Research Article

Evaluation of Weeds Against Root-Knot Nematode (*Meloidogyne incognita*) in Vegetables

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Abstract | The indiscriminate use of pesticides by small holder farmers under unregistered informal sector in vegetable farming has culminated in severe environmental pollution, increase in unacceptable percentage of residue in vegetables and resistance of nematodes to the currently used nematicides. This has prompted the evaluation of medicinal plants as probable sources of nematicides. A study was conducted in the screenhouse to evaluate the nematicidal potential of *Tridax procumbens* and *Sida acuta* (weeds) on root knot nematodes *Meloidogyne incognita* infesting lettuce and carrots. *T. procubmens* and *S. acuta* was applied as soil amendment (400, 600 & 800g) and organic solvent crude extracts (40, 60, 80g/kg soil) in *M. incognita* infested lettuce and carrot plants as treatments. Results showed that lettuce and carrot plants grown in pots amended with the highest quantity of plant materials (800g) had commendatory vegetative growth all through the study weeks as against the plants treated with organic solvent extracts and the untreated control plants. Vegetative parameters differ significantly ($p<0.05$) with increasing quantity of treatment materials applied. Fruit and head weights in carrots and lettuce at harvest decreased significantly in untreated control plants. *T. procumbens* caused significantly more reduction in *M. incognita* reproduction, with higher yield than *S. acuta*. This study demonstrated that *T. procumbens* and *S. acuta* though, classified as weeds could be used successfully as soil amendments in ameliorating the effects of *M. incognita* infection on vegetables like lettuce and carrots thereby forestalling environmental pollution.

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Introduction

Lettuce (*Lactuca sativa* L.) and carrots (*Daucus carota* L.) are important vegetables which provides daily supply of various vitamins (A, B_1, B_2, B_3, B_6, C, E and K) and minerals (K, Ca, Mg, Na and Fe). Lettuce, is a significant source of dietary antioxidant (Still, 2007), it is known to contain, folate, lutein and lactucin, a sesquiterpene lactone which has sedative, analgesic and anti-malarial properties. Carrots are high in beta carotene, dietary fibre and sugar (Sharma *et al*., 2012; Iorrizo *et al*., 2013). Cultivation of these vegetables is impaired with infestation of *Meloidogyne incognita*. Generally, lettuce and carrots are highly predisposed to *M. incognita* infection (Baimey *et al*., 2009; Oleivera *et al*., 2015; Fabiyi, 2021a). Synthetic nematicides are routinely employed to reduce infestation and increase yield, this gave rise to contamination of these vegetables with pesticides by the small holder farmers under unregistered informal sector who popularly practice vegetable farming (Fabiyi, 2021a, b, c). These group of farmer's misuse nematicides greatly mainly because, they are not literate enough to prepare solutions correctly, lack of adequate knowledge on the risk associated with pesticide use, application of non-homologated pesticides and poor respect for dosage (Fabiyi *et al*., 2020a). The general attitude of pesticide handling has led to several cases of poisoning, because the available residue is higher than international maximum residue limits, which is a pointer to public health threat (Cheke and Oluwole, 2009; Fabiyi and Olatunji, 2021a). With this in mind, coupled with the development of resistance by nematodes to synthetic nematicides and in furtherance to research on safer alternatives to synthetic nematicides (Atolani *et al*., 2014a, b; Fabiyi *et al*., 2020b, 2021a, b, 2022; Fabiyi, 2021d; Fabiyi and Olatunji, 2021b), this experiment was conducted to assess the potential of two common weeds (*Tridax procumbens* and *Sida acuta*) as soil amendment in *M. incognita* control. *Tridax procumbens* is a perennial weed which is widely distributed and commonly used in traditional medicine for bacterial infection of gastrointestinal disorders (Gubbiveeranna and Nagaraju, 2015). The leaves are used in the treatment of catarrh, dysentery and diarrheal. *Sida acuta* is commonly found in bushes and road sides (Oboh *et al*., 2007). It is employed in the treatment of fever, gonorrhoea, eczema, dandruffs, intestinal worms and skin diseases (Karou *et al*., 2007; Kumar *et al*., 2012). Carrots and lettuce are vegetables that are essential and indispensable to the general populace. There is a nexus between availability, quality and price of these vegetables. Carrots become displeasing to the consumers with nematode infestation vis-à-vis reduction in obtainability of lettuce. On account of the established biological and customary values associated with *T. procumbens* and *S. acuta*, while also bearing in mind the essence of pesticide residue free vegetables, this study examines the nematicidal potential of *T. procumbens* and *S. acuta* in *M. incognita* control. Indicators such as vegetative growth, yield and nematode population were appraised for each of the test plants (*T. procumbens* and *S. acuta*) to establish their influence as organic crude extracts and soil amendments on *M. incognita* infested lettuce and carrot plants.

