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Cytotoxicity and Nematicidal Potential of Leaf Extracts of *Adansonia digitata* and *Khaya senegalensis* on Root Knot Nematode (*Meloidogyne incognita*) Associated with Cabbage

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ABSTRACT

Purpose: *Cabbage, an indispensable vegetable is often plagued by Meloidogyne incognita, a circumstance which lessens yield. Extracts of Khaya senegalensis and Adansonia digitata were appraised for possible nematicidal activity to check the menace of M. incognita sequel to the undesirable effect of synthetic nematicides in the environment.*

Research Method: *Leaf materials were extracted in organic and aqueous extracts. The extracts were used as soil admix at 0, 150, 200 and 250 g/Kg soil, in a randomized complete block design experiment. Carbofuran a synthetic nematicide served as positive check for the extracts. Data was taken on vegetative growth, yield and nematode population. Lethality of the various extracts to brine shrimp larvae was also assessed.*

Findings: *The aqueous extract was not as productive as the ethanol and methanol extracts. A. digitata extracts demonstrated weak nematicidal activity as against what was observed in cabbage plants treated with K. senegalensis extracts. Cytotoxicity evaluation of the organic and aqueous extracts of A. digitata indicated that the methanol extract expressed weak cytotoxicity (500 µg/ml - 1000 µg/ml), while the aqueous and ethanol extracts were not toxic to the brine shrimps (LC_{50} >1000µg/mL). K. senegalensis extracts were active against brine shrimp larvae with LC_{50} values <1000µg/mL The methanol and ethanol extracts demonstrated strong cytotoxicity with LC_{50} values <100µg/ml. Extracts from K. senegalensis significantly (p=0.05) increased the vegetative growth of cabbage plants.*

Originality/ Value: *These results signify that the species have a probable use in the bio-pesticide industry, without any toxicity as the synthetics.*

Keywords: *Khaya senegalensis, Adansonia digitata, Meloidogyne incognita, nematicide*

INTRODUCTION

Cabbage (*Brassica oleracea*), an important vegetable which is used mostly in salad dishes is a rich source of several vitamins such as B6, C, K, and folate (Janick, 2011). Cabbages are medicinal, it is used as a laxative, antidote in mushroom poisoning, immunity boosting, blood pressure control and in the treatment of constipation (Janick, 2011). The juice can be employed in the treatment of ulcer, appendicitis, pneumonia and it is also reported to have a protective effect against colon cancer (Hatfield, 2004; Dinkova-Kostova and Kostov, 2012; Tse and Eslick, 2014). *Meloidogyne incognita* is known to be a major pest of cabbage in Nigeria. The nematode produces galls on cabbage roots, thus preventing the performance of its basic function, which leads to wilting and stunted growth with yellow leaves (Langston and Coolong, 2017). The globally

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established practical and customised method of controlling *M. incognita* in cabbage is the use of synthetic nematicides. However, resistance strain of root knot nematode has emerged over the years and the agro-ecological system also became polluted with pesticide residue from continuous and indiscriminate use of synthetic nematicides (Conway, 1995; Naz *et al.,* 2015), thus this necessitated research into plant derived alternatives to safe guard the environment from further pollution by the synthetics (Atolani *et al.,* 2014a; Atolani *et al.,* 2014b). The use of plant extracts with biocidal substances has substantially reduced *M. incognita* reproduction on vegetables (Fabiyi *et al.,* 2012; Fabiyi *et al.,* 2016; Atolani and Fabiyi, 2020; Fabiyi, 2021a). Several plant materials with active principles have been reported to be potent against the root knot nematode *M. incognita* (Fabiyi, 2021b). This present study is an advancement of research on environmentally safe materials in the control of *M. incognita.* Leaf extracts of *Adansonia digitata* and *Khaya senegalensis* were evaluated on cabbage plants in the screenhouse. The two plants are commonly used by a large fraction of African population for medicinal purposes (Nguta *et al.,* 2011). *A. digitata,* the baobab produces a lot of diversified natural substances used for medical management by the traditional societies in Africa (Hatfield, 2004; Al-Bakri *et al.,* 2006; Sanchez *et al.,* 2011). It is employed in the treatment of asthma, fever, toothache, tuberculosis, microbial infections, dysentery, diarrheal and as an immune stimulant (Masola *et al.,* 2009; El-Rawy *et al.,* 1987; Eltahir and Elsayed, 2019; Yusha'u *et al.,* 2010; Nguta *et al.,* 2010). The seed oil is an emollient with soothing properties, and also serves as a cure in tooth aches accompanied with gum disease (Sidibe and Williams, 2002), while the insecticidal properties on *Dinoderus porcellus* a key pest of stored yams was documented by John *et al.* (2021). *K. senegalensis,* popularly known as mahogany is a deciduous evergreen tree with considerably high medicinal properties. The antidermatophytic, antimalarial, antidiarrheal, antimicrobial and insecticidal properties have been reported (Nwosu *et al.,* 2012; Abdel-Wareth *et al.,* 2014; Orendu *et al.,* 2016; Loko *et al.,* 2017; Abdullahi *et al.,* 2019). Comparatively, information on the nematicidal activity of these two species is scarce. Hence, this research was conducted with the objective of analysing the effect of leaf extracts of *A. digitata* and *K. senegalensis* on survival and reproduction of *M. incognita* on cabbage in the screenhouse and an estimation of the toxicity of the leaf extracts.

