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Allelopathic Effect Of Invasive Weed Parthenium Hysterophorus (Ragweed) On Seed Germination And Growth Of Field And Pasture Crops In Semi-Arid Regions Of Baringo County

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Abstract

Background: *Parthenium hysterophorus is a notorious invasive weed species exerting significant negative effects on growth, productivity of agricultural crops and rangelands owing to its rapid spread abilities. Its unchecked spread has led to invasions of arable farmlands and pastoral areas, disrupting ecosystem functions, local livelihoods, and the environment. Parthenium weed contains potential allelochemicals within its aerial parts of leaves, flowers, stems, and roots that inhibit germination and growth of a wide range of plant species, including native plants, various crops, and pasture species. Therefore, understanding Parthenium weed impact on seed germination and growth of crops is imperative for the establishment of sustainable land management strategies.*
Material and methods: *A study was conducted to investigate the allelopathtic effects of Parthenium weed on germination and growth of select field crops and pasture grass. Parthenium extracts from stem, roots, flowers, and leaves at different concentrations of 0%, 1%, 5% and 10% were used as treatments. Analysis of germination percentages, root and shoot lengths revealed variations on allelopathic potential of different plant parts of the weed.* ***Results:*** *The extracts significantly inhibited germination, root and shoot lengths of test crops ($p<0.05$) with highest effects recorded at 10% concentrations from Leaves as follows: 65% for grass, 41% for maize, 50% for melon and 50% for Grass respectively. The results indicated an increase in concentration of extracts caused drastic reduction of growth parameters clearly indicating a dose response relationship. Leaf extracts were more potent in inhibiting germination, root and shoot length compared to extracts from other parts. Maize exhibited increased sensitivity to increased concentrations as compared to other crops.*
Conclusion: *It was concluded that Parthenium weed management strategies ought to be initiated at early development stages of the weed to reduce its impacts on crop production.*

Key Words: *Allelopathy, Invasive species, ecosystem, Parthenium hysterophorus, Extracts*

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I. Introduction

Parthenium hysterophorus L. is a global invasive weed species belonging to the Asteraceae family that is highly aggressive and has established its presence in over 46 countries in Africa, Asia, and Australia under very diverse ecological conditions(Olie *et al.*, 2024; Naderi *et al.*, 2024) threathening agriculture and biodiversity around the globe (Malka *et al*., 2023) .

In Kenya, the weed was first reported in coffee plantations around Nairobi areas (Mutua *et al*., 2022) but has spread to the maize and wheat growing areas around Lake Victoria, central, Western and Eastern parts and the Laikipia plains in the Rift valley (Mutua *et al.,* 2021). Parthenium weed was declared noxious weed in Kenya in 2010 under the Suppression of Noxious Weeds act cap 325, (Kenya Constitution, 2010) due to its threats to human health, livestock, agricultural production, and biodiversity (Yaacoby *et al.*,2023; Mutua et al., 2021)

The weed thrives in disturbed areas such as abandoned construction sites, roadsides, railway lines and fallow agricultural lands and pasture fields where interspecies competition is absent (Abbas *et al*., 2024; Yaacoby *et al*., 2023).

Key factor contributing to its rapid spread is possession of allelochemicals (Naderi *et al*., 2024) within its leaves, stems, roots, and inflorescence (Oli *et al.,* 2024). This characteristic has been proposed to play a significant role in its rapid invasion and survival across diverse ecosystems (Kumar *et al*., 2022; Bashar *et al*., 2023; Mao *et al*., 2021). The chemicals effectively suppress growth and establishment of neighboring plants (Naderi *et al*.,2024; Bashar *et al*.,2023; Abbas *et al*.,2024) by conferring the weed with competitive edge for resources. Additionally, the chemicals lower germination, and development of crops and crop productivity (Rehman *et al*.,2020).

The spread of this weed affects biodiversity by exhibiting luxuriant growth in diverse habitants ranging from wastelands, vacant lands, orchards, forestlands, flood plains, agricultural areas, shrub lands, urban areas, overgrazed pastures and along roadsides and railway tracks (Shabir *et al.*,2023).

Parthenium weed stands as a profoundly toxic and aggressive species, presenting a menace to crops, human beings and livestock attaining a notorious reputation earning its place among the world most feared and dreaded weed (Oli *et al*.,2024; Bashar *et al*., 2023). Crop yield reductions of up to 90% in forage crops and up to 40% in maize have been reported (Mutua *et al.,* 2022).

The weed is posing a serious challenge to food security affecting livelihoods of people who totally or partially are dependent on agricultural production. Despite the challenges posed by the weed, there is no adequate evidence on the extent the allelopathic impact from this weed affects germination and growth of economically important crops like maize, green grams, watermelon and Pasture grass. It is, therefore, important to study the allelopathic impact of Parthenium weed on germination parameter of both crops under laboratory conditions.

The fast expansion Parthenium weed in Baringo lowland areas is becoming a menace to crop and livestock production with the mechanism of this spread not clearly understood. Furthermore, information on the allelopathic effect of Parthenium on germination and growth of this crops in Baringo is limited. Therefore, this study reports on the allelochemical impacts of Parthenium hysterophorus on germination and growth attributes of maize, green grams, watermelon, and foxtail grass.

II. Materials And Methods

Experimental site and design

Laboratory experiment was carried at KEFRI Marigat, Baringo county (0°28′N 35°59′E) located in the Rift valley with an average altitude of 700 a.s.l, average annual temperature of 24.6˚C and precipitation of 671mm.

Two sets of experiments were conducted during the season of October-November 2023 and January - March of 2024 to investigate the effects of Parthenium extracts on seed germination and growth of select crops and seeded pasture. Experiment plots were set out in a factorial method under Complete Randomized Design (CRD) with three replications. Four levels of Parthenium extracts (0%, 1%, 5% and 10% v/v) where each was applied on four test crops and kept at room temperature with normal lighting. The test crops included maize (*Zea mays*), green grams (*Vigna radiata*), watermelon (*citrullulus lanatus*) and foxtail grass (*Cenchrus ciliaris*). The crop seeds were procured from the local markets and from the Kenya Seed Company.

