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Use of agro-industrial waste and organic amendments in managing root-knot nematodes in black nightshade in selected parts of Kenya

S.B. NCHORE[1], J.W, WACEKE[2] & G.M. KARIUKI[1]
[1]Plant and Microbial Sciences Department, Kenyatta University, Kenya
[2]Department of Agricultural Science and Technology, Kenyatta University
Corresponding author: nchoree@gmail.com

Abstract A study was conducted in both greenhouse and field to determine the use of agro-industrial waste and organic amendments in the management of root-knot nematodes (RKN) in *Solanum nigrum.* Treatments included cattle manure (CM), goat manure (GM), *Tithonia diversifolia* (Td) and agro-industrial wastes of tea [*Camellia sinensis* residue (Tres)] and pyrethrum [*Chrysanthemum cinerariafolium* Vis.] pymarc (Pm) and vegetable waxy resins (VWR). They were incorporated in sterilized soil at their respective rates into 1 kg plastic pots and *S. nigrum* seedlings planted, across the treatments, two weeks later. Ten egg-masses were inoculated into three pots for each amendment with uninoculated and unamended pots serving as controls. Field experiment was also conducted on plots measuring 1.2x3.2 m in Kisii County, with unamended plots serving as control. The experiments were arranged in randomized complete block design with four replications. All experiments were terminated 60 days after inoculation and data on plant growth and disease parameters collected. The results revealed suppression of RKN population and reproduction by the various amendments compared to their controls in both field and greenhouse. Improved plant growth was also recorded in all the amendments in both tests except for Tres. However, higher levels of Tres and VWR application caused stunted growth despite significant reductions in GI, Rf and J2 populations. These organic amendments can be used as alternatives in eco-friendly management of *Meloidogyne* species and other plant parasitic nematodes.

Key words: *Meloidogyne* spp., organic amendment, Pymarc, vegetable waxy-resins

Introduction

Black nightshade (*Solanum nigrum* L.) is an economically important indigenous leafy vegetable widely cultivated in Kenya (Chweya & Eyzaguirre, 1999). It is a source of income for resource-poor farmers, rich in micro-nutrients, used for treatment of ailments and in management of HIV/AIDS by the Kenyan government (Abukutsa-Onyango, 2007; Ministry of Agriculture, 2007). However, its production is constrained by biotic factors including, diseases and nematode insect pests (Chweya & Eyzaguirre, 1999). Of the nematode pests, root-knot nematode (RKN) is the most important pest causing yield losses up to 60 % (Stirling *et al*., 1992).

Management of RKN has been through the use of nematicides despite their adverse effects to the ecosystem and human being (Udo & Ugwuoke, 2010). Use of eco-friendly alternatives for managing RKN has been reported in other vegetable crops (Waceke, 2001; 2002). Animal manure and agro-industrial tea wastes [*Camellia sinensis* residue (Tres)] have been used in the management of RKN in grapevines (Rivera & Aballay, 2008). *Tithonia diversifolia* (Td) is used in soil fertility improvement in maize production in Western Kenya (Jama *et al*., 2000) as well as an antagonistic plant to RKN in bean production in Kenya (Kimenju *et al*., 2008). Studies conducted in Western Kenya by Abuktsa-Onyango (2007) reported the incorporation of CM, GM and Td into the soil for production of African indigenous leafy vegetables. (Hasabo & Noweer, 2005), reported that plant extracts from fresh leaves of pyrethrum caused 67% mortality rate, at 5% rate in RKN, on *M. incognita* in egg plants. However, there is no information on nematicidal efficacy of CM, GM, Td and agro-industrial wastes of pyrethrum (*Chrysanthemum cinerariafolium* Vis.) [vegetable waxy resins (VWR) and Pymarc (Pm)] in managing RKN and other pythopathogenic nematodes in *S. nigrum* has not been reported. These materials are cheap and locally available in rural farm areas. This study focused on optimizing the use of Tres, Td, VWR, Pm, GM and CM for the management of RKN in *S. nigrum* by the rural poor-resource farmer.