Materials and Methods

Collection of plant materials and preparation of extracts

Tridax procumbens and *Sida acuta* whole plants were collected from the University of Ilorin, Ilorin, Nigeria premises (80, 291 N; 40, 401 E). The plant samples were verified at the herbarium unit of the University. Each plant was air dried in the laboratory for one week to reduce the moisture content and were divided in to 3 parts (Fabiyi *et al*., 2020c) Two parts were extracted separately in methanol and ethanol, while the 3rd part was used as soil amendment. The extracts were decanted and filtered after 5 days and then concentrated with rotary evaporator (Buchi Rota Vapour R-300). The crude extracts and plant materials were coded as follows: *Sida acuta* methanol extract, *Sida acuta* ethanol extract, *Sida acuta* amendment, *Tridax procumbens* amendment, *Tridax procumbens* methanol extract and *Tridax procumbens* ethanol extract. The extracts were then abbreviated respectively as- SDAT/MeOH, SDAT/EtOH, SDAT/AMDT, TDXPS/AMDT, TDXPS/MeOH, TDXPS/EtOH.

Screenhouse experiment

Loamy soil was collected and steam sterilized at 60℃ for 2 hours. The soil was allowed to cool and distributed into two sets of 48 experimental pots at 25kg each per pot. The experimental pots were placed on bricks in the screenhouse to avoid microbial infestation. The plant materials for soil amendments were weighed at 800g, 600g and 400g/kg soil and was mixed with the sterilized soil. This was left for a month to allow disintegration of the plant materials. The contents of the experimental pots were turned and mixed assiduously on weekly basis to ensure uniform distribution of disintegrated plant materials. Each experimental setting had 4 treatments, 3 replicates and 4 dosages of application. Two weeks' old lettuce (cv Mindelo) and carrot (cv Shakira f1) seedlings were transplanted into each experimental pot at a seedling per pot. A week after transplanting, approximately 1000 second stage juveniles of *M. incognita* were inoculated at the base of each seedling (Fabiyi, 2019, 2020). The other sets of treatments (crude extracts of the plant materials) were applied a week after inoculation at 80, 60 and 40g/kg soil. Carbofuran was applied at 0.5, 1.0 and 1.5ai/kg/ha. Agronomic practices, such as fertilizer application and weeding for both vegetables were carried out as required. Data was collected on plant height and numbers of leaves for carrots and lettuce plants during the growth weeks to monitor and assess the vegetative development. At harvest, yield was evaluated for both vegetables. The numbers of nematodes in the soil (250g) and roots (10g) of the plants were determined. 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. All data were subjected to analysis of variance (ANOVA) and means were separated using the Tukey's honesty significant difference test at $p<0.05$.

Results and Discussion

The response of carrot and lettuce plants under *Meloidogyne incognita* infection to *Sida acuta* and *Tridax procumbens* treatment is presented in Tables 1 to 12. Carrot plants treated with *S. acuta* plant materials as soil amendment and crude extracts had higher plant heights than the control from the 6th week after planting to 12th week after planting. Heights of plants treated with methanol extracts of *S. acuta* (SDAT/MeOH) did not significantly ($p<0.05$) differ from those of carbofuran treatment (CBFN). Heights of carrot plants were consistently high in the highest quantity of treatment materials applied as opposed to the heights recorded in the low quantity of materials (Table 1). The numbers of leaves produced by carrot plants grown in amended pots were statistically more than carrot plants treated with other materials. There is no statistical difference between the numbers of leaves produced in cabofuran treated pots and *S. acuta* amended pots. Fewer leaf production was observed in the carrot plants treated with low quantity of plant materials and the untreated carrot plants (Table 2). Mean carrot yield was particularly low in untreated carrot plants, while higher yield was recorded in pots amended with plant materials. An increase in yield which is directly proportional to the quantity of treatment materials was recorded. The gall index was lower in all the treatment materials, control plants had the highest gall index. The least root gall index was observed in carbofuran treated plants. This is accompanied by reduced soil and root nematode population count. Heavily galled roots characterized the untreated control carrot plants (Table 3). The influence of *T. procumbens* on the vegetative growth of carrot plants is depicted in Tables 4, 5 and 6. Heights of carrot plants was up above in experimental pots amended with *T. procumbens* at the highest dose. Carrot plant heights were low statistically in the control plants (Table 4). More leaves were produced in all treated plants, while control, plants had fewer leaves (Table 5). Yield of carrots was increased in treated plants. Increase in yield was directly proportional to the quantity of treatment materials applied. Gall index was statistically low in carrot plants treated with carbofuran. All other treatments also had significantly lower gall index relative to the control.

