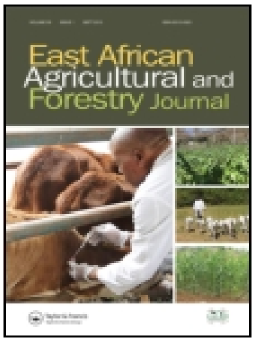

Taylor & Francis
Taylor & Francis Group

East African Agricultural and Forestry Journal

ISSN: 0012-8325 (Print) 2313-450X (Online) Journal homepage: http://www.tandfonline.com/loi/teaf20

Effect of Time of Application of Organic Soil Amendments on Pathogenicity of Meloidogyne Incognita on Okra

J.W. Waceke & S.W. Waudo

E. Afr. agric. For. J. (2001) 67(1), 19-29

EFFECT OF TIME OF APPLICATION OF ORGANIC SOIL AMENDMENTS ON PATHOGENICITY OF *MELOIDOGYNE INCOGNITA* ON OKRA

J.W. Waceke and S.W. Waudo, Department of Botany, Kenyatta University, P.O. Box 43844, Nairobi, Kenya

(*Accepted for publication in April, 2001*)

Organic soil amendments have long been used to manage plant parasitic nematodes (Rodriguez-Kabana, 1986; Waceke and Waudo, 1993, Bridge, 1996). Soil physical and chemical characteristics, quality and quantity of the amendment (Spaulding and Eisenmenger, 1938), nematode inoculum density (Wallace, 1973; Spiegel *et al.* 1989), time of amendment (Miller and Wihrhelm, 1966) and host plant (Thomas and Norton, 1986) are some of the factors that influence the efficacy of soil amendment against nematodes. However, no information is available on the effect of time of application of cheap and easily available organic materials on pathogenicity of *Meloidogyne incognita* in Kenya. Such materials include bean stems, maize stalks, chicken manure, goat manure, sawdust and kale leaves. Studies carried out under greenhouse and field conditions revealed that chicken manure, goat manure, kale leaves, maize stalks and sawdust suppressed pathogenic effects of *M. incognita* by up to 90.25, 75.69, 68.89, 67.24 and 22.09%, respectively (Waceke and Waudo, 1993). This study was conducted to investigate the effect of time of application on efficacy of these organic materials against *M. incognita*.

MATERIALS AND METHODS

Greenhouse Tests

Six organic materials were used chicken manure, goat manure, sawdust produced from cypress (*Cypressus governiana* L.), kale leaves (*Brassica oleracea* L. cv. Acephala), bean stems (*Phaseolus vulgaris* L.) and maize (*Zea mays* L.) stalks. Okra (*Abelmoschus esculentus* L. cv Pusa Sawani) was used as the host. Ninety-day-old bean stems, kale leaves and 240-day-old maize stalks were dried at 80°C for 72 h before being ground 20-μm (Wiley's Grinding Mill). Sun-dried chicken manure, sawdust and goat manure were sieved to remove large lumps. Three 300-g sub-samples of each organic material were analysed at the National Agricultural Research Laboratories, (NARL), Kenya, for content of mineral elements. Results of the analysis are summarised in Table I.

The organic materials were added and thoroughly mixed with unsterilised sandy-clay soil (50% sand, 38% clay, 12% silt and 1.4% organic matter) contained in 15-cm-diameter plastic pots. (ratio = 1:100 w/w). The amended soil was drenched with the recommended dosage of mancozeb (Ridomil Mz 63.5 WP by Ciba-Geigy Ltd, Basel, Switzerland) 14 days prior to infestation to control damping-off pathogens. The amended soil was infested with 4000 *M. incognita* eggs and second stage juveniles (J-2) per pot at 14, 28 or 42 days after organic materials were incorporated. Infestation was done 7 days after transplanting (d.a.t.) at the rate of 1 21 day-old okra seedling per pot. The nematode inoculum was obtained from galled tomato roots (*Lycopersicon esculentum* Mill. cv Money Maker growing in a sterilised sand-soil mixture. The nematodes were extracted from roots using Hussey and Baker's (1973) technique. Okra plants growing in non-amended soil served as the control. The treatments were arranged in a split-plot design where time of incorporation of organic materials formed the subplots and organic materials were the main plots. The treatments were replicated 4 times. Plants were watered regularly band sprayed with recommended dosages of cypermethrin (Ambush

TABLE I - MEAN[1] PERCENTAGE OF MINERAL ELEMENT CONTENTS OF THE ORGANIC MATERIALS USED IN THE TEST

Organic material	N(%)	P(%)	K(%)	Ca(%)	Mg(%)	S(%)
Bean stems	0.43	0.07	1.02	1.22	0.27	0.11
Maize stalks	0.33	0.03	1.02	0.46	0.05	0.02
Chicken manure	2.38	3.43	1.69	3.08	1.34	0
Goat manure	2.04	2.98	2.17	3.5	1.34	0
Sawdust	0.29	0.01	0.72	0.2	0.01	0.02
Kale leaves	0.37	0.31	3.6	2.8	0.43	0.45

[1] Mean of 3 300-g sub-samples of organic materials

CY, Imperial Chemical Industries PLC, England) and benomyl (Benlate, E. I. Du Pont de Nemours & Co (Inc.) to control insect pests and powdery mildew, respectively.