Materials and Methods

Preparation of organic materials and growth medium

Greenhouse experiment 1. The organic materials were collected from potential farmers in Kisii County. Tea residues (Tres) and rejects (Trej) were collected from Kiamokama tea factory and incorporated at the rate of 28.5 g pot^{-1} (25 tons ha^{-1}) (Rivera & Aballay, 2008), while *T. diversifolia* (Td) tender shoots were cut from the hedge, dried under shade and ground and incorporated at the rate of 5 g pot^{-1} (4 tons ha^{-1}) (Jama *et al*., 2000). Well decomposed cattle manure (CM) and goat manure (GM) were collected from the farmers, sun dried and then incorporated into the soil at the rate of 6 g pot-1 (5 tons ha^{-1}).

Greenhouse experiment 2. This experiment was conducted using; CM (0, 3, 6 and 9 g/kg soil), Tres (0, 14, 28 and 32g/ kg soil), Td (0, 2.5, 5 and 8 g/kg soil), VWR ethanol extract (0, 20, 60 and 100 %) and Pm (0, 3, 6 and 9 g/kg soil) ~~and~~ organic amendments (OA) at different levels, slightly above or below the recommended rates to determine their efficacy on RKN. Twenty grams (20 g) of VWR paste were placed in a 150 ml beaker with 80 ml of ethanol and stirred thoroughly for ten minutes. The mixture was left for 24 hours after which it was stirred and decanted carefully forming a standard (S) solution (100%) from which other dilutions were obtained by adding requisite amount of distilled water at the time of experiment.

Red soil and sand mixture (2:1) was sieved through a 3 mm sieve, mixed thoroughly and then steam sterilized at 121^{o}C for 15 minutes. Thereafter, the sandy soil was mixed thoroughly with the various organic amendments at their respective rates in a one kilogram plastic pot with non-amended pots serving as control. The pots were watered regularly for fourteen days. Treatments were arranged in Randomised Complete Block Design with four replications.

Field experiment. The treatment combinations mentioned in section 2.1.1 were used in the field test. The field was cleared, cultivated, ploughed and divided into 48 plots each measuring 1.2 × 3.2 m. The plots were then treated with no manure, Tres (9 kg plot^{-1} or 25 t ha^{-1}), Trej (9 kg plot^{-1} or 25 t ha^{-1}), CM (2 kg plot^{-1} or 5 t ha^{-1}), GM (2 kg plot^{-1} or 5 t ha^{-1}), Td (1.5 kg plot^{-1} or 4 t ha^{-1}), Mocap nematicides (M) as a reference control (36 g plot^{-1} or 100 kg ha^{-1}), CM + M, GM + M, Tres + M, Trej + M, Td + M at their respective rates in a RCBD with four replications. All plots were planted with *S. nigrum* seedlings 14 days after incorporation of amendments into the soil. Each plot had 10 rows with each row having 6 plant units at a spacing of 15 x 30 cm giving a total of 60 plant units per plot. Mechanical weeding was done to ensure the plots were weed free.

Inoculation procedure. A three-week old seedling of *S. nigrum* was planted in each of the amended pots and watered regularly for seven days. Thereafter, four pots for each level of OA were inoculated with ten egg-masses placed at the rhizosphere zone in the treated pots as describe here; cattle manure (CM) + Nematode inoculum (N) at the rate of 0, 3, 6 and 9 g/kg soil each, CM – N, tea residue (Tres) + N at the rate of 0, 14, 28 and 32 g/kg soil each, Tres – N, *T. diversifolia* (Td) + N at the rate of 0, 2.5, 5 and 8 g/kg soil each, Td – N, Pymarc (Pm) + N at the rate of 0, 3, 6 and 9 g/kg soil each, Pm – N, vegetable waxy resins (VWR) + N at the rate of 0, 20, 60 and 100 % respectively, VWR – N, goat manure (GM) + N at the rate of 0, 3, 6 and 9 g/kg soil each, GM – N, no amendment (NA) + N, NA – N treatments replicated four times for each treatment level. Unamended and un-inoculated pots served as controls in this experiment. The experiment was terminated 60 days after inoculation.