MATERIALS AND METHODS

Collection of Plant Materials

The leaves of *A. digitata* and *K. senegalensis* were collected from the University of Ilorin campus in Ilorin, Nigeria. The specimens were identified at the herbarium unit of the University. The collected leaf materials were air dried at room temperature for three weeks, and then pulverised using the laboratory mill (Christy and Norris Ltd type 8) (Fabiyi *et al.,* 2012). The powdered materials were extracted with ethanol, methanol and water (aqueous) individually. After five days the organic solvents were decanted and filtered. The resulting organic crude extracts were concentrated with rotary evaporator under reduced pressure (Buchi Rota Vapour R-300), while the residual solvents in the extracts were allowed to evaporate to dryness thereafter, until the crude extracts were completely free of organic solvents. Water was removed from the aqueous extract by lyophilisation. The extracts were coded ADSD/MeOH, ADSD/EtOH, ADSD/H_2O, KYSG/MeOH, KYSG/EtOH, KYSG/H_2O for *A. digitata* and *K. senegalensis* extracts respectively, while CBFN was for carbofuran.

Cytotoxicity Test

The brine shrimp lethality bioassay was employed for the cytotoxicity test of the plant extracts. Natural sea water environment was simulated by preparing sea water with 35 g of sea salt in 1 litre of distilled water. The sea water was transferred into a plastic container with a division into light and dark areas and brine shrimp eggs were introduced for hatching on the dark side. After 48 hours, hatched nauplii attracted to source of light were collected with a glass pipette. Three concentrations (10, 100 and 1000 µg/mL) of each plant extract (*A. digitata* and *K. senegalensis* aqueous, ethanol and methanol extracts) were prepared in triplicates for replication. Sample

bottles were filled with 5 mL sea water and ten larvae (nauplii) were introduced into every single sample bottle containing different concentrations of the plant extracts with replicates. A control experiment was also set aside where plant extract was not added to the brine shrimp larvae in saline water. After 24 hours, surviving and dead larvae were counted from all the experimental sets with the aid of a magnifying glass. The mean mortality in each concentration was put through the Finney's probit analysis (Finney, 1971). Concentration logarithm was evaluated with the mean percentage mortality to determine the potent concentration for fifty percent of the population using the procedure of Moshi *et al*. (2010).

Screenhouse Experiments

Cabbage seeds (F1 minotaur) were planted in experimental plastic buckets filled with 30 Kg of sterile soil (pasteurized at 70°C for three hours), arranged in randomised complete block design (RCBD) in the screenhouse. Two sets of experiments were conducted concurrently. A set was treated with *Adansonia digitata* extracts while the other had *Khaya senegalensis* as control material. Each experimental set had four treatments (methanol extract, ethanol extract, aqueous extract and carbofuran), four dosages for each treatment, while each treatment and dosage were replicated three times. The cabbage plants were thinned to a plant per pot and inoculated with approximately 1000 eggs of *Meloidogyne incognita* at the base of each plant at two weeks after emergence adopting the method of Fabiyi, (2019). Crude plant extracts from the leaves of *A. digitata* and *K. senegalensis* were applied as soil admix a week after inoculation at 0, 150, 200 and 250 g/Kg soil. Carbofuran 3G, the standard check was applied at 0, 2.0 Kg/a.i/ha, 1.5 Kg/a.i/ha and 1.0 Kg/a.i/ha. Data was collected on leaf number and head diameter from seven weeks after planting to twenty weeks after planting. Cabbage head weight, nematode population in 250 g soil and 10 g root samples were ascertained after harvest. The roots were evaluated for galling severity on a scale of 0-9 provided by Schoonhoven and Voysest (1989), where 1=no galling, 2=< 5% of roots galled, 3=6-10% galled, 4=11-18% galled, 5=19-25% galled, 6=26-50% galled, 7=51-65% galled, 8=66-75% galled, 9=76-100% of roots galled.

