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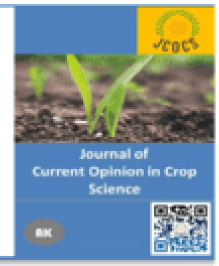

RESEARCH ARTICLE

Seed bank distribution of Kongwa weed (*Astripomoea hyoscyamoides* Vatke Verdc.) for different land use types in Kongwa district, Tanzania

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ABSTRACT

Weed invasion poses significant challenges to agriculture and ecosystems, leading to substantial economic losses globally. *Astripomoea hyoscyamoides* Vatke Verdc. commonly known as Kongwa weed, is a highly invasive species causing a severe infestation in the Kongwa district, Tanzania. This study investigated the seed bank distribution of Kongwa weed across different land use types, specifically arable land, fallow land, and range land in the Kongwa district. Soil samples were collected from chamae, chigwingwili, chimotolo, machenje, msunjulile, ndalibo, Nyerere, and sejeli villages, representing range, arable, and fallow land, at different soil depths (0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm). The results showed significant variations in Kongwa weed seed density among villages, with Msunjulile exhibiting the highest density across all land use types (1.92 seeds/m^2 in arable, 6.67 seeds/m^2 in fallow, and 9.83 seeds/m^2 in range land). In comparison, Chigwingwili displayed the lowest density (0.33 seeds/m^2 in arable land) The study revealed a decline in seed density with increased soil depth, with the topsoil (0-5 cm) showing the highest seed density. Also, range land exhibited the highest seed density, while arable and fallow land was comparable. Generally, kongwa weed seeds are observed to be higher in range land, with a depth of 0-5 cm, particularly in areas near ranch areas. Implementing control measures, especially before the flowering stage, is crucial to mitigating the kongwa weed invasion. Further research on seed germination patterns is recommended to enhance weed management strategies.

Keywords: *Astripomoea hyoscyamoides*, Land use types, Seed bank distribution, Kongwa weed.

INTRODUCTION

In nature, weed invasion has the most pernicious impacts as it unfavourably affects agriculture, interferes with the beautiful value of the environment, alters the balance of the ecological community, and agitates natural diversity (Ekwealor et al., 2019). Weed invasion has been documented to cause both agricultural and economic losses worldwide. The economic loss due to weed has been estimated to reach about US$ 1.4 trillion per year (Schnelle and Gettys, 2021). Weed infestation alone accounted for about 41.6% of the reduction in agricultural produce (Safi et al., 2022). The loss of produce due to weed invasion varied depending on crop type (Gianessi, 2009). In rice, weed invasion is attributed to yield loss of about 50-100%, 50-80% in wheat, 40-80% in sorghum, 50% in common bean, 80% in cotton, and 90% in cassava (Gianessi, 2009).

Astripomoea hyoscyamoides is among the most invasive weed species with fruitful seed production which consequently increases the soil seed bank (Nkombe et al., 2018). *A. hyoscyamoides* is traditionally known as "mahata" and is commonly named "Kongwa weed" due to its severe infestation in the Kongwa district (Nkombe et al., 2018). It is an annual weed that can grow up to the height of 1.8 m, characterized by greyish hairs, and white and purple flowers (Mwalongo et al., 2020). Kongwa weed has had severe effects on pasture and crop production. It has led to the reduction of pasture productivity as it infests about 70% of the Kongwa ranch area (National Ranching Company Limited, NARCO). About 75% of farmers growing various crops such as maize, groundnut, and sunflowers have been affected by this weed as it has caused severe yield reduction (Nkombe et al., 2018). This weed competes with crops and pastures on soil nutrients, water, and sunlight which eventually affects plant growth and productivity (Mkongera et al., 2021). Contaminated agricultural produce, farm tools, equipment, machines, footwear, clothing, wind, and livestock movements during grazing are ways in which seeds of this weed are distributed (Mkongera et al., 2021). Generally, seed size, shape, and nature of soil texture have been described as factors influencing the distribution of seeds in different soil strata (Benvenuti, 2007).