Physical and chemical properties of OAs. The amendments were analyzed for their physical and chemical properties at the National Agricultural Research Laboratories. The results are shown in Table 1.

Data collection

Plant growth parameters. At the end of the experimental period, shoot heights were measured from the first basal node to the last apical node. The plants were then gently uprooted and shoots separated from the roots for fresh weight determination. Soil was gently shaken off the roots and thereafter they were gently washed with tap water to remove adhering soil and then blotted dry with a paper towel before determining their weights.

Galling index. The entire root was spread on a paper towel and scored for gall index using the 0-5 gall rating scale according to Quesenberry *et al*. (1989) where; 0= no galls; 1= 1-2; 2= 3-10; 3= 11-30; 4= 31-100 and 5= > 100 galls per root system.

Extraction of J2 from soil. The soil was thoroughly but gently mixed and a 200 cm^3 sub-sample taken for assessing

Table 1. Physico-chemical properties* of plant tissue and animal manure used for amending soil in greenhouse and field experiments.

Sample description	Organic manure analysis data				
	GM	CM	Trej	Tres	Td
pH-water (1:2.5)	7.77	7.34	6.96	5.83	6.30
Org. Carbon %	3.15	3.70	3.81	3.91	4.26
Nitrogen %	1.05	1.05	4.20	4.10	5.25
C/N ratio	3:1	3.5:1	0.91:1	0.95:1	0.81:1
Phosphorus %	0.27	0.21	0.25	0.52	0.28
Potassium %	1.58	1.58	1.92	0.13	1.65
Calcium %	4.36	0.96	2.09	2.13	0.59
Magnesium %	0.33	0.08	0.34	0.26	0.19
Iron mg/kg	3767	1397	1315	1297	2033
Copper mg/kg	15.0	3.3	3.67	3.58	8.33
Manganese mg/kg	2083	892	1020	1026	1040
Zinc mg/kg	307	85	82	79	78

[f&]Physico-chemical analysis done at National Agricultural Research laboratories (KARI-NARL) in Kenya.

nematode population using modified extraction tray method according to Hooper *et al*. (2005). The soil was spread on a double layer of paper towel supported by a plastic sieve and placed over a shallow extraction tray after which water was gently added to the sides until the soil was just wet. The set up was left for 24 hours after which, the contents from the extraction tray were placed into a 200 ml beaker and poured through a 38 µm sieve held at 45^o and then back washed with water from a wash water bottle into a 50 ml beaker. Excess water was sucked off with a dropper to reduce nematode suspension to 20 ml and nematodes enumerated over a stereo microscope.

Reproductive factor. The nematode reproduction factor (Rf) was determined by expressing final nematode egg-masses/root system (P_f) as the ratio of the initial inoculum (P_f) of 10 egg-masses (Zhang & Schmitt, 1994).

Data analysis. The collected data on nematode galling and population density was checked for normality and log transformed ($\log_{10}$X+1) where X is galling index or the J2/200 cm^3 soil) and thereafter subjected to Analysis of Variance (ANOVA)

Results

Greenhouse test 1. There was no significant difference (P>0.05) in shoot height (SH) among the amendments (Table 2). Tea residue, Trej, GM, Td and CM amended inoculated plants had higher SH that did not differ significantly from the unamended inoculated plants (Table 2). However, a significant difference (P<0.05) was observed among amendments in amended uninoculated plants (Table 2). Cattle manure had significantly higher SH than unamended inoculated plants. Although GM, Trej and Td had higher SH, they did not differ significantly (P<0.05) from unamended inoculated plants (Table 2). Tea residue had significantly lower SH than unamended inoculated plants.