At harvesting time (90 days after inoculation [d.a.i.]), stem diameter, shoot height and weight, root gall index and number of *M. incognita* were recorded. Stem diameter was taken just below the first basal node while shoot height was taken from the first basal node to the last apical node. The shoot system was separated from the root system at the first basal node and was dried at 80°C for 48 h before weighing. The root system was thoroughly washed and assessed for disease severity using Krusberg and Nelson's (1958) rating scale where 0 = no galls, 1 = 1-25%, 2 = 26-50%, 3 = 51-75% and 4 = 76-100% of root system galled. Nematodes were extracted from a thoroughly mixed 300-cc soil sample per pot using Jenkins' (1964) centrifuge-floatation technique and were counted using Hawksley's nematode counter.

Field Test

A field test was conducted at the Botany Research Farm, Kenyatta University, Nairobi, Kenya, to evaluate effects of time of incorporation of organic amendments on the control of *M. incognita* on okra. The site from which soil for the greenhouse tests was obtained served as the site for this field test. The field was poorly infested with *Meloidogyne*, *Pratylenchus*, *Helicotylenchus* and *Paratylenchus* spp.

The organic materials were applied at the rate of 5 t/ha and mixed thoroughly 14 days before infestation (d.b.i.),. A split-plot design with 4 replications per treatment was used. Thinning was done 14 days after planting (d.a.p.) to leave 1 plant per hole. The amended soil was infested with 6000 *M. incognita* eggs and J-2 at 14, 28 or 42 days after application of organic materials. Infestation involved transferring a 5-ml nematode suspension to a 3 cm depression around the root system of okra using a dispenser. The inoculum was obtained as stated for the greenhouse test. Plots without amendment served as controls. When it was dry, watering was done using a portable sprinkler. The plants were sprayed with cypermethrin and benomyl to control insect pests and fungi, respectively.

At harvesting, 90 d.a.i., stem diameter, shoot height and weight of 10 randomly selected plants per experimental unit were taken as previously described for the greenhouse. Border crops were not harvested. In addition, number of fruits and fresh weights of 10 randomly selected fruits per experimental unit were obtained. The roots were thoroughly washed and assessed for disease severity using Krusberg and Nelson's (1958) rating scale. Soil sampling for nematode assay involved taking a 300 cc soil sample from rhizospheres of the 4 randomly selected plants per experimental unit using a hand trowel.

TABLE II - MEAN SHOOT HEIGHTS (SH), STEM DIAMETERS (SD), DRY SHOOT WEIGHTS (DSW), GALL INDICES (GI) AND NUMBER OF *MELOIDOGYNE INCOGNITA* (NMI), 90 d. a. i. FROM A GREENHOUSE TEST

Treatment	Time[1]	SH	SD	DSW	GI[3]	NMI
Bean stems	14	2.55cd[2]	0.78bc	3.3b	2.67g	321hi
	28	4.19f	0.84cd	7.53f	1.33c	190cde
	42	5.5g	0.92de	9.51g	2e	265.68efgh
Maize stalks	14	2.08b	0.58a	2.67ab	2.35f	295.32fghi
	28	2.64cd	0.82cd	6.37de	2.69g	341hi
	42	7.19h	1ef	7.26ef	3h	363I
Chicken manure	14	5.13g	0.91de	5.62cd	0.66b	149.29bc
	28	7.1h	0.94ef	9.54g	1.63d	223.65cdef
	42	9.91j	1.13g	11.61hi	1.67d	241.56defg
Goat manure	14	4.04f	0.77bc	4.94c	1.69d	199.34de
	28	5.65g	1.91h	9.17g	2e	235def
	42	7.85i	1.03f	11.18h	2.72g	290.2ghi
Sawdust	14	1.51a	0.56a	1.99a	0.33a	91ab
	28	2.18bc	0.77bc	5.11c	0.33a	64.76a
	42	3.06de	0.8c	7.06ef	0.33a	78.36ab
Kale leaves	14	2.39bc	0.69b	2.71ab	1.33c	178.21cd
	28	3.44e	0.84cd	6.44de	1.67d	238def
	42	2.66cd	0.83cd	8.66g	2.73a	315.44ghi
Control		4.78f	0.52a	4.62c	3.8i	459.6j

[1] Time in days between organic material incorporation and inoculation
[2] Figures followed by the same letter(s) are not significantly ($P > 0.05$) different with DMRT
[3] Gall index based on a 0-4 rating scale where 0 = no galls, 1 = 1-25%, 2 = 26-50%, 3 = 51-75% and 4 = 76-100% of root systems galled

The soil cores were composited and thoroughly mixed before taking a 300 g sub-sample for nematode extraction using Jenkins' (1964) centrifuge-floatation technique. The nematodes were then counted using Hawksley's slide.