Statistical Analysis

A two-way ANOVA was used to evaluate the data obtained. Comparisons were made among different organic and aqueous extract of each plant material to establish which produces the best results in nematode population suppression and vegetative growth increment. Duncan's multiple range test was used to establish differences between means at alpha level <0.05. Finney's probit analysis was used to determine LC_{50} of plant extracts with brine shrimp larvae.

RESULTS

Cytotoxicity

The LC_{50} for extracts from *A. digitata* are 4966µg/mL, 2343µg/mL and 714µg/mL for aqueous, ethanol and methanol extracts respectively, while LC_{50} values of 537µg/mL, 82µg/mL and 19µg/mL were recorded for aqueous, ethanol and methanol extracts of *K. senegalensis* individually.

Screenhouse

The response of infected cabbage plants to extracts from *A. digitata* leaves is presented in Table 01.

From seven weeks after planting to twenty weeks after planting (WAP), the number of cabbage leaves was not statistically different in methanol and ethanol extracts of *A. digitata*. Nevertheless, methanol extract produced significantly (p=0.05) more leaves at twenty weeks after planting (WAP). Cabbage leaf production was significantly (p=0.05) low in plants treated with the aqueous extracts, plants treated with ethanol extracts produced more leaves than the aqueous extract. However, leaf production was significantly (p=0.05) more in cabbage plants treated with carbofuran. The mean of cabbage head diameter is depicted in Table 02.

Table 01: Effect of treatment and treatment concentration of *A. digitata* extracts on the number of leaves of cabbage plants.

Treatment	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP	13WAP	14WAP	15WAP	16WAP	17WAP	18WAP	19WAP	20WAP
CBFN	14[a]	17[a]	20[a]	21[a]	23[a]	25[a]	26[a]	27[a]	32[a]	38[a]	43[a]	48[a]	51[a]	56[a]
ADSD/MeOH	11[b]	13[b]	16[b]	18[b]	20[b]	21[b]	23[b]	23[b]	24[b]	25[b]	29[b]	33[b]	36[b]	41[b]
ADSD/EtOH	11[b]	13[b]	15[b]	17[b]	19[b]	21[b]	22[b]	23[b]	24[b]	25[b]	27[b]	31[b]	34[b]	37[c]
ADSD/H_2O	8[c]	9[c]	10[c]	10[c]	11[c]	13[c]	15[c]	17[c]	18[c]	20[c]	21[c]	22[c]	23[c]	25[d]
SEM±	0.4	0.5	0.41	0.5	0.5	0.5	0.5	0.5	0.46	0.41	0.42	0.5	0.43	0.5
LSD	1.39	1.53	1.44	1.48	1.50	1.45	1.49	1.43	1.32	1.17	1.41	1.51	1.46	1.42
Level														
Zero (0g/kg soil) control	7[b]	7[b]	8[c]	10[c]	11[c]	12[c]	13[c]	14[c]	15[c]	16[c]	16[c]	18[d]	19[d]	21[d]
One (150g/kg soil)	11[a]	13[a]	14[ab]	15[ab]	15[ab]	17[b]	18[ab]	19[b]	20[b]	21[b]	21[b]	22[c]	23[c]	23[c]
Two (200g/kg soil)	12[a]	13[a]	15[a]	16[a]	17[a]	18[b]	20[a]	23[a]	25[a]	26[a]	27[a]	28[b]	29[b]	27[b]
Three (250g/kg soil)	13[a]	14[a]	17[a]	18[a]	19[a]	21[a]	22[a]	24[a]	25[a]	27[a]	29[a]	31[a]	34[a]	35[a]
SEM±	0.4	0.1	3.2	0.5	0.5	0.4	0.5	0.5	0.61	0.39	0.62	0.31	0.5	0.38
LSD	1.21	1.50	1.21	1.48	1.52	1.41	1.49	1.51	1.34	1.14	1.33	1.20	1.51	1.47

Means in a segment of a given column followed by the same letter are not significantly different at p=0.05 using the new DMRT. DMRT=Duncan's multiple range test.