Preparation of Parthenium Extracts

Plants were picked from farmlands and grazing lands in Baringo South, Njemps flats. Mature Parthenium plants were uprooted at flowering stage and washed off to remove soil. The plants were separated into leaves, stem, root, and flower parts. Each part of the fresh plant was cut into 2–3 cm pieces and ground separately with a pestle and mortar. The ground material weighing 1g, 5g and 10 g of each part was soaked in 100ml of distilled water for 24 hours at room temperature (21–22˚C) and then sieved through cheese cloth to obtain the extract that were designated as 0%, 1 %, 5 % and 10 % v/v aqueous extract respectively.

Experimental set up

The experimental plots were set out in a factorial method in a Complete Randomized Design (CRD) with three replications. The treatments were different concentration of Parthenium extracts (0%, 1%, 5% and 10% volume) where each was applied on four test crops and kept in room temperature with normal lighting.

A hundred seeds each of test species viz maize, green grams, watermelon, and foxtail grass were placed in Petri dishes lined with clean blotting papers and 10 ml of each of the leaf, stem, root and flower extracts respectively. Distilled water was used as a control representing 0% concentration. The paper towels were kept moist with the similar throughout the duration experiment. An equal volume of distilled water was added in the dishes when the moisture content of the blotting paper declined as adopted from Tefera, (2002). The whole experiment was repeated twice and mean data of two experiments were analyzed.

Data Collection

During the study, data on germination (seedlings with visible plumule and radicle growth), plumule and radicle size (cm) were recorded after seven days. Germination percentages were determined by number of seedling emergence out of 100 seeds multiply by 100%.

Shoot length per plant (cm) was measured using a ruler from the base to the tip and the root length per plant (cm) from the base to the longest tip and individual weight (g) for both root and shoot. The data for all parameters were subjected to Analysis of Variance using R statistic version 4.3.1 The significant means were subjected to the LSD test to explain the significant differences of means.

III. Results And Discussions

Seed germination

The Parthenium extracts from the selected parts significantly inhibited germination to all crops in comparison to control. The germination was more inhibited as extracts concentration increased indicating a dose response relationship (Table 1)

Foxtail grass showed no statistical difference in germination under roots and stem concentration 1,5 and 10 vol. but responded significantly to all the extract concentrations, with the lowest germination (65%) observed at 10% Vol. from flower extracts. High germination was observed in the control (90%), as did stem extracts at 1% Vol (table 1 and figure 3.

Green grams showed inhibition for all the extracts from leaves, stems, roots, and flowers at all the concentrations. There was no significant statistical difference ($p < 0.05$) noted for extracts from roots and stem at 5% vol. but flower extracts at high concentration 10% vol. resulted to poor germination (50%). Watermelon showed a similar trend, with extracts from leaves and flowers inhibiting germination by almost 30% (table 1).

Maize was the most affected test crop, with the lowest germination rates observed when leaves extracts were applied (51.66%) and Extracts from flowers (41.67%) at 10% vol. However, the effects from roots and stem across all the concentrations were statistically indifferent at ($p<0.05$) (table 1 and figure 1).

Comparatively, among the parthenium aqueous extracts, extracts from flowers showed a heightened inhibitory effect on germination across the test crops, with Maize recording the lowest percentage (41.67%) at 10%Vol following closely were extracts from leaves at high concentration, as shown in Table 1and Figure 1.

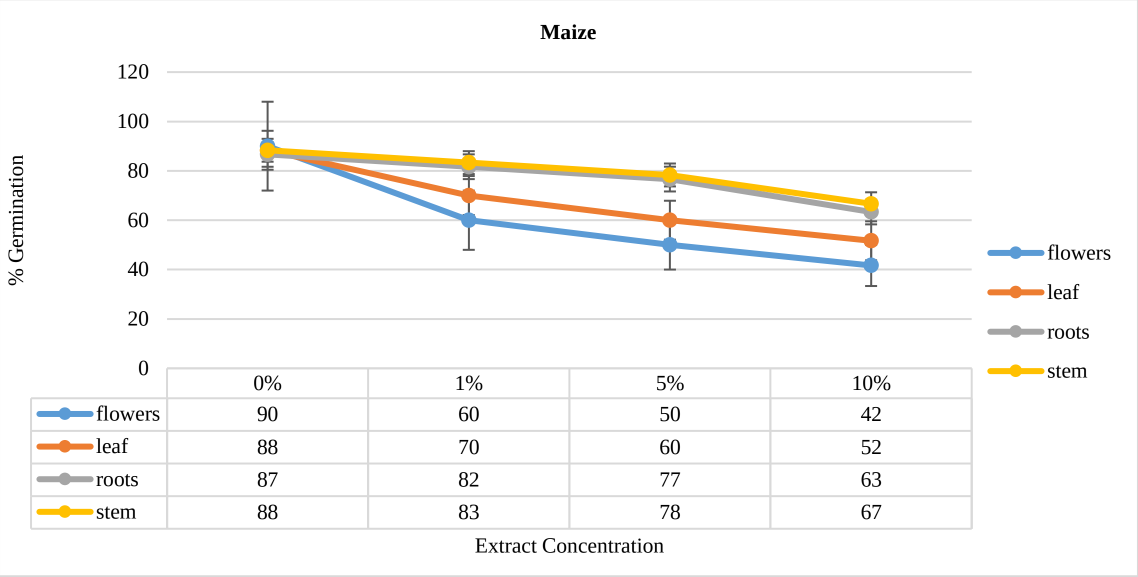
These varied germination percentages could be attributed to the presence of allelochemicals that slow down the activity of germination inducing hormones, Gibberelins. The Gibberelins induce production of hydrolyzing enzymes that stimulate production of digestive enzymes that breaks down food reserves in the endosperms inducing seed germination (Putri, 2022)

Similar results were reported in Tef (Tefera, 2002), Maize, Mung bean and Wheat (Singh.,2021) and Chickpea (Shafiq *et al*.,2020).