RESULTS

Greenhouse Tests

Very highly significant ($P < 0.001$) differences were detected among shoot heights and weights, stem diameters, gall indices and number of *M. incognita* in tests 1 and 2. Since the trends revealed by data collected from the 2 greenhouse tests were fairly similar, only data from greenhouse test 1 are shown in Table II. Soils amended with goat manure, kale leaves or maize stalks 42 days before inoculation (d.b.i.) supported plants whose root galling and numbers of *M. incognita* in the rhizosphere were significantly ($P < 0.05$) higher than those of plants grown in soils amended with the same organic materials 14 or 28 d.b.i. (Table II). Also, root galling and numbers of *M. incognita* for plants grown in soils amended with goat manure, kale leaves, chicken manure or maize stalks 28 d.b.i. were in most cases, significantly ($P < 0.05$) higher than those of plants grown in soils amended with the same organic materials 14 d.b.i. Furthermore, soils amended with the above-mentioned materials 42 d.b.i. supported in most cases, significantly ($P < 0.05$) taller, larger and heavier plants than those grown in soils amended with the same organic materials 14 or 28 d.b.i.

Root galling and number of *M. incognita* for plants grown in soils amended with bean stems 14 d.b.i. were significantly ($P < 0.05$) heavier and higher, respectively, than those of plants grown in soils amended with the same organic material 28 or 42 d.b.i. Although plants grown in soils amended with sawdust 14, 28 or 42 d.b.i. did not differ significantly as regards root galling and number of *M. incognita*, their shoot height, stem diameter and dry shoot weight differed significantly, in most cases (Table II).

A significant ($P < 0.01$, $b = 0.02$) direct relationship occurred between time of incorporating organic material and disease severity of plants grown in soils amended with maize stalk (Fig. 1). As with maize stalks, disease severity of plants grown in soils amended with goat manure, chicken manure or kale leaves increased with time between incorporation of organic material and inoculation. Soils amended with bean stem, however, supported plants whose root galling decreased with increase in time as revealed by a negative slope ($b = 0.02$) (Fig. 1).A significant inverse relationship ($P < 0.05$) occurred between gall indices and shoot heights of plants grown in soil amended with sawdust 28 d.b.i. (Table III). Sawdust incorporated into the soil 14 or 42 d.b.i. suppressed the pathogenic effect of *M. incognita* by up to 85% ($r^2 + 0.85$) and 2% ($r^2 = 0.02$), respectively. Chicken manure incorporated into the soil 14, 28 and 42 d.b.i. suppressed pathogenic effects of *M. incognita* by up to 79, 93 and 68% respectively, as revealed by coefficients of determination (r^2) values of 0.79, 0.93 and 0.68, respectively (Table III). Although goat manure incorporated into the soil at 28 d.b.i. did not suppress pathogenic effects of *M. incognita*, generally, it suppressed nematode activity by up to 37% ($r^2 = 0.37$) and 87% ($r^2 = 0.87$) when incorporated into the soil 14 and 42 d.b.i, respectively (Table III).

Kale leaves suppressed pathogenic effects of *M. incognita* by up to 91% ($r^2 = 0.91$) and 47% ($r^2 = 0.47$) when incorporated into the soil 28 and 42 d.b.i., respectively. Although maize stalks incorporated into the soil 14 or 42 d.b.i did not suppress pathogenic effects of *M. incognita* as shown in Table III, the material suppressed effects of the nematode by up to 98% ($r^2 = 0.98$) when incorporated 28 d.b.i. Bean stems incorporated into the soil 28 and 42 d.b.i. supresed pathogenic effects of *M. incognita* by up to 10% ($r^2 = 0.10$) and 76% ($r^2 = 0.76$), respectively, but had no effect when incorporated into the soil 14 d.b.i. (Table III).