Table 1: *Effect of treatment and treatment concentration of Sida acuta extracts on heights (cm) of carrot plants.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	36.1^{b}	39.3^{b}	40.7^{c}	42.7^{c}	45.4^{b}	45.2^{b}	45.7^{b}
SDAT/EtOH	32.4^{c}	35.7^{b}	35.9^{d}	37.0^{d}	37.1^{c}	39.6^{c}	40.5^{c}
SDAT/AMDT	48.7^{a}	51.7^{a}	51.8^{a}	51.9^{a}	51.9^{a}	52.1^{a}	52.6^{a}
SDAT/MeOH	36.3^{b}	38.8^{b}	45.1^{b}	46.2^{b}	47.0^{b}	47.4^{b}	47.9^{b}
CONTROL	28.6^{cd}	30.3^{d}	30.8^{e}	33.0^{e}	35.8^{c}	37.1^{c}	38.1^{d}
SEM ±	2.33	2.74	3.28	3.22	3.01	3.04	3.04
LSD $p<0.05$	4.21	4.10	4.46	3.28	5.68	4.76	3.77
Level							
One (40g/kg soil)	30.2^{c}	35.3^{c}	36.1^{c}	38.7^{c}	40.4^{c}	40.9^{c}	41.8^{c}
Two (60g/kg soil)	34.6^{b}	38.6^{b}	39.9^{b}	41.0^{b}	44.4^{b}	44.9^{b}	45.0^{b}
Three (80g/kg soil)	41.3^{a}	46.5^{a}	47.8^{a}	48.2^{a}	48.8^{a}	49.2^{a}	49.8^{a}
SEM ±	2.69	2.73	2.80	2.84	2.63	2.66	2.54
LSD $p<0.05$	2.18	3.01	3.21	2.32	3.72	3.79	3.44

CBFN = carbofuran; SDAT/EtOH = S. acuta ethanol extract; SDAT/AMDT = S. acuta soil amendment; SDAT/MeOH = S. acuta methanol extract.

Table 2: *Effect of treatment and treatment concentration of Sida acuta extracts on the number leaves of carrot plants.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	10^{a}	13^{a}	15^{a}	17^{a}	17^{a}	17^{a}	18^{a}
SDAT/EtOH	8^{ab}	10^{b}	10^{b}	11^{c}	12^{b}	12^{b}	13^{c}
SDAT/AMDT	9^{a}	12^{a}	14^{a}	15^{b}	17^{a}	18^{a}	18^{a}
SDAT/MeOH	9^{a}	12^{a}	14^{a}	14^{b}	14^{b}	14^{b}	15^{b}
CONTROL	6^{c}	8^{b}	9^{b}	10^{c}	11^{c}	11^{c}	11^{c}
SEM ±	2.01	2.02	1.62	1.77	1.76	1.79	1.78
LSD p<0.05	2.26	2.83	3.67	3.11	2.00	2.16	3.12
Level							
One (40g/kg soil)	5^{c}	9^{c}	10^{b}	10^{b}	10^{b}	11^{b}	11^{b}
Two (60g/kg soil)	7^{b}	11^{b}	11^{b}	11^{b}	11^{b}	12^{b}	12^{b}
Three (80g/kg soil)	10^{a}	13^{a}	13^{a}	14^{a}	14^{a}	14^{a}	15^{a}
SEM ±	1.39	1.76	1.43	1.54	1.85	1.64	1.63
LSD p<0.05	1.08	1.17	1.20	2.51	2.43	1.82	2.79

CBFN =carbofuran; SDAT/EtOH = S. acuta ethanol extract; SDAT/AMDT = S. acuta soil amendment; SDAT/MeOH = S. acuta methanol extract.

