communities and change botanical composition as well as their tropic food webs (Callaway and Aschehoug. 2000; Brown *et al.* 2002).

The displacement of native plant species by non-native plant species in their ecological habitats, contribute significantly to loss of crop and pasture yield hence accelerate to pastoralists and agro-pastoralists economic losses (Pimentel *et al.* 2002). Severe loss of agricultural and livestock production associated with the effect of the noxious weeds have been documented in various parts of the world (Borokini and Babalola. 2012). The estimated annual management cost of $ 137 billion for invasive and $ 34 billion in the management of noxious weeds was reported in the United State of America and $ 600 million in Queensland (Pimentel *et al.* 2001). Furthermore, South Africa alone spends over $60 million annually for controlling invasive and noxious weeds (Duncan. 2005). In Tanzania, the weed species have been reported to cause death of livestock through poisoning and destroying livestock forage, accelerating biodiversity loss through suppression of native plants, increasing diseases by offering a breeding ground for disease vectors such as mosquitoes and other insects that carry nagana and sleeping sickness (Obiri. 2011).

1.2 Kongwa weed in Africa

The Kongwa weed was previously reported in Kibwezi and Meru National Park in Kenya (Fenner. 1982) and Somalia (Thulin. 2006). Furthermore, the Kongwa weed has been also reported in other tropical countries such as Botswana, Burundi, Cameroon, South Africa (Cape Provinces and KwaZulu-Natal), Central African Republic, Chad, Eritrea, Ethiopia, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sudan, Uganda, Zambia, DRC Kongo and Zimbabwe during range inventory (Lejoly and Lisowski 1993). Despite the appearance of Kongwa weed in different tropical countries, no studies to date have been conducted on biological characteristics or effects of the weed on rangelands and crop lands. Therefore, there is an urgent need to understand the attributes of the species in terms of its biological characteristics, distribution and effects in other plant species on different land use types.

1.3 Kongwa weed in Tanzania

The Kongwa weed had been mentioned since 1940's and 1979 by Peterson and McGinnes on vegetation of south Masailand, Tanzania a Range Habitat Classification research. The distribution and density of Kongwa weed is still increasing in many parts of Kongwa district and the species has been noted in the other locations outside the Kongwa district such as Kiteto, Chamwino, Pwani, Kilindi, Tanga and Morogoro region. It has been noted that, the Kongwa weed covers more than 70% of the area of Kongwa ranch and reported to have impact on pasture production (Lutege R, person communication. 2020). According to Nkombe *et al.* (2018) pastoralists and agro-pastoralists in Kongwa district have experienced poor crop yield and quality of forage species probably due to Kongwa weed infestation. Koukoura and Kyriazopoulos, (2007) reported that the dominance of annual plant species in a given area is attributed to their ability to compete their life cycle during rain period and therefore exploiting better the season rains. For example, Kongwa weeds were reported to dominate in grazing and crop lands of Kongwa district during rain seasons as shown in Fig 1.1 and 1.2.

Fig 1.1: Kongwa weed infestation in the grazing land of Kongwa ranch in Kongwa District, Tanzania during March 2020 (source: field photo)

Fig 1.2: Kongwa weed infestation in the crop land of Sejeli village in Kongwa District, Tanzania during May 2020 (source: field photo)

The Kongwa weed is an increaser species in the grazing lands of Kongwa district as it is not preferred by livestock and only used during critical time of forage shortage (Fig 1.3). Livestock may be a source of spreading of weeds outside its original domicile (Chuong *et al.* (2016). Although many different plant species may be consumed by animals, only a subset of those produce seeds that are able to survive the harsh conditions of the digestive tract Traveset *et al*. (2007).

Fig 1.3: Kongwa weed infestation in the grazing land of TALIRI- Kongwa during May 2020 (source: field photo).

1.4 Problem Statement and Justification of the Study

1.4.1 Problem statement

About 90% of livestock production in Tanzania depends on rangelands characterized by inadequate and low quality of the natural pastures attributed by many factors including weed infestation (Mwilawa *et al.* 2008). Inadequate and low quality forage in many rangelands is due to replacement of desirable forages by undesirable plant species which subsequently lead to poor animal growth and productivity (Nkombe *et al.* 2018). For example, 10% of stocking density of cattle in Kongwa ranch has been reported to decrease yearly due to inadequate pastures mainly due to Kongwa weed infestation (Nkullo. 2013; UNIDO. 2012). Likewise, Kongwa weed affects grazing distribution in the grazing lands because the livestock tends to ignore areas with a high concentration of Kongwa weed as a result the carrying capacity have be substantially diminished. The previous study showed that 75% of livelihoods of farmers in Kongwa district have been negatively affected by infestation of Kongwa weed putting the desirable forages and crops at a competitive disadvantage and finally causing a huge reduction on natural and crop yield that is supporting the population of agro-pastoralists in Kongwa district (Nkombe *et al.* 2018).

1.4.2 Justification of the study

One of the most important aspects of managing the spread of the noxious weeds is to understand the biological characteristics of the weed in a given ecological pattern (Goodland. *et al.* 1998). Knowing the Kongwa weed growth and reproductive characteristics on different land use types is essential for developing environmentally and acceptable controlling management strategies to suppress the rapid spread in and outside its original domicile. The findings from this study aimed at creating a better understanding the biological features of the Kongwa weed that can be useful in the management decisions and therefore lead to evidence based strategies for long-term management of the weed.

1.5 Objectives of the study

1.5.1 General Objective

The general objective of this study was to characterize the biological features of the Kongwa weed in Kongwa District.

1.5.2 Specific objectives

i. To determine distribution and compostion of Kongwa weed in different land-use types.
ii. To assess the soil characteristics in relation to kongwa weed distribution from different land use types
iii. To assess the growth performance and seed yield of kongwa weed subjected to different soil properties collected from different land use types.

1.6 Research Hypothesis

1.6.1 Null hypothesis

i. There is no significant difference on distribution and composition Kongwa weed in the different land-use types.
ii. There is no significant difference on soil characteristics in relation to kongwa weed distribution from different land-use types
iii. There is no significant difference on growth performance and seed yield of kongwa weed subjected to different soil properties collected from different land use types

1.7 Research Limitations

One of the noted limitations was the COVID-19 Pandemic which reduced access of the researcher and research assistants to undertake the surveys on time.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview on weed biology

Weeds are unwanted and undesirable plants which interfere with the utilization of land and water resources and therefore greatly affect human income (Lundkvist and Verwijst. 2011). Weed biology research aims to generate knowledge that is expected to be applied in the practical control of weeds. This should include integrated research from basic to applied with all elements contributing to real improvements in weed control (Moss. 2008). Characterization of biological features of noxious and invasive weed is performed for the benefit of different land users particularly farmers and livestock keepers to minimize yield losses in pasture and agricultural production.

2.2 Classification of weed species

Weed species are classified into two main groups; annual and perennial weed that invade in the new environment. Annual weeds propagate by seeds, grow, flower, set seeds and die within a year after germination while perennial weeds propagate through both seeds and vegetative parts (roots and stems). Kongwa weed is one of noxious annual weed in the rangelands and crop lands in central Tanzania (Nkombe *et al*. 2018).

2.3 Emerging of Weed Species on grazing and cultivated land

Over-utilized lands are frequently colonized by noxious weed species and cause the most palatable species to be depleted to an extent that enclose bare surfaces to relieve them from livestock activity (Mugerwa *et al.* 2012). Livestock can facilitate the establishment of invasive plants by trampling and defoliation of palatable native plant species, therefore reduce their competitive ability and create bare patches and disrupt nutrient cycles (Kimball and Schiffman. 2003; Dorrough *et al*. 2004). The increasing number of livestock in a given land leads to the high soil compaction, bare and alter vegetation composition (Eldridge *et al.* 2016).

Conversion of natural forest to other forms of land use like farmlands and pasturelands can stimulate soil erosion and lead to loss in soil nutrients and modification of soil structure (Maitima *et al.* 2009). Moreover, Yimer *et al*. (2008) reported that change in land use type negatively affects soil productivity characteristics such as soil bulk density and hydraulic conductivity. Islam and Weil. (2000) reported an increase in bulk density and a reduction in porosity and aggregate stability following the conversion of forest land to cropland with consequent degradation of the adjacent aquatic system. The association of weeds with a traditional agricultural practice develops when a particular practice is applied continuously on the farm(Wezel. 2000), changes in land management such as from short to long period of cultivation or even permanent cropping result into soil degradation and high weed infestation(Dorado *et al.* 2006). Different tillage systems may provide different types of manipulated habitats that may facilitate the weed invasion, for example, changes in the soil tillage lead to a shift in weed composition and density (Baker *et al.* 2018).

2.4 Successful establishment of Noxious Weeds in Grazing Lands

The successful of noxious weeds in the rangelands are intimately associated with the inherent characteristics such as high number of seed production, seed dispersal, accumulation of seed reserves in the soil, high percentage seed germination, growth of seedling (Hailu *et al.* 2003). Many noxious weeds, particularly broadleaf species have deep taproot systems and very little surface foliage compared with annual grasses and perennial bunchgrasses (DiTomaso 2000). The deep root systems of noxious weeds allow the plants to actively utilize water deeper in the soil profile and therefore grow well compared with native bunchgrasses and forbs. These plants with deep root are also able to store more carbohydrates in their roots and keep them in reserve through drought period (Deneke. 2013).

Successful establishment of weeds is determined by ability of seed production, seed dispersal, accumulation of seed reserves in the soil, germination of seeds, establishment and growth of seedling and maturation of the plant to produce fruit and seeds (Hailu *et al.* 2003). A high level of resource availability and low level of disturbances select species of weeds that display with traits that make them good competitors (Mahaut *et al.* 2020). However, Alpert *et al.* (2000) reported that the successful emergence of weeds in the new habitat can be linked with many factors such as ability to compete, level of disturbance regime, and high resource availability. Long *et al.* (2015) reported that the duration of seed longevity in the soil differ among species and population and also depends on the physical and physiological characteristics of seeds and how they are affected by the biotic and abiotic environment.

2.5 Factors Influencing Seed Germination and emergence of Noxious Weed on different Land use types.

Various environmental factors influencing seed germination includes temperature, light, moisture, salinity, soil acidity and depth of seed burial. These factors can affect seed germination separately (Koutsovoulou *et al.* 2014). The temperature of soil in dry and sparsely vegetated areas increases more significantly than those in more vegetated area (Massey *et al.* 2014). The direct effect of temperature on seeds and seed bank dynamics therefore suggests that any temperature increase related to climate change will be a critical driver determining species persistence and coexistence in such habitats (Ooi *et al*. 2009). Higher temperatures accelerate dormancy release for many physiologically dormant species (Steadman *et al.* 2003). The optimum temperature range for seed germination is between 5 and 15 ^{o}C (Rao *et al.* 2008). Soil moisture is a basic requirement for seed germination. The speed of germination and seedling establishment are also very important in habitats where water availability is restricted. The amount required is much less than that needed to sustain subsequent seedling and plant growth (Rao *et al.* 2008). If seedlings are to survive in habitats where soil moisture is limited, germination must be related to the soil water content required to sustain further growth.