Table 1: Show extracts from different parts of Parthenium on germination% of test crops

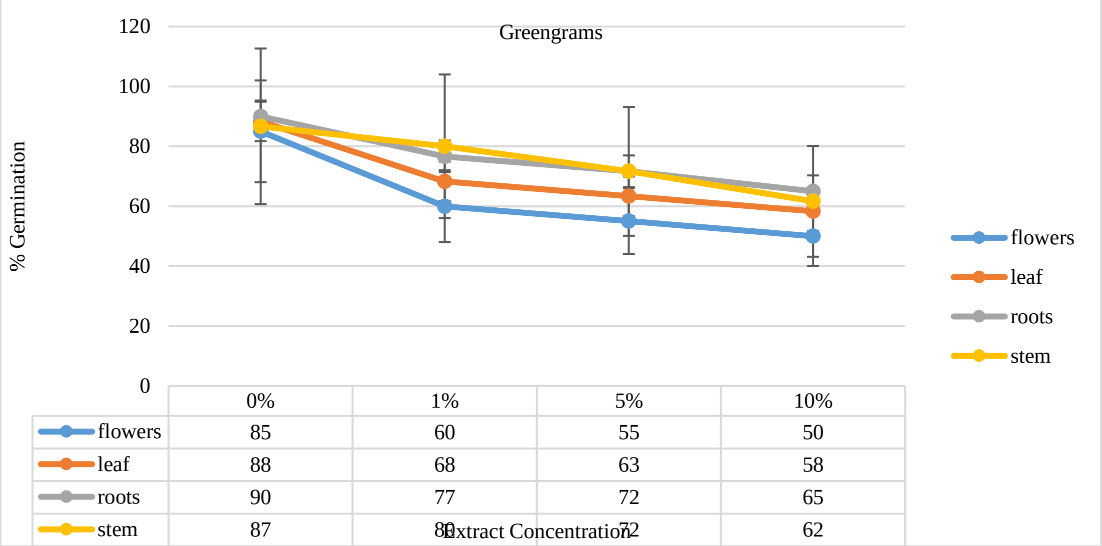
Seed germination	**Treatments**	**0%**	**1%**	**5%**	**10%**
Grass	**stem**	**90.000a**	**86.667a**	**81.667a**	**76.667a**
	roots	**90.000a**	**85.000a**	**80.000a**	**75.000a**
	leaf	**86.667a**	**80.000b**	**75.000b**	**70.000b**
	flowers	**88.333a**	**75.000c**	**70.000c**	**65.000c**
	pr(>f)	***0.5537***	***7.015e-05 ******	***7.015e-05 ******	***7.015e-05 ******
Maize	**stem**	**88.333a**	**83.333a**	**78.333a**	**66.667a**
	roots	**86.667a**	**81.667a**	**76.667a**	**63.333a**
	leaf	**88.333a**	**70.000b**	**60.000b**	**51.667b**
	flowers	**90.000a**	**60.000c**	**50.000c**	**41.667**
	pr(>f)	***0.7288***	***1.093e-05 ******	***2.408e-06 ******	***6.977e-05 ******
Watermelon	**stem**	**85.000a**	**78.333a**	**73.333a**	**66.667a**
	roots	**85.000a**	**75.000b**	**70.000a**	**61.667b**
	leaf	**85.033a**	**70.000c**	**63.333b**	**55.000c**
	flowers	**84.967a**	**65.000d**	**58.333c**	**50.000d**
	pr(>f)	***0.4108***	***3.577e-05 ******	***0.0007949 ******	***0.0001548 ******
Green grams	stem	86.667a	80.000a	71.667a	61.667ab
	roots	90.000a	76.667b	71.667a	65.000a
	leaf	88.333a	68.333c	63.333b	58.333b
	flowers	85.000a	60.000d	55.000c	50.000c
	pr(>f)	0.5299	8.47e-06 ***	0.001029 **	0.0002602 ***

Figure 1. Germination percentage of maize crop under different concentration of Parthenium weed extract of its different parts



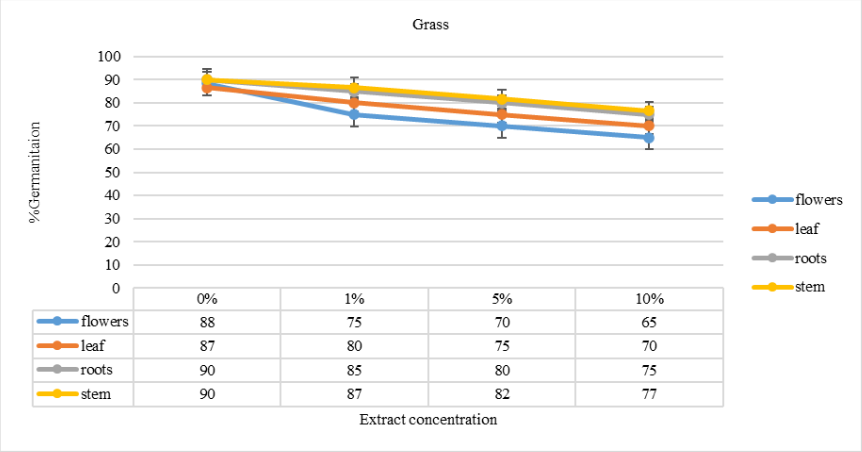
	0%	1%	5%	10%
flowers	90	60	50	42
leaf	88	70	60	52
roots	87	82	77	63
stem	88	83	78	67

Germination percentage of green gram crop under different concentration of Parthenium weed extract of its different parts