Table 3: *Effect of treatment and treatment concentration of Sida acuta extracts on carrot yield, gall index, soil and root nematode population.*

Treatment	Carrot weight (g)	Root gall index	Soil nematode count	Root nematode count
CBFN	716.0^{b} ± 16.3	0.44^{a} ± 0.5	11^{a} ± 6.2	3^{a} ± 0.1
SDAT/EtOH	550.0^{d} ± 70.9	5.89^{c} ± 0.3	59^{c} ± 7.1	52^{c}±0.5
SDAT/AMDT	737.2^{a} ± 55.5	3.00^{b} ± 0.0	31^{b} ± 4.7	25^{b}± 0.0
SDAT/MeOH	564.2^{c} ± 71.0	5.63^{c} ± 0.5	66^{c} ± 0.0	49^{c}± 3.0
CONTROL	115.9^{e} ± 30.0	9.00^{d} ± 0.0	2848^{d} ± 744.0	5178^{d}±30
SEM ±	15.47	0.12	110.4	133.7
LSD p<0.05	34.58	0.34	318.1	259.6
Level				
One (40g/kg soil)	312.5^{c} ± 32.7	7.83^{c} ± 0.4	65^{c} ± 12.1	43^{c} ± 0.8
Two (60g/kg soil)	518.2^{b} ± 59.0	5.75^{b} ± 0.5	28^{b} ± 9.8	31^{b} ± 2.2
Three (80g/kg soil)	549.1^{a} ± 81.1	3.22^{a} ± 0.5	6^{a} ± 7.7	14^{a} ± 1.3
SEM ±	6.47	0.07	1.05	1.68
LSD p<0.05	18.97	0.21	3.07	2.81

CBFN =carbofuran; SDAT/EtOH = S. acuta ethanol extract; SDAT/AMDT = S. acuta soil amendment; SDAT/MeOH = S. acuta methanol extract.

Table 4: *Effect of treatment and treatment concentration of Tridax procumbens extracts on plant height (cm) of carrot plants.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	37.8^{b}	39.5^{b}	40.5^{b}	41.0^{b}	42.7^{b}	43.1^{b}	43.9^{b}
TDXP/EtOH	34.3^{c}	35.4^{b}	36.9^{cd}	38.1^{bc}	38.7^{c}	39.1^{c}	39.4^{c}
TDXPS/AMDT	46.2^{a}	46.8^{a}	47.6^{a}	48.5^{a}	49.6^{a}	50.2^{a}	50.6^{a}
TDXPS/MeOH	35.7^{bc}	36.0^{b}	38.1^{c}	39.2^{b}	39.8^{c}	40.2^{c}	40.6^{c}
CONTROL	26.4^{d}	27.3^{c}	28.7^{e}	30.6^{d}	31.6^{d}	32.0^{d}	33.2^{d}
SEM ±	1.42	1.43	1.45	1.47	1.51	1.43	1.45
LSD p<0.05	4.06	4.09	4.16	4.20	4.32	4.10	4.15
Level							
One (40g/kg soil)	32.3^{b}	33.5^{b}	35.3^{b}	36.2^{c}	37.2^{c}	38.9^{c}	39.6^{c}
Two (60g/kg soil)	33.6^{b}	34.8^{b}	36.1^{b}	38.6^{b}	39.8^{b}	40.6^{b}	41.3^{b}
Three (80g/kg soil)	35.6^{a}	37.4^{a}	39.1^{a}	40.6^{a}	41.8^{a}	42.4^{a}	43.3^{a}
SEM ±	1.27	1.28	1.30	1.31	1.35	1.28	1.30
LSD p<0.05	3.62	3.71	3.72	3.75	3.87	3.67	3.71

CBFN =carbofuran; TDXPS/EtOH = T. procumbens ethanol extract; TDXPS/AMDT = T. procumbens soil amendment; TDXPS/MeOH = T. procumbens methanol extract.

Table 5: *Effect of treatment and treatment concentration of Tridax procumbens extracts on number of leaves of carrot plants.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	11[a]	12[a]	12[a]	14[a]	16[a]	18[a]	19[a]
SDAT/EtOH	9[ab]	9[b]	10[b]	10[b]	11[c]	12[c]	12[d]
SDAT/AMDT	10[a]	11[a]	12[a]	14[a]	15[a]	16[b]	17[b]
SDAT/MeOH	8[b]	10[ab]	11[ab]	12[c]	13[b]	13[c]	14[c]
CONTROL	7[bc]	7[c]	8[c]	9[d]	10[cd]	11[cd]	11[e]
SEM ±	0.93	1.00	1.15	1.20	1.23	1.30	1.34
LSD p<0.05	2.67	2.86	3.29	3.45	3.52	3.72	3.84
Level							
One (40g/kg soil)	7	8	8	9	9	10	11
Two (60g/kg soil)	8	8	9	9	10	10	11
Three (80g/kg soil)	9	10	10	11	11	12	12
SEM ±	0.83	0.89	1.03	1.08	1.10	1.16	1.23
LSD p<0.05	NS	NS	NS	NS	NS	NS	NS

CBFN =carbofuran; TDXPS/EtOH = T. procumbens ethanol extract; TDXPS/AMDT = T. procumbens soil amendment; TDXPS/MeOH = T. procumbens methanol extract.

