

APPLICATION OF COMPOSITED MUNICIPAL REFUSE DUMP SITE SOIL, ORANGE, POTATO AND PINEAPPLE PEELS IN THE CONTROL OF ROOT KNOT NEMATODE (*MELOIDOGYNE INCOGNITA*) INFECTING CARROTS (*DAUCUS CAROTA* L.)

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ABSTRACT

Meloidogyne incognita is known to be a foremost pest of carrot in Nigeria. It is a component to appraise in carrot production. Application of synthetic nematicides as control measures is unsafe to humans and detrimental to the environment. Development of safe control process is worthwhile. Effect of three peels (potato, pineapple, orange) and composited soil from municipal refuse dump site was assessed and compared with carbofuran a standard synthetic nematicide at four different doses (0, 1500, 2000, 2500g and 2.0kg/a.i/ha, 1.5kg/a.i/ha, 1.0kg/a.i/ha and 0kg/a.i/ha for carbofuran) on carrot plants. The concentrations of heavy metals like Cd, Pb, Ni, Cu, Cr, Mn, Zn and Fe in the composited soil was determined with Atomic Absorption Spectrophotometer (AAS). Experimental pots were inoculated with approximately 2000 *M. incognita* juveniles, in a randomized complete block design experiment. The composited municipal refuse soil was analysed for the presence of fungi and bacteria using molecular methods based on 16S rRNA gene sequencing. Reproduction and multiplication of *M. incognita* was significantly ($p < 0.05$) low with all the treatment materials. Best inhibitory effect was observed in the soil of carrot plants treated with composited soil which had 49 nematode populations at harvest rather than 4606 recorded in untreated plants. Equally, heavier carrots were harvested in plants administered with composited soil (1309.6 gram), while the control plants had poor weight (312.7 gram). Performance of each waste material was quantity dependent. Gene sequencing revealed the presence of *Pseudomonas alcaligenes* strain ATCC 14909, *P. putida* strain ATCC 12633, *P. aeruginosa* strain ATCC 10145, *Pseudomonas stutzeri* NBRC 14165, *Acinetobacter venetianus* ATCC 31012, *Enterobacter cloacae* ATCC 130047, *Streptomyces* spp B7-3TC02, *Bacillus subtilis* NBRC 13719, *Aspergillus niger* strain MPVCT 158, *Penicillium georgiense* strain EV 24 and *Rhizopus oryzae* strain ATCC 20344, which are beneficial soil microorganisms. The metal concentration analysis of the composited municipal refuse dump soil exhibited low concentrations of heavy metals which ranges from 0.002-1.03 mg/kg with Zinc (Zn) having the highest concentration. The waste materials are cheap and eco-friendly option that can be adopted as soil amendment in *M. incognita* infested fields to significantly boost yield in carrot production and reduce reliance on mineral fertilizer. The peels, as well as composited municipal refuse dump soil can be used to improve soil properties and substitute lost nutrients to enhance crop production, and at the same time mitigate the environmental consequences of inappropriate waste disposal problems in Nigeria.

Keywords: Municipal refuse, solid waste, *Meloidogyne incognita*, fruit peels, bacteria, fungi

INTRODUCTION

Pests and diseases are major factors which hinders crop production. Plant parasitic nematodes (PPN) are one of the

pests associated with huge crop losses in Nigeria (Agbale *et al.*, 2017; Fabiyi and Olatunji, 2018; Fabiyi, 2020; Fabiyi *et al.*, 2020a; Fabiyi *et al.*, 2021; Bello *et al.*, 2022). The most prevalent is the root knot nematode *Meloidogyne incognita*

