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Biocidal Potential of Livestock and Plant-Derived Organic Amendments on Plant-Destructive Nematodes associated with Rice (*Oryzae sativa* L.) in Makurdi, Nigeria

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Abstract: *Field trials were conducted at the Teaching and Research Station of Joseph Sarwuan Tarka University, Makurdi in 2021 and 2022 to determine the impact of some livestock and plant-based organic manures on the population dynamics of plant-parasitic nematodes (PPNs) associated with rice fields. Treatments comprised six organic amendments [cattle dung (CD), chicken litter (CL), goat dung (GD), neem leaf powder (NLP), moringa leaf powder (MLP), eucalyptus leaf powder (ELP), all applied at the rate of 5 t/ha], furadan 10 G (as check applied at the rate of 1 kg ai/ha) and an untreated plot (control). The experiments were laid-out in a Randomized Complete Block Design (RCBD) with three replications. A total of Ten PPNs were recovered from the field trials and included Meloidogyne incognita., Pratylenchus zeae, Helicotylenchus multicinctus, Tylenchus sp. Xiphinema index, Hirschmaniella oryzaea, Trichodorus sp, Criconemoides sp., Hoplolaimus clarissmus and Rotylenchus sp. Results showed that of the six organic amendments evaluated in the study, NLP consistently suppressed populations of Criconemoides sp., Helicotylenchus multicinctus. Hirschmaniella oryzaea, Hoplolaimus clarissimus, Pratylenchus zaea, Trichodorus sp., Tylenchus sp. and Meloidogyne incognita the most during the two-year field trials. Although plots treated with CD, CL, ELP, GD and MLP reduced total populations of PPNs, again use of NLP suppressed the total population PPNs associated with rice by 74.8% and 68.3%. Chicken litter ranked second after NLP in terms of efficacy of plant-parasitic nematode control, decreasing total number of plant-parasitic nematodes associated with rice by 67.1% and 57.1% in 2021 and 2022, respectively. The current study concluded that Neem leaf powder and Chicken litter applied at the rate of 5 t/ha reduced the population of PPNs associated with rice and has proven to be effective against PPNs and therefore recommended for used in nematode management in rice fields.*
Keywords: Rice, Plant-parasitic nematodes., Organic Amendments., Population Dynamics

INTRODUCTION

Rice (*Oryza sativa* L.) is a plant belonging to the family of Poaceae. It is one of the three major food crops of the world and forms the staple diet of about half of the world's population with a global production of approximately 800 million tons (FAOSTAT, 2025). Two species have emerged as the most popular cultivated rice, *Oryza sativa,* and *Oryza glaberrima*; of the two species, the more widely produced are *Oryza sativa*. It is a food for over 2.7 billion people, more than half the world's population (Amna *et al*., 2006). Boiled rice is consumed with stew or as "jollof" in most countries in Africa. It can be processed into rice flakes, rice wafers, or canned rice. It is also used in starch and brewing industries. Rice straw is used for animal feed besides being used in making hats, mats, and ropes. Rice is a strategic component of food security and a crucial element in the food economies of several African countries (International Rice Research Institute, 2009). Just like a number of crops, rice is also affected by both biotic and abiotic stressors.

Plant-parasitic nematodes (PPNs) are one of the biotic stressors on rice fields accounting for 20% economic losses in rice production systems (Sasser and Freckman 1987). A number of PPNs have been found to be associated with rice fields. In a study conducted by Namu et al. (2018) a total of twenty-two (22) plant-parasitic nematode genera were isolated from some rice fields in Kenya. Nine genera of PPNs were isolated from rice fields in Benue State, Nigeria (Eche et al., 2021). Jena et al. (2024) reported that rice is parasitized by over 210 species of PPNs comprising 35 genera. Some of the economically important PPNs associated with the crop are *Meloidogyne graminicola*, *Ditylenchus angustus*, *Heterodera oryzicola*, *Aphelenchoides besseyi* and *Hirschmanniella oryzae* to mention but a few. A survey conducted in Togo documented 12 plant-parasitic nematode genera among which ten, (*Hirschmanniella* spp., *Meloidogyne* spp., *Xiphinema* spp., *Scutellonema* spp., *Helicotylenchus* spp., *Heterodera* spp., *Criconema* spp., *Pratylenchus* spp., *Trichodorus* spp. and *Tylenchid* spp.), were recorded from lowland, two (Helicotylenchus and Scutellonema) from upland and five (*Dolichodorus* spp., *Helicotylenchu*s spp., *Tylenchorhynchus* spp., *Scutellonema* spp. and *Xiphinema* spp.), from flooded ecosystem (Gnamkoulamba *et al.,* 2018). The direct and indirect damage caused by these PPNs result in delayed crop maturity, toppling, reduced yield and quality of crop product, high production costs, and consequently income loss (Onkendi *et al*., 2014). Global damage caused by plant-parasitic nematodes has been estimated to be 80 billion US dollars per year (Nicol *et al*., 2011).