Table 6: *Effect of treatment and treatment concentration of Tridax procumbens extracts on carrot yield, gall index, soil and root nematode population.*

Treatment	Carrot weight (g)	Root gall index	Soil nematode count	Root nematode count
CBFN	829.0[b] ± 25.0	0.53[a] ± 0.1	10[a] ± 4.1	7[a] ± 0.0
TDXPS/EtOH	614.2[d] ± 15.3	5.18[c] ± 0.6	50[d] ± 3.2	39[d]±0.3
TDXPS/AMDT	884.0[a] ± 39.7	2.13[b] ± 0.1	22[b] ± 2.0	16[b]± 0.1
TDXPS/MeOH	659.1[c] ± 24.3	5.42[c] ± 0.4	43[c] ± 0.1	31[c]± 2.1
CONTROL	208.7[e] ± 0.9	9.00[d] ± 0.0	2649[e] ± 322.7	4302[e]±179
SEM ±	26.13	0.17	0.94	116.0
LSD p<0.05	39.16	0.22	276.6	231.0
Level				
One (40g/kg soil)	336.2[c] ± 0.7	8.16[c] ± 0.8	48[c] ± 8.1	36[c] ± 1.2
Two (60g/kg soil)	642.0[b] ± 10.6	4.57[b] ± 0.3	23[b] ± 4.2	28[b] ± 0.6
Three (80g/kg soil)	673.8[a] ± 59.3	2.16[a] ± 0.0	4[a] ± 3.8	11[a] ± 2.0
SEM ±	7.38	0.05	1.01	0.83
LSD p<0.05	21.65	0.14	2.83	2.69

CBFN =carbofuran; TDXPS/EtOH = T. procumbens ethanol extract; TDXPS/AMDT = T. procumbens soil amendment; TDXPS/MeOH = T. procumbens methanol extract.

Table 7: *Effect of treatment and treatment concentration of Sida acuta extracts on height of lettuce plants.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	5.68[bc]	9.03[ab]	14.89[a]	19.13[b]	23.5[b]	27.4[b]	32.3[d]
SDAT/AMDT	6.01[b]	10.22[a]	14.74[a]	20.86[a]	27.6[a]	33.8[a]	48.3[a]
SDAT/EtOH	5.33[bc]	9.12[ab]	13.30[ab]	16.00[c]	18.4[c]	24.1[c]	35.5[c]
SDAT/MeOH	8.06[a]	11.06[a]	16.22[a]	20.11[a]	27.4[a]	35.1[a]	44.6[b]
CONTROL	5.26[bc]	9.37[ab]	11.50[bc]	13.97[d]	16.7[d]	19.0[d]	26.1[e]
SEM ±	1.03	1.21	1.27	2.03	3.66	5.02	6.94
LSD p<0.05	3.04	4.76	5.65	4.83	9.30	9.47	12.01
Level							
One (40g/kg soil)	7.22[c]	10.67[c]	12.68[c]	18.73[c]	23.1[c]	25.7[c]	31.6[c]
Two (60g/kg soil)	12.42[b]	14.10[b]	16.08[b]	22.94[b]	27.3[b]	35.3[b]	42.5[b]
Three (80g/kg soil)	15.31[a]	17.25[a]	20.35[a]	26.65[a]	31.2[a]	39.6[a]	46.9[a]
SEM ±	0.61	0.78	0.96	1.62	2.99	4.34	9.17
LSD p<0.05	3.11	3.62	3.81	4.75	4.76	8.73	9.01

CBFN =carbofuran; SDAT/EtOH = S. acuta ethanol extract; SDAT/AMDT = S. acuta soil amendment; SDAT/MeOH = S. acuta methanol extract.