The fresh shoot weight (FSW) did not differ significantly (P>0.05) among the amendments (Table 2). *Tithonia diversifolia* amended and inoculated plants had significantly higher FSW than the unamended inoculated plants. Although FSW of GM, Tres, Trej and CM amended plants were generally heavier than those growing in unamended inoculated soil, they were not significantly different. Fresh shoot weight of amended and inoculated plants did not in most cases differ significantly from those grown in amended and uninoculated plants. Fresh shoot weights of amended and uninoculated plants did not differ significantly (P>0.05) from those grown on unamended and inoculated plants. Although all the amendments had generally high FSW than unamended inoculated plants, they did not differ significantly (Table 2).

The treatments did not differ significantly (P>0.05) on their effect on fresh root weight (FRW) among the amendments. All the amendments except Trej in amended and inoculated plants, had heavier roots than the unamended inoculated plants although they did not differ significantly (P>0.05). Trej had lower FRW that did not differ significantly from unamended inoculated plants. The FRW of amended uninoculated plants differed significantly (P<0.05) among the amendments. Significantly heavier roots were found in Td amended and uninoculated plants than unamended inoculated plants. However, all the other amendments though they had heavier roots, did not differ significantly from unamended inoculated plants (Table 2).

There was a significant difference on galling index (GI) among the amendments. Tea rejects, Td and Tres amended plants had some of the lowest GI with Trej having the lowest though they were not significantly lower than the unamended plants (Table 3). Goat manure and CM had some of the highest GI though they were not significantly higher than the unamended plants.

The reproduction factor (Rf) differed significantly (P<0.05) among the amendments. *Tithonia diversifolia*, Trej and Tres amended plants had the lowest Rf with Td having the lowest although there was no significant difference established from unamended plants (Table 3). The highest Rf were found in GM and CM though they were not significantly (P>0.05) higher than the unamended plants. The amendments differed significantly on their suppression on J2 population in soil. All the amendments had lower J2 population with Td having the lowest though they were not significantly lower than those of unamended plants (Table 3).

Greenhouse test 2. The SH differed significantly (P<0.05) among the different levels in Td amended and inoculated plants. Except soils amended with Td at 5 and 8 g kg^{-1} soil that had significantly higher SH than those at level 1.

Table 2. Effect of OAs and agro-industrial wastes on growth of *S. nigrum* green in the greenhouse test 1.

Amend	SH		FSW		FRW	
	+ N	- N	+ N	- N	+ N	- N
GM	49.25b	60.98ab	18.75ab	19.18ab	1.9ab	1.45ab
CM	44.0b	68.13a	13.08ab	22.64a	1.75ab	1.18ab
Trej	51.38ab	52.0ab	15.48ab	22.07a	0.99b	1.2ab
Tres	52.75ab	34.5ab	18.65ab	14.9ab	1.6ab	0.89b
Td	47.13b	51.25bc	22.03a	18.23ab	1.95ab	2.7a
Unamended	42.25b	38.0bc	8.58b	15.8ab	1.1ab	0.89bc
P-Value	0.460	0.000	0.074	0.076	0.585	0.021

Means on the same column followed by the same letter (s) are not significantly different at P>0.05.

However, those amended and inoculated at level 2 were not significantly shorter than those at level 1 (Table 4). The SH in amended and uninoculated plants at levels 2 to 4 were higher though not higher than those at level 1. The levels of Pm differed significantly with soils amended and inoculated at 6g kg^{-1} soil having significantly lower SH than those at level 1 (Table 4). Although those amended at levels 2 and 4 had higher SH, they did not differ significantly from those at level 1. The SH, in amended and uninoculated plants, did not differ significantly among the levels. However, levels 2 to 4 had SH that were not significantly higher than those at level 1. Plants amended and inoculated with Tres at levels 2 to 4 had significantly (P<0.05) higher SH than those amended at level 1. Levels 2- 4 had some of the highest SH in Tres amended and uninoculated plants that were not significantly (P>0.05) higher than those at level (Table 4). All the levels, in amended inoculated plants, differed significantly with levels 2 to 4 having higher SH than level 1. The SH in amended and uninoculated plants differed significantly with levels 3 and 4 having higher SH than level 1 although level 2 did not differ significantly. Shoot heights of VWR amended and inoculated plants were significantly shorter (P<0.05) than those in level 1. Levels 3 and 4 of VWR had some of the highest SH however, they were significantly taller than those of level 1 (Table 4).