The ability of seeds to germinate at low soil water potentials may lead to establishment failures if dry weather ensures whereas seeds with a more exacting requirement for germination may establish more successfully (Fenner. 2017). Absence of germination in salinity soil is usually due to the high concentration of salt in the soil where the seeds are sown and the reason is that the salt solution moves upward following the evaporation at soil level (Homa *et al.* 2007). However, Kim *et al.* (2012) reported that the soil salinity disturbs the seed germination and seedling growth hence, seedlings, growth, leaf area; root biomass and shoot biomass are reduced.

High soil acidity is associated with aluminum, hydrogen, iron and manganese toxicities to plants in the soil solution and corresponding deficiencies of the available phosphorus, molybdenum, calcium, magnesium and potassium (Rahman *et al.* 2018) Burial depth of seeds also affects germination and seedling emergence and these depths vary in availability of moisture, diurnal temperature fluctuation, and light exposure (Koger *et al.* 2004). Seed germination varies among 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 (Yadav *et al.* 2018).

2.6 Invasive Weeds Species versus Native Noxious Weeds

Invasive weed species are those colonizing an area from outside their range with or without human interference. They have a large impact on the new environment and this impact can involve community, ecosystem and economic effects (Davis *et al.* 2000). These noxious weeds have deep root system that allows the plants to get nutrient requirement far away as a result fast growth than the other native vegetation in the grazing areas (Shiferaw *et al.* 2018).

2.7 Effect of land use on native plant species

Human land use is the main current driver of changes in land cover on approximately 53% of the Earth's terrestrial surface (Hooke and Martin-Duque. 2012). These human-induced changes in land use shift the composition and spatial configuration of land cover types (Fahrig *et al*. 2011). Livestock such as cattle, goats and sheep can influence the establishment of undesirable plant species by trampling and defoliation of palatable native plant species; reduce their competitive ability and therefore create bare patches and disrupt nutrient cycles (Kimball and Schiffman. 2003; Dorrough *et al.* 2004) . Intensive grazing causes high compaction of the soil resulting in the prevention of water movement into and through the soil profile particularly during the rainy season. Grazing in general affects the ecosystem, disrupting both physical characteristics and the surrounding species population (Yitbarek *et al.* 2013).

The use of heavy machines like Tractors in the crop land increase soil compaction, hence lower soil porosity in the crop land use type (Eze *et al.* 2011). However, continuous cultivation practices and application of inorganic fertilizer might be one of the factors which are responsible for the variation in pH of the soil profiles (Muche *et al.* 2015). The invasive plant species usually possess broader tolerance to environmental condition including soil with low soil pH than crop and native plant species which have an optimum pH mostly ranging from 5.5 to 6.5 (Hae *et al.* 2017).The removal of vegetation cover by livestock grazing, crop residues in the crop land use type and expose the surface layer of the land to direct rain drop could be creating more surface runoff which can remove the animal and plant residues from the surface soil layer thereby cause soil nutrients depletion (Blanco-Canqui *et al.* 2015; Thomas. 2012).

2.8 Effects of Weeds on grazing and Crop Lands

Noxious weeds seriously prevent the growth of the native plant species in the crop and grazing lands due to its rapid growth, vegetative reproduction and inhibition of the regeneration of other native plant species through allelochemichals (Qi *et al*. 2014). The competitive ability of the noxious weed plants whether is an annual or perennial depend on the best utilization of limiting resources (nutrients, water, light and space) and capacity to cope with low resource level. Such ability depends on a combination of species traits that allow a species to compete for resource with neighboring native plant species (Weiner. 1993), including relative growth rate, height, lateral spread, storage organs, shoot thrust, leaf and shoot longevity and specific leaf area (Grime. 2001).

Noxious weeds may also change the soil biota through feedbacks with potential negative effect on native species particularly those caused by soil borne pathogens and parasites (Eviner *et al.* 2010). Furthermore, Richardson *et al.* (2000) reported that the noxious weeds can indirectly affect other plants species and change the 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. Some of noxious weed produce harmful chemicals as defacing mechanism that may be ingested, inflicting physical harm to grazing animals and reducing accessibility to forage (O'Connor *et al.* 2020). Noxious weeds cause inadequate of forage production when the weed is dominated in the area. Lowered grass forage production can have a negative herbivore carrying capacity in the grazing land with consequent economic and conservation implications (Mworia *et al.* 2009).

2.9 Effect of soil texture on plant growth characteristics

The relative proportions of sand, silt and clay particles also called soil texture has a major role in determining the extent to which specific soils become compacted and the possible effects on root growth (Kay. 2018).

The major effects on soil physical properties can prevent root growth, reducing the growth and yield of both annual and perennial plant species. Soils consisted predominantly of finer particles such as clay and silt can pack more closely within a define volume; however a large overall volume of pore space remains to allow growing root to extend rather easily

(White. 2006). The low performance of a plant in clay soils might be due to the lower macroporosity that could have attributed a greater resistance for root growth together with lower aeration of the rhizosphere which could have affected both root growth, vegetative and seed production Bécel *et al*. 2012).

2.10 Morphological Features of the Convolvulaceae Family

Convolvulaceae family is distinguishable by its plicate corolla, axile placentation with few ovule, bicollateral 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). However, 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.

2.10.1 Leaf size of the Convolvulaceae Family

Leaf blades elliptic to elliptic lanceolate, 2–16 x 1–6.3 cm, cuneate at the base, acute and apiculate at the apex, with margins entire or wavy above the middle; petiole 2.5–4.4 cm long. The leaves of the Convolvulaceae family are unbranched and a node bears only one similar organ such as a leaf or flower in most species (Ogunwenmo1998).The Convolvulacea family is annual or perennial herb, 0.5–2.4 m tall; stems often much branched above (Stefanovic *et al.* 2002). The tropical and sub-tropical Convolvulaceae family members have been observed to possess hairy/winding, creeping long stem with numerous internodes. Some of species of the Convolvulacea family have different length, for example *Ipomoea batata* plant has length between 14-100 cm, *Ipomoea triloba*120-186 cm, *Ipomoea vegans* 50-110 cm, *Ipomoea involucrate* 144-450 cm, *Merremia aegyptia* 90- 152 cm, *Hewittia sublobata*110-180 cm and *Evolvulus alsinoides* 28-45 cm (Okereke. 2015). 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). The variation of fruit morphology of the Convolvulaceae family often results from diversification in the structure of flowers (Ogunwenmo.2006). Even fruits derived from the same type of flowers may undergo distinctive on togenic pathways leading to variation in morphology (Esau. 1965).

Table 2.1: Summary of the Morphological features of Convolvulaceae Family

Plant Name	**Successive**	**Internode**	**Leave Breadth**	**Flower Length**
I. Batata	4.49 ± 6.29	2.2 ± 22.5	3.82 ± 5.4	3.69 ± 4.11
I. triloba	5.62 ± 13.28	5.2 ± 15.52	3.71 ± 11.85	4.65 ± 5.12
H. sublobata	3.98 ± 6.84	4.66 ± 9.8	1.84 ± 7.98	5.56 ± 6.92
I. Involucratea	3.79 ±11.71	11.17± 14.43	3.65 ± 7.63	13.65 ± 16.35
E. alsinoides	1.1 ± 1.7	2.4 ± 7.76	0.99 ±1.33	1.33 ± 3.29
M. aegyptia	9.07 ± 11.89	12.25± 58.27	8.17 ± 12.71	0.5 ± 7.26
I. vegans	2.4 ± 8.74	6.61 ± 21.73	1.46 ± 7.88	3.19±6.13
I. eriocarpa	1.04 ± 9.94	5.76 ± 15.50	8.78 ± 12.48	3.39 ± 19.77

Source: Okereke. (2015). International journal of herbal medicine

2.11 Conclusion

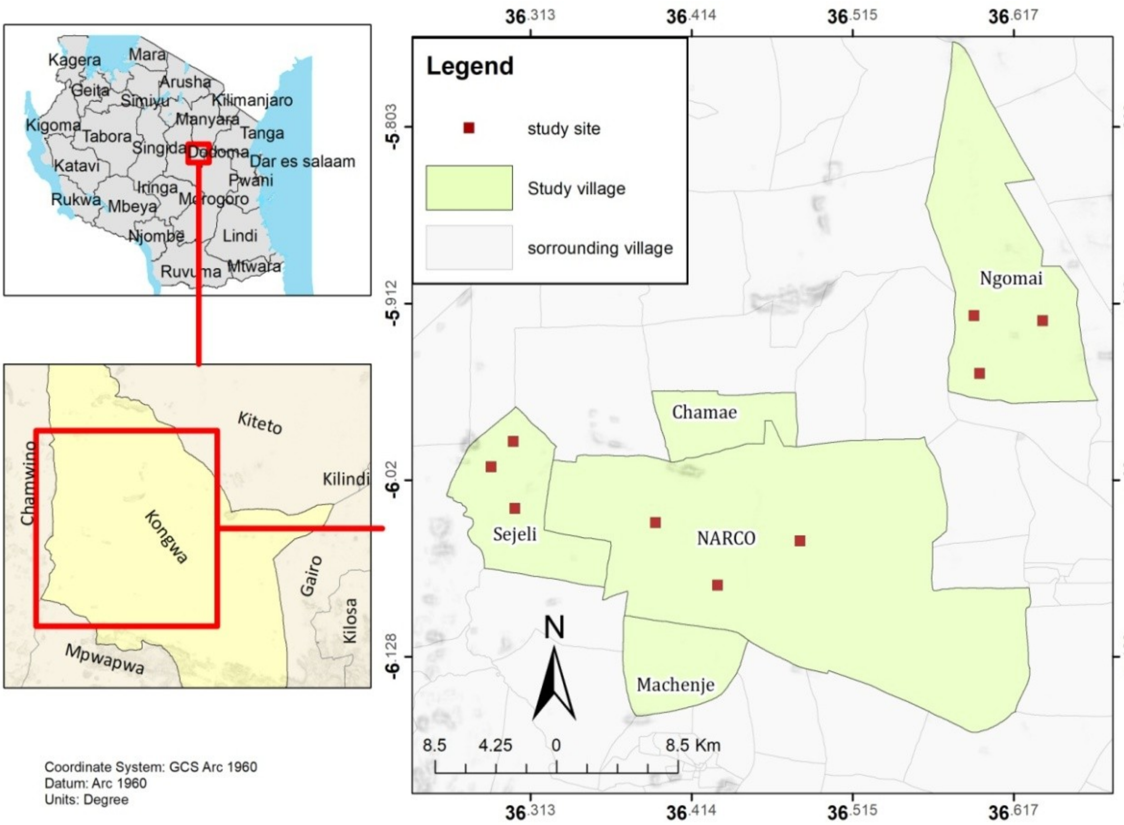
The literature review has revealed that noxious and invasive weed species are the most limiting factors to pasture yield in highly overgrazed rangelands and crop yield in continuously cultivated lands. Determination of species composition, assessment of status of the soil properties in different land use types and evaluation of weed growth characteristics on different soil types are very important in weed management. Scanty information has been documented on the biological features of Kongwa weed (a species belong to Convolvulaceae Family) in Tanzania. As a result there is high spread of Kongwa weed in and out of Kongwa district probably due to lack of knowledge of the biological features of Kongwa weed to pastoralist, agro- pastoralists and other stakeholders.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study Area

