MANAGEMENT OF ROOT-KNOT AND OTHER PHYTONEMATODES INFECTING OKRA WITH SOIL AMENDMENTS

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This study investigated the effects of Mexican sunflower and Siam weed applied as organic amendments on the population densities of phytonematodes infecting okra with a view to reduce the quantity of synthetic nematicides used in the management of phytonematodes. Two field trials of 2 × 5 factorial experiment were laid out in a randomized complete block design with two okra cultivars (NH47-4 and LD88) and five treatments made up of 7 or 14 plants of either Mexican sunflower or Siam weed and the unamended control. The population densities of *Meloidogyne incognita*, *Pratylenchus* species and *Tylenchus* species were significantly higher in control plots than in amended plots. Mexican sunflower and Siam weed applied at 7 or 14 plants per plot significantly reduced population densities – of *Meloidogyne incognita* by 38 %, *Pratylenchus* spp. by 39 %, and *Tylenchus* spp. by 49 % in the early rainy season trial and by 32 %, 28 % and 35 %, respectively, in the late rainy season trial with correspondingly higher yield of okra in amended plots compared to those unamended in both trials.

vegetable, nematode pest, organic amendment, *Tithonia diversifolia, Chromolaena odorata*

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INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is an annual warm season vegetable from the family *Malvaceae* (Naveed et al., 2009). It is distributed across tropical and subtropical countries (Arapitsas, 2008). Every part of okra is economically important and has medicinal, nutritional and industrial potentials (Oyelade et al., 2003). High incidence of pests and diseases such as plant parasitic nematodes have been a major constraint in okra production and they have caused losses of up to 80 % in vegetable fields (Kaskavalci, 2007), therefore preventing production maximization. Plant-parasitic nematodes are cosmopolitan pests and have been reported to reduce the economic value of several crops (Berry et al., 2008). Several genera of nematodes like *Meloidigyne* spp. (Adekunle, 2009), *Pratylenchus* spp. (Yaw et al., 2016), *Tylenchus* spp. and *Heterodera* spp. (Olabiyi, Oladeji, 2011) are reported to cause diseases in okra. Root-knot nematodes (*Meloidogyne incognita*) are reported to be the most serious nematode pests of okra (Hussain et al., 2011a). They burrow into young roots forming galls on the roots, therefore reducing the ability of the roots to absorb water and minerals from the soil, leading to stunted growth and yield reduction (Bolles, Johnson, 2012). Bao, Neher (2011) reported that *Pratylenchus* spp. (root lesion nematodes) causes above ground symptoms such as curled leaves, fewer fruits, wilting and chlorosis apart from the brown lesions on plant roots. Yeates et al. (1993) discovered *Tylenchus* spp. in the rhizospheres of plant feeding on plant roots, especially the root hairs, therefore reducing water uptake. Against this background, management of nematode pests of okra becomes imperative. The use of synthetic nematicides has been found to be effective in the control of plant-parasitic nematodes (Amulu, Adekunle, 2015), however their high costs (Chitwood, 2002), high toxicity to non-target soil microorganisms and man (Oka et al., 2014) have reduced their usage (Amulu, Adekunle, 2015).

All these challenges have led to the development of alternatives to synthetic nematicides including the use of organic amendments of plant origin (O g u n d e l e et al., 2016). Organic amendments of plant origin have greatly contributed to management of phytonematodes since upon decomposition they release compounds that are nematotoxic (A d e k u n l e , 2009) and also improve soil fertility by releasing soil nutrients (M a r t e n s , 2000). In this study, Mexican sunflower, *Tithonia diversifolia* (Hemsley) Gray A. and Siam weed, *Chromolaena odorata* (L.R.M.) King and Robinson were used as amendments. These are invasive weeds that contain nematotoxic substances, sesquiterpenes (C h u k w u k a , O j o , 2014) and 1,2-dehydropyrizidine alkaloids (T h o d e n et al., 2007). They also release soil nutrients, therefore improving soil fertility. This study compared the effects of Mexican sunflower and Siam weed as soil amendments on the population densities of *Meloidogyne incognita* and other phytonematodes on okra and investigated their effects on the yield of okra infected with *Meloidogyne incognita* and other phytonematodes.

