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INFLUENCE OF BRICK-KILN DUST ON PENETRATION AND DEVELOPMENT OF *MELOIDOGYNE JAVANICA* IN EGGPLANT ROOTS AND ITS IMPACT ON PLANT GROWTH AND YIELD

R. Rizvi[1] and A.A. Khan

[1] Department of Botany, Aligarh Muslim University, Aligarh- 202002, India

Summary. Soil amendments with different proportions (5-50%) of brick-kiln dust were assessed for their effects on penetration and development of *Meloidogyne javanica* juveniles in roots of eggplant and on plant growth and yield, in comparison with inoculated or non-inoculated non-amended soil. All brick-kiln dust levels suppressed the penetration of the juveniles into the roots and their further development to older stages. The least plant growth and yield occurred in soil inoculated and non-amended. Brick-kiln dust amendment improved plant growth and increased yield components of eggplant, compared to inoculated soil, with the largest yield observed at the 30% level which was even significantly more than the yield in non-inoculated soil. Thus, brick-kiln dust can be used as an eco-friendly nematicide-cum-non-conventional fertilizer up to the 30% level.

Key words: Control, industrial waste, root-knot nematode, soil amendment.

In India, the brick-making industries have flourished over the last three decades and have produced a huge amount of brick-kiln dust, i.e. a mixture of coal and wood ash and soil dust particles. The physico-chemical properties of brick-kiln dust were found to be similar to those of fly ash, though with slightly lesser values (Upadhyay, 2004). Moreover, soil amendments with brick-kiln dust resulted in a better growth and yield of different crops (Raghav and Khan, 2002; Raghav, 2006)

Root-knot nematodes (*Meloidogyne* spp.) are devastating pests on most vegetable crops in India, as causing heavy yield losses every year (Krishnappa, 1985; Khan and Khan, 1990; Khan and Siddiqui, 2005). Control of these nematodes is necessary for successful cultivation of vegetables. Recent withdrawal of some hazardous broad spectrum pesticides has emphasized the need for new, eco-friendly nematode control methods. In previous experiments, different concentrations of brick-kiln dust extract inhibited egg hatching and increased juvenile mortality of *Meloidogyne javanica* (Treub) Chitw. (Rizvi and Khan, 2009a), but the suppressive potential of soil amendment with this material on root-knot nematodes has not yet been assessed. So, keeping in view the recent agricultural utilization of brick-kiln dust, it was planned to evaluate its potential for suppressing penetration and development of the root-knot nematode, *M. javanica*, in eggplant roots and the subsequent impact on plant growth and yield.

[1] Corresponding author: rose.amu@gmail.com

MATERIALS AND METHODS

Amendment of soil. Fresh brick-kiln dust was collected in gunny bags from the brick kiln, Manzoor Garhi, situated about 15 km away from Aligarh, India. Soil was collected from an agricultural field to a depth of 20 cm, after discarding the surface litter. The soil was steam sterilized in an autoclave at 20 lb pressure for 20 minutes. The autoclaved soil was dried and then mixed with brick-kiln dust in different ratios (w/w) separately.

Soil pH. The pH of each soil sample was determined by adding 20 g soil samples to 40 ml of double distilled water (DDW) in a 100 ml beaker. Each suspension was stirred at regular intervals for 30 minutes and pH was recorded by pH meter.

Preparation of inoculum. Second stage juveniles (J_2) of *M. javanica* were used for inoculation. The inoculum was prepared by incubating egg masses of a population of *M. javanica* (maintained in culture pots) in sterilized water in an incubator at 25 °C for 72 h. The freshly hatched juveniles were collected in water suspension and their number per ml was counted.

Effect on penetration of juveniles. For the penetration experiment, brick-kiln dust was mixed with autoclaved soil to obtain mixtures (w/w) of 5, 10, 20, 30, 40 or 50%. The control was 100% autoclaved soil.