Use of synthetic chemical nematicides is the predominant method of nematodes population management. Nematicides are highly toxic compounds that have low LD_{50} values and concerns over their negative effects on the environment, health of end-users and profit margin at the end of each production cycle continue to be on the rise (Tiwari, 2024). Most farmers depend entirely on synthetic pesticides for quick and effective reduction in pest and disease incidence (Tsay *et al*., 2004; Gahukar, 2018). Even though use of nematicides boost production, they are toxic to livestock and man, have poor target specificity and are also not cost-effective, especially to resource-poor farmers (Youssef and Eissa, 2014; Wonang and Danhap, 2016). The incorrect use of chemicals, such as overdose, frequent applications, and application of pesticides beyond the expiry date and illiteracy of applicators is common in developing and less developed countries (Gahukar, 2014) and this has a negative impact on crop production.

Agrawal et al. (2010) stated that when nematicides, fertilizers, herbicides, insecticides and fungicides are applied to cropland, some residues remain in the soil after plant uptake and they may leach into the subsurface waters or they may move to surface water by dissolving in runoff or adsorbing sediment. These residues transform into products that may also contaminate water due to chemical and physical processes and this poses significant risks to the environment and non-target organisms ranging from beneficial soil microorganisms to insects, plants, fish and birds. The negative effects associated with the use of nematicides have raised the need to find alternative, low input, cost-effective and environmentally-friendly nematode strategies to reduce nematode attack on crops. Reduction in populations of PPNs in response to application of organic amendments have been reported in many studies.

The natural product of plants, animals or microbial origin are vast source of bioactive substances which have been exploited only to a limited extent in the preparation of pesticides (Chindo *et al*., 1985). Organic amendments are known to have a nematode suppressive effect which depends on many interactions that include the type of compounds released, the dosages, soil characteristics and also the level of nematode population (Olimi *et al*., 2023). As reported by Mashela (2002), farmers in low input agricultural farming systems use organic amendments to suppress plant-parasitic nematodes and to provide essential nutrients to the plants. The inorganic fertilizers containing ammoniacal nitrogen or formulations releasing this form of nitrogen in the soil are effective for suppressing nematode populations (Rodriguez-Kabana, 1986). It is against this backdrop that this study was conducted to evaluate the nematicidal effect of some plant-derived organic manures such as powders of neem (*Azadirachta indica*), moringa (*Moringa oleifera*) and eucalyptus (*Eucalyptus globulus*), and two livestock-derived manures (cattle dung, chicken litter and goat dung) against PPNs associated with rice.

MATERIALS AND METHODS

Experimental site:

Two trials were carried-out in 2021 and 2022 and established at the Teaching and Research Station of Federal University of Agriculture, Makurdi. The Station was located at latitude 07^0 45^0 N to 070 50^0 N, longitude 08^0 45^0 E to 08^0 50^0 E, 98^0 m above sea level. Both trials were established during the raining seasons between July and October of both years. The total annual rainfall was about 2000-2500 mm and the maximum and minimum temperature ranged between 21^0 C to 31^0 C respectively, while the relative humidity was in the range of 80-70%. The experimental site was manually cleared of weeds and flat ridged using cutlass and hoe respectively. The site was mapped into plots, using rope and tape. The total number of plots used was 24 with flat size of 5x3 m^2 separated by an alley way of 0.5 m and 1 m boundary rows. Rice seeds (FARO 52) were obtained from National Cereals Research Institute (NCRI), Badeggi, Niger State and raised in a nursery bed composed of sterilized topsoil. At 2 weeks after planting, seedlings were transplanted at spacing of 8 cm x 8 cm. Manual weeding was carried out subsequently using hoes to manage weeds.

Collection and preparation of organic soil amendments

Physiologically mature leaves of Moringa, Neem and Eucalyptus were collected from the environs of the Federal University of Agriculture Makurdi (Now Joseph SaruwanTaraka University, Makurdi). Authentication of each plant's leaves were done in a taxonomy unit.

Separated batches of leaves according to their type were air-dried at room temperature (25˚C) for 2 weeks afterwards and pulverized into powder with mortar and pestle. The powders were sieved and stored in air-tight bottles until needed.

Cattle dung, Goat dung, and chicken litter were collected from the Animal Research Farm (ARF) of Joseph Saruwan Taraka University, Makurdi. Fifty kilogrammes (50 kg) of cattle, goat dung and chicken litter wastes were collected, measured into clean sack. The chicken litter was obtained from the battery cage system of poultry production unit of the farm. The poultry pen of the ARF is usually cleaned approximately once a month. The primary constituent of the litter was chicken excrement. Cow and goat dungs were collected from specific paddocks of the ARF. The paddocks are usually cleaned daily. The dungs and chicken litter were left on a concrete slab for about two months before they were used. During the period of curing, faecal materials were separately and evenly spread on clean sacks, placed on slabs under shade and partially covered, allowing for minimal ventilation. Within the period of curing, faecal materials were turned over in between days during the duration of the curing process.