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(Bridge, 1996; Okendi *et al.*, 2014; Atolani and Fabiyi, 2020), it is destructive, widely distributed and of high economic importance (Sikora *et al.*, 2018). Owing to its high infectivity of virtually all cultivated crops, it is thus a great threat to agriculture and consequently food security (Fabiyi *et al.*, 2020b). Several vegetables are susceptible to *M. incognita* infestation (Fabiyi and Atolani, 2011; Fabiyi, 2021a; Fabiyi, 2021b; Fabiyi, 2021c; Fabiyi 2022). Carrot (*Daucus carota* L.) an important vegetable crop in Nigeria, largely cultivated by the smallholder farmers under intensive farming system is highly susceptible to plant parasitic nematodes infestation (Hay and Pethybridge, 2005; Fabiyi, 2021c). Several nematode species are known to be associated with carrot, some of which include, *Meloidogyne* spp, *Pratylenchus* spp, *Belonolaimus* spp, *Longidorus* spp, *Xiphinema* spp, *Tylenchorhynchus* spp, *Merlinius* spp, *Rotylenchus* spp and *Hemicycliphora* spp (Boag, 1979; Walker, 2004; Tangvik, 2017). However, *M. incognita* is the most significantly damaging, and poses a great threat to carrot cultivation because of disfigurement by gall formation which lowers market values and leads to rejection by the consumers culminating a times to about 72% yield loss (Abawi *et al.*, 2001). The consequence of unskilled handling of synthetic nematicides by the peasant farmer, include compromising sources of water, human health, wildlife and in general the entire environment (Williamson, 2008; Lagerkvist, 2013; Dey, 2014; Fabiyi and Olatunji, 2021a). The limitations associated with the use of synthetic nematicides like carbofuran to control *M. incognita* have spurred research into several alternative approaches for nematode management (Atolani *et al.*, 2014a; Atolani *et al.*, 2014b; Fabiyi *et al.*, 2020c; Fabiyi *et al.*, 2020d; Fabiyi and Olatunji, 2021b; Fabiyi *et al.*, 2022). It is in light of this that waste materials (composited municipal refuse dump soil, potato, orange and pineapple peels) were assessed for the control of *M. incognita* infecting carrots. Composited municipal refuse soil is employed in agriculture as soil amendments (Pascual *et al.*, 1999). Large amounts of municipal refuse compost are used to augment crop nutrient requirements and increase yield (Hargreaves, 2007). The growth of beneficial microorganisms which parasitize plant parasitic nematodes can be stimulated with municipal refuse compost (Renco *et al.*, 2009).

The municipal refuse is heterogeneous in most cases and consist of household wastes, wastes from the streets, sanitation residue, fruit wastes, ash from firewood, charcoal, food remnants, plastics, glass, metals, dead animals, ceramics, polythene, rubber, cardboard, cartons, waste papers, baby diapers, rubber, nylons, animal dung's, plant residues, empty tins, rotten vegetables, chicken feathers and faeces (Oguntoyinbo, 2012). The only management method employed is open burning system which is catastrophic, due to emission of methane, carbon dioxide and dioxin (Hamer, 2003; Dilletti *et al.*, 2008; Triassi *et al.*, 2015) which impairs the air quality and may cause health problems among the residents in the community. A huge volume of potato peels is produced which contributes to environmental pollution especially during decomposition (Gebrechistos and Chen, 2018). Potato peels have been reported to have antimicrobial activities. The antimicrobial activity was reported to be comparable to strepto-

cycline against *Pseudomonas aeruginosa*, *Clavibacter michiganensis*, *Klebsiella pneumonia* and *Streptococcus pyogenes* (Prasad and Pushpa, 2007; Amanpour, *et al.*, 2015; Hanaa, 2019; Singh *et al.*, 2019). Pineapple and orange peels are the major waste of juice processing industry. The methanol extract of pineapple peels was reported to contain antimicrobial compounds (Pavan, 2012; Niramol *et al.*, 2018) against *Bacillus cereus*, *Staphylococcus aureus*, *Salmonella typhimurium* and *Escherichia coli*, while orange peels essential oil is known to be antimicrobial and herbicidal (Ribeiro and Lima, 2012). Improper waste dumping habit is a threat to the environment and people's health in Nigeria. It is the most pressing environmental challenge in urban and rural areas of the country (Adesewa and Morenikeji, 2017).

The idea of indiscriminate refuse dumping in Nigeria by householders, traders, artisans and small cottage industries is of grave concern. Indiscriminate and uncontrolled refuse dumping is regarded as part of environmental pollution (Adesewa and Morenikeji, 2017). Nigeria with over 190 million inhabitants is the largest producer of solid waste in Africa. Over 40, 000 tonnes of waste are generated daily across the country. On the average about 32, million tonnes are generated annually, 70% of this defaces the cities. It is a common practice for individuals in a community to dump refuse on the streets, beside their homes and into drainages (Imam *et al.*, 2008). There are huge deposits of waste at unauthorised open dump sites, streets, drainages, underneath bridges and beside homes in the neighbourhood (Agunwamba, 1998). Refuse heaps are a common sight in urban centres in the country (Imam *et al.*, 2008). The reckless disposal of wastes has blocked drainage networks, sewers and water bodies, which causes severe flooding in the homes and streets (Oguntoyinbo, 2012). The foremost intent of this research is to prepare compost with dump site soil, analyse heavy metals in the composited soil, collect and air dry potato, orange and pineapple peels. The composited soil and dried peels will be administered as soil amendment on *M. incognita* infected carrot plants. It is anticipated that this will contribute to global effort in finding solutions to municipal refuse management.