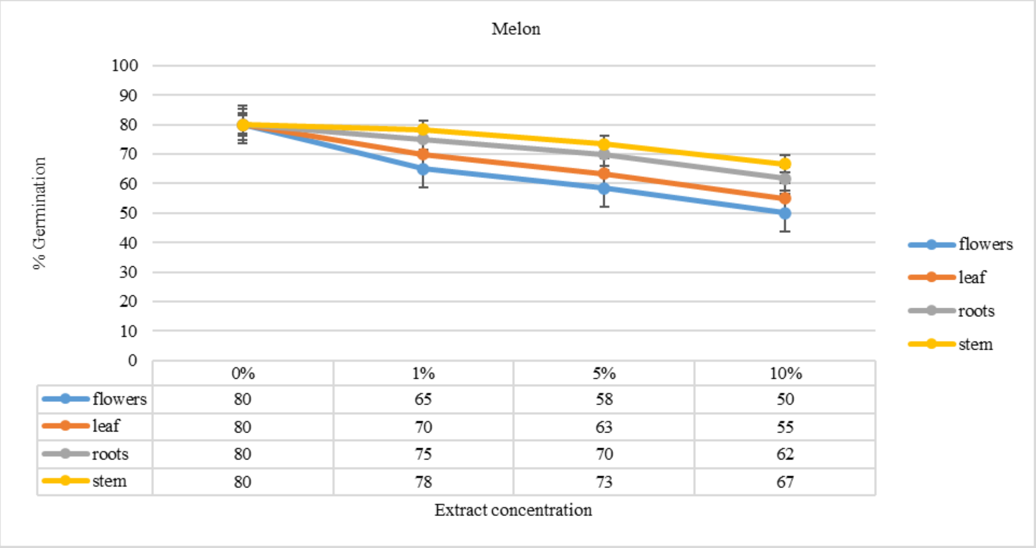
	0%	1%	5%	10%
flowers	85	60	55	50
leaf	88	68	63	58
roots	90	77	72	65
stem	87	80	72	62

Germination percentage of fox grass under different concentration of Parthenium weed extract of its different parts



	0%	1%	5%	10%
flowers	88	75	70	65
leaf	87	80	75	70
roots	90	85	80	75
stem	90	87	82	77

Germination percentage of melon crop under different concentration of Parthenium weed extract of its different parts



Root length

Root length of test crops responded significantly($p<0.05$) to the leaf, root, stem, and flower extracts at various concentrations, with extracts from Flowers and leaves demonstrating greater potency. The impact became more pronounced with the increasing concentration of the extracts. For instance, Root length of grass was significantly reduced (2.033) and (1.33) when exposed to high (10% Vol) concentration extracts from leaves and flowers, respectively, compared to the control. Extracts from roots at all concentrations did not exhibit any statistical difference. It was further noted that even a lower concentration of all extracts from all parts at 1% was effective in significantly $p<0.05$) reducing the root length.

Stem extracts across all the concentrations showed no statistical difference in Maize and watermelon compared to leaves, root, and flower extracts.

The lowest average value of root length was reported in Maize (0.567), watermelon (0.833), grams (1.1) and grass (1.33) when high concentration (10% Vol) extracts from flowers were used. This may be attributed to higher accumulation of allelochemicals in flowers than the other parts of the weed.

Effect of treatments and all concentrations were significant at $p<0.05$ while it was non-significant for the control as depicted in (Table 2 and Figure 2).

From the results, extracts from different parts across all the concentration reduced root growth and elongation. Direct contact with the extracts may have led to increased inhibition, as the roots possibly absorbed water soluble allelochemicals that hindered cell division and elongation by reducing the activity of growth stimulating hormones (Singh.,2021)

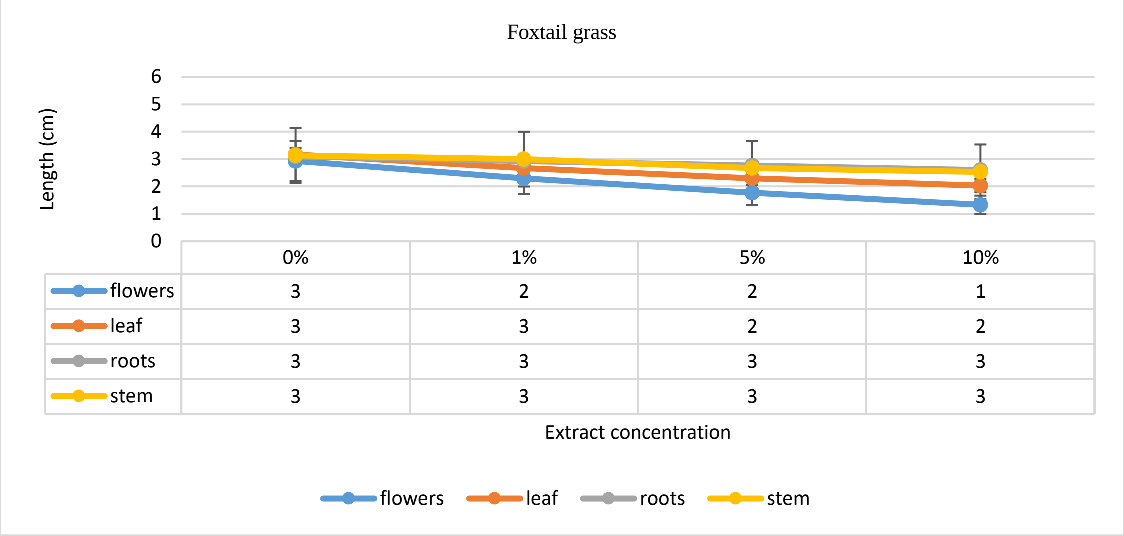
These findings align with previous reports in Wheat, Sorghum, maize, and cotton (Dhole *et al.*,2021) and tef (Tefera, 2002). These effects are primarily attributed to secondary metabolites produced by the weed, which have been documented to inhibit growth and development of various plant species (Kumar *et al.*,2022). These metabolites find their way into the environment and to other plants through leaching, volatilization, exudation from underground structures, direct release from different plant parts, root release and decomposition of leaves, roots, and stems (Bashar *et al.*,2023)