Rapid dominance of invasive weeds in the seed bank and vegetation may be facilitated by the increased number of weed seeds in the soil. The summation of seeds shed from the plant after maturation, accumulated in different soil profiles is defined as a seed bank (Sharshar et al., 2022). Different ways have been employed to control Kongwa weed infestation, but still, infestation has been increasing which is associated with unknown seed banks in the soil. The soil seed banks act as reservoirs of weed seeds that may be subjected to different fates like to emerge to produce a new plant or die due to unfavourable conditions (Murono and Abuto, 2019). Determination of seed banks is very crucial in forecasting and selecting suitable management strategies for a particular weed (Hossain and Begum, 2015). It provides basic information on the concentration of weed seeds in the soil. The way weed seed banks relate to the above-ground weed community can provide pointers to the uses of such infested land and determine effective management strategies (Colbach et al., 2021). This necessitates the need to determine the seed bank dynamic of *A. hyoscyamoides* since no information has been documented based on the seed bank dynamic of this weed. This study aimed to determine the weed seed banks of *A. hyoscyamoides* at different soil strata present in arable, fallow, and range land.

MATERIALS AND METHODS

Study area

This study was conducted in the Kongwa district, one among the seven districts constituting the Dodoma region in central Tanzania. Kongwa district is semi-arid and covers 1,272 square (8% of the total region land area) kilometres in the eastern central part of Tanzania receiving a total annual rainfall ranging between 400 and 800 mm (Figure 1). It is located between latitude 50 30' and 60 0' south of the equator and longitudes 360 15' and 360 0' East, with an altitude ranging between 900 to 1000 m above sea level. Currently, the estimates of livestock population are about 33896 sheep, 117,599 cattle, 2680 donkeys, and 73196 goats. It also includes 5627 ducks, 3,744 dogs, 376,877 chickens and 866 cats. Kongwa district has been reported as the leading district in the production cultivation of maize in the Dodoma region (131930 ha) (Lusamila et al., 2021).

Sampling design

Soil samples were collected from eight (8) villages. In each village, the fields sampled were under land use types (fallow land, range land, and arable land). In each field, soils were sampled in four (4) strata of 0-5 cm, 5-10 cm, 10-15 cm and 15-20 cm. This constituted a split-split plot arrangement in a randomized complete block design (RCBD) with three replications. Villages were the main factor, land use type as the subfactor and soil strata as a sub-subfactor.

Soil sampling procedure

In each sampling site, a hundred-meter (100m) long transect was established. The soil samples were collected along the established transect line. In collecting soil samples, ten quadrats with 1m2 were laid after every 10 meters. At a depth of 0-5cm, 5-10cm, 10-15cm, and 15-20cm at each quadrant the soil samples were taken. At the sampling site, soil samples from each stratum in 10 spots were mixed thoroughly to form a composite sample and to capture the spatial heterogeneity of the seed distribution in the soil. One kilogram of each composite sample was packed in envelope bags and then transported to Sokoine University of Agriculture for seed bank determination.

To determine seed bank seed extraction method by Hussain et al. (2017) was used. In 0-5, 5-10, 10-15 and 15-20cm soil depth, a sample weighing 200g was passed through a sieve of 2 mm size, then dipped in sodium hexametaphosphate solution (40g/L of water) to promote fragmentation of the soil particles. Soil samples were placed in a plastic bucket of 10 litres filled with water and shaken in such a way that only the solid particles remained. The remaining particles in the sieves were dried under air where all Kongwa weeds were identified and counted.