MATERIAL AND METHODS

Experimental site

In the early (April–July) and late (August–November) rainy seasons of 2017, field trials were conducted on the Teaching and Research Farm of Obafemi Awolowo University, Ile-Ife, located at latitude 7° 28′ N and longitude 4° 33′ E at 244 m a.s.l., in the tropical rainforest zone of Nigeria. The experimental site was naturally infested with plant-parasitic nematodes (*Meloidogyne incognita*, *Pratylenchus* spp., and *Tylenchus* spp.).

Sources of seeds

Seeds of okra cultivars NH47-4 and LD88, which are moderately susceptible to *Meloidogyne incognita* (A d e k u n l e , 2009), and seeds of *Celosia argentea* (cv. TLV8) were obtained from the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria. The seeds of Mexican sunflower and Siam weed were collected from the Teaching and Research Farm, Obafemi Awolowo University.

Production of nematode inoculum, seedlings of Mexican sunflower and Siam weed

Pure cultures of *Meloidogyne incognita* race 2 were maintained on *Celosia argentea* (cv. TLV8) in the nematode culture plot of the Department of Crop Production and Protection, Obafemi Awolowo University, for eight weeks. Seeds of Mexican sunflower and Siam weed were sown separately in sterilized soil put in seed trays and the seedlings were maintained under screen house conditions for four weeks.

Experimental layout and planting

In the early rainy season (April–July) of 2017, the experimental field was ploughed, harrowed and inoculated with chopped galled roots of *Celosia argentea* cv. TLV8 infected with *Meloidogyne incognita* (from the nematode culture plots) to increase *M. incognita* population on the site. The experiment was a 2 × 5 factorial experiment laid out in a randomized complete block design with two okra cultivars (NH47-4 and LD88) and five treatments made up of 7 or 14 plants of either Mexican sunflower or Siam weed and the unamended control, replicated four times. The field was divided into four blocks of 24.5 × 2 m, while each block was in turn divided into ten 2 × 2 m plots to give a total of 40 plots. There was a space of 1 m between blocks and 0.5 m between plots. In each replicate, four-week-old Mexican sunflower and Siam weed seedlings were transplanted into the field at 7 or 14 plants per plot (17 500 or 35 000 plants per ha), each replicate contained control plots without Mexican sunflower and Siam weed plants. The transplanted plants were incorporated into each plot two weeks after transplanting. Soil samples of 15 cores each were collected two weeks after the incorporation of the Mexican sunflower and Siam weed into the soil of all 40 plots for nematode population and soil chemical analyses.

Okra seeds, cvs NH47-4 and LD88, were planted two weeks after incorporation of Mexican sunflower and Siam weed into soil, at the rates of three seeds per hole with a spacing of 60 cm between and 40 cm within rows. The plants were thinned to one plant per stand one week after planting. There were 20 plants per plot giving a total of 800 plants. The experiment was rainfed and manual weeding was carried out weekly. Fertilizers and insecticides were not applied on the experimental plots. At maturity (7 weeks after planting), okra fruits were harvested every four days and weighed and the cumulative fruit weights were calculated for each plot when fruiting ceased. The study was terminated 110 days after planting. Soil samples were also taken at termination for final nematode population and soil chemical analyses. The experiment was repeated once in the late rainy season (August–November) of 2017 on an adjacent field, 100 m away from the field for first trial and, supplementary irrigation was carried out, when rainfall ceased.

Nematode analysis

Nematodes were extracted from soil samples using the Baermann extraction tray arrangement (W h i t e h e a d , H e m m i n g , 1965). A 200 ml sub-

Table 1. Combined analysis of variance of cumulative fruit yield and plant-parasitic nematode population densities infecting okra in response to Mexican sunflower and Siam weed as soil amendments in early and late rainy seasons of 2017