Table 2: Show effects of extracts from different parts of Parthenium on root length of test crops

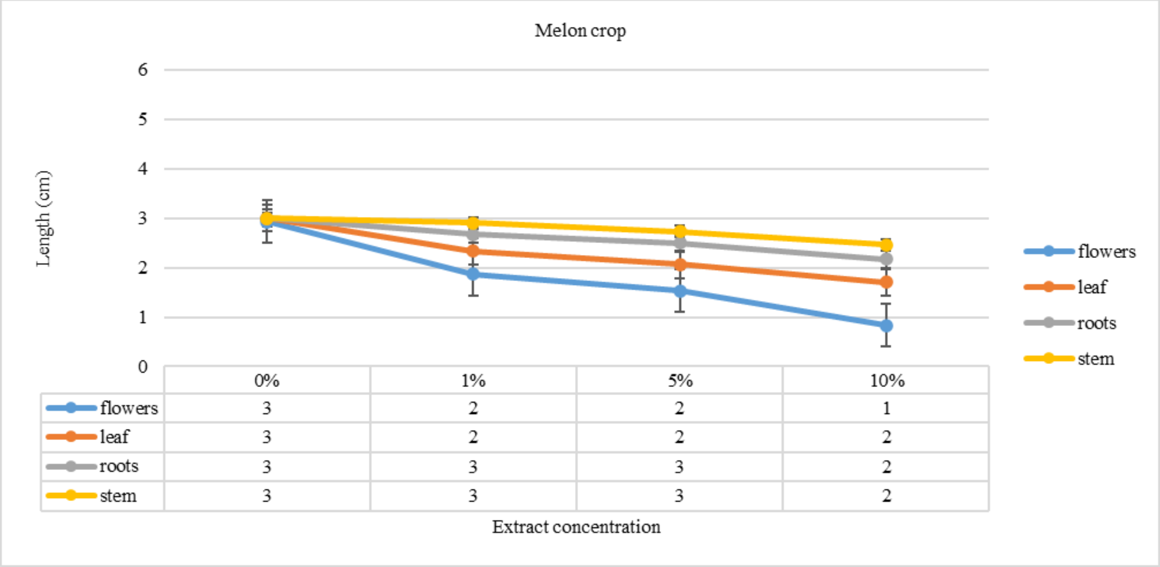
Root length	**Plant part**	**0%**	**1%**	**5%**	**10%**
Grass	**STEM**	3.133a	3.000a	2.667b	2.533a
	ROOTS	3.100a	2.933a	2.767a	2.600a
	LEAF	3.167a	2.667b	2.300c	2.033b
	FLOWERS	2.933a	2.300c	1.767d	1.333c
	PR(>F)	0.2085	8.404e-07 ***	1.687e-08 ***	3.991e-08 ***
Maize	**STEM**	4.133a	4.000a	3.000a	2.367a
	ROOTS	4.100a	3.866b	2.633b	2.033b

	LEAF	4.167a	3.700c	2.033c	1.233c
	FLOWERS	3.933a	2.800d	1.400d	0.567d
	PR(>F)	0.2085	3.452e-08 ***	1.87e-07 ***	1.199e-08 ***
Watermelon	**STEM**	3.000a	2.900a	2.733a	2.467a
	ROOTS	3.000a	2.667b	2.500b	2.167b
	LEAF	3.000a	2.333c	2.067c	1.700c
	FLOWERS	2.933a	1.867d	1.533d	0.833d
	PR(>F)	0.7438	2.884e-05 ***	8.158e-08 ***	1.266e-07 ***
Green grams					
	STEM	5.400a	4.700b	3.800b	1.800b
	ROOTS	5.367a	5.033b	4.133a	2.133a
	LEAF	5.500a	4.333c	3.500c	1.500c
	FLOWERS	5.367a	3.833d	3.100d	1.100d
	PR(>F)	0.666	2.015e-05 ***	2.078e-05 ***	2.078e-05 ***

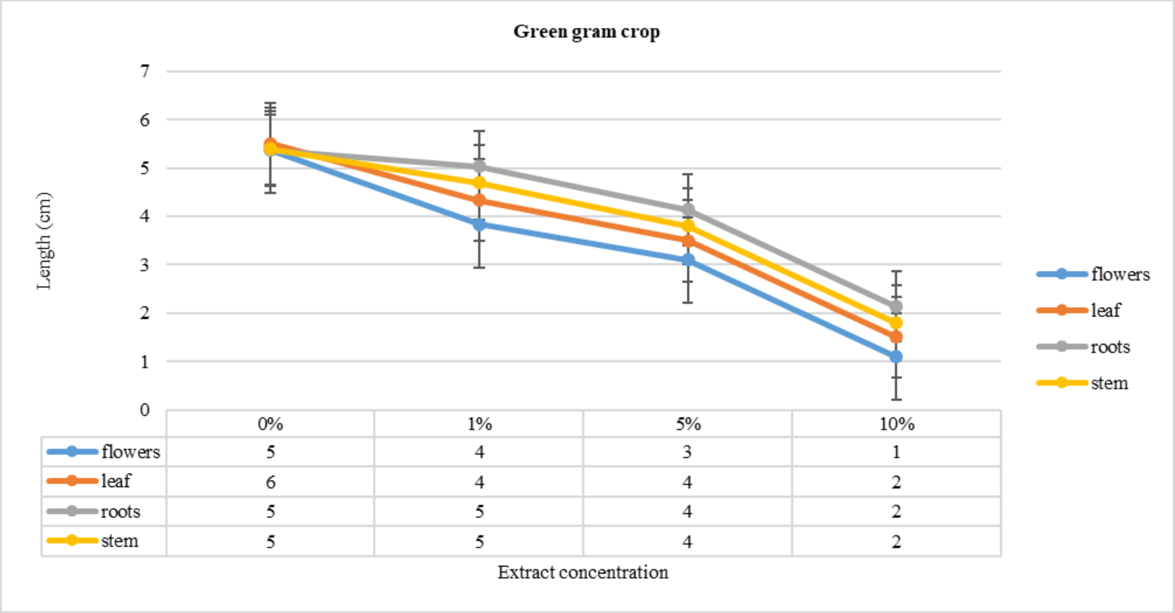
Figure 2. Root length of foxtail grass under different concentration of Parthenium weed extract of its different parts