The study was conducted in Kongwa district, a semi-arid central part of Tanzania. The district is located about 86 km east of Dodoma city of Tanzania. The study area receives unimodal rainfall distribution starting from December to April ranged from 500 mm to 800 mm per annum (Nkombe *et al.* 2018). The mean temperature is ranging from 20°C to 33°C (PORA and LGOVT. 2016). The major economic activities for the residents are subsistence farming and livestock keeping both of them are rainfall dependent. The current estimates of livestock population stand about 117,599 cattle, 73196 goats, 33896 sheep and 2680 donkeys. Other animals including 3,744 dogs, 866 cats, 376,877 chickens and 5627 ducks (KDC. 2012). Three sites were randomly selected for conducting field survey and research experiments includes Kongwa ranch (06.08075S and 36.44792E), Sejeli (06.05134S and 36.31467E), Ngomai (06.91317S and 36.57979E) (Fig 3.1).



: Map showing the study sites in Kongwa district.

3.2 Research design and data collection

The research was conducted from January to June 2020 when most plant species were in the flowering stage. Sampling procedure, data collection and research design were done per specific objective. However, vegetation characteristics include ground cover, species frequency, density of Kongwa weed, Kongwa weed abundance, species diversity, richness, and evenness were determined among three land-use types (grazing, crop and bush lands).

3.2.1 Sampling procedure and data collection fordetermining Kongwa weed distribution in different land-use types

The line intercept method was used to assess vegetation composition and coverage. Three parallel line transects were established at 60 m apart started at 20 m away from the edge of grazing, crop and bush land to minimize edge effects. Twelve (12) stations of 10 m were established at every 20 m to make a total of 36 sampling units for each land-use type. Tape measure stretched out along the ground and the point where a vertical projection of the edge of the crown or base of a plant intercepts the tape-recorded in centimeters. A quadrat of 1 m × 1 m was used as a sampling unit for determining species frequency of occurrence, abundance, and density of Kongwa weeds on three land-use types. Each quadrat of 1 m × 1 m placed at 5 m intervals along the line transect makes 108 quadrats for each land-use type. Plant species within a quadrat were individually identified, counted, and recorded. Plant species identification performed through guide book of weeds of East Africa (Terry and Michieka. 1987), Guide to the naturalized and invasive plants of Eastern Africa (Witt and Luke. 2017), and the natural Forestry Resources Monitoring and Assessment of Tanzania (Vesa *et al.* 2010). The samples of unidentified plant species were taken to the Sokoine University of Agriculture for further identification.

The ground covered by vegetation was obtained by dividing the total linear length along the tape intercepted by the crown/base of a plant species (of all vegetation) by total length of the tape measure (1000 cm). The density of Kongwa weed (plants m^{-2}) was computed as a total number of weeds in all quadrats/ total number of quadrats used. While the % frequency of occurrence = (Total number of quadrats in which the weed occurred/ total number of quadrats studied) × 100 (El-Azazi *et al.* 2013). The species diversity was determined using Shannon-Wiener's diversity index $(H') = - \sum (ni/N) \times Ln\ (ni/N)\ N$. Where, ni = is the number of individuals of each species, N = is the total number of individuals (or amount) for the site, Ln = is the natural logarithm of the number. Species richness (S) was calculated as the total number of species per quadrat. While evenness was also calculated as (J) = H'/In (H_{max}), Where H′ is Shannon-Wiener's diversity index for the quadrat and H_{max} is the natural log of species richness.

3.2.1.1 Data analysis

The R software program version 3.3.4 (R Core Team, 2018) was used to analyse species diversity, richness, and evenness data. Vegetation ground cover, Frequency of occurrence by species and density of Kongwa weed were analyzed using the General Linear Model (GML) procedure of the Statistical analysis system (SAS. 2013). The mode used in this experiment was Yijl = μ + Li +Sij + Eijl. Where Yijl = Observation on the l^{th} plant species from the j^{th} land use type within the i^{th} site

μ = general means common to all observations

Li = effect of the i^{th} (Study sites)

Sij = effect of the j^{th} (land use type within site)

Eijl= Random error

3.2.2 Procedure and data collection for assessing soil characteristics in relation to kongwa weed distribution in three land use types

The soil samples were collected among three land-use types into two categories and replicated three times to make nine sites. The first category was undisturbed soil samples (structure, texture, density, and natural water content were not disturbed) and the second category was disturbed soil samples (The natural conditions of a sample such as its structure, texture, density, water content were distracted). One disturbed and eighteen (18) undisturbed soil samples were from each sampling site at a depth of 0 – 20 cm made a total of nine disturbed and 54 undisturbed soil samples. The size of each land use type was about 4 ha thus, a zigzag pattern of 60 m apart was used for sampling disturbed and undisturbed soil samples. The sampled area was cleaned using a hoe and bush knife thereafter the undisturbed soil samples were taken using a soil core sampler for determination of the soil bulk density and particle size, whereas six samples of disturbed soil were taken and mixed thoroughly to get one representative disturbed sample of each land-use type for determination of soil total nitrogen (TN), organic carbon (OC), available phosphorus (P), potassium (K+) and soil pH). Each sample site, coordinates were took using a handheld GPS (German), and all soil samples were packed, labeled, and transported to the Sokoine University of Agriculture Soil Science Laboratory.

3.2.2.1 Data analysis

The data for soil properties including soil particle size distribution, soil bulk density, soil pH, total nitrogen, organic carbon, soil organic matter, phosphorus and potassium were subjected to analysis of variance (ANOVA) at 5% using GenStat 16^{th} Edition statistical package. Treatment means were separated using Turkey’s significant test.

The model Yijk = μ + Li +S(ij) + Eijk. Where Yijk = Observation on the k^{th} soil properties from j^{th} land use type within the i^{th} site

μ =general mean common to all observations

Li = effect of the i^{th} (Study sites)

Sij = effect of the j^{th} (Land use type within the site)

Eijk= Random error

3.2.3 Evaluation of Kongwa weed characteristics in different soil texture types

The experiment was conducted during the rainy season from January to June 2020. Soils were from three land-use types; grazing, crop, and bushland of Kongwa Ranch, Sejeli, and Ngomae villages used in this experiment. The seedlings were counted and recorded from day one up to 28 days after sowing. The Kongwa weed stem heights, leaves, branches, stem girth, leaf length, and width were measured every two-week interval. Fruits and seeds were counted at the mature stage of the plant, and each plant was uprooted for the root length measurement. The Kongwa weed stem girth was measured in millimeters (mm) whereas, plant height, leaf length, leaf width, and root lengths were measured in centimeters (cm) using a tape measure.

3.2.3.1 Experimental design and layout

The experiment was laid out in split-split plot design where three sites (Kongwa Ranch, Sejeli, and Ngomae)were the main factor, while subplots were three land-use types (grazing, bush, and croplands) and sub-sub plots contained soil textural types with three levels (Clay, loamy sand and sandy clay loam) replicated three times to make twenty-seven planted pots. Each pot was sown five seeds of Kongwa weed at a depth of 1.5 cm. Pots were watered in absence of rainy by 1.5 liters of water per day for 112 days after sowing.

Table 3.1 Experimental layout

REP NO 01	REP NO 02	REP NO 03
BLB BLA BLC	GLC GLA GLB	BLB BLC BLA
GLC GLA GLB	BLA BLB BLC	CLA CLB CLC
CLB CLC CLA	CLB CLA CLC	GLC GLA GLB

Key

BLA- Bushland clay soil
BLB- Bushland loamy sand soil
BLC- Bushland sandy clay loam soil
GLA- Grazing land clay soil
GLB- Grazing land loamy sand soil
GLC- Grazing land sandy clay loam soil
CLA- Cropland clay soil
CLB- Cropland loamy sand soil
CLC- Cropland sandy clay loam soil

3.2.3.2 Data collection

Three days after sowing, the seedlings that emerged in each pot were counted and recorded at an interval of seven days until 28 days after sowing. The percentage of seedling emergence was determined as the number of seeds that emerged divided by the total number of sown seed*100

Growth characteristics

The data for growth characteristics were collected in fourteen days intervals from 28, 42, 56, 70, 84, 98, and 112 days after sowing. The height (cm) of Kongwa weed was measured from the root collar to the epical meristem for two plants per pot and their averages were recorded in centimeters. Data on the number of leaves was obtained by counting leaves per plant for two Kongwa weed plants per pot and their averages were recorded. Data for weed stem girth (mm) was obtained by measuring each weed at the centre of the weed using a vernier calliper. Number of branches was obtained by counting branches of the two Kongwa weeds in each pot and their average was recorded. Data for leaf length and width was obtained by measuring three leaves from lamina tip to the point of intersection of the lamina and the petiole, along the midrib of the lamina. Moreover, three leaves were measured from end to end between the widest lobes to the lamina perpendicular to the lamina midrib by tape measure to obtain leaf width (Fig 3.1). Three leaves were randomly selected from lower, middle and upper part of each Kongwa weed for length measurements.

Fig 3.1: Leaf length and width (cm) measured in May 2020(Source: Field photo)

Fruits were counted from two Kongwa weeds in each pot and their average was recorded. The number of seeds per fruit was obtained by counting seeds from each selected nine fruits per Kongwa weed in each pot and their average were recorded as shown in the figure 3.2. The number of seeds per plant was obtained by counting the seeds of the two Kongwa weeds in each pot and their average was recorded. The root length was measured from root collar to epical meristem of each plant for two plants per pot using a tape measure and their average was calculated.