Sources of variation	DF	Cumulative fruit yield (t ha^{-1})	*Meloidogyne incognita*	*Pratylenchus* spp.	*Tylenchus* pp.
Season	1	1.59**	0.54	10.77**	12.71**
Rep (season)	6	0.25**	0.64**	0.79**	0.62
Cultivar	1	0.07	0.01	1.19*	3.76**
Amendment	1	0.73**	10.73*	2.59**	2.28*
Rate	1	1.70**	1.58**	8.06**	8.12**
Cultivar × Amendment	1	0.01	0.29	0.98*	0.24
Cultivar × Rate	1	0.22	0.09	0.63	1.29
Cultivar × Season	1	0.26	0.05	1.33*	0.48
Amendment × Rate	1	0.05	0.01	0.03	0.63
Amendment × Season	1	0.09	0.01	0.16	0.18
Rate × Season	1	0.20	0.02	0.14	0.32
Cultivar × Amendment × Season	1	0.03	0.01	0.38	0.47
Cultivar × Rate × Season	1	0.02	0.02	1.95**	0.42
Cultivar × Amendment × Rate	1	0.03	0.05	0.02	0.16
Cultivar × Amendment × Rate × Season	2	0.04	0.12	0.04	0.11
Error	58	0.076	0.15	0.21	0.39
R-square		0.72	0.85	0.88	0.84
CV (%)		46.70	6.94	8.48	10.43

DF = degree of freedom, CV= coefficient of variation

*significant at 0.05 level of probability, **significant at 0.01 and 0.05 levels of probability

sample of each bulk soil sample collected from each of the 40 experimental plots was placed in a double plastic sieve separated by a double ply facial tissue and placed in an extraction tray and 300 ml of water was added. The set-up remained undisturbed for 24 h. The nematode suspension was concentrated to about 10 ml by passing it through a 325 mesh sieve. Nematodes were killed by heat and fixed in 4 % (w/v) formaldehyde (Coyne et al., 2009). They were counted in a Doncaster counting dish under a stereomicroscope at a magnification of 250× (Model WILD M5; WILD HEERBRUGG, SWITZERLAND). Individual nematodes from each sample were examined and identified under a compound microscope at a magnification of 100–400× (Model ST-30C-2LOO; MIOTIC MICROSCOPES, EUROPEAN DIVISION) to genus and *Meloidogyne* was identified to species using perineal pattern characteristics (Eisenback et al., 1981). This was done by dissecting matured female obtained from large galls on the root of celosia plants. Perineal pattern slides were prepared and examined under the compound microscope.

Soil chemical analysis

Portions of soil samples taken before planting and at final harvest were analyzed for soil pH, total N, available P, exchangeable K, and organic carbon (OC). The samples were air dried and sieved through a 2 mm mesh sieve to remove unwanted particles in the samples. Soil pH was determined using the method of Thomas (1996), OC was determined using the method of Nelson, Sommers (1996), total N was determined using the macro-Kjeldahl method as described by Bremner (1996). Available P was extracted using Bray-1 method as described by Kuo (1996) and measured using a spectrophotometer (Model 721; AXIOM MEDICAL LTD., CANTERBURY, UK), while exchangeable K was measured using a digital flame photometer (Model 2655-00 Digital Flame Analyser; COLE-PALMER INSTRUMENTS, CHICAGO, IL, USA) (Knudsen et al., 1982).

Statistical analysis

All data obtained were subjected to analysis of variance (ANOVA) using the data obtained from the nematode population count which were earlier square root transformed. Computed result for the seasons were used to determine differences between the two cultivars of okra for each treatment. Significant treatment means were separated by Fisher's Least Significant Difference at $P \leq 0.05$. Means of nematode population and fruit weight of okra for two levels of Mexican sunflower and Siam weed and the control were compared for each season.

Table 2. Effects of Mexican sunflower and Siam weed as soil amendments on percentage change in soil population densities of plant-parasitic nematodes infecting okra under field conditions (early rainy season of 2017)

Treatment	NH47-4			LD88		
	Meloidogyne incognita	*Pratylenchus* spp.	*Tylenchus* spp.	*Meloidogyne incognita*	*Pratylenchus* spp.	*Tylenchus* spp.
MS at 7 s.p.p.	–39.95	–38.82	–41.99	–34.61	–36.10	–49.41
MS at 14 s.p.p.	–41.17	–44.64	–63.16	–39.02	–45.61	–57.44
SW at 7 s.p.p.	–35.33	–33.85	–41.44	–34.88	–33.57	–40.43
SW at 14 s.p.p.	–38.47	–39.58	–57.89	–38.33	–43.24	–43.97
Control	+14.61	+10.94	+21.15	+19.87	+24.50	+17.11
LSD	6.80	5.35	6.98	6.80	5.35	6.98