MATERIALS AND METHODS

Collection and Processing of Waste Materials

The municipal refuse soil was collected from two refuse dump hills (Figure 1). One was from a popular market in Ilorin metropolis called "Ipata market" Kwara state (Plate 1) and the other, from Tanke Bubu (Plate 2) community area in Ilorin town. After scrapping off the surface debris, soil samples were collected up to a depth of 15 cm from the surface into large black sterile plastic bags which were labelled appropriately and transported to the laboratory where the soils were sieved through a 2mm mesh to remove tiny particles of plastics, nylons, half decayed fruit materials, cartons, and rotten clothes (Mandal, 2019). The soil samples were then mixed together properly. Sweet potato peels were collected from a local sweet potato frying point and Irish potato peels

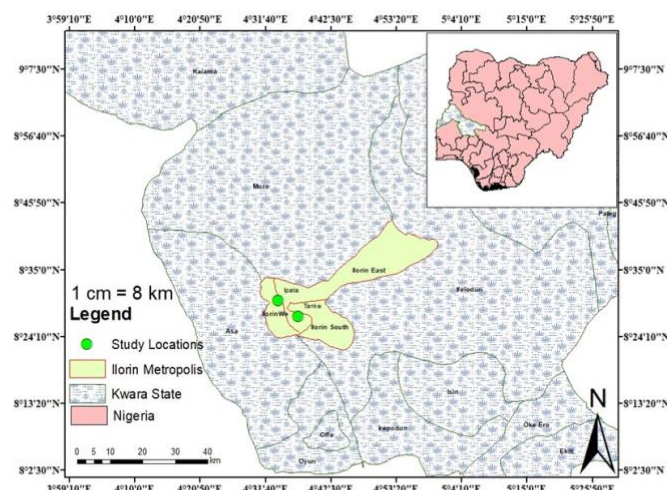


FIGURE 1
Map of Study Area



Plate 1
Ipata market refuse dump site

were from a restaurant in Ilorin town. Equal quantity of each peel was mixed together. The orange peels were collected from a local orange seller, while pineapple fruits were bought in large quantity and the peels were set aside for the experiment. The municipal refuse soil compost was prepared by cutting a part of the peels set aside for the research (potato, pineapple, orange peels and pawpaw peels) into sizes of about 1-3 cm length before drying (pawpaw peels were used only as a part of the compost). These were mixed meticulously with the municipal refuse soil at a quantity of 50% weight each relatively to the municipal refuse dump soil and composited behind the screenhouse on a concrete floor as a square heap. The compost heap was covered with thick transparent polythene sheet of about 1000 gauge, which was held down

at the edges with heavy stones to prevent wind from blowing it off. Moisture content was on the average of about 54% as indicated by moisture meter. The materials were turned and remixed at a span of 10 days, while composting lasted for 8 weeks after which the compost soil was subjected to analysis of heavy metal concentration. All the remaining set of peels were dried until brittle and were ground to powder for separate application. The waste materials were coded MCPW, SWTP, PNAP, ORGP and CBFN, that is composited municipal waste soil, potato peels, pineapple peels, orange peels and carbofuran respectively.



Plate 2
Tanke refuse dump site

Isolation of fungi and bacteria in municipal refuse soil

One gram of soil sample from the dump site was weighed aseptically and homogenized in 9 ml sterile physiological water (0.86% NaCl) by vortexing vigorously. Two different media, namely Potato Dextrose agar (PDA) containing 0.2ml of streptomycin and Nutrient agar (NA) were used to isolate fungi and bacteria respectively by plating 10^{-2} and 10^{-4} soil dilution with saline following the methodology of Mandal *et al.*, (2019) with some modifications. The growth media used were purchased from Oxoid, UK and prepared according to the specification. The Nutrient agar plates were incubated for 48 hours at 37°C while the PDA plates were incubated between 4-5 days at 25°C. Distinct colonies were picked and streaked on plates to get pure culture for molecular identification (Mandal, 2019). The isolated organisms were coded MSB1-4 and MSF1-3 (Municipal soil bacteria and Municipal soil fungi).