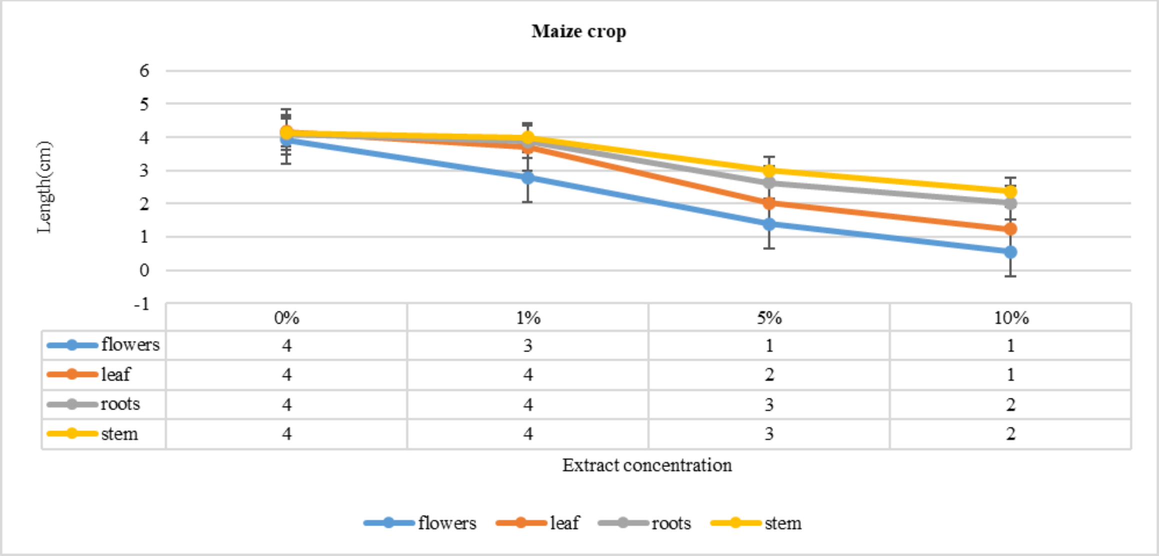
Root length(cm) of melon crop under different concentration of Parthenium weed extract of its different parts



Root length (cm) of green gram crop under different concentration of Parthenium weed extract of its different parts



Root length(cm) of maize crop under different concentration of Parthenium weed extract of its different parts



Shoot length.

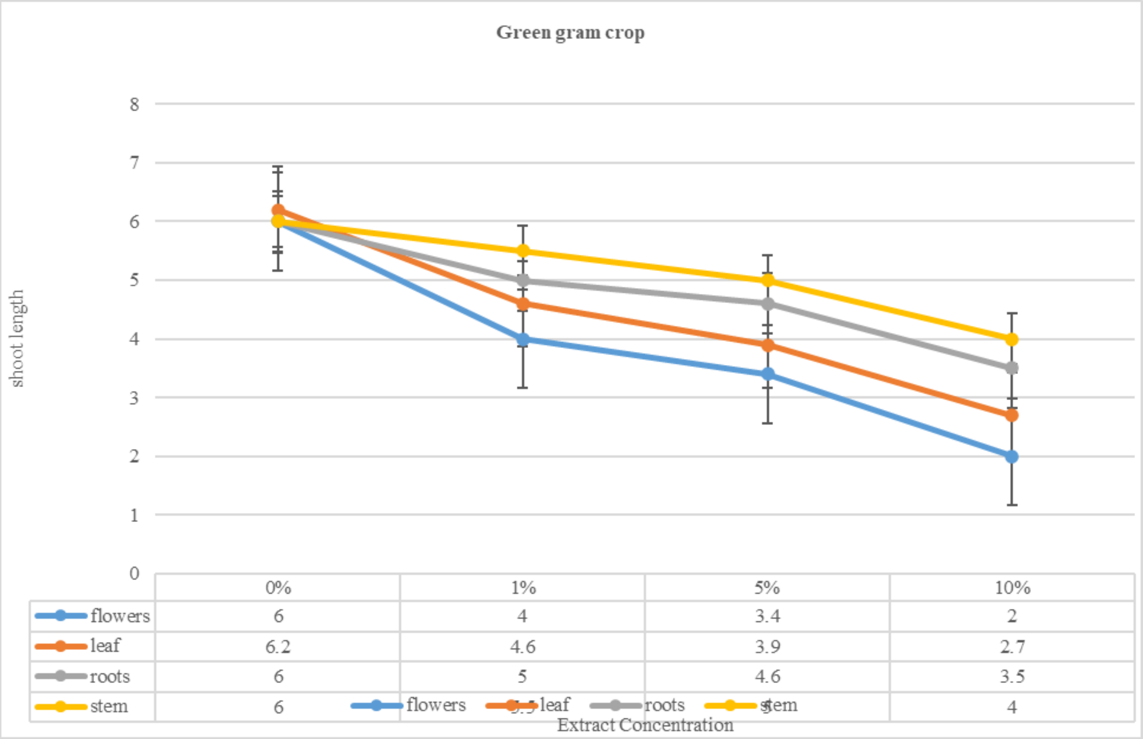
Various extract concentrations showed significant($p<0.05$) effects on shoot length of the test crops. Similarly, maize, grass, and grams showed slight reductions in shoot length across all concentrations. The most pronounced reductions were observed in maize (0.566), watermelon (0.667), grams (2.03) and grass (2.33) when exposed to high concentration(10%vol) from flowers compared to the control as shown in Table 3 and Figure 3

Comparable findings were documented in previous studies in green gram, black gram, and groundnuts (Pathasarathi *et al.*,2012). *Parthenium hysterophorus* parts are rich in various allelochemicals (Bashar et al.,2023).