Disposable cups of 7 cm diameter were filled with 170 g of the different brick-kiln dust mixtures. A total 140 cups (7 treatments × 5 replicates × 4 intervals) were prepared. A 15-day-old eggplant seedling at the four leaves stage was transplanted into each cup. After five days, the seedlings were inoculated with 500 freshly hatched juveniles of *M. javanica* (3 juveniles/g soil). Cups were placed on a glasshouse bench at 25-27 °C. Five seedlings from each treatment were harvested carefully from the cups at different intervals (1st, 2nd, 3rd and 4th day) and the roots were thoroughly washed free of soil particles under tap water. Then the roots were cut and boiled gently in acid fuchsin (0.1%) lactophenol solution. Each root was observed separately under a stereoscopic microscope and the numbers of penetrated juveniles were counted. Percentages of penetration of the inoculated juveniles were calculated for each treatment.

Effect on development of the nematode juveniles. Brick-kiln dust and autoclaved soil were mixed as in the penetration experiment. One kg of each brick-kiln dust mixture was poured into each of twenty 15 cm diameter earthenware pots. Pots containing only autoclaved soil served as controls. A total of 140 pots (7 treatments × 4 weekly observations × 5 replicates) were prepared. A 15-day-old seedling of eggplant at the four leaves stage was transplanted into each pot. The pots were kept on a glasshouse bench at 25-27 °C and after five days each seedling was inoculated with 1000 juveniles of *M. javanica*. Five seedlings were harvested from each treatment at different intervals (1st, 2nd, 3rd and 4th week) and processed as in the penetration experiment. Different developmental stages of the nematode were counted under a stereoscopic microscope.

Effect on plant growth, yield and disease intensity. The brick-kiln dust mixtures were the same as in the previous experiment, with five replicates. Pot size, amount of soil and number of nematode juveniles also remained the same and four-leaf eggplant seedlings were transplanted into each pot. However, one set of five pots without brick-kiln dust and juveniles was also maintained, as a non-inoculated control. Thus, there were 40 pots (8 treatments × 5 replicates).

Pots were arranged in a randomized block design on glasshouse benches. After two months, plants were harvested carefully and components of plant growth (length and fresh weight of shoots and roots; leaves/plant; leaf area/plant; branches/plant) and yield (flowers/plant; fruits/plant) were recorded. The disease intensity in terms of gall index (GI) and egg mass index (EMI) were assessed according to a 0-5 scale (Taylor and Sasser, 1978), in which 0 = 0, 1 = 1-2, 2 = 3-10, 3 = 11-30, 4 = 31-100, and 5 = more than 100 galls or egg masses per root system.

Statistical analysis. Data were subjected to analysis of variance (ANOVA) and means compared by least significant difference (LSD) at 5 and 1% probability levels (Pansey and Sukhatme, 1978).

RESULTS

Effects on penetration of juveniles. All levels of brick-kiln dust in soil were harmful to the nematode (Table I) as they suppressed significantly the number of *M. javanica* juveniles that penetrated into the roots of eggplants, as compared to control, at all the time intervals, and the penetration of juveniles was inversely proportional to brick-kiln dust levels. The largest proportion of juveniles that had penetrated into the roots on the fourth day was observed in the control (39.0%) and the smallest (16.8%) on the fourth day at the 50% brick-kiln dust level.

Effect on development of the nematode juveniles. The development of juveniles of *M. javanica* in the roots of eggplant (Table II) was also significantly suppressed by all brick-kiln dust and soil mixtures. The J_2 developed to J_3/J_4 stages at all levels of brick-dust amendment, but their number were less than in the control and decreased with the increase of the brick-kiln dust up to 40% soil mixture. By the end of the first week, neither premature nor mature females were found. During the second week, J_2 developed to older stages. However, while pre-mature females occurred in all roots (but in decreasing numbers as the brick-kiln dust proportion increased), only a few mature females occurred in the control (22) and at the 5-10% levels of brick-kiln dust (8-3) and none at larger proportions of the amendment. During the third week, the juveniles that had penetrated into the roots developed further. However, numbers of pre-mature females were significantly suppressed by all proportions of brick-kiln dust while mature females were significantly suppressed at 5-10% of this amendment and were still absent at larger proportions. After 4 weeks, all the J_3/J_4 had developed further but pre-mature females were still significantly less than in the control at all proportions of the amendment and a few mature females were observed only up to 20% of the amendment, with none at all at greater proportions.