Table 02: Effect of treatment and treatment concentration of *A. digitata* extracts on the head diameter of cabbage plants

Treatment	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP	13WAP	14WAP	15WAP	16WAP	17WAP	18WAP	19WAP	20WAP
CBFN	11.10[a]	11.33[a]	11.89[a]	12.22[a]	13.61[a]	14.32[a]	14.66[a]	15.23[a]	15.52[a]	16.87[a]	17.33[a]	17.69[a]	18.85[a]	19.94[a]
ADSD/EtOH	7.11[b]	7.32[b]	8.57[b]	8.70[b]	9.32[b]	9.61[b]	9.85[b]	9.92[b]	10.36[b]	10.61[b]	10.87[b]	11.07[b]	11.31[b]	11.59[b]
ADSD/MeOH	7.29[b]	7.88[b]	8.12[b]	8.33[b]	8.89[b]	9.12[b]	9.91[b]	10.24[b]	10.71[b]	10.89[b]	11.15[b]	11.51[b]	11.83[b]	12.20[b]
ADSD/H_2O	5.10[b]	5.24[b]	5.41[c]	5.63[c]	5.81[c]	5.94[c]	6.23[c]	6.59[c]	6.80[c]	6.95[c]	7.10[c]	8.33[c]	8.51[c]	9.13[c]
SEM±	0.5	0.4	0.49	0.5	0.47	0.5	0.41	0.5	0.5	0.4	0.43	0.47	0.5	0.5
LSD	1.32	1.38	1.41	1.38	1.36	1.40	1.39	1.31	1.37	1.42	1.40	1.39	1.43	1.40
Level														
Zero (0g/kg soil) control	3.07[b]	3.26[b]	3.41[b]	3.69[b]	3.82[b]	4.50[b]	5.31[b]	5.80[c]	6.11[b]	6.46[b]	6.71[b]	7.09[c]	7.44[c]	7.87
One (150g/kg soil)	5.01[a]	5.17[a]	6.42[a]	6.94[a]	7.31[a]	7.75[a]	8.03[a]	8.22[b]	9.55[a]	10.07[a]	10.92[a]	11.14[ab]	11.28[ab]	12.34[ab]
Two (200g/kg soil)	6.16[a]	6.48[a]	6.61[a]	7.00[a]	7.67[a]	8.81[a]	9.74[a]	10.30[a]	11.31[a]	11.88[a]	12.67[a]	13.24[a]	13.38[a]	14.46[a]
Three (250g/kg soil)	6.88[a]	7.21[a]	7.92[a]	8.07[a]	8.71[a]	9.29[a]	9.95[a]	10.41[a]	11.26[a]	12.04[a]	12.85[a]	13.97[a]	14.20[a]	15.29[a]
SEM±	0.4	0.4	0.71	0.48	0.5	0.49	0.47	0.4	0.47	0.41	0.4	0.5	0.46	0.4
LSD	1.44	1,38	1.40	1.42	1.22	1.41	1.36	1.23	1.37	1.43	1.41	1.36	1.44	1.38

Means in a segment of a given column followed by the same letter are not significantly different at p=0.05 using the new DMRT. DMRT=Duncan's multiple range test.

A wider leaf diameter was recorded in cabbage plants treated with methanol and ethanol extracts of *A. digitata,* smaller diameter was seen in aqueous extract treated plants. Cabbage plants treated with carbofuran recorded a larger diameter than all plant extracts tested. Head weight was significantly heavier in cabbage plants treated with carbofuran as against the weight recorded in cabbages treated with plant extracts of *A. digitata*. Significantly (p=0.05) more nematodes were counted after harvest in 250 g soil and 10 g root samples of *A. digitata* treated cabbage plants, this was accompanied with higher gall rating as opposed to carbofuran treated cabbage

plants which recorded fewer nematodes in soil, root samples and lower gall rating (Table 03).

Generally, the 250 g/Kg soil dosage of application had more numbers of leaves than the untreated control plants (Table 01). Head diameter was also relatively wider in the highest dose of treatment application in comparison with control (Table 02). Significantly (p=0.05) fewer nematodes were counted in the soil of cabbage plants treated with 250 g/Kg soil dose. Gall rating was equally significantly low, while there was a heavier cabbage weight in carbofuran treated plants as opposed to what was obtained in all *A. digitata* treated plants (Table 03). From Table 04, the extracts of *K. senegalensis* acted significantly (p=0.05) better than *A. digitata* extracts on cabbage plants.