Field Test

Highly significant ($P < 0.01$) differences were detected among shoot heights and weights, stem diameters, fresh weights and number of fruits, gall indices and numbers of *M. incognita* 90 d.a.i. as shown in Table IV. Gall indices and number of *M. incognita* in plants grown in soils amended with kale leaves 42 d.b.i were significantly ($P < 0.05$) higher than those of plants grown in soils amended with the same organic materials 14 or 28 d.b.i. Bean stems incorporated into the soil 14 d.b.i. supported plants which performed poorer and had higher gall indices and numbers of *M. incognita* than those of plants grown in soils amended with the same organic material 42 d.b.i. Although root galling of plants grown in soils amended with maize stalk, chicken manure, goat manure or sawdust 14, 28 and 42 d.b.i did not differ significantly, numbers of *M. incognita* extracted from rhizospheres of plants grown in soils amended with the above-named organic materials 42 d.b.i were higher than those from soils amended with the same organic material 14 or 28 d.b.i. incorporated into the soil 14 d.b.i. with the same organic materials 14 or 28 d.b.i. Besides, plants grown in soils amended with chicken manure, goat manure, maize stalk or sawdust 42 d.b.i. performed significantly ($P < 0.05$) better, in most cases, than plants grown in soils amended 14 and 28 d.b.i.

TABLE III - REGRESSION COEFFICIENTS (b), CORRELATION COEFFICIENTS (r) AND COEFFICIENTS OF DETERMINATION (r^2) OF THE RELATIONSHIPS BETWEEN MEAN GALL INDICES, AND MEAN SHOOT HEIGHTS (SH), STEM DIAMETERS (SD) AND DRY SHOOT WEIGHTS (DSW), IN A GREENHOUSE TEST

Treatment	Time	SH			SD			DSW		
		b	r	r^2	b	r	r^2	b	R	r^2
Bean stems	14	-0.15	-0.6	0.36	-0.04	-0.52	0.27	-0.36	-0.63	0.4
	28	0.34	0.32	0.1	-0.04	-0.82	0.67	-0.03	-0.79	0.62
	42	0.35	0.86	0.74	0.01	0.08	0.006	0.35	0.87	0.76
Maize stalks	14	-0.03	-0.04	2^{-3}	-0.02	-0.53	0.28	-0.01	-4^{-3}	2^{-5}
	28	0.3	0.99	0.98	0.08	0.52	0.27	1.4	0.98	0.96
	42	0	0	0	0	0	0	0	0	0
Chicken manure	14	0.83	0.89	0.79	0.1	0.79	0.62	1.26	0.59	0.35
	28	0.9	0.96	0.93	-0.03	-0.84	0.7	1.56	0.7	0.49
	42	1.15	0.61	0.37	0.18	0.64	0.41	2.21	0.82	0.68
Goat manure	14	0.23	0.4	0.16	0.07	0.6	0.37	0.27	0.16	0.03
	28	0	0	0	0	0	0	0	0	0
	42	0.53	0.93	0.87	0.12	0.5	0.25	1.02	0.68	0.46
Sawdust	14	0.22	0.92	0.85	0.03	0.75	0.56	0.03	0.39	0.15
	28	-0.4*	-1*	1	-0.07	-0.8	0.64	-0.19	-0.91	0.83
	42	0.14	0.14	0.02	0.06	0.1	0.01	0.14	0.14	0.02
Kale leaves	14	-0.24	-0.59	0.35	-0.04	-0.56	0.32	-0.3	-0.64	0.41
	28	0.12	0.95	0.91	0.04	0.75	0.56	0.12	0.95	0.91
	42	0.04	0.52	0.27	0.06	0.69	0.47	0.04	0.52	0.27

• = b and r values are significant ($P < 0.05$)