Fig 3.2: Number of seeds fruit $^{-1}$ of the Kongwa weed counted on June 2020 (Source: Field photo)

3.2.3.3 Data analysis

The data for evaluation of Kongwa weed growth characteristics were summarized using Microsoft Excel Spreadsheet computer program to generate descriptive statistics such as mean and percentage. A General Linear Model (GML) procedure of Statistical analysis system (SAS. 2013) was used to analyze the growth and production parameters of Kongwa weed. The model used in this experiment was Yijkl = μ + Li + Si(j) +Pi(jk) + Eijkl. Where Yijkl = Observation on the l^{th} plant growth characteristics from the k^{th} soil texture within the j^{th} site and i^{th} land use type

μ = general mean common to all observations

Li = effect of the i^{th}(study sites)

Sij = effect of the j^{th}(land use type within the site)

Pijk= effect of the k^{th}(soil texture within the j^{th} site and the i^{th} land use type)

Eijkl= Random Error

CHAPTER FOUR

4.0 RESULTS

4.1 Vegetation characteristics and their percentage ground cover among three land use types

Forty-one different plant species were identified and recorded from three surveyed land-use types of which 12 were grasses and 29 were forbs (Table 4.1). The percentage ground cover of desirable forage species was not significantly ($P<0.05$) differed among three land-use types. On the other hand, percentage ground cover of other weed species highest in the cropland (30.8 %), followed by bushland (27.2 %), and the lowest was in grazing land (17.2 %). In addition, percentage ground cover of Kongwa weed was significantly higher in grazing land (38.7 %) and lowest in the crop (1.9 %) and bushlands (1.7 %). The percentage of bare land was highest in the crop land (54.7 %) as compared with grazing and bush lands. Likewise, the percentage cover of litter was higher in the bush land (7.7 %) rather than in the two land use types. The percentage tree/shrub cover was significantly ($P \leq 0.5$) higher in the bushland (24.5 %) compared with the other two land-use types (Table 4.1).

Table 4.1: Mean percentage cover Kongwa weed (*Astripomoea hyoscyamoides)* and other vegetations among three land use types

	% Cover				
Vegetation	**Grazing**	**Crop**	**Bush**	**SE±**	**P-Value**
Astripomoea hyoscyamoides	38.7^{a}	1.9^{b}	1.7^{b}	8.8	0.04
Forage	19.5	8.2	10.3	3.5	0.13
Forbs	1.1	1.1	1.7	0.9	0.85
Other weeds	17.2^{b}	30.8^{a}	27.2^{ab}	3.1	0.05
Litter	0.5^{b}	0.0^{b}	7.7^{a}	1.3	0.01
Bare	16.4^{b}	54.7^{a}	26.9^{b}	7.8	0.03
Tree/shrub canopy	6.7^{b}	3.2^{b}	24.5^{a}	4.6	0.04
Total	100	100	100		

Values with same letter within a row are not significantly different ($P \geq 0.05$) and values with different letter within a row are significantly different ($P \leq 0.05$) according to Duncan significance test and SE ± is Standard Error Mean

4.1.1 Frequency of common plant species across three land use types

Analysis of plant species frequency across the three land use types indicated significant difference (P<0.05) for eight common species including Kongwa weed (4.2). On the other hand, seven species had none significant difference across the land use types (P>0.05). However the result showed that the Kongwa weed was most dominant (26.8 %) in grazing land compared to other land use types. Nevertheless, the percentage frequency of *Digitaria sanguinalis (14.2 %)* and *Bracharia species (1.2.3 %)* were significantly recorded higher in the grazing land as compared with the other two land use types. However, the percentage frequency of *Setaria* species *(7.1%)* was recorded higher in the bush land as compared with the grazing and crop land. *Oxygonum sinuatum (10.5%)* and *Acanthospermum hispidum (12 %)* were recorded with highest percentage frequency in crop land followed by bush land and the lowest percentage frequency was found in grazing land. In addition, *Sida acuta* (7.1 %) *was* recordedhigher percentage frequency of occurrence in bush land as compared with the other two land use types. The percentage frequency of *Commelina benghalensis* (12.9 %) was recorded higher in bush land followed by crop land and the lowest was recorded in grazing land.

Table 4.2: Frequency of fifteen common plant species across three land use types

Species	Frequency of Occurrence (%)					
	Grazing	**Crop**	**Bush**	**SE ±**	**P-value**	**Grazing preference**
Astripomoea hyoscyamoides	26.8[a]	12.4[b]	4.0[b]	3.3	0.01	Undesirable
Dactyloctenium aegyptium	7.1	8.1	3.1	1.5	0.12	Undesirable
Digitaria sanguinalis	14.2[a]	8.3[b]	5.6[b]	1.6	0.02	Desirable
Bracharia species	12.3[a]	1.9[b]	2.8[b]	1.7	0.01	Desirable
Setaria sp	2.2[b]	0.0[b]	7.1[a]	1.5	0.04	Desirable
Cynodon sp	4.0	0.6	5.9	3.6	0.61	Undesirable
Aristida adscensionis	0.3	0.0	10.5	3.3	0.11	Undesirable
Cleome hirta	4.3	10.8	10.2	2.5	0.22	Undesirable
Oxygonum sinuatum	2.2[b]	10.5[a]	6.5[ab]	1.6	0.03	Undesirable
Solanum incanum	8.0	5.0	3.1	2.5	0.43	Undesirable
Sesamum alatum	3.1	9.8	6.2	2.0	0.14	Undesirable
Sida acuta	3.4[ab]	3.1[b]	7.1[a]	1.1	0.05	Undesirable
Bidens sp	7.4	8.6	7.1	3.2	0.94	Undesirable
Acanthospermum hispidum	2.8[b]	12.0[a]	8.0[a]	1.2	0.01	Undesirable
Commelina benghalensis	2.2[b]	8.6[ab]	12.9[a]	2.3	0.04	Undesirable
Total	100	100	100			

Values with same letter within a row are not significantly different (P≥0.05) and values with different letter within a row are significantly different (P≤ 0.05) according to Duncan significance test and SE ± is Standard Error Mean

4.1.2 Mean density of Kongwa weed (plants m^{-2}) among three land-use types

The data from the field survey showed a significant difference (P<.0001) in Kongwa weed density among three land-use types. The highest mean density (7 plants m^{-2}) was recorded in the grazing land, while the lowest mean density was in the crop and bush land (Fig 4.1).

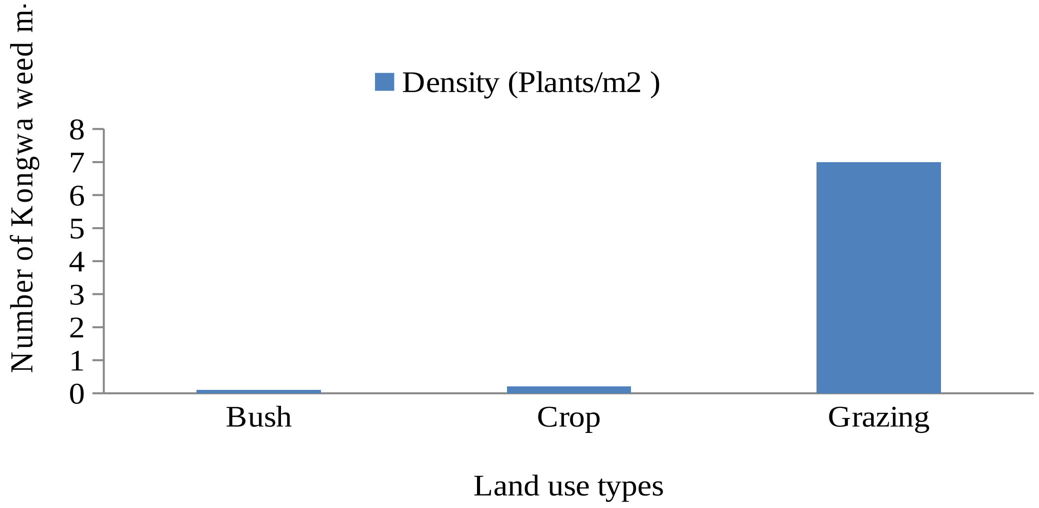


Fig 4.1: Mean density of Kongwa weeds (plants m^{-2}) among three land use types

4.1.3 Abundance of Kongwa weeds among three land use types and sites

The result from analysis of variance shows significant effects (P<.0001) on three land use types and sites. The highest mean number of Kongwa weed (86 plants transect $^{-1}$) was recorded in the grazing land as compared with the crop (2 plants transect $^{-1}$) and bush land (1 plants transect $^{-1}$). The result also indicated that the Kongwa weed was highly dominant in Kongwa Ranch (68 plants transect $^{-1}$) site as compared with Sejeli (15 plants transect $^{-1}$) and Ngomae site (3 plants transect $^{-1}$).

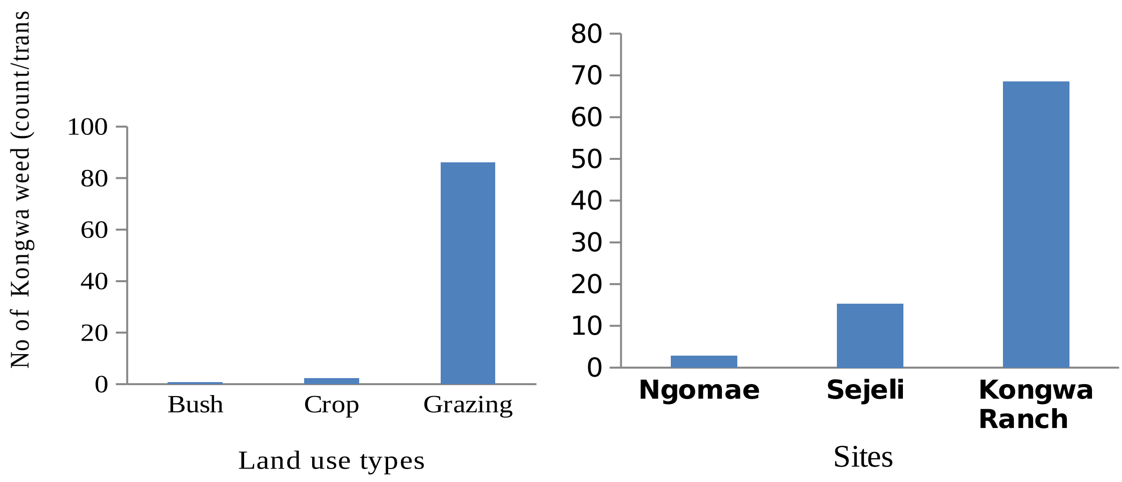


Fig 4.2: Abundance of Kongwa weeds among three land use types and sites

4.1.4 Species diversity, richness and evenness across three land use types.

The results shows no significant difference (P>0.05) in the plant species diversity and richness existing among selected three land use types. However, a significant difference was observed only in the plant species evenness among three land use types. The value of plant species evenness was significantly (P< 0.004) lowest in the grazing land (5.6) than in the crop (0.87) and bush land (0.79) (Table 4.3).