Table 03: Effect of treatment and treatment concentration of *A. digitata* extracts on the head weight, root gall rating, nematode count in 250g soil and 10g root sample of cabbage plants infected with *M. incognita*

Treatment	Head Weight (g)	Gall Rating	Nematode Count in 250g Soil Sample	Nematode Count in 10g Root Sample
CBFN	949.2±2.16^{a}	0.50±0.12^{a}	12 ±2.28^{a}	09±1.10^{a}
ADSD/EtOH	291.3±3.02^{c}	6.00±0.02^{b}	129 ±1.01^{c}	88±1.00^{c}
ADSD/MeOH	345.1 ±1.89^{b}	6.01±0.03^{b}	104±2.11^{b}	75±1.49^{b}
ADSD/H_2O	194.5 ±2.08^{d}	8.03±0.02^{c}	438 ±3.70^{d}	202±4.21^{d}
SEM±	12,24	0.04	14.6	16.3
LSD	25.35	0.12	31.4	11.8
Level				
Zero control (0/kg soil)	95.5±2.05^{d}	8.25±0.08^{c}	2305±1.55^{c}	1943±2.1^{d}
One (150g/kg soil)	252.6±1.09^{c}	5.05±0.01^{b}	84±1.21^{b}	147±4.6^{c}
Two(200g/kg soil)	277.2±1.82^{b}	5.42±0.06^{b}	82±2.44^{b}	94±3.20^{b}
Three (250g/kg soil)	455.9 ±1.15^{a}	2.25±0.03^{a}	55±1.72^{a}	25 ±2.54^{a}
SEM±	12.24	0.04	14.6	16.3
LSD	25.35	0.12	31.4	11.8

Means in a segment of a given column followed by the same letter are not significantly different at p=0.05 using the new DMRT. DMRT=Duncan's multiple range test

Table 04: Effect of treatment and treatment concentration of *K senegalensis* extracts on the number of leaves of cabbage plants

Treatment	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP	13WAP	14WAP	15WAP	16WAP	17WAP	18WAP	19WAP	20WAP
CBFN	18^{a}	20^{a}	22^{a}	25^{a}	29^{a}	33^{a}	34^{a}	36^{a}	42^{a}	46^{a}	51^{a}	53^{a}	56^{a}	62^{a}
KYSG/EtOH	18^{a}	19^{a}	21^{a}	23^{a}	25^{b}	26^{c}	28^{c}	30^{c}	31^{c}	33^{c}	37^{c}	42^{bc}	45^{c}	47^{c}
KYSG/MeOH	18^{a}	20^{a}	23^{a}	25^{a}	28^{a}	29^{b}	31^{b}	33^{b}	35^{b}	38^{b}	41^{b}	44^{b}	48^{b}	53^{b}
KYSG/H_2O	12^{b}	14^{b}	17^{b}	18^{b}	19^{c}	20^{d}	22^{d}	23^{d}	25^{d}	26^{d}	30^{d}	31^{d}	34^{d}	38^{d}
SEM±	0.6	0.6	0.8	0.6	0.8	0.9	0.8	1.0	0.9	0.9	0.9	1.1	1.2	1.3
LSD	1.6	2.7	2.3	1.8	2.3	2.7	2.2	2.9	2.5	2.7	2.7	3.1	3.4	3.8
Level														
Zero control (0/kg soil)	10^{bc}	11^{c}	13^{c}	15^{b}	16^{c}	18^{b}	19^{c}	20^{c}	21^{c}	22^{c}	24^{c}	25^{d}	27^{d}	28^{d}
One (150g/kg soil)	12^{b}	14^{b}	16^{b}	17^{ab}	19^{b}	20^{b}	21^{c}	22^{c}	23^{c}	25^{b}	27^{b}	28^{c}	30^{c}	31^{c}
Two (200g/kg soil)	14^{b}	15^{b}	17^{b}	19^{a}	21^{b}	23^{a}	24^{b}	25^{b}	26^{b}	27^{b}	29^{b}	31^{b}	33^{b}	35^{b}
Three (250g/kg soil)	17^{a}	19^{a}	20^{a}	21^{a}	24^{a}	25^{a}	27^{a}	28^{a}	30^{a}	33^{a}	34^{a}	36^{a}	39^{a}	40^{a}
SEM±	0.4	0.6	0.9	0.5	0.7	1.0	0.8	0.4	0.7	1.1	1.1	0.7	1.0	0.7
LSD	1.4	3.2	2.3	1.2	2.5	2.7	2.2	2.7	2.9	1.4	1.4	3.4	3.4	3.2

Means in a segment of a given column followed by the same letter are not significantly different at p=0.05 using the new DMRT. DMRT=Duncan's multiple range test.