Table 8: *Effect of treatment and treatment concentration of Sida acuta extracts on number of leaf of lettuce plant.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	6^{ab}	7^{b}	9^{b}	10^{b}	12^{bc}	13^{bc}	16^{b}
SDAT/AMDT	7^{a}	9^{a}	11^{a}	13^{a}	16^{a}	17^{a}	21^{a}
SDAT/EtOH	5^{bc}	7^{b}	$8b^{c}$	9^{bc}	11^{c}	12^{c}	14^{c}
SDAT/MeOH	5^{bc}	8^{ab}	9^{b}	10^{b}	13^{b}	14^{b}	15^{bc}
CONTROL	4^{c}	6^{bc}	7^{cd}	9^{bc}	11^{c}	12^{c}	14^{c}
SEM ±	0.43	0.61	0.77	0.90	1.30	1.37	1.92
LSD p<0.05	1.95	2.07	2.22	1.59	1.74	1.95	4.54
Level							
One (40g/kg soil)	2^{bc}	5^{bc}	7^{b}	8^{ab}	10^{bc}	12^{bc}	13^{c}
Two (60g/kg soil)	3^{b}	6^{b}	7^{b}	9^{a}	11^{b}	13^{b}	15^{b}
Three (80g/kg soil)	6^{a}	8^{a}	9^{a}	11^{a}	14^{a}	15^{a}	19^{a}
SEM ±	0.48	0.56	0.61	0.74	1.06	1.09	1.65
LSD p<0.05	1.08	1.01	2.80	1.17	2.11	2.18	2.83

CBFN = carbofuran; SDAT/EtOH = S. acuta ethanol extract; SDAT/AMDT = S. acuta soil amendment; SDAT/MeOH = S. acuta methanol extract.

Table 9: *Effect of treatment and treatment concentration of Sida acuta extracts on lettuce yield, gall index, soil and root nematode population.*

Treatment	Lettuce head weight (g)	Root gall index	Soil nematode count	Root nematode count
CBFN	200^{b}±23.0	0.42^{a} ± 0.2	6^{a} ± 6.2	9^{a} ± 14.0
SDAT/AMDT	213^{a}±25.2	3.57^{b} ± 0.1	33^{b} ± 7.1	23^{b} ± 20.0
SDAT/EtOH	138^{d}±9.0	5.31^{c} ± 0.0	48^{d} ± 4.7	72^{c} ± 45.7
SDAT/MeOH	153^{c}±11.1	5.35^{c} ± 0.3	41^{c} ± 0.0	77^{c} ± 49.4
CONTROL	94^{e} ±7.2	9.00^{d} ± 0.0	3573^{e} ± 385.2	4530^{d} ± 53.2
SEM ±	11.21	0.14	126.7	9.00
LSD p<0.05	19.41	0.38	243.4	25.92
Level				
One (40g/kg soil)	70^{c}± 2.1	7.16^{c} ± 0.3	65^{c} ± 12.1	83^{c} ± 51.8
Two (60g/kg soil)	105^{b}±5.2	5.01^{b} ± 0.1	28^{b} ± 9.8	39^{b} ± 32.5
Three (80g/kg soil)	128^{a} ±10.3	3.59^{a} ± 0.5	6^{a} ± 7.7	14^{a} ± 15.5
SEM ±	9.02	0.05	1.05	3.75
LSD p<0.05	13.01	0.26	3.07	10.99

CBFN =carbofuran; SDAT/EtOH = S. acuta ethanol extract; SDAT/AMDT = S. acuta soil amendment; SDAT/MeOH = S. acuta methanol extract.

Table 10: *Effect of treatment and treatment concentration of Tridax procumbens extracts on height of lettuce plants.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	7.03^{a}	10.22^{a}	12.41^{b}	16.22^{b}	25.9^{b}	31.23^{b}	38.1^{b}
TDXPS/AMDT	5.17^{b}	9.10^{a}	15.08^{a}	19.27^{a}	28.31^{a}	34.42^{a}	41.01^{a}
TDXPS/EtOH	4.02^{bc}	7.20^{b}	10.36^{bc}	12.32^{c}	19.27^{d}	23.81^{d}	31.49^{d}
TDXPS/MeOH	7.13^{a}	9.09^{a}	11.06^{b}	16.00^{b}	22.41^{c}	29.12^{c}	35.13^{c}
CONTROL	4.71^{bc}	7.28^{b}	9.26^{d}	11.07^{cd}	15.36^{e}	20.54^{e}	26.32^{e}
SEM ±	1.07	1.13	1.25	2.12	3.57	5.17	6.82
LSD p<0.05	3.12	4.29	5.41	4.70	9.28	9.60	12.18
Level							
One (40g/kg soil)	4.22^{c}	8.11^{c}	11.51^{c}	16.02^{c}	23.05^{c}	29.28^{c}	33.6^{c}
Two (60g/kg soil)	7.15^{b}	12.03^{b}	17.11^{b}	24.10^{b}	29.48^{b}	35.41^{b}	40.03^{b}
Three (80g/kg soil)	14.29^{a}	17.11^{a}	23.07^{a}	29.18^{a}	34.52^{a}	39.00^{a}	43.11^{a}
SEM ±	0.35	0.51	1.05	1.70	3.06	4.59	9.21
LSD p<0.05	3.32	3.09	3.63	4.81	4.91	8.91	9.36

CBFN =carbofuran; TDXPS/EtOH = T. procumbens ethanol extract; TDXPS/AMDT = T. procumbens soil amendment; TDXPS/MeOH = T. procumbens methanol extract.