Table 4.3: Mean ± Standard deviation of the species diversity, richness and evenness parameters within the studied land use types and the probability at 5% critical value

	Bush	**Crop**	**Grazing**	**P-value**
Parameters	(n = 9)	(n = 9)	(n = 9)	
Diversity index	1.86 ± 0.34	2.17 ± 0.17	1.47 ± 0.74	0.066
Richness	10.89 ± 3.37	12.0 + 1.22	13.44 ± 2.88	0.20
Evenness	0.79 ± 0.10	0.87 ± 0.06	0.56 ± 0.26	0.004

Source: computed from field data, 2021

4.2 Effects of land use types on soil particle size distribution

Within the different land use types, the sand content in the surface layer of 0 – 20 cm varied from 67.38 to 70.5%, whereas clay content ranged from 25.32 to 28.22% (Table 4.4). The percentage sand practical size fraction was significantly higher in the crop land (70.50 %) followed by grazing land (68.17%), and the lowest was recorded in the bush land (67.38 %). However, the highest percentage clay particle size fraction (28.22 %) was found in bushland, whereas the lowest percentage clay particle size fraction (25.32 %) was in the soil of crop land. However, there was no significant (P>0.05) difference on percentage silt particle size fractions across three land-use types (Table 4.4).

Table 4.4: Mean of the soil physical properties across three land use types

Soil physical properties	Land use type				
	Bush	**Crop**	**Grazing**	**SE±**	**P-Value**
Clay (%)	28.22[a]	25.32[b]	26.32[ab]	0.67	0.01
Silt (%)	4.40	4.18	5.51	0.56	0.12
Sand (%)	67.38[b]	70.50[a]	68.17[ab]	0.8	0.02

The mean values followed by the different letters across rows are significantly different (P<0.05)

4.2.1 Effect of land use types on soil bulk density

The results showed that the soil bulk density significantly (P<0.05) differed among the three land-use types (Fig 4.3). The highest mean value of soil bulk density (1.57 g/100 cm^{-3}) was in grazing land followed by crop land (1.49 g/100 cm^{-3}) and thereafter, bush land (1.49 g/100 cm^{-3}).

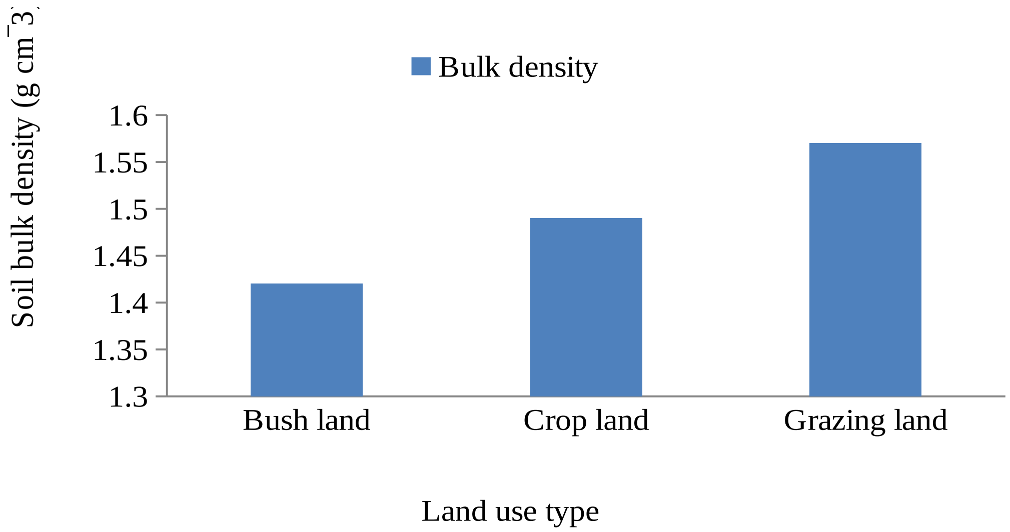


Fig 4.3: Status of soil bulk density at different land use types

4.2.2 Effect of land use types on chemical soil properties

There were no significant differences (P≥0.05) on selected soil chemical properties under three land use types. Despite the absence of statistical difference, the soil pH was lower in the grazing and crop land as compared to bush land. However, crop land had rather lower SOC, SOM, P and K^+ as compared to the other two land use types (Table 4.5).

Table 4.5: Effect of land use types on chemical soil properties

Soil chemical properties	Land use type				
	Bush	**Crop**	**Grazing**	**SE±**	**P-Value**
Soil pH (1:2.5 in H_2O)	7.11	5.72	5.35	0.75	0.12
TN-Kjeld (%)	0.01	0.01	0.01	0.003	0.42
SOC-BlkW (%)	0.59	0.45	0.54	0.2	0.77
SOM (%)	1.02	0.77	0.93	0.35	0.77
Ext. P Bry-1 (mg/kg)	3.4	0.87	1.58	2.89	0.68
Potassium (Cmol kg^{-1})	0.68	0.46	0.55	0.34	0.81

TN = Total nitrogen SOC = Soil organic carbon, SOM = Soil organic matter, Exch. P = Exchangeable phosphorus

4.2.3 Correlation coefficient for selected physical and chemical soil properties on the Kongwa weed growth among three land use types.

The results showed that some soil properties have positive and others have negatively correlated with Kongwa weed abundance at $P<0.05$ among three land use types. The Kongwa weed density in the grazing land indicated high positive correlation with soil pH, SOC, SOM, P, and K^+. In crop land, weak positive correlation with Kongwa weed abundance was noted in SOC, SOM, K^+ and soil bulk density, while negative correlation were soil bulk density, pH, and phosphorus. Moreover, Kongwa weed density have positive correlated with soil pH and negative correlation to bulk density, SOC, SOM, P and in the bush land (Table 4.6).

Table 4.6: Correlation coefficient for physical and chemical properties in relation to Kongwa weed abundance in the different Land use type.

Soil Properties	Abundance of Kongwa Weed Species		
	Grazing Land	Crop Land	Bush Land
Bulk density (g cm^{-3})	0.57	-0.64	-1
Soil pH (1:2.5 in H_2O)	0.99	-0.87	0.97
SOC (%)	0.91	0.37	-0.32
SOM (%)	0.91	0.37	-0.32
P Bry-1 (mg kg^{-1})	0.72	-0.96	-0.7
K^+ (Cmol kg^{-1})	0.99	0.31	-0.06

Source: computed from field data 2021

4.3 Seedling emergence, growth characteristics and seed production of Kongwa weed under three locations

The results showed that there was no significant (P ≥ 0.5) difference on percentage seedling emergence, stem height, number of leaves, number of branches, stem girth, leaf length, leaf width root length, number of fruits, and number of seeds Kongwa $weed^{-1}$ among three locations (Table 4.7)

Table 4.7: Mean Seedling emergence, growth characteristics and seed production of Kongwa weed under three locations

Parameters	Sites				
	Kongwa Ranch	Ngomae	Sejeli	SE±	P-value
Seedling emergence (%)	97.8	93.3	91.1	3.1	0.3
Height $plant^{-1}$	70.3	62.1	73.2	5.4	0.3
No of leaves $plant^{-1}$	127	103	136	12.2	0.2
Stem girth $plant^{-1}$ (mm)	6.1	6.5	6.5	0.4	0.6
No of branches $plant^{-1}$	10	8	9	0.6	0.3
Leaf length (cm)	11	10.8	10	0.3	0.1
Leaf width $plant^{-1}$ (cm)	5.9	5.6	5.5	0.3	0.6
Root length $plant^{-1}$(cm)	36.2	36.3	40.5	3.4	0.6
No of fruits $plant^{-1}$	370	304	339	43	0.6
No of seeds $fruit^{-1}$	4	4	4	0.1	0.4
No of seeds $plant^{-1}$	1479	1214	1356	175	0.6

No = number cm = centimetre, mm = millimetres and SE± = Standard Error of mean

4.4 Seedling emergence, growth characteristics and seed production of Kongwa weed under selected three land use type

The results showed that all paramenters were none significant among selected land use types; except the weed stem girth. The highest stem girth of Kongwa weed was in the grazing land (7.4 mm stem girth plant^{-1}) followed by crop land (6.2 mm stem girth plant^{-1}) and the lowest was in the bush land soil (5.8 mm girth plant^{-1}) (Table 4.8).

Table 4.8: Seedling emergence, growth characteristics and seed production of Kongwa weed under selected three land-use type

Parameters	Land-use types				
	Bush	Crop	Grazing	SE±	P-value
Seedling emerged (%)	95.6	95.6	91.1	3.1	0.5
Height plant^{-1}	67.3	65.9	72.4	5.4	0.7
No of leaves plant^{-1}	113	119	134	12.3	0.5
Stem girth plant^{-1} (mm)	5.8^{b}	6.2^{ab}	7.4^{a}	0.4	0.002
No of branches plant^{-1}	8	9	10	0.6	0.12
Leaf length (cm)	10.3	11.0	10.5	0.4	0.5
Leaf width plant^{-1} (cm)	5.7	5.7	5.7	0.3	1.0
Root length plant^{-1}(cm)	37.5	37.8	37.7	3.5	1.0
No of fruits plant^{-1}	323	354	335	44	0.9
No of seeds fruit^{-1}	4	4	4	0.1	0.4
No of seeds plant^{-1}	1293	1417	1339	178	0.9

No = number cm = centimetre, mm = millimetres andValues with same letter within a row are not significantly different (P≥0.05) and SE± = Standard Error of mean

4.5 Effect of soil texture on Kongwa weed height among three soil textures

The results showed significant differences (P<0.001) on Kongwa weed heights, the number of leaves, and branches among soil textures (Fig 4.4 and 4.5). The mean Kongwa weed height and number of leaves, and branches were highest in sandy clay loam soil texture (81.2 cm height, 155 leaves and 10 branches), followed by loamy sand soil texture (74.3 cm height, 130 leaves and 11 branches) and height Kongwa weed (50.1 cm), number of leaves (82) and branches (5) were lowest in clay soil texture (Figure 4.4 and 4.5). However, the results showed that the short plant (25.2 cm), plant stem girth (5.4 mm), few numbers of fruits (182), and seeds (728) of Kongwa weed were in the clay textural of soils than the loamy sandy and sandy clay loam textural soils. The percentage seedling emergence, leaf length, leaf width, and seeds per fruit were not significantly affected by three textural soil types (Table 4.9).