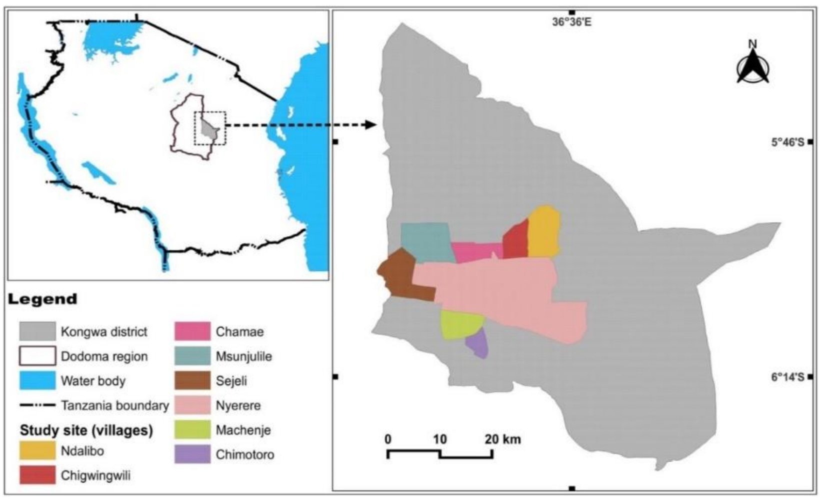


Figure 1. A map showing sampling locations across the Kongwa district.

Particle size analysis

The hydrometer (Bouyoucos) method was used to determine soil particle size (Huluka and Miller, 2014). Soil samples from each sampling site were air-dried and ground to pass a 2 mm sieve. The fine soil particles after grinding 50g were weighed and put into a 250 ml plastic container followed by the addition of 50 ml and 100 ml of sodium hexametaphosphate (5%) and deionized water respectively into the container. The containers were covered tightly and left overnight in a shaker to allow mixing of soil contents. The suspension of samples and blank samples (with no soil sample) were transferred into a sedimentation cylinder and then filled with deionized water to the mark 1000 ml. The suspension was left to equilibrate at room temperature for one hour, then plunged up and down stroke for 1 minute to mix sediments from the bottom of the cylinder. The mixture was left undisturbed for 5 minutes then the dry hydrometer was slowly inserted in it such that the first hydrometer reading was recorded. The temperature of the suspension was then measured using a thermometer. The cylinders were left undisturbed for 5 hours and similar procedures except plunging of the hydrometer and thermometer were used to record the second hydrometer and thermometer readings. The data collected was used to determine soil particle size as per calculations below;

Calculations,

$C_i=(\llbracket HR \rrbracket_1-\llbracket BL \rrbracket_1 \pm 0.36(T_1-20))$ ………… (1)

$C_{ii}=(\llbracket HR \rrbracket_2-\llbracket BL \rrbracket_2 \pm 0.36(\llbracket 0.5(T \rrbracket_1+T_2)-20))$ ..(2)

$\%Clay=(C_{ii}/wt)\times 100$ ………………………… (3)

$\%Silt=((\llbracket (C \rrbracket_i-C_{ii}))/wt)\times 100$ ……………… (4)

$\%Sand=100-(\%Clay+\%Silt)$ ………………… (5)

Where; C_i= concentration clay and silt; C_ii= concentration of clay; HR1 first hydrometer reading of the sample, HR2 second hydrometer reading of the sample, BL1 first hydrometer reading for blank, BL2 second hydrometer reading for blank, T1=first reading temperature, °C; T2=second reading temperature, °C; concentration of silt, and wt= weight (in gram); %Clay=percentage of clay soil; %Silt=percentage of silt soil, and %Sand=percentage of sand.

Data analysis

Analysis of Variance (ANOVA) was conducted to determine variation in the number of weed seeds between and within different villages, soil depths and land use types. This was conducted to understand the extent to which different factors are influencing the dynamics of the seed bank of Kongwa weed. Post hoc analysis using Bonferroni was used to compare means within each independent variable and Tukey HSD was used for pair-wise multiple comparisons for interactions between factors. Upon exploration of the dependent variable which is the seed density of Kongwa weed, it was observed to be over-dispersion and a large number of counts being zeros, we, therefore, employed zero-avoidance log-transformation (Berry, 1987; Warton et al., 2016) to correct for a large number of zero values and overdispersion of data as shown in equation below, where; Y; is the initial value for seed density, and Y‘; is the transformed value of seed density.