Cabbage leaf number was statistically more in *K. senegalensis* treated plants, with wider leaf diameter and heavier head weight at harvest (Tables 05 & 06). Nematode population was significantly (p=0.05) lower in plants administered with *K. senegalensis* extracts as against *A. digitata* treated plants (Table 06). Gall rating is directly proportional to the quantity of extracts applied. Fewer galls were counted in *K. senegalensis* treated plants (Table 06).

Table 05: Effect of treatment and treatment concentration of *K. senegalensis* extracts on the head diameter of cabbage plants

Treatment	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP	13WAP	14WAP	15WAP	16WAP	17WAP	18WAP	19WAP	20WAP
CBFN	10.45^{a}	11.30^{a}	11.88^{a}	12.21^{a}	12.97^{a}	13.31^{a}	13.78^{a}	14.81^{a}	15.89^{a}	16.95^{a}	17.32^{a}	17.69^{a}	18.22^{a}	19.47^{a}
KYSG/EtOH	8.20^{b}	8.71^{b}	9.55^{b}	9.82^{b}	10.31^{b}	10.71^{b}	11.11^{b}	11.56^{b}	11.90^{b}	12.40^{b}	13.78^{b}	14.44^{b}	14.98^{b}	15.30^{c}
KYSG/MeOH	10.31^{a}	11.22^{a}	12.17^{a}	12.73^{a}	13.58^{a}	13.90^{a}	14.65^{a}	14.90^{a}	15.45^{a}	15.80^{a}	16.39^{a}	16.92^{a}	17.38^{a}	17.69^{b}
KYSG/H_2O	6.36^{bc}	6.70^{c}	7.09^{c}	7.41^{c}	7.84^{c}	8.18^{c}	8.59^{c}	8.94^{c}	9.27^{c}	9.88^{c}	10.67^{c}	11.05^{c}	11.38^{c}	11.92^{d}
SEM±	0.1	0.2	0.4	0.4	0.4	0.6	0.4	0.4	0.5	0.5	0.7	0.6	0.7	0.8
LSD	0.9	1	1.1	1.2	1.2	1.7	1.2	1.3	1.3	1.6	2	1.8	2.2	2.2
Level														
Zero (control) (0/kg soil)	3.10^{c}	3.51^{c}	3.70^{c}	3.82^{c}	3.91^{c}	4.22^{c}	4.73^{c}	5.34^{c}	6.63^{c}	7.00^{c}	8.41^{c}	8.85^{c}	9.22^{c}	9.80^{c}
One (150g/kg soil)	6.30^{ab}	6.61^{ab}	6.94^{ab}	7.53^{ab}	7.91^{b}	8.37^{b}	8.76^{b}	9.53^{b}	9.91^{b}	10.22^{b}	10.68^{b}	11.00^{b}	11.39^{b}	11.80^{b}
Two (200g/kg soil)	7.41^{a}	7.73^{a}	8. 10^{a}	8.81^{a}	9.03^{b}	9.54^{b}	9.89^{b}	10.12^{b}	10.69^{b}	11.22^{b}	11.64^{b}	11.97^{b}	12.10^{b}	12.30^{b}
Three (250g/kg soil)	8.46^{a}	8.72^{a}	9.50^{a}	9.85^{a}	11.24^{a}	11.60^{a}	12.38^{a}	12.79^{a}	13.47^{a}	14.50^{a}	15.08^{a}	15.59^{a}	16.62^{a}	17.28^{a}
SEM±	0.1	0.3	0.4	0.1	0.2	0.4	0.7	0.1	0.4	0.3	0.5	0.6	0.4	0.6
LSD	1.1	0.9	1.4	1.5	1.0	1.5	1.2	1.3	1.3	1.4	2.1	1.8	2.1	2.1

Means in a segment of a given column followed by the same letter are not significantly different at p=0.05 using the new DMRT. DMRT=Duncan's multiple range test.