LSD = Least Significant Difference, MS = Mexican sunflower, SW = Siam weed, s.p.p. = seedlings per plot, + = percentage increase in plant-parasitic nematode population, – = percentage reduction in plant parasitic nematode population

each value is a mean of four replicates

initial population densities of *M. incognita* per plot = 205–510 J_2 stage per 200 ml of soil; *Pratylenchus* spp. = 75–250 J_2 stage per 200 ml of soil; *Tylenchus* spp. = 285–780 J_2 stage per 200 ml of soil

Table 3. Effects of Mexican sunflower and Siam weed as soil amendments on percentage change in soil population densities of plant-parasitic nematodes infecting okra under field conditions (late rainy season of 2017)

Treatment	NH47-4			LD88		
	Meloidogyne incognita	*Pratylenchus* spp.	*Tylenchus* spp.	*Meloidogyne ncognita*	*Pratylenchus* spp.	*Tylenchus* spp.
MS at 7 s.p.p.	–33.11	–24.19	–34.33	–27.02	–25.47	–28.67
MS at 14 s.p.p.	–38.82	–41.54	–48.90	–31.77	–28.80	–34.19
SW at 7 s.p.p.	–31.36	–17.64	–35.63	–25.76	–25.00	–26.67
SW at 14 s.p.p.	–31.93	–29.05	–38.89	–31.33	–27.04	–31.17
Control	+17.24	+15.87	+18.56	+27.51	+17.94	+18.35
LSD	3.34	5.68	10.12	3.34	5.68	10.12

LSD = Least Significant Difference, MS = Mexican sunflower, SW = Siam weed, s.p.p. = seedlings per plot, + = percentage increase in plant-parasitic nematode population, – = percentage reduction in plant parasitic nematode population

each value is a mean of four replicates

initial population densities of *M. incognita* per plot = 260–510 J_2 stage per 200 ml of soil; *Pratylenchus* spp. = 125–400 J_2 stage per 200 ml of soil; *Tylenchus* spp. = 340–695 J_2 stage per 200 ml of soil

RESULTS

Cumulative fruit yield and plant-parasitic nematode population densities infecting okra in response to Mexican sunflower and Siam weed as soil amendments in early and late rainy seasons of 2017 is presented in Table 1 showing that season had a highly significant effect on the cumulative fruit yield and on the nematode populations of *Pratylenchus* spp. and *Tylenchus* spp. Amendments highly significantly affected the increase of cumulative fruit yield of okra and the reduction of *Pratylenchus* spp. and also significantly affected the reduction of *Meloidogyne incognita* and *Tylenchus* spp. (Table 1). The rates of amendment applied showed a highly significant effect on the increase of cumulative fruit yield of okra and on reducing the nematode populations. Cultivars showed a significant effect on reducing the populations of *Pratylenchus* spp. and *Tylenchus* spp. (Table 1). The interaction between cultivar and amendment and the 3-way interaction between cultivar, rate and season had a significant effect on reducing the population of *Pratylenchus* spp. (Table 1).

The effects of Mexican sunflower and Siam weed as soil amendments on the percentage change in the population densities of plant-parasitic nematodes

Table 4. Effects of Mexican sunflower and Siam weed as soil amendments on fruit weight (t ha^{-1}) of plant-parasitic nematode-infected okra under field conditions (early and late rainy seasons of 2017)

Treatments	Early rainy season		LSD ($P \leq 0.05$)	Late rainy season		LSD ($P \leq 0.05$)
	NH47-4	LD88		NH47-4	LD88	
MS at 7 s.p.p.	0.62	1.05	0.63	0.45	0.50	0.36
MS at 14 s.p.p.	1.20	1.25	1.52	0.75	0.53	1.06
SW at 7 s.p.p.	0.28	0.65	0.36	0.28	0.29	0.12
SW at 14 s.p.p.	0.89	1.08	0.82	0.59	0.52	0.59
Control	0.27	0.25	0.08	0.20	0.15	0.05
LSD ($P \leq 0.05$)	0.45	0.45		0.33	0.33	