$$Y' = \log(Y + 1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

RESULTS

Soil textural analysis

To gain a comprehensive understanding of the soil composition in the study area, a soil textural analysis was conducted as the initial step before delving into the assessment of the soil seed bank. The results of the soil texture classification revealed a predominant presence of sand particles throughout all villages, with clay particles also being notable constituents. This characterization laid the foundation for a detailed examination of the soil's physical properties. Interestingly, the comparative analysis showed no statistically significant differences (p=0.053) among the various soil textural classes concerning the abundance of Kongwa weed seeds in the studied area (**Table 1**).

Table 1. Textural classification of selected villages in Kongwa district

Sample Name	%Clay	%Silt	%Sand	Name (Texture)
Chimotoro (Al)	23.24	2.92	73.84	sandy clay loam
Chimotoro (Fl)	13.24	0.92	85.84	loamy sand
Chimotoro (Rl)	21.24	2.92	75.84	sandy clay loam
Machenje (Al)	29.24	2.92	67.84	sandy clay loam
Machenje (Fl)	35.24	0.92	63.84	sandy clay
Machenje (Rl)	27.24	2.92	69.84	sandy clay loam
Msunjulile (Al)	37.24	2.92	59.84	sandy clay
Msunjulile (Fl)	29.24	4.92	65.84	sandy clay loam
Msunjulile (Rl)	27.24	4.92	67.84	sandy clay loam
Sejeli (Al)	25.24	2.92	71.84	sandy clay loam
Sejeli (Fl)	35.24	4.92	59.84	sandy clay
Sejeli (Rl)	19.24	6.92	73.84	sandy loam
Chamae (Al)	43.04	5.28	51.68	sandy clay
Chamae (Fl)	47.04	7.28	45.68	sandy clay
Chamae (Rl)	43.04	7.28	49.68	sandy clay
Chigwingwili (Al)	33.04	1.28	65.68	sandy clay loam
Chigwingwili (Fl)	33.04	1.28	65.68	sandy clay loam
Chigwingwili (Rl)	31.04	3.28	65.68	sandy clay loam
Ndalibo (Al)	37.04	5.28	57.68	sandy clay
Ndalibo (Fl)	33.04	3.28	63.68	sandy clay loam
Ndalibo (Rl)	33.04	5.28	61.68	sandy clay loam
Nyerere (Al)	19.04	3.28	77.68	sandy loam
Nyerere (Fl)	17.04	3.28	79.68	sandy loam
Nyerere (Rl)	17.04	1.28	81.68	sandy loam

Note: Al= arable land, Fl= fallow land and Rl= range land.

Distribution of Kongwa weed seed density for different land use types across study villages and within soil profiles

The results in (**Table 2**) present density of the weed seed (seeds/m^2) of three predominant land use types; arable, fallow, and range across eight villages in Tanzania and within the four categories of depth in soil profile. Notably, Msunjulile exhibited the highest weed seed density across all land use types; 1.92 seeds/m^2 in arable, 6.67 seeds/m2 in fallow, and 9.83 seeds/m^2 in range land. Conversely, Chigwingwili displayed the lowest weed seed density in arable land with 0.33 seeds/m^2, while Ndalibo had the lowest densities in fallow and range land with 1.17 and 1.00 seeds/m^2, respectively.

Variability in weed seed density among villages and land use types was depicted by the standard deviations whereby, Chamae displayed the highest variability in arable land (2.68 seeds/m^2), and Msunjulile exhibited the highest variability in fallow and range land (4.74 and 6.93 seeds/m^2, respectively). These results also offer insights into the distribution of the weed seed density at various depth ranges and characteristics of Arable, Fallow, and Range land use types.