Table 06: Effect of treatment and treatment concentration of *K. senegalensis* extracts on the head weight, root gall rating, nematode count in 250g soil and 10g root sample of cabbage plants infected with *M. incognita*

Treatment	Head Weight (kg)	Gall rating	Nematode Count in 250g Soil Sample	Nematode Count in 10g Root Sample
CBFN	962.6±1.47^{a}	0.43±0.06^{a}	11±0.09^{a}	05±1.09^{a}
KYSG/EtOH	796.2±1.89^{c}	3.01±1.04^{b}	65±3.11^{c}	26±1.51^{c}
KYSG/MeOH	885.4±2.32^{b}	2.96±2.09^{b}	41±1.23^{b}	18±1.24^{b}
KYSG/H_2O	203.2±0.97^{d}	6.23±0.08^{c}	89±0.12^{d}	64±1.31^{d}
SEM±	13.8	0.01	3.1	10.1
LSD	29.93	0.18	7.4	26.5
Level				
Zero (control) (0/kg soil)	141.8±3.35^{d}	7.19±0.15^{c}	2811±3.65^{d}	1549±3.22^{d}
One (150g/kg soil)	358.1±2.94^{c}	4.31±0.23^{b}	56±2.10^{c}	63±3.89^{c}
Two (200g/kg soil)	370.4±1.15^{b}	4.02±0.05^{b}	43±3.07^{b}	37±1.21^{b}
Three (250g/kg soil)	506.7±1.89^{a}	1.67±0.03^{a}	21±1.05^{a}	13±2.20^{a}
SEM±	10.5	0.01	2.01	15.2
LSD	17.2	0.18	4.21	36.3

Means in a segment of a given column followed by the same letter are not significantly different at p=0.05 using the new DMRT. DMRT=Duncan's multiple range test

DISCUSSION

Extracts of *A. digitata* are not toxic to brine shrimp larvae, howbeit *K. senegalensis* extracts were deemed toxic. This deduction is with reference to the reports of Ngutha *et al.* (2011). They put forward that LC_{50} values above 1000 µg/mL: non-toxic, any value between 500 and 1000 µg/mL has a weak toxicity. If the value falls between 100 and 500µg/mL, it will be considered as fairly toxic, while LC_{50} values between 0 and 100 is classified as very toxic. The ethanol and methanol extracts of *K. senegalensis* with 82µg/mL and 19µg/mL respectively are very toxic to *Artemisia salina* larvae (brine shrimps). This supports the nematicidal activity exhibited by the extracts in this research. *A. digitata* extracts are not lethal to the shrimp's larvae, values above 1000 µg/mL were obtained (4966µg/mL, 2343µg/mL and 714µg/mL) for the aqueous, ethanol and methanol extracts separately. The obtained values corroborate the non-toxicity of *A. digitata* to humans and affirm the reason why the plant parts are generally consumed. The non-toxicity of *A. digitata* plant parts was corroborated by Ramadan *et al.* (1994), they reported a LD_{50} >8000µg/mL for *A. digitata* fruit pulp aqueous extract. In spite of the non-toxic nature of *A. digitata* to brine shrimp larvae, the plant extracts were relatively potent on *M. incognita* compared to the untreated control cabbage plants. This then establishes the innate toxicity of the extracts and validates the medical uses in traditional African societies. *A. digitata* leaves are known to have good antimicrobial properties. Abdallah and Ali (2019), reported that the ethanol leaf extract was particularly more effective than the aqueous extract. A 21 mm inhibition zone was observed at 50 mg/mL of ethanol extract, while the aqueous extract had 19 mm. The leaf extracts were noted to be more effective than the stem extracts. In the same vein, Samatha *et al.* (2017), affirmed the antibacterial properties of methanol extract of *A. digitata* leaves. They authenticated that the extracts inhibited the growth of *Escherichia coli*, *Klebsiella*, *Proteus* spp, *Enterobacter* and *Staphylococcus* at 40 mg/mL. *A. digitata* is also known to inhibit the growth of some gram-negative, gram-positive bacteria and yeast, the ethanol extract demonstrated maximum inhibition concentration values from 1.6 to 5 mg/mL (Masola *et al.,* 2009). Equally, Magashi and Abdulmalik (2018), attested to the anti-bacterial actions of *A. digitata* extracts on some clinical isolates. The insect repellent activity of *A. digitata* pellets was recorded by Denloye *et al*. (2006), they documented that smoke from leaf pellets showed toxicity against the African malaria mosquito *Anopheles gambiae* and housefly, *Musca domestica*. Analogously, Krishnappa *et al.* (2012) substantiated the lavicidal and insect repellent action of *A. digitata* leaf organic extracts (benzene, chloroform, hexane and methanol) on *Anopheles stephensi.* The methanol extract provided the best insecticidal action at lower concentration, while other organic extracts were active at higher concentrations. The toxicity of leaf and bark extracts of *A. digitata* was also evaluated by Atawodi (2005), on *Trypanosoma brucei*. Leaf extracts were found to be very effective in immobilising the organism. Immobilisation was achieved with 2 mg/mL of leaf extracts. Several studies have indicated that the leaves of *A. digitata* is antiviral. Ananil *et al.,* (2000) in their study found *A. digitata* leaf extracts to be the most potent on polio viruses, herpes simplex and sindbis among the various plant extracts tested. Reports by Vimalanathan and Hudson (2009), indicated that leaf extracts of *A. digitata* was active against the influenza virus and herpes simplex virus. The minimum inhibitory value of the aqueous leaf extract was 2.8µg/mL for the influenza virus and 11.7µg/mL for the herpes simplex virus. Similarly, Ateya *et al.* (2016), corroborated the antiviral activity of extracts from *A. digitata*, they indicated a 56.6% reduction on adenovirus type-7 by the methanol extract, 63.3% reduction was recorded on rotavirus Wa strain and 70% on coxsakievirus. Strong nematicidal activity was exhibited by *K. senegalensis* extract, which is directly proportional to the observed cytotoxicity value. Abdullai *et al.* (2019), also registered LC_{50} values <500µg/mL for the chloroform extract of *K. senegalensis* stem bark, thus substantiating the findings in this study. The plant is known for its remarkable pesticidal activity. Idu *et al.* (2014), evaluated the effects of *K. senegalensis* extracts on bacterial and fungal isolates. They found the ethanol extract to be more active with higher bacterial activity at 20 mg/mL than the aqueous extract. The extract was highly effective