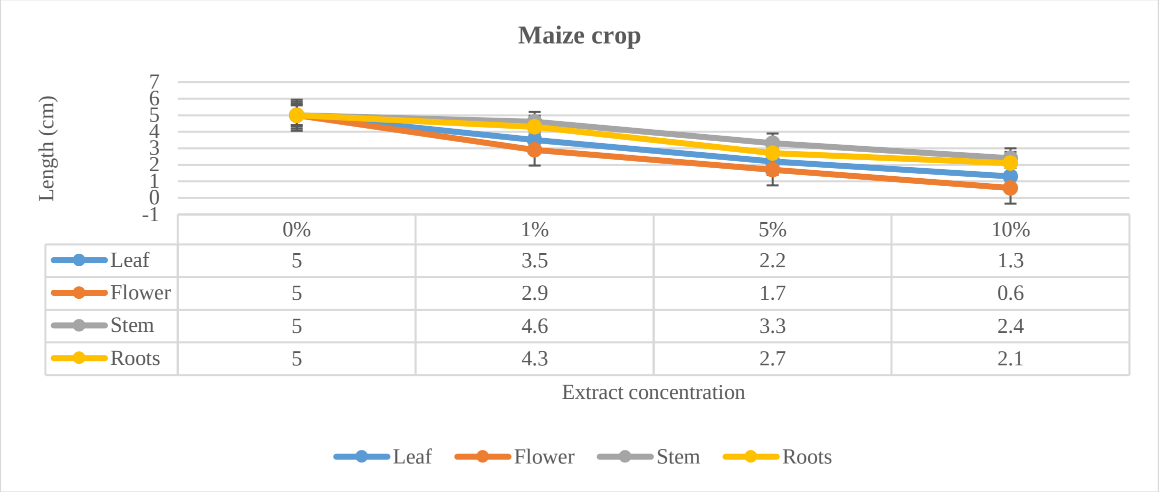
Table 3: Effects of extracts from different parts of Parthenium on shoot length of test crops

		Extract concentration (%volume)			
Shoot length.	**Plant part**	**0%**	**1%**	**5%**	**10%**
Grass	**STEM**	4.233a	4.000a	3.933a	3.700a
	ROOTS	4.367a	3.700b	3.500b	3.200b
	LEAF	4.167a	3.433c	3.200c	3.033c
	FLOWERS	4.200a	2.867d	2.500d	2.333d
	PR(>F)	0.622	3.717e-05 ***	9.353e-08 ***	3.743e-07 ***
Maize	**STEM**	5.000a	4.633a	3.300a	2.433a
	ROOTS	5.000a	4.267b	2.733b	2.067b
	LEAF	5.033a	3.467c	2.200c	1.333c
	FLOWERS	4.967a	2.900d	1.667d	0.566d
	PR(>F)	0.9249	4.854e-07 ***	7.323e-08 ***	3.294e-08 ***
Watermelon	**STEM**	3.433a	2.967a	2.700a	2.533a
	ROOTS	3.500a	2.600b	2.367b	1.967b
	LEAF	3.400a	2.300c	1.967c	1.667c
	FLOWERS	3.400a	1.800d	1.333d	0.667d
	PR(>F)	0.4366	2.055e-06 ***	3.874e-08 ***	4.074e-07 ***
Greengrams	**STEM**	6.133a	5.500a	5.033a	4.033a
	ROOTS	6.167a	5.167b	4.633b	3.567b
	LEAF	6.233a	4.667c	3.967c	2.700c
	FLOWERS	6.133a	4.100d	3.433d	2.033d
	PR(>F)	0.621	5.441e-05 ***	2.502e-07 ***	1.949e-07 ***

Figure 3. shoot length(cm) of green gram crop under different concentration of Parthenium weed extract of its different parts

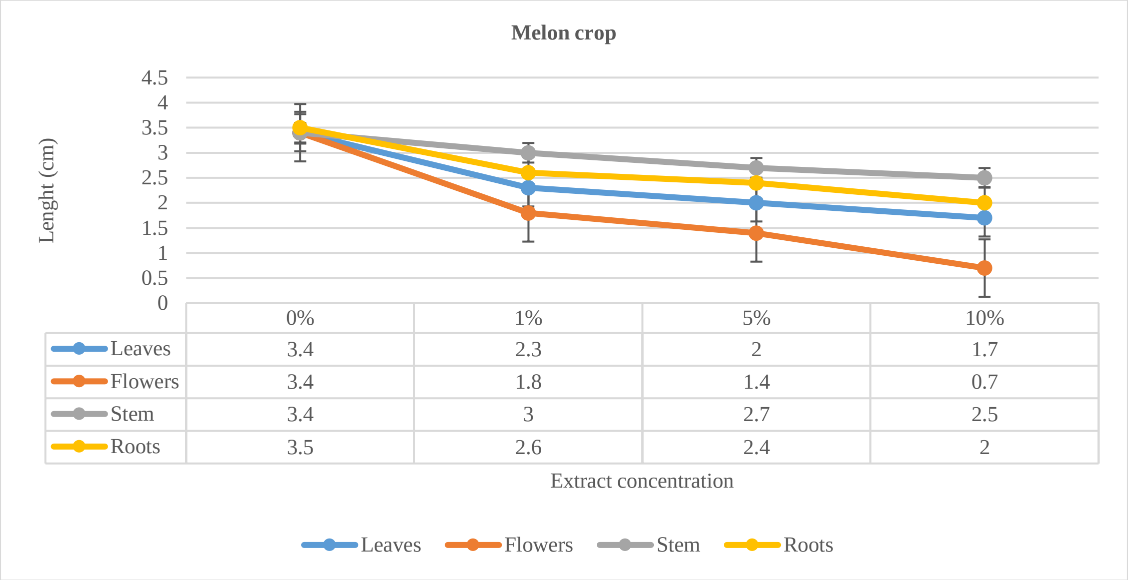


Shoot length(cm) of Maize crop under different concentration of Parthenium weed extract of its different parts.