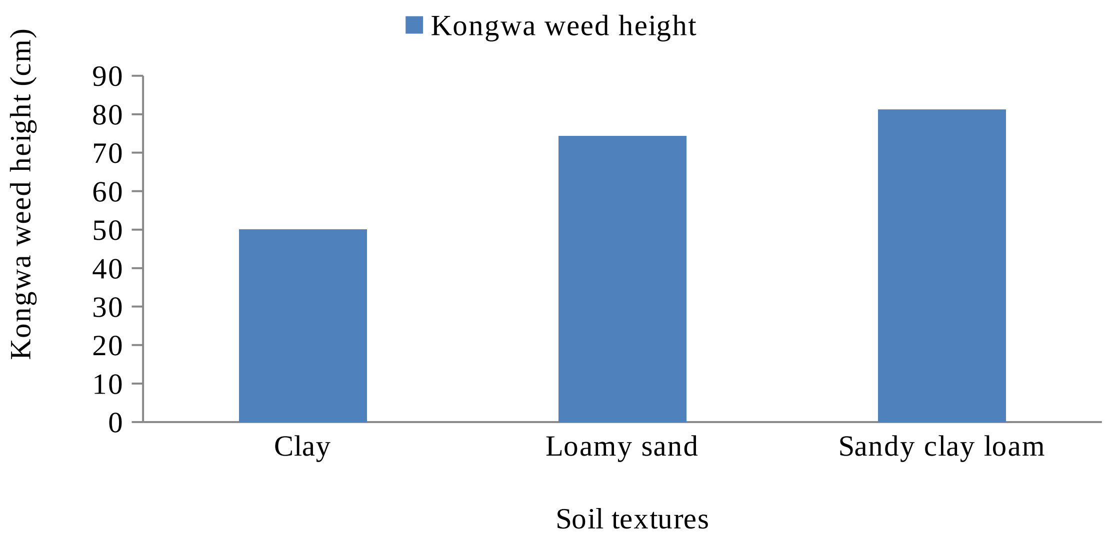


Fig 4.4: Effect of soil texture on Kongwa weed height among three soil textures

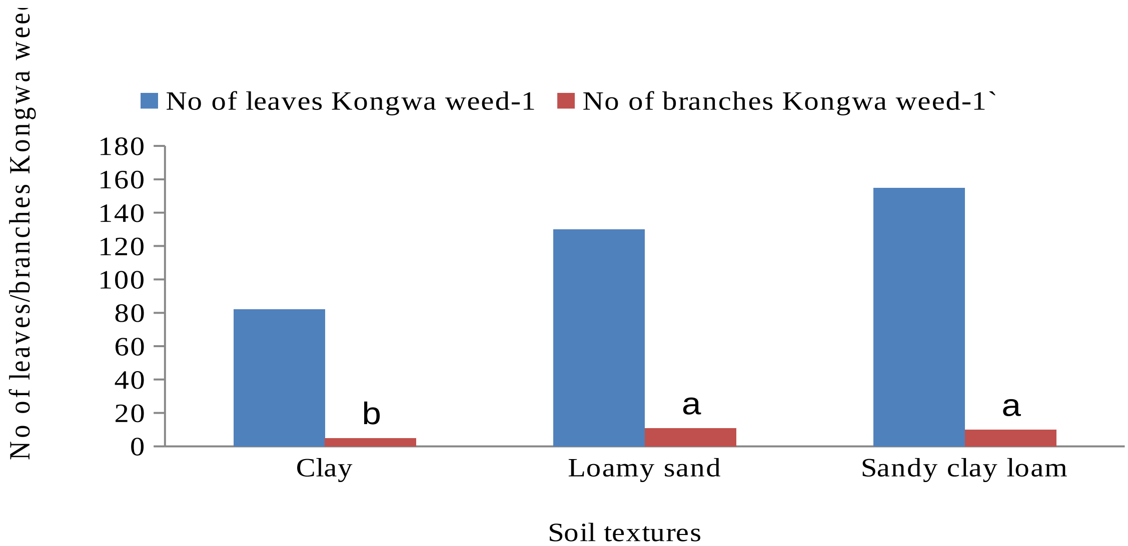


Fig 4.5: Effect of soil texture on leaves and branches of Kongwa weed among three soil textures

Table 4.9: Mean effect of soil textures on seedling emerged (%), root, stem girth, leaf length, leaf width, fruits and seeds

Parameters	Soil texture				
	Clay	**Loamy sand**	**Sandy clay loam**	**SE±**	**P-value**
Seedling emerged (%)	91.1	95.6	95.6	3.1	0.5
Root length plant^{-1} (cm)	25.2^{b}	45.0^{a}	42.9^{a}	1.5	<.0001
Stem girth plant^{-1}(mm)	5.4^{b}	6.9^{a}	6.9^{a}	0.4	0.003
Leaf length plant^{-1}(cm)	10.2	10.9	10.8	0.4	0.4
Leaf width plant^{-1}(cm)	5.4	6	5.7	0.3	0.3
No of fruits plant^{-1}	182^{b}	440^{a}	390^{a}	21.3	<.0001
No of seeds fruit^{-1}	4	4	4	0.1	0.4
No of seeds plant^{-1}	728	1761	1560	85	<.0001

Values with different letter within a row are significantly different (P< 0.05)

4.6 Interaction effects of land uses with soil textural types on Seed emergence and growth of Kongwa weed.

The results indicated that there was significant (P≤0.05) difference on Kongwa weed height, number of leaves and root length among interaction of land use types and soil textural types. Bushland ^{x} soil textural type interactions; The tallest of Kongwa weed was recorded in the interaction of bush land ^{x} loamy sand (77.7 cm) fallowed by bushland ^{x} sandy clay loam (73.5 cm) and the shortest height of Kongwa weed recorded in bushland ^{x} clay soil (50.7 cm). The highest mean number of leaves was recorded in the interaction of bushland^{x} sandy clay loam (147) fallowed by interaction of bushland^{x} loamy sand (109) and the lowest mean number of leaves was in bushland ^{x} clay interaction(84). Likewise, the longest of Kongwa weed root was recorded in the interaction of bushland^{x} loamy sand (46.9 cm), bushland ^{x} sandy clay loam (43.3) and the shortest root of Kongwa weed was recorded in the interaction of bushland ^{x} clay (22.3).

Cropland ^{x} soil textural type interactions; The tallest of Kongwa weed was recorded in the interaction of cropland ^{x} Sandy clay loam (78.6 cm) fallowed by cropland ^{x} loamy sand (71.2 cm) and shortest height was recorded in cropland ^{x} clay(48.1 cm). The highest mean number of leaves was recorded in the interaction of cropland ^{x} Sandy clay loam (151) fallowed by cropland ^{x} loamy sand (128) and shortest mean number of leaves was recorded in cropland ^{x} clay (80). Furthermore, the longest root of Kongwa weed was recorded in the interaction of cropland^{x} loamy sand (43.6 cm), bushland ^{x} sandy clay loam (41.5 cm) and the shortest plant root was recorded in the interaction of bushland ^{x} clay (28.4 cm).

Grazing land ^{x} soil textural type interactions; the mean height of Kongwa weed was higher in the interaction of grazing land ^{x} Sandy clay loam (91.5 cm) fallowed by grazing land ^{x} loamy sand (74.2 cm) and shortest plant height was recorded in grazing land ^{x} clay (51.6 cm). The highest mean number of leaves was recorded in grazing land ^{x} Sandy clay loam (167) fallowed by grazing land ^{x} loamy sand (154) and the lowest mean number of leaves was recorded in grazing land ^{x} clay (81). The longest root of Kongwa weed was recorded in the interaction of cropland^{x} loamy sand (44.3 cm), bushland ^{x} sandy clay loam (43.9 cm) and the shortest root was recorded in the interaction of bushland ^{x} clay (24.8 cm). However, the percentage seedling emergence, number of branches, leaf length, and leaf width were not affected by all land use types ^{x} soil textural type interactions (Table 4.10)

Table 4.60: Interaction effects of land uses with soil textural types on Seedling emergence and growth of Kongwa weed.

Treatment combinations	SE (%)	Kh(cm)	NoL	WG (mm)	NoB	LL (cm)	LW (cm)	RL (cm)
Bush land x Clay	93.3	50.7^{b}	84^{bcd}	5.3	5.3	9.8	5.2	22.3^{c}
Bush land x Loamy sand	100	77.7^{ab}	109^{abcd}	6.2	8.3	10.2	6.4	46.9^{a}
Bush land x Sandy clay loam	93.3	73.5^{ab}	147^{ab}	6.7	9.7	10.9	5.4	43.3^{a}
Crop land x Clay	86.7	48.1^{b}	80^{d}	4.9	6.6	10.8	5.9	28.4^{bc}
Crop land x Loamy sand	100	71.2^{ab}	128^{abcd}	7.4	10.5	11.2	5.9	43.6^{a}
Crop land x Sandy clay loam	100	78.6^{ab}	151^{ab}	6.3	8.8	11.0	6.2	41.5^{ab}
Grazing land x Clay	93.3	51.6^{b}	81^{cd}	5.9	5.5	9.9	5.0	24.8^{c}
Grazing land x Loamy sand	86.7	74.2^{ab}	154^{a}	7.1	12.3	11.2	5.5	44.3^{a}
Grazing land x Sandy clay loam	93.3	91.5^{a}	167^{a}	7.6	10.5	10.4	5.7	43.9^{a}
SE±	7.7	10.1	19.2	1.2	2.2	1.0	0.7	3.9
P-value	0.4	0.05	0.05	0.79	0.62	0.83	0.30	0.05

SE (%) = percentage Seedling emergence percentage; Kh = Kongwa weed height; NoL = Number of leaves; WG = Weed girth; NoB = Number of branches; LL = Leaf length; LW = Leaf width and RL = Root length and SE± is Standard Error Mean

4.7 Interaction effects of land use with soil textural types on Seed production of the Kongwa weed

According to the results of analysis of variance showed that there was a significant ($P \leq 0.02$) difference in on number of fruits and seeds Kongwa weed^{-1}. Bushland x soil textural type interactions; The highest mean number of fruits was recorded in the interaction of bush land x sandy clay loam (422) fallowed by bushland x loamy sand (370) and the lowest mean number of fruits was recorded in bushland x clay soil (178). However, the highest mean number of seeds was recorded in the interaction of bushland x sandy clay loam (1688) fallowed by the interaction of bushland x loamy sand (1480) and the lowest mean number of seed was in bushland x clay interaction (710).

Cropland x soil textural type interactions; the highest mean number of fruits was recorded in the interaction of cropland x loamy sand (480) fallowed by cropland x Sandy clay loam

(383) and the lowest mean number of fruits was recorded in cropland ^{x} clay soil (200). However, the highest mean number of seeds was recorded in the interaction of cropland^{x} loamy sand (1919) fallowed by the interaction of cropland^{x} sandy clay loam (1531) and the lowest mean number of seeds was in cropland ^{x} clay interaction (810).