Fresh shoot weight in all amendments except Pm in amended and uninoculated plants differed significantly (P>0.05). Levels 2 to 4 in Td amended and inoculated had significantly high FSW than level 1. Level 4 in amended and uninoculated plants at level had significantly higher FSW than level 1. The other levels, though they had higher FSW, did not differ significantly from level 1 (Table 4). There was no significant difference in FSW in amended

Table 3. Effect of OAs and agro-industrial wastes on RKN galling index, Rf and population in *S. nigrum* in the greenhouse test 2.

Amendment	Galling index (GI)	Reproduction factor (Rf)	J2/200 cc soil
GM	3.0a	3.44a	248.5a
CM	3.0a	4.2a	278.3a
Tres	1.5abc	2.15ab	288.8a
Td	1.25bc	0.5bc	99.8ab
Trej	1.0bc	1.23b	171.5ab
Unamended	2.75ab	3.03ab	313.3a
p-value	0.001	0.000	0.016

Means on the same column followed by the same letter (s) are not significantly different at P>0.05.

Table 4. Effects on the plant growth, J2 population, galling index (GI) and reproduction factor (Rf) in greenhouse test 2.

OA	Level	SH		FSW		FRW		J2/200cc soil	GI	Rf
	g/kg soil	+ N	- N	+N	-N	+ N	-N	+N	+N	+N
Td	0	10.5c	25.75ab	0.2c	2.31b	0.66a	0.51c	24.8a	5.3a	7.5
	2.5	14.0bc	28.63a	2.19ab	2.37b	0.28bc	0.64bc	22.5a	3.3b	2.9
	5	23.13a	30.8a	2.51a	3.46ab	0.15c	1.28ab	14.0ab	3.0b	2.6
	8	24.76a	32.4a	2.8a	3.77a	0.33bc	1.79a	11.3ab	1.0c	-0.3
	P-value	0.000	0.348	0.000	0.000	0.011	0.001	0.395	0.000	
Pm	0	22.38ab	26.25ab	3.84a	2.44b	1.29a	0.87b	5.8a	6.0a	11.5
	3	14.88b	28.23ab	2.05ab	3.65ab	0.56bc	1.09b	4.3ab	3.3b	3.7
	6	24.73a	30.83a	3.96a	3.93ab	0.57bc	1.84ab	2.5ab	3.3b	2.7
	9	20.78ab	31.2a	3.78a	5.03a	0.29c	2.61a	1.8b	1.5c	1.0
	P-value	0.017	0.052	0.129	0.074	0.013	0.011	0.114	0.000	
Tres	0	15.88b	24.98a	3.26c	3.71c	1.3a	0.9b	5.5a	5.5a	13.7
	14	28.25a	25.95a	6.43ab	7.93a	0.6bc	1.1b	2.5ab	3.3b	7.2
	28	29.88a	27.7a	8.48a	7.88a	0.57bc	1.8ab	3.0ab	1.5c	-0.3
	32	23.13ab	26.7a	6.65ab	6.87ab	0.3c	2.6a	1.0b	1.0c	-0.7
	P-value	0.011	0.061	0.001	0.000	0.013	0.011	0.328	0.000	
CM	0	6.63c	19.75b	0.11c	1.96ab	0.7a	0.48ab	35.8a	4.0a	6.2
	3	17.5b	24.25ab	0.56b	3.72a	0.26ab	0.7a	20.8b	3.0ab	2.7
	6	22.25ab	26.1a	0.23c	1.09b	0.25ab	0.44ab	9.3cd	1.8bc	0.3
	9	25.85a	28.28a	0.25c	0.9b	0.32ab	0.55ab	4.3d	1.5c	-0.1
	P-value	0.000	0.000	0.006	0.019	0.310	0.900	0.000	0.000	
VWR (%)	0	5.83c	20.63a	0.32b	3.06a	0.23b	1.85a	15.7a	5.0a	12
	20	12.73a	16.75ab	1.51ab	2.47ab	1.0a	1.86a	8.0b	3.0b	1.6
	60	12.17ab	11.13bc	1.85a	1.05ab	0.78ab	0.7ab	4.0bc	2.5bc	1.2
	100	11.0ab	11.63bc	1.54ab	0.58b	0.71ab	0.9ab	2.3c	1.5c	0.2
	P-value	0.004	0.011	0.067	0.029	0.045	0.079	0.000	0.000	