Variations of Kongwa weed seed density across study sites

The finding showed a clear difference in species density of Kongwa weed between study villages (p-value = 1.61e-05). Msunjulile had a significantly higher mean seed density, mean = 1.123 (0.864) while Ndalibo was observed to have the lowest mean seed density per unit area, mean = 0.376 (0.476) (**Figure 2**).

Variations of Kongwa weed seed density down soil profile

Generally, the number of Kongwa weed seeds was observed to decrease with increased soil depth (p-value = <2e-16). Topsoil (T1) had the highest mean density of Kongwa weed seed, mean = 1.234 (0.726); followed by depth (T2) having mean density = 0.898 (0.642). Seed density at depths T3 and T4 were not statistically different (**Figure 3**).

Table 2. Summary for seed density of Kongwa weed

Factors		Types of Land Use		
	Levels	Arable Mean (s.d)	Fallow Mean (s.d)	Range Mean (s.d)
Villages	Chamae	2.50 (2.68)	2.58 (2.61)	3.33 (2.71)
	Chigwingwili	0.33 (0.65)	1.42 (1.24)	1.75 (1.22)
	Chimotoro	0.58 (0.79)	1.42 (1.16)	2.00 (1.86)
	Machenje	1.00 (1.28)	1.83 (2.21)	2.42 (2.47)
	Msunjulile	1.92 (1.73)	6.67 (4.74)	9.83 (6.93)
	Ndalibo	0.83 (0.83)	1.17 (1.27)	1.00 (1.21)
	Nyerere	1.50 (1.62)	2.33 (1.78)	4.17 (4.59)
	Sejeli	0.92 (1.00)	2.42 (2.23)	3.58 (2.81)
Soil depths (cm)	0 – 5	2.5 (1.29)	5.25 (3.57)	7.12 (5.11)
	5 – 10	1.75 (2.01)	2.96 (2.22)	4.08 (4.20)
	10 – 15	0.375 (0.647)	1.17 (1.34)	2.21 (2.28)
	15 – 20	0.167 (0.381)	0.542 (0.658)	0.625 (0.824)

Variations of Kongwa weed seed density between contrasting land use types

The seed density of Kongwa weed was also observed to vary across different types of land use (p-value = 3.4e-10). Rangeland was observed to have a significantly higher mean density of Kongwa weed seed per unit area, mean = 0.957 (0.720) while arable land and fallow lands were not statistically different from each other (**Figure 4**).