Table 11: *Effect of treatment and treatment concentration of Tridax procumbens extracts on number of leaf of lettuce plant.*

Treatment	6WAP	7WAP	8WAP	9WAP	10WAP	11WAP	12WAP
CBFN	10^{b}	11^{b}	12^{b}	13^{b}	16^{b}	18^{b}	21^{b}
TDXPS/AMDT	12^{a}	14^{a}	16^{a}	19^{a}	22^{a}	23^{a}	25^{a}
TDXPS/EtOH	7^{c}	8^{c}	9^{c}	11^{bc}	13^{cd}	14^{c}	16^{c}
TDXPS/MeOH	8^{c}	9^{c}	11^{b}	12^{b}	14^{c}	17^{b}	20^{b}
CONTROL	5^{d}	7^{cd}	8^{cd}	9^{d}	10^{e}	13^{d}	16^{c}
SEM ±	0.62	0.83	0.80	0.93	1.52	1.46	1.98
LSD p<0.05	2.06	2.20	2.31	1.61	1.86	2.18	4.69
Level							
One (40g/kg soil)	3^{b}	4^{bc}	7^{b}	9^{c}	12^{b}	14^{c}	16^{c}
Two (60g/kg soil)	5^{a}	5^{b}	8^{b}	11^{b}	15^{a}	17^{b}	19^{b}
Three (80g/kg soil)	6^{a}	7^{a}	10^{a}	13^{a}	16^{a}	21^{a}	22^{a}
SEM ±	0.30	0.65	0.53	0.82	1.13	1.31	1.49
LSD p<0.05	0.94	0.81	2.56	1.35	2.48	2.36	2.70

CBFN =carbofuran; TDXPS/EtOH = T. procumbens ethanol extract; TDXPS/AMDT = T. procumbens soil amendment; TDXPS/MeOH = T. procumbens methanol extract.

Table 12: *Effect of treatment and treatment concentration of Tridax procumbens extracts on lettuce yield, gall index, soil and root nematode population.*

Treatment	Lettuce head weight (g)	Root gall index	Soil nematode count	Root nematode count
CBFN	265^{b}±31.2	0.21^{a} ± 0.6	5^{a} ± 4.1	7^{a} ± 5.0
TDXPS/AMDT	327^{a}±22.1	2.03^{b} ± 0.3	19^{b} ± 5.3	14^{b} ± 17.2
TDXPS /EtOH	181^{d}±7.1	5.07^{c} ± 0.2	40^{d} ± 3.1	53^{c} ± 31.5
TDXPS/MeOH	219^{c}±16.3	5.19^{c} ± 0.0	31^{c} ± 1.2	49^{c} ± 28.3
CONTROL	126^{e} ±8.0	9.00^{d} ± 0.0	4258^{e} ± 284.6	5181^{d} ± 71.6
SEM ±	15.03	0.12	143.1	8.22
LSD p<0.05	21.15	0.29	256.9	21.75
Level				
One (40g/kg soil)	107^{c}± 4.6	7.01^{c} ± 0.8	51^{c} ± 16.8	55^{c} ± 46.2
Two (60g/kg soil)	168^{b}±3.1	6.23^{b} ± 0.5	22^{b} ± 7.2	26^{b} ± 11.5
Three (80g/kg soil)	203^{a} ±11.2	4.48^{a} ± 0.3	4^{a} ± 9.5	9^{a} ± 8.8
SEM ±	10.17	0.03	1.28	3.29
LSD p<0.05	16.22	0.24	3.19	10.63

CBFN =carbofuran; TDXPS/EtOH = T. procumbens ethanol extract; TDXPS/AMDT = T. procumbens soil amendment; TDXPS/MeOH = T. procumbens methanol extract.