Means on the same column followed by similar letter (s) are not significantly different (P>0.05).

and inoculated plants among the levels of amendment in Pm. However, levels 2 to 4 had high FSW though thet were not significantly higher than level 1. Although significantly high FSW were recorded in level 4 of amended uninoculated plants, those in level 2 and 3 of Pm did not differ significantly. The FSW were significantly different (P<0.05) in amended inoculated and amended uninoculated plants with level 3 of CM recording significantly higher FSW than level 1. The FSW in level 2 of CM in amended inoculated plants had significantly higher FSW than level 1. Although levels 3 and 4 of CM had high FSW they did not differ significantly with level 1. The levels of VWR did not differ significantly in amended inoculated plants (Table 4). Level 3 of VWR had significantly higher FSW than level 1 though levels 2 and 4 did not differ significantly. In amended and uninoculated plants, there was significant difference established with levels 3 and 4 having significantly higher FSW than level 1. Although FSW in level 1 of amended uninoculated plants were high, they were not significantly higher than those of level 1 of VWR (Table 4).

Heavier roots (P<0.05) were recorded in soils amended with Td, Pm and Tres although, CM amended soils inoculated with and without nematodes did not differ significantly (P>0.05). In VWR, soils amended at 0% in nematode inoculated plants significantly differed from the uninoculated control while those of the other levels did not differ significantly (Table 4). The nematode population did not differ significantly (P>0.05) in soils treated with Td, Pm and Tres. However, significantly lower J2 populations (P<0.05) were recorded in CM and VWR at levels 2 to 4 compared to nematode inoculated and uninoculated controls. All the amendment levels differed significantly in suppressing galling index(P<0.05), with levels 2, 3 and 4 recording lower GI than level 1 in all the amendments, except for CM amended plants at level 2 that did not differ significantly from level 1. All the amendments had lower Rf at level 2 to 4 of application with level 4 recording negative Rf in all amendments except for CM and VWR amended plants compared to level 1 (Table 4).

Field test. The treatments differed significantly (P<0.05) on their effect on shoot height. Taller plants were found in Tres and Td compared to the unamended plants with mocap (Table 5). Although Trej, GM and CM had higher SH than the unamended plants with mocap, they were not significantly higher (P>0.05). In amended plants with mocap, the amendments differed (P<0.05) significantly (Table 5). All the amendments had higher SH with CM, Tres and Td having the highest compared to unamended plants without mocap (Table 5).

Except for GM, all the other amendments had higher FSW that did not differ significantly (P>0.05) from unamended plants without mocap (Table 5). There was no significant difference (P>0.05) among the amendments in amended plants without mocap. Although FSW of amended plants with mocap were generally higher than those of unamended plants without mocap, they were not significantly different (P>0.05). Cattle manure, Tres and Trej had the highest FSW than unamended plants with mocap (Table 5).

The amendments differed significantly on their effect on FRW in amended plants without mocap. Tea rejects, GM, CM and Td amended plants without mocap had some of the highest FRW that did not differ significantly (P>0.05) from the amended plants with mocap (Table 5). However, Tres amended plants without mocap had the lowest FRW that were not significantly lower than unamended plants with mocap. On the other hand, FRW in amended plants without mocap differed significantly (P<0.05). The FRW was significantly higher in GM, Tres and Trej amended plants without mocap than unamended plants with mocap. lower FRW was found in Td amended plants without mocap than unamended plants with mocap (Table 5).