Effect on plant growth, yield and disease intensity. All growth components (Table III) were greatly suppressed

Table I. Effect of different levels of brick-kiln dust on numbers of juveniles of *Meloidogyne javanica* penetrating the roots of eggplant.

Brick-kiln dust level (%)	pH	Penetration of juveniles after			
		1 day	2 day	3 day	4 day
0 (Control)	6.89	112	138	164	195
5	7.73	103	116	135	168
10	8.04	90	105	123	144
20	8.44	81	96	107	129
30	8.87	72	86	93	112
40	9.35	65	75	84	96
50	9.80	57	64	72	84
LSD at 5%	-	4.33	5.16	4.75	5.78
LSD at 1%	-	5.85	7.02	6.41	7.80

Each value is a mean of five replicates.

Table II. Effect of different levels of brick-kiln dust on developmental stages of *M. javanica* in roots of eggplant, after 1, 2, 3, and 4 weeks from inoculation of nematode juveniles.

Brick-kiln dust level (%)	1st week				2nd week				3rd week				4th week			
	J2	J3/J4	PF	MF	J2	J3/J4	PF	MF	J2	J3/J4	PF	MF	J2	J3/J4	PF	MF
(0) Control	132	376	-	-	110	133	109	22	-	146	183	81	-	-	85	153
5	154	325	-	-	107	131	99	8	-	139	170	25	-	-	76	39
10	200	212	-	-	145	102	73	3	-	130	153	12	-	6	31	12
20	216	165	-	-	156	92	45	-	-	126	139	-	2	15	20	4
30	255	90	-	-	160	77	26	-	109	98	80	-	17	78	18	-
40	260	61	-	-	168	143	15	-	121	157	31	-	35	105	15	-
50	240	58	-	-	144	158	8	-	95	154	25	-	22	132	10	-
LSD at 5%	10.3	18.6	-	-	2.5	3.3	6.6	-	-	4.5	7.1	-	-	-	2.2	-
LSD at 1%	14.1	25.1	-	-	3.3	4.5	8.9	-	-	6.4	9.6	-	-	-	3.1	-

Each value is a mean of five replicates. J2 = Second stage juveniles; J3/J4 = Third and fourth stage juveniles; PF = Pre-mature females; MF= Mature females.

Table III. Effect of brick-kiln dust and *M. javanica* on plant growth, yield and disease intensity in eggplant.

Treatment BKD + J2	Length (cm)		Fresh wt. (g)		Leaves/ plant	Leaf area/ plant (cm^2)	Branches/ plant	Flowers /plant	Fruits/ plant	Disease intensity (GI/EMI)
	Shoot	Root	Shoot	Root						
Non-inoculated	46.8	23.9	108.9	53.2	40	104	12	8	8	-
Inoculated	19.7	11.8	90.4	38.7	18	42	4	-	-	5-5/3-4
5% + 1000 J2	39.6	19.6	99.0	48.5	32	69	8	6	4	2-3/1-2
10% + 1000 J2	43.1	21.3	103.3	51.4	36	73	11	8	6	1-2/0-1
20% + 1000 J2	47.3	24.0	109.6	53.7	41	106	14	10	8	0-1/0-1
30% + 1000 J2	50.4	27.6	115.5	57.3	45	109	16	13	11	-
40% + 1000 J2	46.0	23.5	108.4	54.1	39	103	12	7	6	-
50% + 1000 J2	35.5	17.4	96.7	44.0	30	53	7	3	2	-
LSD at 5%	1.60	1.22	2.46	1.09	0.68	0.96	0.42	0.59	0.32	-
LSD at 1%	2.16	1.65	3.32	1.47	0.92	1.35	0.7	0.8	0.43	-