Molecular identification of fungi and bacteria in municipal refuse soil

Preliminary taxonomic characteristics of the isolated bacteria and fungi were determined by colony morphology, pigment colour, growth pattern and biochemical analysis (Mandal *et al.*, 2019). Pure cultures were cryopreserved in 50% glycerol at -80°C (New Brunswick, Effendorf). Genomic DNA was extracted with the QIAamp DNA Mini Kit (250) following the manufacturer's protocol (Qiagen Sciences, LLC, MD, USA). Universal bacterial primers, (27F 5' AAGGAGGTGWTCCARCCGCA-3' and 1525R 3' AGAG-TTTGATCMTGGCT CAG-5) were used to amplify internal fragments of 16S rRNA gene that amplify 850 bp for the bacterial isolates while ITS4TCCTCCGCTTATTGATATGS and ITS5 GGAA GTAAAA G TCGTAACAAGG were used for the fungal isolates (Lau *et al.*, 2015). Amplicon from both reactions above were loaded on 1.5% agarose gel. The ladder used is hyper ladder 1 from Bio online. The base pair of the

amplicon is around 850bp for bacteria and 650bp for fungi. The amplified PCR products were purified with a PCR product purification kit. The PCR products were loaded on the 3130xl genetic analyser from International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria to give the sequences of the DNA. For identification of closest relatives, sequences were compared to 16S sequences available in the GenBank databases by BLASTn.

Screenhouse experiment

The experiment was carried out at the screenhouse of the Department of Crop Protection, Faculty of Agriculture, University of Ilorin, Nigeria (Lat 8°, 29' N of the Equator; Long: 4°, 40' E of the Greenwich Meridian), between the month of September-May in the year 2017/2018 and 2018/2019. Carrot seeds (variety Touchon Mega) were planted in steam sterilized soil (70°C for four hours) distributed into 50 cm diameter, experimental plastic pots at 40 kg each (dry weight). The experimental design was a randomized complete block design (RCBD). There were five treatments, each replicated three times, with four treatment dosages. Two weeks after emergence, the carrot plants were thinned down to a single plant per pot. Eggs of *M. incognita* pure culture multiplied on the roots of *C. argentea* were extracted following the account of Hussey and Baker (1973). The extracted eggs were hatched into juveniles. Approximately 2000 freshly hatched out juveniles of *M. incognita* were inoculated at the base of each carrot plant in the experimental pot (Fabiye, 2019). Two weeks after inoculation, the various treatments were mixed with soil and added to the base of each carrot plant in banded form. The composited municipal refuse soil and the peels were applied at 0, 1500, 2000 and 2500g while carbofuran 3G was applied at 0kg/a.i/ha, 2.0kg/a.i/ha, 1.5kg/a.i/ha and 1.0kg/a.i/ha. Carbofuran served as standard positive control for all the treatments. Untreated inoculated pots were used as the negative control. The vegetative growth of the carrot plants was monitored by measuring plant height (cm) and counting numbers of leaves during the experimental period.

Nematode population in 20g root sample and 250 g soil was counted in the laboratory after harvest. The carrots (roots) were rated for galling severity on a scale of 0-9 provided by Schoonhoven and Voysest (1989), where 1=no galling, 2=< 5% of roots galled, 3=6-10% galled, 4=11-18% galled, 5=19-25% galled, 6=26-50% galled, 7=51-65% galled, 8=66-75% galled, 9=76-100% of roots galled. Data on heights of carrot plants, number of leaves, yield, nematode population in roots/soil and gall index were subjected to analysis of variance with a generalised linear model. Significant means were separated using the New Duncan's Multiple Range Test at 5% level of probability ($p<0.05$). All statistical analyses were done with IBM SPSS statistics version 21.

Heavy Metal Analysis of Compositd Soil

The account of Maurya *et al.* (2018) with some adjustments was adopted. The reagents used were of analytical grade, 1.0g of soil was introduced into a 250 ml beaker with 30 ml of concentrated hydrochloric acid and nitric acid (HCl and HNO₃) in ratio 3:1 and was digested for 3 hours. Concentrated hydrofluoric acid (HF) at 5ml was added and the mixture was heated for another 45 minutes. The digest was filtered and made up to 50 ml mark with de-ionize water in a volumetric flask. The extraction was done trice and the

filtrates were turned out for analysis with Atomic Absorption Spectrometer (AAS), values were recorded in triplicate. The mean values were calculated and taken.