LSD = Least Significant Difference, MS = Mexican sunflower, SW = Siam weed, s.p.p. = seedlings per plot
each value is a mean of four replicates

infecting okra under field condition are presented in Tables 2, 3. The results presented in Table 2 (early rainy season) show a significant reduction in the population of *Meloidogyne incognita*, *Pratylenchus* spp. and *Tylenchus* spp. in all the plots amended with 7 and 14 plants of both Mexican sunflower and Siam weed for the two okra cultivars if compared to their respective control plots. The population densities of *Pratylenchus* spp. and *Tylenchus* spp. in plots amended with 14 plants of Mexican sunflower and Siam weed showed a reduction that was significantly higher than in plots amended with 7 plants of both okra cultivars (Table 2). In the late rainy season of 2017, the population densities of *Meloidogyne incognita, Pratylenchus* spp. and *Tylenchus* spp. in plots amended with 14 plants of Mexican sunflower showed a significantly higher reduction in comparison to 7 used plants for cv. NH47-4 and also for *Meloidogyne incognita* infecting cv. LD88. The population densities of *Pratylenchus* spp. in cv. NH47-4 and *Meloidogyne incognita* in cv. LD88 in plots amended with 14 plants of Siam weed displayed a significantly higher percentage reduction than if 7 plants were amended (Table 3).

The effects of Mexican sunflower and Siam weed as soil amendments on the fruit yield (t ha^{-1}) of nematode-infected okra under field conditions are presented in Table 4. In the early rainy season of 2017, the amendment of soil with 14 plants of Mexican sunflower and Siam weed in plots planted with cv. NH47-4 produced significantly higher okra fruit yield than in the control plot, the late rainy season trial showed the same trend (Table 4). The fruit yield of cv. LD88 in all amended plots was significantly higher than that of the control plot except for plot amended with 7 plants of Siam weed. With respect to cv. NH47-4, the fruit yield of okra in plots amended with 14 plants of both Mexican sunflower and Siam weed were significantly higher than those with 7 plants per plot in the early rainy season trial, while for cv. LD88, the fruit yield from plots amended with 14 or 7 plants of both amendments were not significantly different (Table 4). In the late rainy season of 2017, the fruit yield in plots amended with 14 plants of Mexican sunflower and Siam weed did not significantly differ from fruit yields in plots amended with 7 plants for either amendment for both cultivars. There was no significant difference between the two cultivars for each of the treatments in both trials (Table 4).

The chemical analysis results of soil in the experimental field planted with okra in the early rainy season trial showed that the levels of OC, total N, available P and exchangeable K were significantly higher in the plots amended with 7 and 14 plants of Mexican sunflower and Siam weed at the time of harvest compared to their levels before planting, while the pattern of change in the level of soil pH was not definite (Table 5). The levels of total N, available P and exchangeable K were significantly higher in the plots amended with 7 and 14 plants of Mexican sunflower and Siam weed at the time of harvest compared to their levels before planting while organic carbon was not definite (Table 6). Also there was a significant reduction in the soil pH level in all amended plots at harvest compared to that before planting (Table 6). The OC, total N, available P, exchangeable K and pH levels in the control plots for both cultivars before planting did not significantly differ from those at harvest in both seasons. With reference to cv. NH47-4, the OC, total N, available P and exchangeable K levels in all amended plots were significantly higher than those in the control plots for both seasons while the level of soil pH in amended plots was significantly lower than that in the control plots at harvest for the two seasons (Tables 5, 6). In the early rainy season, the levels of OC, total N and available P at harvest for cv. NH47-4 were significantly higher in plots amended with 14 plants of both Mexican sunflower and Siam weed if compared with plots amended with just 7 plants, while the levels of soil pH and exchangeable K did not significantly differ if 7 and 14 plants

Table 5. Chemical properties of soil in experimental okra field before planting and at harvest (early rainy season of 2017)