on *Pseudomonas aeruginosa*, with a growth inhibition zone of 22 mm, *Staphylococcous aureus* had 19 mm, *Bacillus subtilis* 14.3 mm, *Escherichia coli* 19.7 mm while the growth of *Candida albicans, Penicillum notatum* and *Aspergillus niger* was not inhibited. Kubmarawa *et al.* (2008), evaluated the effectiveness of *K. senegalensis* extract on human pathogenic bacteria. They found that, the ethanol extract was more active than the aqueous extract. The zone of growth inhibition was observed to be wider in the ethanol extract. The anti-plasmodial activity of *K. senegalensis* extract was reported by Manga *et al.* (2018). They confirmed that the extracts were very active on chloroquine resistant strain of *Plasmodium falciparum*. The insecticidal action of *K. senegalensis* powder and leaf extract on *Dinoderus porcellus* a key pest of stored yam chips was documented by Loko *et al.,* (2017). Yakubu and Nda (2012) affirmed the insecticidal properties of dry leaf and seed powder of *K. senegalensis*, on *Tribolium confusum* infecting stored millet. The action of the plant powders was not significantly different from what was recorded in Actellic dust. Abdullahi *et al.,* (2012) emphasized that *K. senegalensis* ethanol extract was effective on wood termites, 100 percent mortality was achieved within 10 days of application. Similarly, Bamaiyi *et al.* (2007) reported that *K. senegalensis* seed oil was effective on *Callosobruchus maculatus* of stored cowpea. The seed oil was significantly effective and was comparable with the standard Actellic emulsion. Correspondingly, Liman *et al.* (2011), indicated the nematicidal action of *K. senegalensis* infecting tomato plants. A significant ($P<0.05$) reduction of *M. incognita* population was observed in treated tomato seedlings. Notable differences were also seen in the effect of the varying concentrations on growth of tomato plants. Comparably, Abu and Matouke, (2015) in their findings attested to the toxicity of *K. senegalensis*. Leaf extracts of methanol was highly toxic to *Clarias gariepinus*, the experimental fishes exhibited signs of distress like alteration in respiration, increase in opercula ventilation and tail fin flaps. Thus *K. senegalensis* is affirmed to be a piscicide with 70 % mortality at 230 mg/L after 96 hours of exposure. The extracts of *K. senegalensis* could be safely used in *M. incognita* management.

CONCLUSION

Through this research the extracts of *K. senegalensis* have been confirmed to be nematicidal. Though *A. digitata* has demonstrated a very weak nematicidal activity. *K. senegalensis* is a promising candidate for the bio-pesticide industry.

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