RESULTS AND DISCUSSION

Results

Results from Table 1 revealed the presence of bacteria such as *Acinetobacter venetianus*, *Enterobacter cloacae*, *Pseudomonas putida*, *Pseudomonas stutzeri*, *Streptomyces* spp and *Bacillus subtilis*, while *Aspergillus niger*, *Rhizopus oryzae* and *Penicillium georgienses* are the major fungi dominating the municipal refuse dump soil. This corroborates the findings of Jang (2016) and El-Nagdi and El-Khair (2008). They reported *Aspergillus* spp, *Aspergillus niger*, *Penicillium* spp and *Rhizopus nigricans* as the most common specie of fungi found in soil, while Mandal *et al.* (2019) also reported the isolation of *Bacillus subtilis* from waste dumpsite soil.

Screenhouse. The concentration of heavy metals in the composited soil is presented in Table 2. Remarkably low concentration of heavy metals was detected. However, zinc had the highest value, while nickel and copper were not detected. Figures 2-8 summarises the effect of soil amendment with

TABLE 1
Bacteria and Fungi isolates based on 16S rRNA gene sequencing

Isolate code	Organisms Name	Specie Description	Strain	Accession Number	Query Cover	Per. Identity
MSB1	<i>Acinetobacter</i>	<i>venetianus</i>	ATCC 31012	NR042049.1	97%	98.64
MSB2	<i>Enterobacter</i>	<i>cloacae</i>	ATCC 130047	NR118568.1	97%	98.90
MSB3	<i>Pseudomonas</i>	<i>stutzeri</i>	NBRC 14165	NR113652.1	95%	99.50
MSB4	<i>Pseudomonas</i>	<i>putida</i>	ATCC 12633	NR114479.1	95%	98.02
MSB5	<i>Streptomyces</i>	spp.	B7-3TC02	KF600445.1	89%	99.43
MSB6	<i>Bacillus</i>	<i>subtilis</i>	NBRC 13719	NR112629.1	95%	99.02
MSF1	<i>Aspergillus</i>	<i>niger</i>	MPVCT 158	EU440768.1	96%	99.48
MSF2	<i>Penicillium</i>	<i>georgiense</i>	EV24	MR108398.1	97%	99.30
MSF3	<i>Rhizopus</i>	<i>oryzae</i>	ATCC 20344	JQ745257.1	93%	97.68

TABLE 2
Concentration of Heavy Metals in Composited Municipal Refuse Soil

Metals	Concentration (mg/kg)
Cadmium (Cd)	0.002±0.00
Lead (Pb)	0.02±0.01
Nickel (Ni)	ND
Copper (Cu)	ND
Chromium (Cr)	0.03±0.00
Manganese (Mn)	0.40±0.02
Zinc (Zn)	1.03±0.06
Iron (Fe)	0.58±0.00