Treatments	pH	OC (g kg^{-1})	Total N (%; w/w)	Available P (mg kg^{-1})	Exchangeable K (cmol kg^{-1})
Before planting					
7 MS + NH47-4	6.2	15.85	1.44	65.86	0.40
14 MS + NH47-4	6.2	18.05	1.64	77.39	0.44
7 SW + NH47-4	6.5	15.97	1.35	62.75	0.36
14 SW + NH47-4	6.3	15.25	1.41	65.42	0.38
NH47-4 (Control)	6.4	14.05	1.23	50.48	0.25
7 MS + LD88	6.8	11.10	1.06	44.26	0.26
14 MS + LD88	6.7	11.36	1.06	48.70	0.27
7 SW + LD88	6.8	10.54	0.94	42.07	0.23
14 SW + LD88	6.2	10.34	0.90	44.92	0.24
LD88 (Control)	6.5	10.80	0.80	36.92	0.22
At harvest					
7 MS + NH47-4	5.9	20.02	1.69	74.41	0.47
14 MS + NH47-4	5.9	22.65	1.99	89.99	0.52
7 SW + NH47-4	5.9	17.28	1.54	71.21	0.45
14 SW + NH47-4	5.8	18.90	1.72	78.75	0.48
NH47-4 (Control)	6.4	13.38	1.12	50.22	0.26
7 MS + LD88	6.2	12.79	1.28	53.82	0.34
14 MS + LD88	6.3	13.40	1.40	61.28	0.36
7 SW + LD88	6.5	12.01	1.11	49.74	0.30
14 SW + LD88	5.8	12.23	1.21	57.98	0.33
LD88 (Control)	6.5	9.99	0.76	34.78	0.20
LSD ($P \leq 0.05$)	0.39	1.11	0.14	5.58	0.06

OC = organic carbon, N = nitrogen, P = phosphorus, K = potassium, MS = Mexican sunflower, SW = Siam weed
each value is a mean of four replicates

of both amendments were compared (Table 5). The late rainy season showed a reverse trend (Table 6). In okra cv. LD88, at harvest, the levels of OC, total N, available P and exchangeable K were significantly higher than those detected in the control plots both in early and late rainy seasons (Tables 5, 6). The level of soil pH was significantly higher than that found in the control plots only in the late rainy season (Table 6). In the early rainy season trial, only the level of available P was significantly higher in plots amended with 14 plants of both Mexican sunflower and Siam weed if compared with plots amended with 7 plants (Table 5).

DISCUSSION

The incorporation of Mexican sunflower and Siam weed at 17 500 plants per ha or 35 000 plants per ha singly to nematode-infested plots sown to okra resulted in reduced population densities of *Meloidogyne incognita*, *Pratylenchus* spp. and *Tylenchus* spp. with a corresponding increase in the fruit weight of okra. Higher rates of both Mexican sunflower and Siam weed (35 000 plants per ha) were more effective in reducing the nematode population and increasing fruit yield of each cultivar of nematode-infected okra in comparison to the lower rate (17 500 plants per ha).

In the early rainy season, both Mexican sunflower and Siam weed reduced the population densities of *Meloidogyne incognita* by 41 %, of *Pratylenchus* spp. by 46 %, and of *Tylenchus* spp. by 64 %, while in the late rainy season, the amendments reduced the population densities of *Meloidogyne incognita* by 39 %, of *Pratylenchus* spp. by 42 %, and of *Tylenchus* spp. by 49 %. The findings of this current study are in agreement with those reported by Hussain et al. (2011b) that 75 g of dried leaves of *Calotropis procera* and *Datura stramonium* (jimson weed), *Tagetes erecta* (marigold) and *Azadirachta indica* (neem) were more effective in increasing the shoot height, shoot weight and root length of okra and in decreasing the root weight, number of galls, egg mass and the reproduction factor of *M. incognita* compared with those of 20 g and 50 g. The reduction in nematode population densities

Table 6. Chemical properties of soil in experimental okra field before planting and at harvest (late rainy season of 2017)