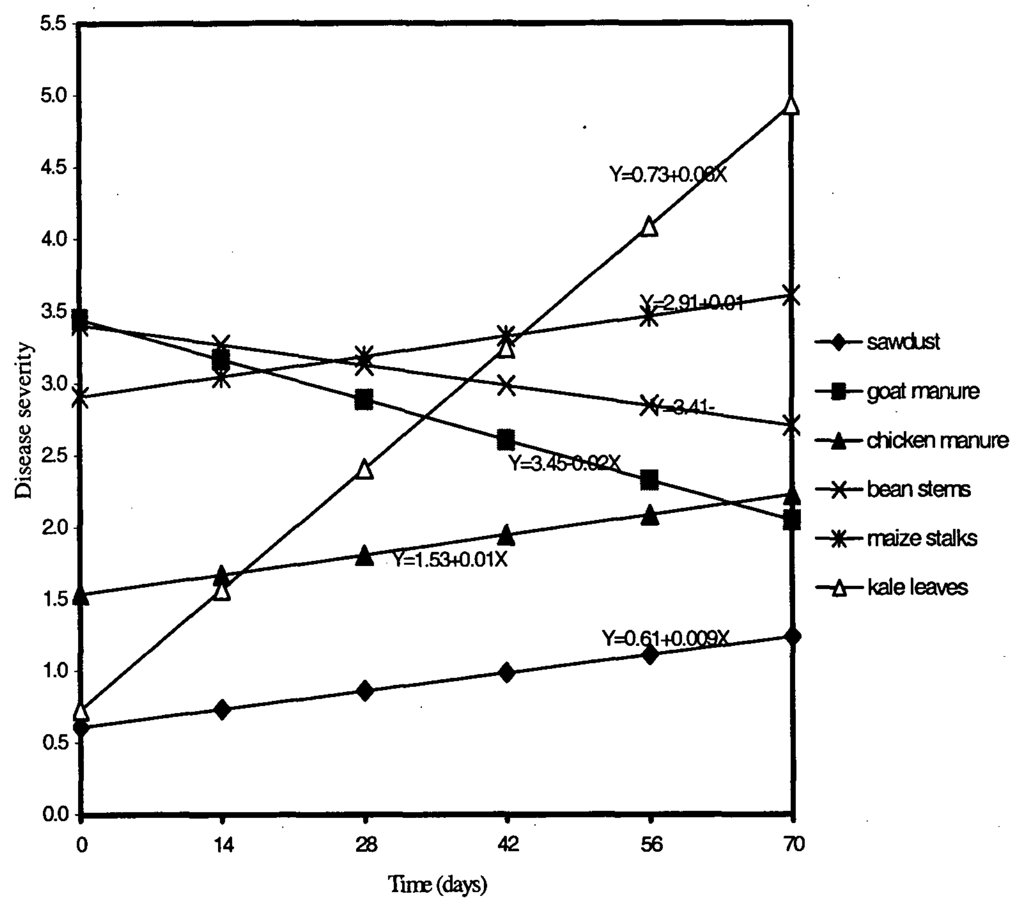

Fig. 1 - Relationship between time of organic material incorporation and disease severity, 90 days after inoculation in a Greenhouse test

TABLE IV- MEAN SHOOT HEIGHTS (SH), STEM DIAMETERS (SD), NUMBER OF FRUITS PER PLANT (NFP), FRESH FRUIT WEIGHT (FFW), DRY SHOOT WEIGHTS (DSW), GALL INDICES (GI) AND NUMBER OF *MELOIDOGYNE INCOGNITA* (NMI), 90 d.a.i., FIELD TEST

Treatment	Time[1]	SH	SD	NFP	FFW	DSW	GI[3]	NMI
Bean stems	14	29.5abcde[2]	0.9bcd	2.9cde	57.1de	21.2bcd	3.86i	300def
	28	43.3efgh	1.04efghi	3.8fgh	71.6hij	31.4efgh	1.97cde	364.8i
	42	45.5fghi	1.1ghij	4.3hi	76.7jkl	35.8ghi	3.59hi	174.6b
Maize stalks	14	19.8ab	0.85b	1.8ab	44.3b	13.5ab	3fgh	395.7h
	28	30.7abcdef	0.94bcde	3.2def	58.7de	22.9bcde	3.36ghi	296.7def
	42	59.6ij	1.16jk	5.11j	84.1mn	52.5j	3.31ghi	345.8fgh
Chicken manure	14	44.5efghi	1.06fghij	4gh	74.1ijk	32.8fghi	1.71bcd	164.5b
	28	55.1hij	1.14ijk	5.1j	80.2lm	42i	1.78bcd	187.9b
	42	78.9k	1.33m	6.1k	90.8b	76.6k	2.02cde	216bc
Goat manure	14	41.1defgh	1.02defgh	3.8fgh	69.2ghi	29.3efgh	3.17fghi	368gh
	28	51.8ghij	1.12hij	4.8ij	78.4kl	37hi	2.66efg	257.3cd
	42	64.6j	1.24km	5.4j	88.03np	71k	2.49def	263.5cde
Sawdust	14	16.2a	0.69a	1.6a	36a	10.1a	0.78a	38.8a
	28	22abc	0.88b	2.4bc	43.3bc	14.7abc	0.77a	70.3a
	42	34.9bcdef	1cdefg	3.3defg	65fg	25.4def	1.03ab	263.5cde
Kale leaves	14	26.4abcd	0.9bc	2.7bcd	53.5cd	17.4abcd	1.68bc	184.3b
	28	37.2cdefg	1cdefg	3.5efgh	66.4fgh	26.7defg	2.14cde	228.6bc
	42	34.2bcdef	0.96bcdef	3.2def	62.2ef	23.6cdef	3.33ghi	328.4efg
Control		39.3defgh	1.14ijk	3.8fgh	77.5jkl	17.8abcd	3.08fgh	468.5i

[1] Time in days between organic material incorporation and inoculation
[2] Figures followed by the same letter(s) are not significantly (P > 0.05) different with DMRT
[3] Gall index based on a 0-4 rating scale where 0 = no galls, 1 = 1-25%, 2 = 26-50%, 3 = 51- 75% and 4 = 76-100% of root systems galled

Root galling (disease severity) of plants grown in soils amended with kale leaves, maize stalks, chicken manure and sawdust increased with increases in time of organic material incorporation as revealed by positive slopes (b) of 0.06, 0.01, 0.01 and 0.009, (Fig. 2). Soil amended with bean stems or goat manure supported plants whose disease severity decreased with increase in time after organic material incorporation.