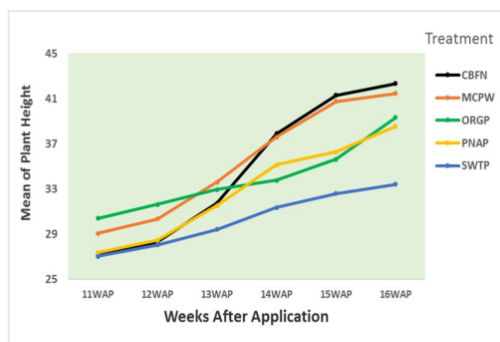


FIGURE 2

Effect of treatments on heights of carrot plants

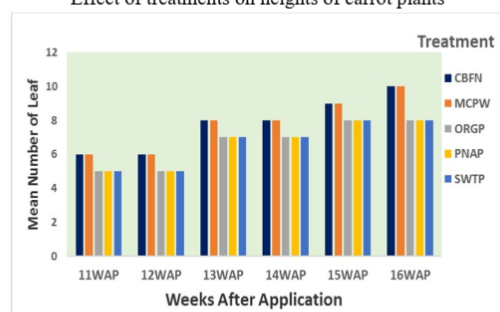


FIGURE 3

Effect of treatments on numbers of leaves of carrot plants

composited municipal refuse dump soil and fruit peels. Soil amended with composited municipal refuse soil showed significantly ($p < 0.05$) higher values in vegetative parameters of carrot plants and lower values in the population of *M. incognita* at harvest. The performance of the composited municipal refuse dump soil is similar to that of the synthetic nematocide. All fruit peels reduced the reproduction and multiplication of *M. incognita* on carrot (Fig. 5). The action of fruit peels and composited municipal refuse soil was dose dependent (Fig. 5), the highest quantity of materials applied reduced significantly ($p < 0.05$) *M. incognita* reproduction (Fig. 5), the control plants did not resist nematode development, higher nematode population build up was observed (Fig. 5) and was characterised by high root gall index, while gall index was significantly low in treated carrot plants (Fig. 6). There was increase in vegetative growth of carrot plants treated with the highest quantity of fruit peels and composited municipal refuse dump soil. However, the most impressive growth was seen in the carrot plants treated with composited municipal refuse soil (Fig. 2 & 3). A similar trend was observed in the yield, carrot plants treated with composited municipal refuse dump soil recorded the highest yield among all treatments (Fig. 64). Fewer numbers of nematodes were seen in the soil

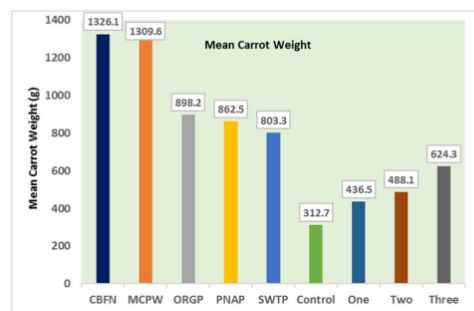


FIGURE 4

Effect of treatments and dosage of application on weight of carrots at harvest

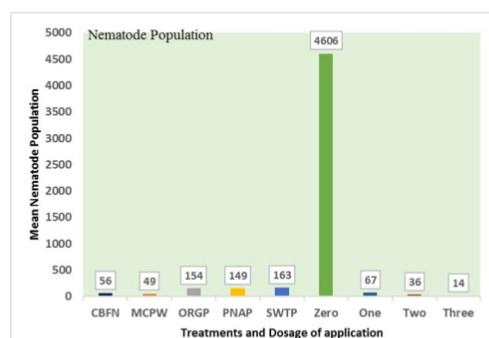


FIGURE 5

Effects of treatments and dosage of application on nematode population at harvest

of carrot plants treated with composited municipal refuse soil (Fig. 5). The dosage of utilisation of these materials was equally significant on vegetative growth of carrot plants as shown in figures 7 & 8. The mean height of carrot plants was significantly low in untreated carrot plants as opposed to the treated plants (Fig. 7). In the same vein, the first and second rate of application had significant effect on the numbers of leaves of carrot plants (Fig. 8).

Discussion

Municipal refuse consists of about 40-70% of food wastes in developing countries (Yunmei, 2017). The wastes decay easily through anaerobic digestion (Pan *et al.*, 2018). This study established that composited municipal refuse dump soil, potato, pineapple and orange peels qualify as good alternative in *M. incognita* management. Renco *et al.* (2009), observed a significant decrease in the population of *Bitylenchus*, *Helicotylenchus*, *Heterodera*, *Paratylenchus* and *Rotylenchus* with the application of municipal green waste. Reports by

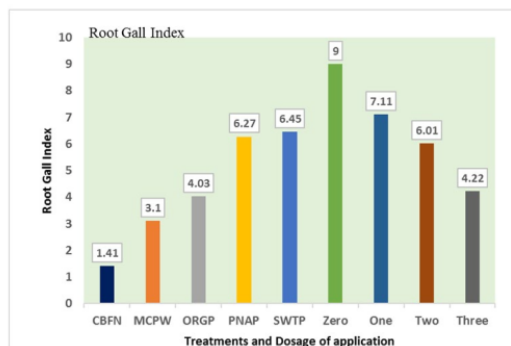


FIGURE 6
Effects of treatments and dosage of application on root gall index at harvest

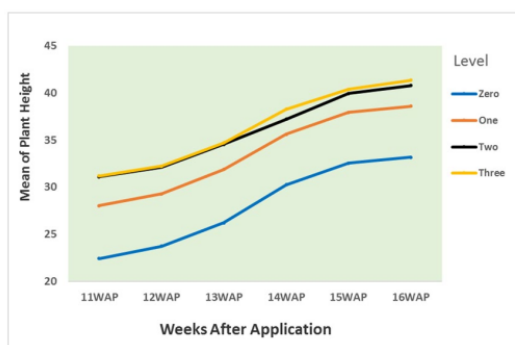


FIGURE 7
Effect of dosage of application on height of carrot plants

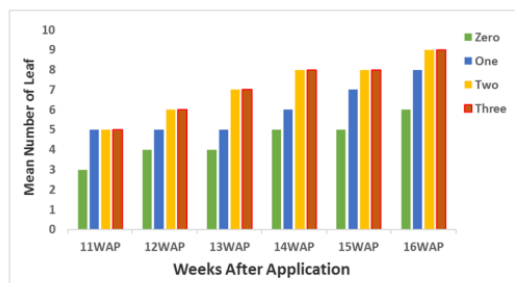


FIGURE 8
Effect of dosage of application on numbers of leaves of carrot plants

Akhtar and Lam (1993), indicated a successful control of nematodes with the use of municipal refuse. The application of municipal solid waste compost in combination with miner-