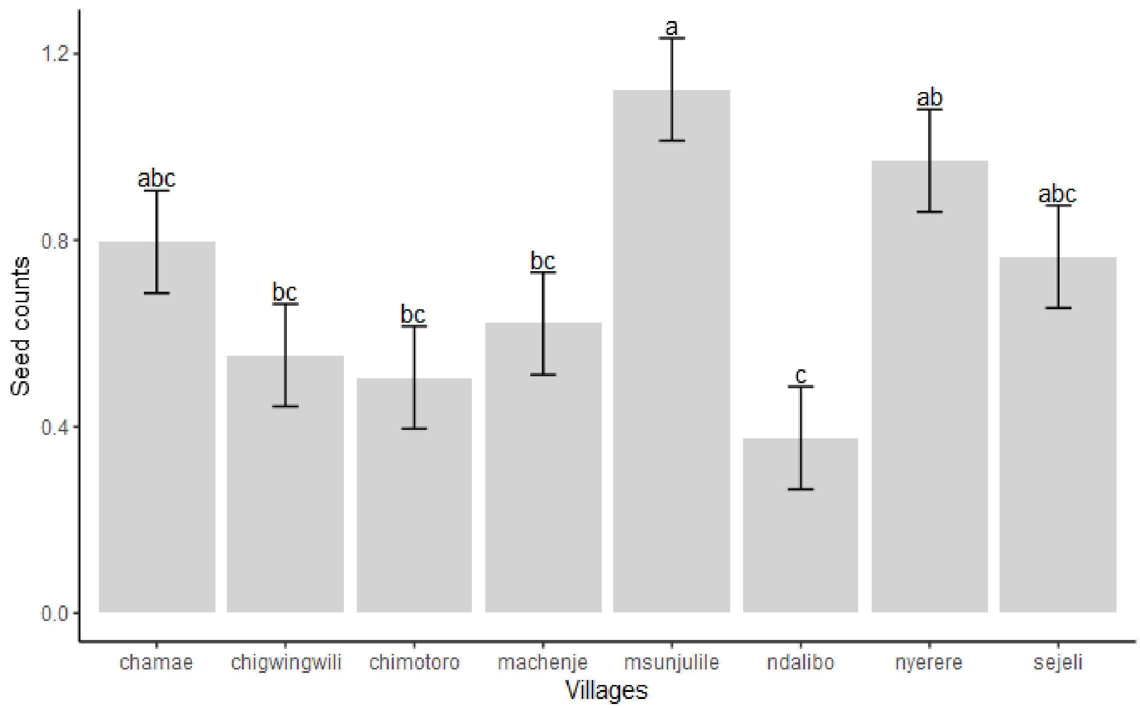
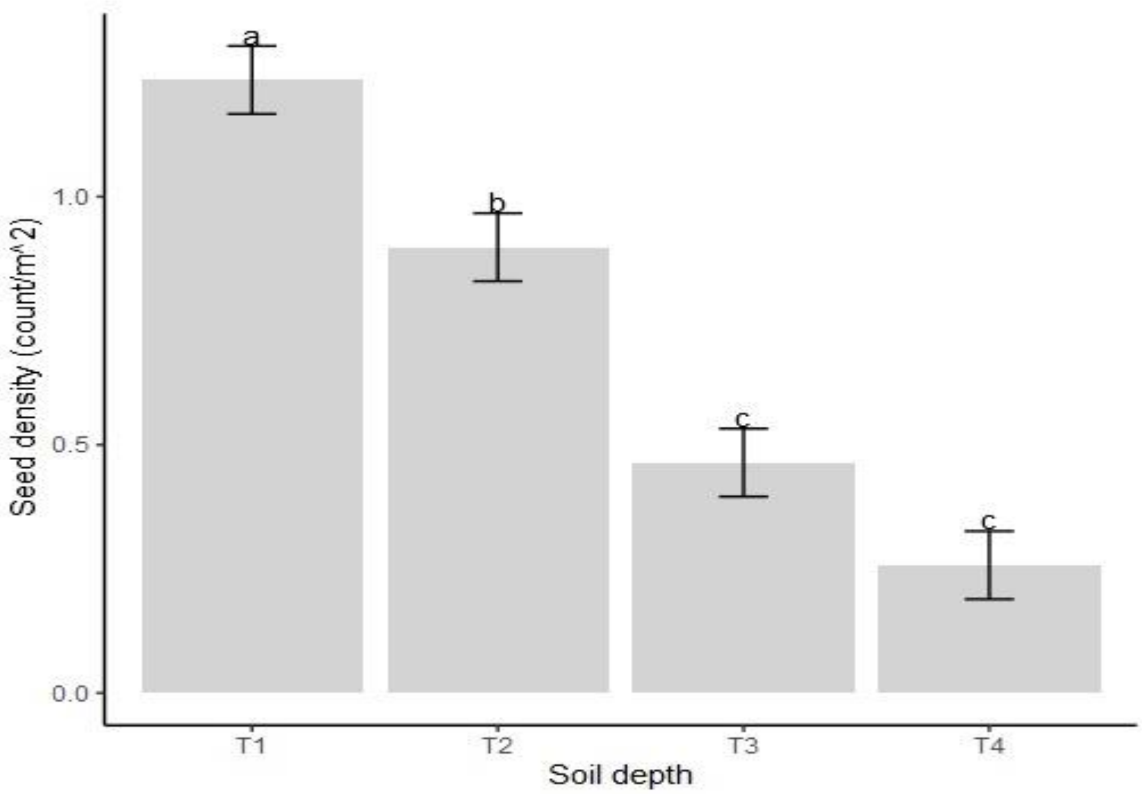


Figure 2. The bar graph for weed seed means separation across villages.