Treatments	pH	OC (g kg^{-1})	Total N (%; w/w)	Available P (mg kg^{-1})	Exchangeable K (cmol kg^{-1})
Before planting					
7 MS + NH47-4	5.4	12.19	1.21	34.21	0.25
14 MS + NH47-4	6.1	12.11	1.16	34.50	0.33
7 SW + NH47-4	6.1	11.09	0.81	27.02	0.25
14 SW + NH47-4	6.0	11.64	0.95	31.87	0.28
NH47-4 (Control)	6.0	10.83	0.52	24.70	0.23
7 MS + LD88	5.7	10.73	0.71	21.55	0.30
14 MS + LD88	5.2	10.53	0.58	21.96	0.32
7 SW + LD88	5.9	9.93	0.55	16.74	0.26
14 SW + LD88	6.7	10.49	0.48	20.87	0.29
LD88 (Control)	6.3	10.10	0.53	17.98	0.18
At harvest					
7 MS + NH47-4	5.0	14.32	2.19	49.14	0.34
14 MS + NH47-4	5.3	14.96	2.19	50.39	0.53
7 SW + NH47-4	5.7	13.18	1.80	41.04	0.32
14 SW + NH47-4	5.3	14.08	1.94	45.81	0.37
NH47-4 (Control)	6.0	10.83	0.57	27.08	0.22
7 MS + LD88	5.2	12.85	1.70	35.88	0.38
14 MS + LD88	4.8	12.98	1.64	36.27	0.40
7 SW + LD88	5.4	12.02	1.56	30.34	0.34
14 SW + LD88	5.9	13.09	1.56	35.22	0.38
LD88 (Control)	6.2	10.15	0.52	17.72	0.17
LSD ($P \leq 0.05$)	0.29	2.10	0.68	8.42	0.07

OC = organic carbon, N = nitrogen, P = phosphorus, K = potassium, MS = Mexican sunflower, SW = Siam weed

each value is a mean of four replicates

observed in this study may be due to nematode-toxic substances released by the amendments on decomposition. Thoden et al. (2007) reported that Siam weed contains 1, 2-dehydropyrrolizidine alkaloid which is lethal to plant-parasitic nematodes. The authors in an *in vivo* experiment showed that mulch or aqueous extracts from Siam weed reduced the population of *M. incognita* infecting lettuce by 99 %.

This current study showed that the application of Mexican sunflower and Siam weed increased fruit yield by approximately 400 % and 332 %, respectively. The higher fruit yield recorded in plots amended with Mexican sunflower or Siam weed may be partly due to the improvement in the soil fertility associated with the organic amendments or a result of the reduction in the population densities of the nematodes. Martens (2000) reported that soil organic amendments greatly contributed to soil fertility by releasing soil nutrients after decomposition and increasing water holding capacity resulting in improved plant growth. Ogundele et al. (2016) also reported that plant parasitic nematode-infected *Telfairia occidentalis* plants treated with 10 or 20 plants of both African marigold and Siam weed increased the leaf weight of *Amaranthus cruentus* by 35-65% or 32-85%, respectively, in comparison with control.

The increase in soil fertility was confirmed by the increase in the levels of OC, total N, available P and exchangeable K in amended plots at harvest. Jama et al. (2000) asserted that the average nutrient concentrations of green leaves of *T. diversifolia* collected in East Africa were 3.5 % N, 0.37 % P and 4.1 % K on a dry weight basis, and concluded that this plant has a great potential as an organic fertilizer. Similarly, Ogundele et al. (2016) reported an increase in the levels of total N, available P and exchangeable K with a decrease in soil pH level at harvest in nematode-infected plots amended with African marigold and Siam weed if compared with the control plots. Plant-parasitic nematodes including *M. incognita*, *Pratylenchus* spp. and *Tylenchus* spp., isolated and identified on the two experimental fields planted with okra in the current study, have also been reported to be isolated on other fields planted with okra (Adekunle, 2009; Amulu, Adekunle, 2015). The incorporation of whole plants of Mexican sunflower and Siam weed into the soil, as reported in this study, is an innovative way of applying plant organic amendments into the soil for nematode management. This practice represents a significant improvement on the age-long method of organic amendment processing into powder or slurry and then introducing large quantities of such amendment into soil for nematode management. The innovative procedure used in this study, that is, transplanting the living plants of Mexican sunflower and Siam weed to the plots prior to incorporating them into soil, conditioned a more effective nematode control by plant substances toxic to nematodes. Presumably, during the growing period of the amendment plants, before incorporating them into soil, some substances toxic to nematodes could have been released from the plant roots into soil. This procedure ensured a better nematode pest management in comparison to the traditional method of just incorporating the amendments into soil.

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