Nematode count at harvest was more in control plants compared to the treated plants (Table 6). All treatments notably altered the growth of lettuce plants. Taller plants and more leaves were recorded over the period of observation in treated plants, which translated into higher yield at harvest, contrary to the control lettuce plants. *S. acuta* and *T. procumbens* cuttings as soil amendment had positive effect in the overall vegetative growth of lettuce plants. Lettuce plants treated with low quantity of extracts and plant materials had decreased numbers of leaves, lower height, higher gall index and low yield (Tables 7-12).

There is apparent increase in the vegetative growth of carrot and lettuce plants with the application *S. acuta* and *T. procumbens* as soil amendments. *S. acuta* is known to contain several alkaloids which are good inhibitors of microorganism growth. Several secondary metabolites associated with the Malvacea family which contains about 200 species of *Sida* are reported as a good source of biologically active compounds (Konate and Souza, 2010; Rizk and Soliman, 2014). Criptolepine, vacisine, ephedrine and quindoline are the major alkaloids present in *S. acuta* (Karou *et al.*, 2005; Ahmed *et al.*, 2011). The presence of these alkaloids may be associated with the nematicidal action portrayed by *S. acuta* in this research. The anti-bacterial and anti-protozoan activity of *S. acuta* was reported by Cimanga *et al*. (1998), and Wright *et al*. (2001) respectively. Correspondingly, Karou *et al*. (2003), Banzouzi *et al*. (2004) and Koudovou *et al*. (2011) demonstrated the anti plasmodial activity of *S. acuta*. *S. acuta* has significantly good inhibitory activity on the growth of *Mycobacterium smegmatis, Escherichia coli, Klebsiella species, Proteaus vulgaris, Pseudomonas pyocyanae, Staphylococcus albus, Pseudomonas circhorii,* and *Salmonella typhimurium* (Pongpan *et al*., 1982; Kumar *et al*., 1997; Karou *et al*., 2005). Comparable inhibitory activity of ethanol extracts of *S. acuta* on gram positive bacteria was demonstrated by Oboh *et al*. (2007). Equivalently, Konate *et al*. (2012) reported the bio activity of *S. acuta* on trimoxazol resistant bacteria strains. At 5 hours of exposure there was a 100% mortality of test organisms. The insecticidal activity of *S. acuta* extracts was reported by Adeniyi *et al*. (2010), they recorded a 31.47% mortality at 1.50 minutes of exposure of *Acanthscelides obtectus* to 4% solution of *S. acuta*. Similarly, Ouedraogo *et al*. (2012), reported the antifungal activity of *Sida cordifolia* (L). *T. procumbens* contains several secondary metabolites which is responsible for the biological activities associated with the plant. *T. procumbens* is authenticated to contain quercetin, beta sitosterol, dexamethasone, luteolin, lucoluteolin, esculetin, puerarin, betulinic acid and flavones such as 8,3′-dihydroxy 3,7,4′-trimethoxy-6-O-β-D-glucopyranosyl flavone, 6,8,3′ trihydroxy 3,7,4′ trimethoxyflavone and terpenes like bis-bithiophene (Runsheg *et al*., 2010; Bhalerao and Kelkar, 2012). In this study *T. procumbens* promoted significant positive changes in the vegetative development of treated carrot and lettuce plants compared to the control plants. Thus, the observed nematicidal performance could be linked to the synergistic effect of the several constituents of the plant. The antibacterial action of *T procumbens* was registered by Mir *et al*. (2016), while the insecticidal action of *T. procumbens* was equally substantiated by Ikewuchi *et al*. (2009). Reports by Nazeruddin *et al*. (2011), and Rappiah-Opong *et al*. (2011) confirmed the anti-plasmodial characteristics of *T. procumbens*, extracts from the plant showed repellent action against *Anopheles stephensi* at 6% concentration. Mani and Chitra (1989), indicated that the extracts of *T. procumbens* is nematicidal. They reported 48% juvenile mortality at 500ppm. Sharma and Tiagi (1989) equally reported that root galling was reduced on pea with application of leaf powder of *T. procumbens*. Bioactive molecules produced by plants allow them to interact with microorganisms in the environment (Atolani and Fabiyi, 2020) and these metabolites are responsible for the promising nematicidal activity detected in this study.

Conclusions and Recommendations

The application of *S. acuta* and *T. procumbens* as soil amendment will go a long way in redeeming the environment from pesticide pollution, while safely addressing nematode reduction in the farmer's field.

Novelty Statement

The manuscript expresses the importance of medicinal plants hitherto classified as weed and unavailing in the art of *Meloidogyne incognita* management on vegetables.

Conflict of interest

The authors have declared no conflict of interest.

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