Where; T1= 0-5 cm, T2= 5-10 cm, T3= 10-15cm, and T4 = 15-20cm

Figure 3. Bar graph for weed seed means separation across different soil depths.

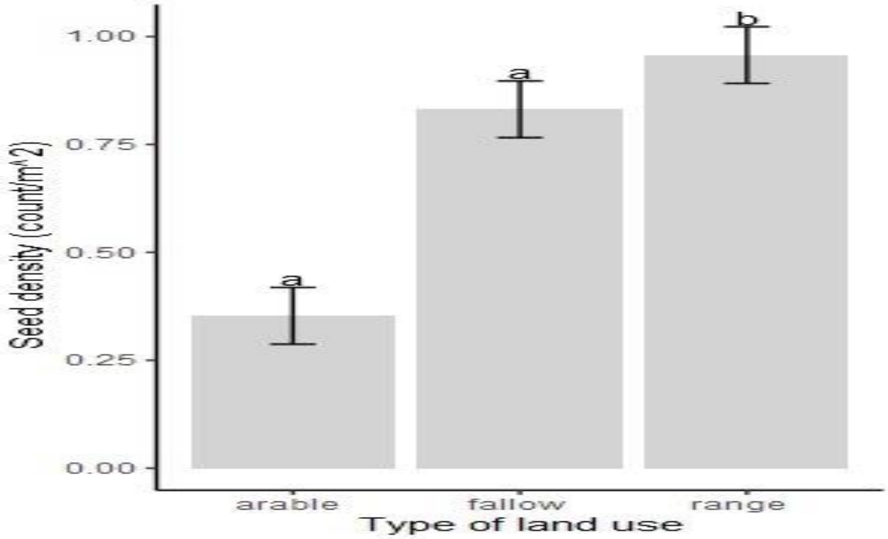


Figure 4. Bar graph for weed seed mean separation across different land use types

Variations of Kongwa weed seed density within soil profile of different types of land uses

Assessment of the combined effect of land use types and soil depth on the seed bank of Kongwa weed in study sites was not observed to have statistical significance (p-value = 0.0571) at our 0.05 alpha level. Nevertheless; post hoc exploration of pair-wise multiple comparisons using Tukey HSD showed some sublevel interactions with statistical significance, some had a positive effect on seed counts while others had a negative effect.

DISCUSSION

Findings revealed range land is highly infested with *A. hyoscyamoides*, the dominance of this weed in range land is attributed to the movement of animals during grazing (Mkongera et al., 2021), zero disturbance of land that may influence the growth and development of weed (Chauhan, 2012). Since there is no or little disturbance of soil in range land areas, weed plants are allowed to grow and produce more seeds, which eventually results in a higher seed bank (Buhler et al., 1997). When exposed to favourable conditions, weed seed in the soil can germinate to form new seedlings and a new cycle of weed seed begins (Mashavakure et al., 2019). However, higher seed banks were recorded in fallow land compared to arable land. This is attributed to a similar factor as in range land explained above, most of these areas near Range area (NARCO) are used for grazing. The low seed bank in arable land is attributed to the continuous disturbance of land that exposes seeds to favourable conditions for germination (Andreasen et al., 2018). Germinated weed seeds are controlled during weeding regimes before the vegetative stage. Therefore, this plays a critical role in the reduction of seeds that could be produced by growing plants. It has been reported by Chauhan and Johnson (2010) that the decline in weed seeds in the soil can be influenced by germination, decay, and predation. However, it is possible when weed seeds are exposed to the upper soil surface during tillage practices in arable lands, can be lost due to physical damage and predators (Lamichhane et al., 2018). However, exposed seeds to the upper soil layer may germinate but be predated by insects in the seedling stage. This aligns with the findings reported by White et al. (2007) that 5 – 15% of emerged weed seedlings were reduced by common ground beetles or crickets. Other seeds may be consumed by rodents, and birds, and infected by soil pathogens (Hossain and Begum, 2015). Also, seeds shifted into deep soil depth would be able to germinate but failed to emerge in the soil surface (lethal germination) (Gardarin et al., 2010). This is in line with Odeleye et al. (2018) who reported on the position of the seeds in the soil as a main factor for successful germination and emergence.