Grazing land ^{x} soil textural type interactions; the highest number of fruits was recorded in the interaction of grazing land ^{x} loamy sand (471) fallowed by grazing land ^{x} sandy clay loam (365) and the lowest number of fruits was recorded in grazing land ^{x} clay soil (168). However, the highest number of seeds was recorded in the interaction of grazingland^{x} loamy sand (1885) fallowed by the grazing land ^{x} sandy clay loam (1461) interaction and the lowest number of seeds was recorded in the interaction of grazing land ^{x} clay (672).The number of seeds fruit^{-1} was not affected by the interaction of land-use type ^{x} soil textural types (Table 4.11)

Table 4.71: Interaction effects of land use with soil textural types on Seed production of the Kongwa weed

Treatment combination	No of fruits plant $^{-1}$	No of seeds fruit $^{-1}$	No of seeds plant $^{-1}$
Bush land ^{x} Clay	178^{c}	4	710^{c}
Bush land ^{x} Loamy sand	370^{ab}	4	1480^{ab}
Bush land ^{x} Sandy clay loam	422^{a}	4	1688^{a}
Crop land ^{x} Clay	200^{bc}	4	$801b^{c}$
Crop land ^{x} Loamy sand	480^{a}	4	1919a
Crop land ^{x} Sandy clay loam	383^{a}	4	1531^{a}
Grazing land ^{x} Clay	168^{c}	4	672^{c}
Grazing land ^{x} Loamy sand	471^{a}	4	1885^{a}
Grazing land ^{x} Sandy clay loam	365^{ab}	4	1461^{ab}
SE±	50.5	0.2	202.0
P-value	0.02	0.43	0.02

Interaction values with the same letter within a column are not significantly different (P>0.05) and values within a column are the significant difference (P<0.05) and SE± is Standard Error Mean

CHAPTER FIVE

5.0 DISCUSSION

5.1 Vegetation characteristics in three land-use types

The findings of this study showed that Kongwa weed invasion in the grazing lands provides a competitive advantage over native species and become a dominant species in a community. It has probably caused the lowest species compostion in terms of evenness in the grazing lands. Cavalcanti and Larrazabal. (2004) considered that species diversity to be higher when the calculated diversity index value is ≥ 3.0, medium when it is between 2.0 and 3.0 and very low when it is ≤ 1.0. The current study indicated relatively lower diversity index of less than three in all studied land use types. Factors for the lowest species diversity and evenness in the study sites could be attributed with frequency defoliation of palatable species, continuous cultivation and high percentage tree canopy cover in the bush lands. This finding can be strongly supported by Debalkie and Ebro. (2006) who reported that decrease in species diversity in the grazing land-use type could be the loss of seedling of some species that unable to establish at early stage of development .and selective defoliation and trampling by grazing herbivores. The findings here show that evenness at which native species are not distributed within a study area may be a more important predictor of weed abundance in a study area. Possibly, species that are not evenly distributed in space may use resources inequitably and make poor competitive environment that is difficult for forage species to spread. This observation was more evident in the grazing land which could be associated with severe Kongwa weed species invasion.

Intensive grazing could be the causative for Kongwa weed species distribution through trampling and defoliation of palatable native plant species; therefore reduce their competitive ability and create bare patches and disrupt nutrient cycles (Kimball and Schiffman, 2003 and Dorrough *et al.* 2004). The forage species were less than twenty percent ground cover in all land-use types probably due to the highest percentage ground cover of 38.7%, frequency of occurrence of 26.8 %, and densities of Kongwa weed (7 m^{-2}), continuous cultivation and tree canopy in the bush land. The forage species component was *Digitaria sanguinalis* and *Bracharia species* with frequency of occurrence of 14.2 % and 12.3 % respectively in the grazing land. There were also some other notable unpalatable plant species such as *Acanthospermum hispidum, Cleome hirta, Commelina benghalensis, Sesamum alatum, Biden sp, Solanum incanum, Oxygonum sinuatum* and *Sida acuta.* These unpalatable plant speciesgrow fast and have short life cycle except *Solanum incanum* and *Sida acuta* which have competitive ability with Kongwa weed across three land-use types. The existence of some plant species in Kongwa weed invasion showed positive association possibly due to tolerance and facilitation processes between both groups of species. Contrary to the findings of recent studies that weed species established in disturbed landscapes prevent the re-establishment of native species (Vilà *et al.* 2011).

Surprisingly, the Kongwa weed had less ground cover, frequency of occurrence and abundance in the crop and bush lands which could be attributed to cultivation and shade from encroachment of bushes respectively. The highest percentage of bare ground spots (54.7%) in the crop land is an evidence of land degradation due to human activities such as free in situ grazing of crop residues after grain harvest. On the other hand, the higher percentage of tree canopy cover in the bush land found to have negative effect on herbaceous vegetation including the kongwa weed. High canopy cover normally hinder accessibility of the sunlight especially to sun growing leaves of herbaceous species which in turn resulting in the reduction of photosynthetic rates (Limb *et al.* 2010).

5.2 Effect of land use types on soil physical properties

The physical soil properties were varied across three land use types. The proportion of sand fraction was highest in the crop land as compared with grazing and bush lands possibly due to disturbances by tillage operations which often crush the soils and turn into finer particles susceptible to erosion agencies like water and wind. Similar type of result has been reported by Abubakar. (1997) in the Kabomo basin of Nigeria. The highest and the lowest values of respectively clay and sand fractions in the bush land could probably be attributed to relatively low removal clay particles by erosion process or destruction of clay in the top layer soil. Unprotected lands, the fine soil particles would be selectively removed by erosion thereby increasing the proportional of the coarser particles in the soil which leaves more sand particles (Bewket. 2003). Similar results were also reported by Lemenih. (2004) and Belayneh. (2009) who reported that deforestation, farming practices and intensive grazing change soil texture by aggravating soil erosion.

However, the highest bulk density values in grazing and crop land might be due to the response of excessive wet season livestock trampling and repeated shallow depth cultivation which disturb the soil structure causing a compacted surface soil layer.In line with this, Islam and Weil. (2000) reported that continuous tillage practice has facilitated an increase in soil bulk density in the crop land. Selassie *et al.* (2015) also reported that the increase in bulk density due to deforestation and continuous cultivation in the top plough layers lead to the decrease in soil organic matter content and compaction from tillage. The highest livestock population in National Ranching Company (NARCO)-Kongwa (8,000 heads of cattle) and surrounding villages possibly increases soil compaction and hence increase bulk density in the grazing lands. In support of this, Herbin *et al.* (2011) also revealed that livestock trampling have immediately and negative impact on soil physical properties in the grazing land. However, the soil bulk density recorded lower in the bush land which could be attributed with large amount of organic matter and less disturbances the bush soils.However, the soil bulk density of the three land-use types was however out of the expected values(1.1 to 1.4 g cm^{-3}) as suggested by Gupta. (2004), thus the aeration and water movement within the soil structure are not the conducive situation that cannot attain plant growth.

5.3 Status of soil chemical properties among three land use types

The finding of this study did not detect any difference in soil chemical properties across land use types. There was however a number of slight variations of the soil chemical properties in three land-use types which could probably be due to the removal of large amount of organic materials in the grazing and crop lands. For example, the alkaline soil was found in the bush land, while the moderate acidic recorded in the grazing and crop lands. The present finding is strongly supported with the findings of Muche *et al.* (2015) who reported that soils in the natural forest have higher soil pH value and low exchangeable acidity as compared to grazing and cultivated land. Furthermore, Tang and Rengel. (2003) reported that trees and shrubs play a role in increasing soil pH by developing deep layer root systems capable of taking up bases such as Ca and Mg from deep layers of the soil profile returns them to the topsoil as leaf litter containing excess basic or alkaline cations. Many weed species can tolerate a wide range of soil pH levels which is a trait for an invasive generalist species (Rezvani and Zaefarian. 2016). The Kongwa weed species is probably tolerant to a wide range of soil pH since it is distributed widely in grazing and croplands. In addition, the Kongwa weed was negatively correlated with total N ($r = -0.27$ $P<0.05$) in all land-use types and this could be due to its ability to convert nitrogen into nitrate through bacteria present in the root nodules of the weed. Physiological mechanisms of adaptation of plants to non-optimal soil pH like plant root induce charges in the rhizosphere occur through the release of H+ or OH- to balance cation-anion uptake at the soil root interface (Hinsinger *et al.* 2003).

The mean total N content, phosphorus (P), and exchangeable Potassium (K) values at a depth of 0 – 20 cm were within the range of low in soils of all land use types as suggested by Nega. (2013); Olsen. (1954) and Wang *et al.* (2001). The low amount of soil nutrients in three land use types could be due to the removal of vegetation cover and crop residues by livestock grazing and increase the surface layer of the land to soil erosion. Urioste *et al.* (2006) reported that the addition of organic matter increases the amount of exchangeable cations bases and lower cations bases in cultivated fields are due to the intensive cultivations that enhance the loss of base cations through erosion, crop harvest, and leaching. However, the finding of this study revealed that high positive correction between Kongwa weed abundance and soil chemical properties in the grazing land was probably due to tolerance of the weed in low amount of soil nutrients.

5.4 Correlation of soil properties and Kongwa weed density among three Land use type.

The findings of this study indicated that Kongwa weed density in different land use types have positive and negative correlation with soil properties. For example, the soil pH, soil organic carbon, soil organic matter, phosphorus potassium and soil bulk density in the grazing land have positive correlation. While, soil organic carbon, soil organic matter and potassium in the crop land have positive correlation with Kongwa weed. Likewise, the soil pH in the bush land has showed positive correlation and other soil properties were negative correlated in a given land use type. As the Kongwa weed increases, the soil nutrients tend to increase in the grazing land probably due to organic materials come from Kongwa weed especially leaves and roots into the soil.This result is in line with the finding of Tang and Rengel. (2003) who reported that plant roots may play a role in increasing soil pH through the development of deep layer root systems capable of taking up bases such as Ca and Mg from deep layers of the soil profile and returning them to the topsoil as leaf litter containing excess basic or alkaline cations. However, some soil properties such soil bulk density, soil organic carbon, soil organic matter, phosphorus tend to increase with decreasing of Kongwa weed density in the bush land.

5.6 Evaluation of the growth characteristics and seed production of Kongwa weed in the different soil texture

Evaluation of growth characteristics and reproduction of Kongwa weed in different soil types increases knowledge of which soil type favor the weed establishment for better weed management. The present finding showed that the percentage seedling emergence, growth, and the number of seeds were not significantly affected by three locations and land-use types except the Kongwa weed stem girth in the land use types. The Kongwa weed stem girth was largest in the grazing land soils rather than crop and bushland soils probably due to influence of livestock manure that increases carbon, and nitrogen pool into the land, while improving other soil properties includes aggregation, water holding capacity, and erosion resistance.