al fertilizer brought about a significant increase in tomato yield (Ribas-Augusti *et al.*, 2017). Composting of municipal refuse is known as an excellent medium for crop development (Dhayagode *et al.*, 2011). The vegetative growth and yield of rice improved significantly with the application of municipal waste compost (Bhattacharyya, 2007). The study confirmed that municipal waste compost is high in potassium which can increase the organic matter content of soil. Likewise, Eriksen *et al.* (1999) established that municipal solid waste compost enhanced soil organic matter with a high yield in maize. Montemurro *et al.* (2007) noticed increase in growth, yield and quality of sugar beet with the application of municipal solid waste compost, compared to tillage method and use of mineral fertiliser. An improvement in the physical and chemical properties of soil was recorded with the addition of municipal waste by Westernman (2005). Municipal waste serves as a good source of essential nutrients for plants, it increases soil fertility by adding nitrogen, phosphorus and potassium (Hossain *et al.*, 2017). Municipal waste soil is a store house of valuable microorganisms, this study identified organisms such as *Pseudomonas* spp, *Bacillus* spp, *Streptomyces* spp, *Acinetobacter* spp, *Trichoderma* spp, *Aspergillus niger*, *Penicillium georgiense* and *Rhizopus oryzae* in the municipal dump site soil. *Pseudomonas* species are known as antagonists of plant parasitic nematodes (Mhatre *et al.*, 2019; Ali *et al.*, 2021). El-Hadad *et al.* (2011) in their research also corroborated the nematocidal activity of *Pseudomonas* spp. Reports by Khan *et al.* (2012) equally affirmed the nematocidal activity of *Pseudomonas fluorescence*, *P. stutzeri* and *Bacillus subtilis*, they observed a significant suppression of gall formation and reduced soil population of *M. incognita*. Similarly, El-Sayed *et al.* (2014) documented the nematocidal activity of *Bacillus* spp, *Pseudomonas* spp and *Enterobacter* spp. They found juvenile mortality to increase with exposure period and 81-100% mortality was recorded. A significant reduction in the number of hatched eggs was recorded. A handful of un-hatched eggs were damaged severely under the microscope. Also, Ruanpanun *et al.* (2010), reported the nematocidal activity of *Streptomyces* species. The strain CMU-MH021 reduced egg hatch of *M. incognita* by 79.6% and increased juvenile mortality by 82% as against control which had 33.1 and 3.6% respectively. The culture filtrate of *Aspergillus niger* is reported to be highly nematocidal against *M. incognita*. The viability of juveniles was significantly reduced, and a higher percentage reduction in egg hatch was observed by Jang *et al.* (2016). The nematocidal activity of metabolites from *A. niger* against *Aphelenchus avenae* was also reported by Mankau, (1969), while Kurt and Poltorak (1980) similarly reported that *A. niger* exhibited moderate toxicity on *Aphelenchus avenae* and *Aphelenchus besseyi*. The production of Kojic acid by *Aspergillus oryzae* was reported by Tae *et al.* (2016) noting a dose dependent mortality and egg hatch inhibition of *M. incognita*.

Furthermore, the nematocidal activity demonstrated by the composited municipal waste dump soil could be attributed to the presence of *Rhizopus oryzae* which is one of the organism detected through molecular analysis of the soil. The production of cyanophycin by *R. oryzae* is reported by Meussen *et al.* (2012). The effect of this metabolite could be attributed to