Higher infestation of Kongwa weed has been attributed to the closeness of studied villages to Kongwa Ranch (NARCO) where there are higher Kongwa weed invasions. Since this weed was first reported infesting the ranch area, during its spread the nearby villages were affected first too (Nkombe et al., 2018). The movement of animals, wind, birds, and farm implements led to the spread of this weed into other areas starting with nearby villages such as Msunjulile. Therefore, those villages nearby recorded a larger number of seeds than others which are found far from the ranch except Nyerere village which is located a bit far but recorded with higher concentrations of weed seed. This may be attributed to a free-range grazing system in which animals are allowed to move freely in search of food and water. On the other hand, in most of the villages with cultivated lands and located far from the ranch, Kongwa weeds are well controlled compared to villages near the ranch. This is done through different routine agricultural practices such as hand and hoe weeding, herbicide application, and fire during off season. When this weed is controlled before the reproductive stage, it helps to reduce the amount of seed bank in the soil (McErlich and Boydston, 2014). In range lands these methods are difficult to apply, for example, the application of herbicide can affect animals when they come in contact with or ingest contaminated pastures.

Moreover, *A. hyscamoides* seeds have been significantly distributed in various layers of soil. The highest abundance of seeds has been recorded in upper soil depth (0-5 cm) than other depths. Karim et al. (2017) discovered that the accumulation of many seeds was in the upper soil 0-5 cm, and Hussain et al. (2021) also reported the accumulation of weed seeds in the upper soil surface (0-10 cm). This is consistent with the findings of Hossain et al. (2021) who discovered that more than 60% of the seed pool was condensed in the top 5 cm. This revealed that the accumulation of weed seeds in the soil decreases with the increase of soil depth. Accumulation of weed seeds in the upper soil layer is influenced by, the dropping of fresh seeds from the plant direct to the soil surface before being distributed vertically or horizontally. Some of the seeds succeed in shifting into deep soil layers but the majority remain in the upper layer. Most of the seeds from a depth of 15-20 cm are destroyed by predators as well as physiological changes (Bagavathiannan and Norsworthy, 2013). This means seeds present near the soil surface have a higher possibility of germinating and emerging before lost viability. Most of the soil samples were dominated by large soil particles. Domination of sand particles in the soil facilitates penetration of seeds inside the soil easily when any kind of soil disturbance is employed either naturally or artificially (Burmeier et al., 2010). For instance, in arable lands, these types of soil are easy to till compared to clay-dominated soil and thus can facilitate vertical and horizontal movements of weed seeds.

CONCLUSION

Generally, higher seed banks have been recorded in range land areas, with upper depth of 0-5 cm as well as villages near ranch areas. livestock movements during grazing and human activities such as the cultivation of crops have played a big role in the alteration of seed banks. Therefore, control of seed bank concentration should be firstly employed by putting much emphasis on taking action on possible ways in which this weed spread in various areas. Management strategies shall be employed mainly in range land (Kongwa ranch) and villages around the ranch to minimize or control further spread of the weed. However, Management of this weed before the flowering stage will be very helpful in the reduction of weed banks. Further study on the Kongwa weed seeds' survival about dormancy should be done to understand the critical time for weed seed germination and emergence. This will be useful in establishing proper and effective strategies in the management of Kongwa weed.

AUTHOR'S CONTRIBUTION

D.P.M, K.P.S and A.K designed the study, D.P.M experimented, collected data, conducted data analysis, and drafted the manuscript. K. P.S. and A.K. reviewed and edited the study concept.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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