Significant ($P < 0.05$) relationships (Table V) occurred between gall indices and (i) shoot heights of plants grown in soils amended with maize stalks 42 d.b.i. ($b = 15.45$), (ii) stem diameters of plants grown in soils amended with sawdust ($b = 0.83$) and chicken manure ($b = 0.12$) 14 and 28 d.b.i., respectively, (iii) number of fruits obtained from plants grown in soils amended with kale leaves ($b = 1.28$) and goat manure ($b = 0.23$) 14 d.b.i and (iv) fresh weight of fruits obtained from plants grown in soils amended with goat manure ($b = 2.1$) and sawdust ($b = 28.1$) 14 and 28 d.b.i., respectively. Maize stalks incorporated into the soil 14 and 28 or 42 d.b.i. suppressed pathogenic effects of *M. incognita* by up to 96% ($r^2 = 0.96$) and 98% $r^2 = 0.98$), respectively. Chicken manure incorporated into the soil 14, 28 and 42 d.b.i suppressed pathogenic effects of *M. incognita* by up to 94% ($r^2 = 0.94$), 100% ($r^2 = 1$), 74% ($r^2 = 0.74$), respectively. The 100, 58 and 76% suppression of pathogenic effects of *M. Incognita* on okra was attributed to the incorporation of goat manure into the soil 14, 28 and 42 d.b.i., respectively. Although sawdust incorporated into the soil at 42 d.b.i. did not suppress pathogenic effects of *M. incognita*, it suppressed the effects by up to 100% when incorporated into the soil 14 or 28 d.b.i .Kale leaves incorporated into the soil 14, 28 and 42 d.b.i. suppressed pathogenic effects of *M. incognita* by up to 98, 41 and 77% respectively, as shown by coefficients of determination (r^2) values of 0.98, 0.41 and 0.77, respectively. Although bean stems incorporated into the soil 14 d.b.i did not suppress pathogenic effects *M. incognita,* they suppressed nematodes by up to 77 and 18% when incorporated into the soil 28 and 42 d.b.i., respectively.

DISCUSSION

The increases in gall indices with increasing in time after incorporation of chicken manure, goat manure, kale leaves, maize stalks or sawdust into the soil, in most cases, indicated that the suppressive effects of organic materials decreased with time. Presumably suppressive effects decreased because of accumulation of toxic decomposition products, temperature and/or antagonism (Linford *et al.*, 1938; Baker and Cook, 1974) over time probably led to their decreased suppressive effects. Further work however, needs to be done to ascertain these speculations.

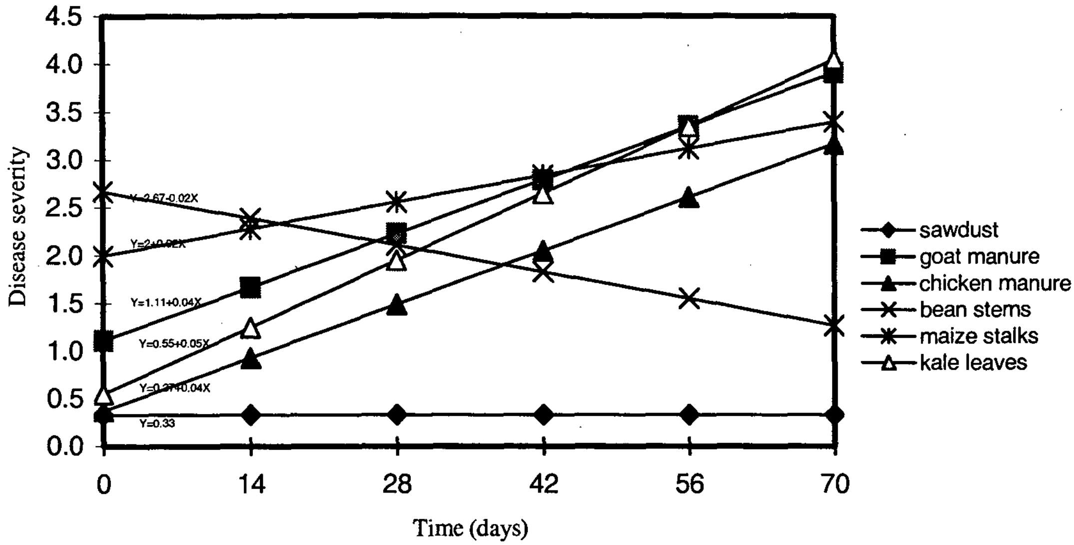

Fig. 2 – Relationship between time of organic material incorporation and disease severity, 90 days after inoculation in a field test