Despite absence of significant difference on seedling emergence percentage of Kongwa weed in different textural soils, the kongwa weed height, stem girth, number of leaves, number branches, root length, number of fruits and number of seeds per plant were varied among three textural of soils. The shortest kongwa weed height, stem girth, root length, few number of leaves, branches, fruits and seeds were recorded in clay textural of soil. This could be attributed with clay soil resistance of root growth to access the water and available nutrients in the soil. The present findings are in line with the findings of Clark *et al*. (2003); Gil *et al.* (2012) and Lamber *et al.* (2008) who reported that the low performance of a plant in clay soils might be due to the lower macroporosity that could have attributed a greater resistance for root growth together with lower aeration of the rhizosphere which could have affected both root growth, vegetative and seed production. While, loamy sand and sand clay loam soils have optimum porosity for the extensive root systems such as longer roots, more lateral roots and more root hairs to gain access of those non-bioavailable nutrients for the plant growth and reproduction (Ma *et al.* 2013). The results also demonstrated that almost four seeds per fruit were produced by Kongwa weed and they released into the soil as means of regeneration of new plants. Seedless fruit can occur when the ovary develops directly without fertilization or when pollination and fertilization trigger ovary development, but the embryo aborts without producing mature seeds (Picarella *et al.*, 2019). When seed set fails, the abscission of the flower could be a standard pathway to avoid the wastage of resources in growing structures not fulfilling a biological process.

5.7 Interaction effects of land use with soil textural types on kongwa weed characteristics and seed production

The finding of this study demonstrated that the Kongwa weed performance affected by the interaction of land use types and soil textural types in terms of height, number of leaves and length of root. The Kongwa weed showed poor performance in the interaction of bush land ^{x} clay, crop land ^{x} clay and grazing land ^{x} clay probably due to high percentage clay particle size which prevent the roots to access soil nutrients and water in the soil.Sağlam and Bécel *et al.* (2012) reported that the clay soil has high nutrient contents with relatively higher root penetration resistance; hence poor ability to access water and available nutrients for the physiological development and plant seed setting. The highest performance of Kongwa weed was noted in the interactions of the crop land ^{x} soil textural types and grazing land ^{x} soil textural types. This implies that the two interactions have less problem of water logging and root resistance to nutrients and water.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

Recently, the Kongwa weed has become a weed of economic importance in Kongwa district central part of Tanzania. This study discovers a total of forty one different plant species in the study area of which Kongwa weed was the most dominant in the grazing land of Kongwa Ranch because of its high drought tolerance and capacity to withstand heavy grazing. However, in semi-arid environments, the Kongwa weed has ability to rapidly invade any land use type and soil texture if the environmental condition would favour its occurrence.The Kongwa weed grows better and produces many seeds in loamy sand, sandy clay loam soils than in the clay texture soils. This implies that the areas occupied with high percentage clay soil particle size may be less invaded by Kongwa weed. The present finding has highlighted on the biological characteristics, density and species biodiversity impacts on Kongwa weed to facilitate habitat protection and identification of other areas requiring urgent management. It is recommended that the biological features of Kongwa weed observed on this study will facilitate the development of effective integrated control measures and increasing awareness of the Kongwa weed among a wider range of stockholders such as researchers, agro-pastoralist, pastoralist and policy makers. Moreover, the Kongwa weed was found to be dominant in the grazing lands and still rapidly spreading in and out its origin domicile particularly in Kongwa Ranch and other surrounded villages therefore; attention should be given by developing effective strategic control measures and the community to be involved in control.

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APPENDICES

Appendix 1: Percentage ground cover of Kongwa weed (*Astripomoea hyoscyamoides*) in three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	2718.408889	1359.204444	5.81	0.0395
Error	6	1403.500000	233.916667		
Corrected Total	8	4121.908889			

R-Square	CoeffVar	Root MSE	Astr Mean
0.659502	108.5560	15.29433	14.08889

Appendix 2:Percentage ground cover of Forage species in three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	217.6355556	108.8177778	2.91	0.1311
Error	6	224.7266667	37.4544444		
Corrected Total	8	442.			

R-Square	CoeffVar	Root MSE	Forg Mean
0.491985	48.35824	6.120004	12.65556

Appendix 3: Percentage ground cover of forb species in three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	0.80222222	0.40111111	0.17	0.8509
Error	6	14.51333333	2.41888889		
Corrected Total	8	15.31555556			

R-Square	CoeffVar	Root MSE	Frb Mean
0.052380	121.7174	1.555278	1.277778

Appendix 4: Percentage ground cover of other weed species in three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	300.6466667	150.3233333	5.15	0.0499
Error	6	175.1333333	29.1888889		
Corrected Total	8	475.7800000			

R-Square	CoeffVar	Root MSE	Ows Mean
0.631903	21.55322	5.402674	25.06667

Appendix 5: Percentage ground cover of tree/shrub species in three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	780.442222	390.221111	6.08	0.0360
Error	6	384.893333	64.148889		
Corrected Total	8	1165.335556			

R-Square	CoeffVar	Root MSE	Tc Mean
0.669715	69.78093	8.009300	11.47778

Appendix 6: Percentage frequency of occurrence by Kongwa weed (*Astripomoea hyoscyamoides*) among three land use types.

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	798.5688889	399.2844444	12.14	0.0078
Error	6	197.2800000	32.8800000		
Corrected Total	8	995.8488889			

R-Square	CoeffVar	Root MSE	AH Mean
0.801898	39.78950	5.734108	14.41111

Appendix 7: Percentage frequency of occurrence by *Dactyloctenium aegyptium* across three land use types.

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	41.60222222	20.80111111	3.06	0.1215
Error	6	40.82666667	6.80444444		
Corrected Total	8	82.42888889			

R-Square	CoeffVar	Root MSE	DA Mean
0.504704	42.84087	2.608533	6.088889

Appendix 8: Percentage frequency of occurrence by*Digitaria sanguinalis* among three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	116.6066667	58.3033333	7.53	0.0231
Error	6	46.4733333	7.7455556		
Corrected Total	8	163.0800000			

R-Square	CoeffVar	Root MSE	DS Mean
0.715027	29.71264	2.783084	9.366667

Appendix 9: Percentage frequency of occurrence by *Bracharia mutica* among three land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	201.8822222	100.9411111	12.06	0.0079
Error	6	50.2000000	8.3666667		
Corrected Total	8	252.0822222			

R-Square	CoeffVar	Root MSE	BM Mean
0.800859	51.14474	2.892519	5.655556

Appendix 10: Percentage of seed emerged in different textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	118.518519	59.259259	0.67	0.5227
Error	24	2133.333333	88.888889		
Corrected Total	26	2251.851852			

R-Square	CoeffVar	Root MSE	SE Mean
0.052632	10.02199	9.428090	94.07407

Appendix 11: Kongwa weed heights among three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	33651.0007	16825.5004	10.29	<.0001
Error	186	304239.9070	1635.6984		
Corrected Total	188	337890.9077			

R-Square	CoeffVar	Root MSE	Hgt Mean
0.099591	59.00326	40.44377	68.54497

Appendix 12: Number of leaves per plant on three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	174329.175	87164.587	10.09	<.0001
Error	186	1607193.968	8640.828		
Corrected Total	188	1781523.143			

R-Square	CoeffVar	Root MSE	NoL Mean
0.097854	76.07471	92.95605	122.1905

Appendix 13: Number of branches per plant on three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	888.010582	444.005291	26.59	<.0001
Error	186	3105.904762	16.698413		
Corrected Total	188	3993.915344			

R-Square	CoeffVar	Root MSE	NoB Mean
0.222341	46.24693	4.086369	8.835979

Appendix 14: Girth of Kongwa weed in different textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	96.145185	48.072593	6.08	0.0028
Error	186	1469.659048	7.901393		
Corrected Total	188	1565.804233			

R-Square	CoeffVar	Root MSE	WG Mean
0.061403	44.01557	2.810942	6.386243

Appendix 15: Leaf length of Kongwa weed on different of soil textures

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	2.82888889	1.41444444	1.07	0.3592
Error	24	31.75777778	1.32324074		
Corrected Total	26	34.58666667			

Appendix 16: Root length of Kongwa weed on three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	2132.346667	1066.173333	50.89	<.0001
Error	24	502.833333	20.951389		
Corrected Total	26	2635.180000			

R-Square	CoeffVar	Root MSE	LR Mean
0.809184	12.15204	4.577269	37.66667

Appendix 17: Leaf width of Kongwa weed on three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	1.47629630	0.73814815	1.13	0.3404
Error	24	15.71333333	0.65472222		
Corrected Total	26	17.18962963			

R-Square	CoeffVar	Root MSE	LW Mean
0.085883	14.20483	0.809149	5.696296

Appendix 18: Number of fruits plant^{-1} on three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	337756.1296	168878.0648	41.38	<.0001
Error	24	97953.7222	4081.4051		
Corrected Total	26	435709.8519			

R-Square	CoeffVar	Root MSE	NoF Mean
0.775186	18.93330	63.88588	337.4259

Appendix 19: Number of seeds plant^{-1} on three textural of soils

Source	DF	Sum of Squares	Mean Square	F Value	Pr> F
Model	2	5404098.074	2702049.037	41.38	<.0001
Error	24	1567259.556	65302.481		
Corrected Total	26	6971357.630			

R-Square	CoeffVar	Root MSE	NoS Mean
0.775186	18.93330	255.5435	1349.704

Appendix 20: Girth of Kongwa weed in different land use types

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	104.947804	52.473902	6.67	0.0016
Error	186	1462.708095	7.864022		
Corrected Total	188	1567.655899			

R-Square	Coeff Var	Root MSE	WG Mean
0.066946	44.09219	2.804286	6.360053

Appendix 21: Analytical methods for soil samples

Soil characteristics	**Method of analysis**	**Source**
Soil bulk density	Determined by oven dry	Klute, A. (1986)
Soil Particle distribution	Determined by the hydrometer method	Bouyoucos, 1936
Total Nitrogen	Determined by the Micro-Kjeldahl Method	Bremner (1996)
Organic Carbon	Determined by Walkley and Black Method	Nelson and Sommers (1983)
Soil pH	Determined in 1: 2.5(soil:water) suspensions using a pH meter	McLean (1983)
Available P	Extracted by the Bray-1 Procedure	Bray and Kurtz, 1945
Exchangeable base K^+	Determined by the Flame Photometer Method	Thomas, 1982