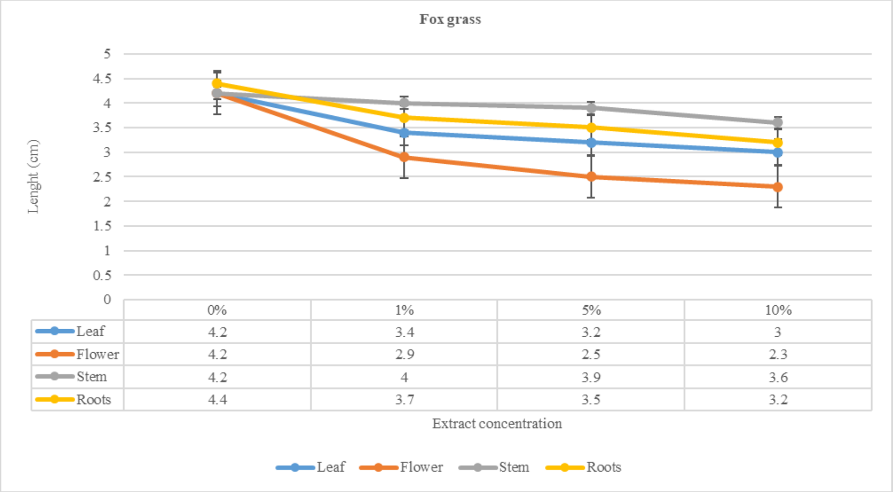
	0%	1%	5%	10%
Leaf	5	3.5	2.2	1.3
Flower	5	2.9	1.7	0.6
Stem	5	4.6	3.3	2.4
Roots	5	4.3	2.7	2.1

Shoot length(cm) of green gram crop under different concentration of Parthenium weed extract of its different parts



	0%	1%	5%	10%
Leaves	3.4	2.3	2	1.7
Flowers	3.4	1.8	1.4	0.7
Stem	3.4	3	2.7	2.5
Roots	3.5	2.6	2.4	2

Shoot length(cm) of foxtail grass under different concentration of Parthenium weed extract of its different parts



	0%	1%	5%	10%
Leaf	4.2	3.4	3.2	3
Flower	4.2	2.9	2.5	2.3
Stem	4.2	4	3.9	3.6
Roots	4.4	3.7	3.5	3.2

Parthenium hysterophorus possess allelochemicals that can be beneficial or detrimental to other surrounding plants (Tiawoun., *et al*., 2024; Bashar., *et al.*, 2021; Shafiq., *et al.*, 2020). They play a crucial role in the capacity of Parthenium weed to outcompete agricultural crops, natural vegetation and disrupt natural succession. The metabolites produced by Parthenium weed have been extensively documented for their ability to inhibit growth and development of other species (Kumar., *et al.*, 2022; Tiawoun., *et al.*, 2024).

These secondary metabolites find their way into the environment through various mechanisms such as leaching, volatilization, exudation of water-soluble toxins from underground structures, release of toxins from non-living plant parts, root release and decomposition of leaves, roots and stems (Bashar., *et al*., 2023; Shafiq., *et al*. 2020)

Parthenium weed is allelopathic, and this characteristic has been proposed to play a significant role in its invasion and long-term survival across diverse native and non-native ecosystems (Tiawoun., *et al.*, 2024). These chemicals afford the weed a competitive advantage over other species where they affect the germination, development and growth of other crops (Kumar., *et al*., 2023; Abbas., *et al*., 2024; Naderi., *et al.*, 2024)

These chemicals can be found in various parts of the weed, including leaves, flowers, roots, fruits, or stems as well as in the surrounding soils (Oli., *et al*., 2024; Kumar., *et al.*, 2023; Bashar., *et al*., 2023). They have the potential to hinder nutrient uptake and disrupt naturally occurring symbiotic relationships thereby depriving plants of essential nutrients (Bagchi., *et al.*, 2016). The chemicals inhibit germination and growth of a wide range of plant species, crops, and pasture species (Dhole., *et al*., 2011; Bagchi., *et al*., 2016).

Several researchers carried out phytochemical analyses on the weed and identified several chemicals that are classified as; amino acids (Moitmainna., *et al.*, 2021), flavovoids (abbas., *et al*., 2013), Sesqueterpenes lactones (Biswanath., *et al*., 2006), and Phenolics (Bezuneh., *et al*.,2015)

From their study, it was evident that Parthenium hysterophorus has a rich phytochemical profile, including Alkanoids, amino acids, Sesquinterpene lactones, steroids, Phenolics, flavonoids, terpenoids, and other bioactive chemicals (Moitmainna., *et al.*, 2021). Most of these chemicals are believed to impede the growth and germination of various agricultural crops due to the osmotic effects on the fate of imbibition, which in turn reduce the commencement of germination and cell elongation (Singh., *et al.*, 2021).

IV. Conclusion

This study concluded that Parthenium hysterophorus contains a diverse range of phytochemical compounds, providing the weed with a competitive advantage over agricultural crops. It was evident that allelochemicals from *Parthenium hysterophorus* have the potential to retard growth of agricultural crops.

The germination and growth of maize, green grams, watermelon, and Pasture grass seeds were greatly inhibited throughout the study with the aqueous extracts from parthenium parts. Therefore, *Parthenium* h*ysterophorus* should be controlled early enough before the impacts are felt, and the crop should be prevented from the contact of this weed.

V. Recommendation

Similar studies with other crops are recommended given that Parthenium weed infestation in Baringo County continues to spread rapidly.