TABLE V - REGRESSION COEFFICIENTS (b), CORRELATION COEFFICIENTS (r) AND COEFFICIENTS OF DETERMINATION (r^2) OF THE RELATIONSHIPS BETWEEN MEAN GALL INDICES, AND MEAN SHOOT HEIGHTS (SH), STEM DIAMETERS (SD), NUMBER OF FRUITS PER PLANT (NFP), FRESH FRUIT WEIGHTS (FFW) AND DRY SHOOT WEIGHTS (DSW), FIELD TEST

Treatment	Time	SH			SD			NFP			FFW			DSW		
		b	r	r^2	b	r	r^2	b	r	r^2	b	r	r^2	b	r	r^2
Bean stems																
	14	-53.58	-0.97	0.94	0	0	0	-4.17	-0.87	0.76	-43.79	-0.92	0.85	-38.63	-0.89	0.79
	28	-0.86	-0.75	0.56	0.02	0.88	0.77	-0.14	-0.17	0.03	2.19	0.51	0.26	5.15	0.77	0.59
	42	-1.99	-0.64	0.41	-0.1	-0.19	0.04	0.03	1.2^{-3}	1.4^{-6}	-4.25	-0.29	0.08	5.64	0.43	0.18
Maize stalks																
	14	5.27	0.98	0.96	0.03	0.97	0.94	0.63	0.77	0.59	3.99	0.45	0.2	2.52	0.4	0.16
	28	9.79	0.95	0.9	-0.02	-0.82	0.67	0.77	0.97	0.94	7.76	0.99	0.98	3.55	0.35	0.12
	42	15.45*	0.99*	0.98	-0.02	-0.02	4^{-4}	1.12	0.71	0.5	9.06	0.98	0.96	17.32	0.89	0.79
Chicken manure	14	4.68	0.77	0.59	-0.09	-0.67	0.45	0	0	0	11.14	0.97	0.94	15.68	0.8	0.64
	28	15.04	0.92	0.85	0.12*	1*	1	1.36	0.99	0.98	2.76	0.5	0.25	10.51	0.7	0.49
	42	12.13	0.47	0.22	0.14	0.67	0.45	1.26	0.84	0.71	2.51	0.75	0.56	13.05	0.86	0.74
Goat manure																
	14	3.49	0.98	0.96	0.02	0.95	0.9	-0.23*	-1*	1	2.1*	1*	1	1.63	0.11	12^{-2}
	28	48.66	0.75	0.56	0.42	0.76	0.58	3.01	0.55	0.3	12.95	0.36	0.12	-15.87	-0.52	0.27
	42	36.58	0.8	0.64	0.16	0.58	0.34	2.04	0.47	0.22	17.12	0.87	0.76	14.74	0.21	0.04
Sawdust	14	35.93	0.98	0.96	0.83*	1*	1	2.51	0.58	0.34	6.19	0.06	4^{-3}	37.63	0.91	0.83
	28	7.07	0.44	0.19	-0.03	-0.03	9^{-3}	1.6	0.79	0.62	28.1*	1*	1	9.78	0.17	0.03
	42	-8.73	-0.29	0.08	0	0	0	-0.39	-0.09	8^{-3}	-0.85	-3^{-3}	8^{-6}	-13.64	-0.88	0.77
Kale leaves																
	14	6.2	0.95	0.9	0.01	0.01	1^{-4}	1.28*	0.99*	0.98	10.68	0.8	0.66	12.69	0.89	0.79
	28	2	0.09	8^{-3}	0	0	0	0.26	0.56	0.31	-3.53	-0.21	0.04	-4.15	-0.64	0.41
	42	2.5	0.08	6^{-3}	-0.03	-0.84	0.71	0.9	0.61	0.37	13.87	0.88	0.77	-0.76	-0.01	1^{-4}

Another probable reason for the reduced suppressive effects of organic materials on the pathogenicity of *M. incognita* is the narrowing of C:N ratios of sawdust (C:N = 400:1) and maize stalks (C:N = 81:1) with time (Baker and Cook, 1974; Lewis and Papavizas, 1975; Tisdale *et al.*, 1985). A narrowing of C:N ratios to 20:1 less favours mineralisation (Lewis and Papavizas, 1975). The decrease in gall indices with progressive time of incorporation of bean stems indicated that the efficacy of organic materials to suppress growth and development of *M. incognita* increased with time. Enhanced release of mineral elements through mineralisation of bean residues into the soil over time might have improved the nutritional status of the plant, which, in turn, might have enhanced resistance to nematode invasion (Veena *et al.*, 1983).