the nematocidal activity displayed by the composited municipal waste soil. In the same vein, research by Peeran *et al.* (2018) revealed that benzene,1,2-dimethoxy-4-(2-propenyl) is a major metabolite in *R. oryzae* and this is associated with the antibiotic activity of the organism, which is responsible for inhibition against the growth of *R. solani*. Siddiqi and Futai (2009) achieved a significant reduction in the multiplication of *M. incognita* on tomato by the application of *Aspergillus niger*, *Bacillus subtilis* and *Pseudomonas putida*. The use of soil amendments is a good practice in nematode management (Rodriguez-Kabana *et al.*, 1987; Iqbal and Azeem, 2021), while Hunt *et al.* (1973) stated that water extracts of composited municipal refuse was toxic to sting nematodes, *Belonolaimus longicaudatus*, all 50 nematodes tested were immobile for three hours, after 144 hours the nematodes were totally dead. Potato peels are reported to contain bioactive compounds such as glycoalkaloids α -chaconine, α -solanine, uronic acid and phenolics like chlorogenic acid, ferullic acid, caffeic acid, gallic acid and protocatechinic acid which are active against pathogenic strains of trichomonads (Sotillo *et al.*, 1998; Friedman *et al.*, 2018; Scharf, 2020), the peels are documented to be bacteriostatic and bactericidal at high concentrations. Comparably, Silva-Beltran (2017) reported that potato peel extract reduced viral titers of the MS2 and Av-05 bacteriophages. The phenolic with bactericidal compounds can be found in the water extract of potato peels. The peels are also known to contain 10% glycoalkaloids and 43% phenolic acids (Chem, 2009), sweet potato peels are rich in terpenes and flavonoids (Nostro *et al.*, 2000) which has exhibited satisfactory antibacterial activity. The nematocidal activity of potato peels was reported by Hehir and Jones (2014) they reported a synergistic effect of the peels with oxamyl when added to *Globodera pallida* infested soil. Orange peel extract was evaluated by Tsai (2008). A 93.5% nematostatic action was established against *Meloidogyne incognita* juveniles and 91% egg hatch inhibition, while infection of mung bean roots was also significantly reduced. Stephen *et al.* (2014) confirmed that powdered orange peels used as soil amendments increased soil fertility, enriched plant growth with increase in yield. Pineapple peels are known to contain compounds such as flavonoids, tannin, saponin and bromelain.

These compounds have been implicated for the series of biological activities observed. Reports by Intan *et al.* (2018) stated that ethanol extract of pineapple peels inhibited the growth of *Enterococcus faecalis*. Rahmi *et al.* (2019) corroborated that extracts from pineapple peels had minimum inhibition on the growth of *Streptococcus mutans*. The ability of the peels to inhibit the growth was associated with bromelain. The activity of pineapple extract against nosocomial infection was also reported by Praveen *et al.* (2014) and Zharfan *et al.* (2017). It exhibited antimicrobial activity against periodontal micro-organisms and multidrug resistant *Pseudomonas aeruginosa*. Juice from pineapple peels were found useful in the treatment of gastro intestinal helminths in chicken. Pineapple peel juice is reputed to be an alternative anti-helminth and it has been proved on several animal nematodes such as *Heligmosomoides bakeri*, *Protospirura muricola* and *Trichuris muris* (Steppek *et al.* 2007; Cormanes *et al.*, 2016). The acaricidal effect of pineapple peel extract was demonstrated by

Amornrat *et al.* (2018). *Rhipicephalus sanguineus* reproduction was reduced, with 100% mortality. Utilisation of wastes in nematode control is a significant contribution to proper solid waste management (Fabiya *et al.*, 2018). Heavy metal concentration in the composted soil was appreciably low. All values were below the recommended values by Federal Environmental Protection Agency (FEPA) of Nigeria and the European Commission. The allowable level of cadmium by FEPA is 0.01mg/kg, while 3.0mg/kg is set by the EU. The limit for chromium is 0.03mg/kg and 50mg/kg by FEPA and EU respectively (EU, 1986; FEPA, 1991). The low concentration detected may be in connection with composting of the soil. Composting has been established to decrease the concentration of heavy metals. The health consequences of indiscriminate waste dumping such as asthma, respiratory infections, congenital anomalies and chronic respiratory diseases can be mitigated by converting wastes to useful bio-nematicides to improve agriculture in Nigeria (Capenter *et al.*, 2008), and this will be in line with global best practices.

CONCLUSION

This research has shown clearly that application of composited municipal waste soil and fruit peel wastes as soil amendment reduces *M. incognita* population. By further modification, they have the potential of replacing synthetic nematicides. Treatment of soil with composited municipal refuse soil and fruit peels seemed to have enabled the soil to replenish lost nutrients without the use of mineral fertilizer. Some of the indirect benefits derivable from the results of this research would include significant reduction of the cost of production in agriculture (since input is less) and substantial increase in yield, while relieving the environment of pollution arising from indiscriminate waste dumping.

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