Each value is a mean of five replicates. BKD = Brick-kiln dust; J2 = Second stage juveniles; GI = Gall index; EMI = Egg mass index.

in pots inoculated with the nematode but without brick-kiln dust amendment as compared to non-inoculated and brick-kiln dust-treated controls. Also, all brick-kiln dust proportions significantly improved plant growth compared to the inoculated, non-treated control. When all brick-kiln dust proportions were compared with the non-inoculated, non-treated control, there were reductions of the plant growth components at brick-kiln dust proportions of 5, 10, 40% and 50%, no reduction at 20% and an improvement at 30%.

Numbers of flowers/plant and numbers of fruits/plant were all significantly increased in the treatments with 20-40% levels of brick-kiln dust, with greatest increase occurring at the 30% level. At the highest level (50%), all the yield components declined when compared to the non-inoculated control (Table III).

Root gall and egg mass indices were greatest in the inoculated control, followed by the treatments with 5%, 10% and 20% of brick-kiln dust. In the rest of the combinations, no galls and no egg masses were produced by the nematode in eggplant roots (Table III).

DISCUSSION

Brick-kiln dust contains Ca, Mg, Na, Cd, Zn, N, Cl, S, Mo and Si elements plus high levels of P and K, and its nature is alkaline with pH ranging from 8.2-10.5 (Upadhyay, 2004). In the present study, soil amendment with brick-kiln dust was harmful to the nematode at all levels. The alkaline nature of brick-kiln dust may have directly affected the juveniles, leading to less penetration into the roots and subsequently delayed development. Rizvi and Khan (2009a) also reported the harmful effect of brick-kiln dust extract on hatching and mortality of *M. javanica* juveniles. Edongali (1982) stated that juvenile penetration is affected by the concentration of different elements, irrespective of the type of element in the soil solution.

As the level of brick-kiln dust increased, the amount of elements added also increased, some of which perhaps were toxic to nematodes. Whatever the reason, the penetration of juveniles was inversely proportional to the level of brick-kiln dust. Due to suppression in penetration and development of the nematode, no gall or egg masses of the nematodes were observed beyond the 20% level of amendment.

Soil application of brick-kiln dust at lower levels (20% and 30%) even in the presence of nematodes, increased plant growth and yield of eggplant, with the greatest increase being at the 30% level. However, at the 5 and 10% levels the nematodes were able to cause some damage to plant, and the growth response was not beneficial. The beneficial effect of brick-kiln dust at amendment levels of 5-40% have also been observed on crops such as *Brassica juncea* L., *Linum usitatissimum* L., *Solanum tuberosum* L. and *Solanum melongena* L. (Upadhyay, 2004; Raghav, 2006; Rizvi and Khan, 2009b).

The largest proportions (40 and 50%) of brick-kiln dust were found to be harmful to growth and yield of eggplant. This shows that the available nutrients present in brick-kiln dust were beneficial up to a certain level but that at larger concentration they were toxic or inhibitory to plant growth. Such plant growth suppression might also be due to higher pH (9.35 and 9.80) of the amended soil mixtures. Upadhyay (2004) and Raghav (2006) also reported adverse effects of brick-kiln dust at higher levels of application (50-100%), which were attributed to excess of micro-nutrients. In brick-kiln dust + nematode-inoculated treatments, growth and yield responses of eggplant were significantly much better than in the inoculated non-amended soil treatment.

The development of galls and egg masses was completely inhibited at concentrations of 30% upwards. Perhaps nematode activity was reduced and they later could not survive in the presence of these concentrations of brick-kiln dust. This antagonistic effect was beneficial for the crop. The best level of brick-kiln dust amendment was 30%. Thus, it can be used as an eco-friendly nematicide-cum-non-conventional fertilizer in agricultural fields at the rate of 3 t/h. Although the use of brick-kiln dust may have rather local importance, it may very much help in getting rid of accumulations of this residual material.

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