SUMMARY

Chicken manure, goat manure, dried and ground sawdust, kales leaves, beans stems and maize stalks were incorporated into the soil at 14, 28 and 42 days before infesting the soil with M. incognita J-2s. Seven days before infestation, 1-21-day old okra seedling was transplanted into each pot. The treatments were arranged in a split-plot design and replicated 4 times Plant growth parameters (stem diameters, shoot heights and weights) and disease parameters (gall indices and number of nematodes in the soil) were determined 90 days after inoculation. The period between incorporation of organic amendments into soil and inoculation with nematodes is an important factor in influencing the efficacy of organic materials' suppressive effects on growth

and development of *M. incognita.* The suppressive effects of kale leaves, sawdust, chicken manure, goat manure and maize stalks, for instance, decreased over time while that of bean stems increased.

ACKNOWLEDGEMENT

We are grateful to the Ministry of Education, Kenya, for funding the project through Kenyatta University, and to Kenyatta University for providing research facilities.

REFERENCES

[1] Baker K.F. and Cook, J.R. (1974). *Biological control of plant pathogens.* San Francisco: W.H. Freeman and Company. 433 pp.

[2] Bridge J. (1996). Nematode management in sustainable and subsistence agriculture. *Ann. Rev. Phytopath. 34,* 210-225

[3] Hussey R.S. and Baker, K.R. (1973). A comparison of methods of collecting inocula of *Meloidogyne* species including a new technique. *Pl. Dis. Rep.* 57, 1025-1028.

[4] Jenkins W.R. (1964). A rapid centrifuge floatation technique for separating nematodes from soil. *Pl. Dis. Rep. 48,* 692.

[5] Krusberg L.R. and Nelson, W. (1958). Pathogenesis of root-knot nematodes to Porto Rico variety of sweet potato. *Phytopath. 48,* 30-39

[6] Lewis J.A. and Papavizas, G.C. (1975). Survival and multiplication of soil-borne plant pathogens as affected by plant tissue amendments. In: *Biology and control of soil-borne plant pathogens. Third International Symposium on factors determining the behaviour of plant pathogens in soil.* Bruehl, G.W. (ed.), pp. 84-89. The American Phytopathological Society Press, Minnesota.

[7] Linford M.B., Yap, F. and Oliveira, J.M. (1938). Reduction of soil population of the root-knot nematode during decomposition of organic matter. *Soil Sc.* 45, 127-141.

[8] Mankau, R. (1963). Effect of organic soil amendments on nematode populations. *Phytopath. 53,* 881-882.

[9] Miller P.M. and Wihrhelm, S. (1966). Invasion of roots by *Heterodera tabacum* reduced by cellulosic amendments or fertilizers in soil. *Phytopath. 56,* 890 (Abstract).

[10] Rodriguez-Kabana R. (1986). Organic and inorganic amendments to soil as nematode suppressants. *J. Nemat. 18,* N 129-135.

[11] Spaulding M.F. and Eisenmenger, W.S. (1938). Factors influencing the rate of decomposition of different types of plant tissue in the soil and the effect of the products on plant growth. *Soil Sc. 45,* 427-445.

[12] Spiegel Y., Cohn, E. and Chet. I. (1989). Use of Chitin for controlling *Heterodera avenae* and *Tylenchulus semipenetrans. J. Nemat. 21,* 419-422.

[13] Thomas S.H. and Norton, D.C. (1986). Influence of selected maize hybrids on nematode populations under differing edaphic conditions. *Pl. Dis. 70,* 234-237.

[14] Tisdale S.L., Nelson, W.L. and Beaton, J.D. (1985). *Soil fertility and fertilizers.* MacMillan Publishing Company, New York. 754pp.

[15] Veena P., Hakim, S. and Saxena, S.K. 1983. Effect of different levels of N-P-K on the growth of tomato cv. marglobe and on the morphometrics of root-knot nematode (*Meloidogyne incognita*). *Indian J. Nemat. 13,* 110-113.

[16] Waceke J.W. and Waudo, S.W. (1993). Effects of soil amendments in pathogenicity of *M. incognita* on okra. *Inter. J. Pest Management 39(4),* 385-389.

[17] Wallace K.R. (1973). *Nematode ecology and plant disease.* Arnold, London. 17P