There was a significant difference among the amendments on J2 population in amended plants without mocap. Significantly (P<0.05) lower J2 population was found in Trej, Td and Tres compared with the unamended plants without mocap (Table 6). Although CM and GM had lower J2 than unamended plants without mocap, they did not differ significantly (P>0.05).

There was no significant difference in GI among the amendments (P>0.05). Tea residue had significantly lower GI than unamended plants. Although CM, GM, Td and Trej had the lowest GI, they did not differ significantly from the unamended plants. A significant difference was recorded among the amendments on Rf. All the

Table 5. Effect of OAs and agro-industrial waste on RKN and growth of *S. nigrum* in the field test.

Amend	SH		FSW		FRW	
	-M	+M	-M	+M	-M	+M
Trej	71.0a	55.7ab	83.8a	78.83a	5.85b	8.78a
Td	73.4a	70.6ab	61.5ab	67.8a	4.84bc	3.68c
Tres	68.0ab	72.6a	84.74a	80.63a	4.31c	7.98ab
GM	69.8ab	46.8b	48.65ab	49.0ab	5.53bc	8.93a
CM	68.4ab	72.6a	86.43a	91.6a	5.5bc	5.13bc
Unamended	59.0bc	27.2c	69.1ab	34.59ab	4.63bc	1.72d
P-value	0.000	0.048	0.109	0.601	0.003	0.000

Means on the same column followed by the same letter (s) are not significantly different at P>0.05.

Table 6. Effect of amendments on RKN in the field test.

Amendment	Without Mocap		
	J2/200 cc soil	GI	Rf
Trej	45.75b	2.5ab	0.88bc
Td	19.75bc	2.0ab	0.49bc
Tres	33.8b	1.5b	0.3bc
GM	78.0ab	2.3ab	0.47bc
CM	75.0ab	2.0ab	0.35bc
Unamended	119.5a	3.0a	15.0a
P-value	0.002	0.162	0.000

Means on the same column followed by the same letter (s) are not significantly different at P>0.05.

amendments had significantly lower Rf than unamended plants (Table 6).

Discussion

Root-knot nematode is among the greatest threats to vegetable production in Kenya. The agro-industrial wastes have potential in the management of RKN on *S. nigrum* by the poor-resource farmers. They are readily available at farm levels. The various OAs increased plant growth as depicted in Tables 2 and 5. However, tea residue caused stunting at higher rates and this may be attributed to the presence of high levels of phenolic compounds and tannins present in tea (Rivera & Aballay, 2008). The study findings concur with Rivera & Aballay (2008) who observed that tea residue caused necrosis in roots of grapevines at levels more than 28 g kg^{-1} soil in Chile.

The study findings indicated the potential of the agro-industrial wastes, *T. diversifolia* and cattle manure in reduction of RKN population density, Rf and galling index (Table 1), may be attributed to low potassium levels, narrow C:N ratio and high nitrogen content present in these materials (Jama *et al*., 2000; Waceke, 2001; 2002). Huber, (1980) and Oka *et al*. (2000) reported that amending soils with materials with narrow C: N ratio and high nitrogen content with low potassium levels reduced galling and reproduction of RKN. The reduction in galling index and Rf on *S. nigrum* signifies the viability and efficacy of the materials tested in this study in management of RKN pests.

Conclusion and Recommendation

The agro-industrial wastes, *Tithonia diversifolia*, cattle and goat manure have potential in the management of RKN on *S. nigrum*. Nematode GI, Rf and J2 population was suppressed by agro-industrial wastes, Td, CM and GM. Increased plant growth in amended plants confirms potential of the agro-industrial and organic amendments into improve plant growth. However, higher levels of tea residue and vegetable waxy resins caused stunting. Therefore, lower rates of 28g kg^{-1} soil and 20% of Tres and VWR, respectively, are recommended. Further studies are therefore necessary for identification of the active components of these materials in the wake of reducing dependence on chemical nematicides.

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