Treatments and Experimental Design

Six organic-based materials including Cattle dung (CD), Chicken litter (CL), Goat dropping (GD), Neem leaf powder (NLP), Moringa leaf powder (MLP), and Eucalyptus leaf powder (ELP) all applied at 5 t/ha were evaluated in the study. For experimental purpose Furadan 10G applied at 1kg ai/ ha and untreated plots were used as check and control, respectively.

Pre-planting and post-planting sampling for nematode extraction

Pre-planting and post-planting samples (250 g/core sample) were collected from the 24 experimental plots and taken to Crop and Environmental Protection laboratory for nematode extraction using the modification of Whitehead and Hemming (1965) tray method. Pre-planting samples were collected one week before planting while post-planting samples were collected at harvest. Two plastic sieves of same diameter with a double-ply tissues paper sandwiched in between was setup. The setup was later placed in a plastic bowl of a bigger diameter containing 200 ml of water. Soil samples were thoroughly mixed to obtain homogenous composite afterwards 200 g of each sample was distributed into the setup and left undisturbed for 48 hours. Plant-parasitic nematodes were identified using the identification key of Mai and Lyon (1975). Only nematodes found in pre-planting and post-planting samples were included in the study.

Data Collection and Analysis

Data collected included initial nematode population and finial nematode population. Occurrence of plant-parasitic nematodes recovered from core samples obtained from each trial was expressed as percentages. The data on growth and yield parameter were subjected to statistical analysis variance (ANOVA) using GENSTAT Software, 17th Edition (2015). Mean separation was done using Duncan Multiple Range Test (DMRT) at 5% probability level (Steel and Torrie, 1980). Percentage decrease in average plant-parasitic nematode population was calculated using the formula below where *PopC* = Average population of PPN in control plot; *PopT* = Average population of PPN in treatment plot.

$$Percentage\ nematode\ population\ decrease = \frac{PopC - PopT}{Pop\ C} \times 100$$

RESULTS

Application of plant-based and livestock amendments significantly (p≤0.05) reduced populations of plant-parasitic nematodes identified in the study as shown in Tables 1a and b. Although the effect varied with each nematode species, Of the six organic amendments evaluated in the study, Neem Leaf Powder suppressed populations of *Criconemoides* sp., *Helicotylenchus multicinctus*. *Hirschmaniella oryzaea*, *Hoplolaimus clarissimus*, *Pratylenchus zaea*, *Trichodorus* sp., *Tylenchus* sp. and *Meloidogyne incognita* the most, and consistently so during the two-year field trials. Although plots treated with cattle dung, chicken litter, eucalyptus leaf powder, goat dropping and moringa leaf powder also resulted in reduced populations of plant-parasitic nematodes, amendment with neem leaf powder suppressed the PPNs associated with rice. Of the ten (10) PPNs included in the study *M. incognita*, *H. oryzae* and *P. zeae* recorded the highest grand mean values across the treatments in 2021 and 2022 viz: 2,999.25 and 2,660.67 (*M. incognita*), 739.91 and 2,091.75 (*H. oryzae*), and 781.81 and 1,662.13 (*P. zeae*) indicating that these three nematodes were the most populated in the field trials. When applied, neem leaf powder significantly reduced their populations in different proportions. Plots treated with neem leaf powder recorded a population of approximately 83 nematodes/250 g soil and 1,252 nematodes/250 g soil which represent 94.2% and 72.5% reduction when compared to *H. oryzae* population in the control plots. A comparable trend was observed on populations of *P. zaea* which decreased by 88% and 70.2% in 2021 and 2022, respectively when rhizosphere of rice was treated with neem leaf powder. Similarly, plots treated with neem leaf powder suppressed *M. incognita* decreasing its population by 65.7% and 56.5% when compared to control plots.

Figure 1 shows the effect of soil amendments on average nematode population isolated from the rhizophere of rice. The least average nematode population was consistently recorded in plots treated with Furan 10G (check) with a population of approximately 30 and 78 nematodes/250 g soil, respectively in 2021 and 2022 against 1,234 and 1,595 nematodes/250 g soil recorded in the control plot. Of the six amendments evaluated in this study Plots treated with neem leaf powder was the most effective and resulted in 74.8% and 68.3% reduction in average nematode population in 2021 and 2022, respectively. Chicken litter ranked second after neem leaf powder in terms of efficacy of plant-parasitic nematode control, decreasing total number of plant-parasitic nematodes associated with rice by 67.1% and 57.1% in 2021 and 2022, respectively.

DISCUSSION

Soil amendments with organic composts of plant or animal residues have showed significant nematicidal effect against plant-parasitic nematodes, although the use of organic soil amendments is a traditional agricultural practice for improving physical and chemical soil properties, soil structure, temperature and humidity conditions as well as nutrients content which are needful for plants growth. Application of organic materials to soil can cause a change in soil microflora and microfauna including soil nematodes (Renčo, 2013), classic examples of these organic amendments include chicken litter, cattle dung, green manure, dry crop residues and industrial by-products such as neem and castor oil cakes (Akhtar and Alam 1992). Significant reduction has been achieved in nematode population in both greenhouse and field conditions with increases in growth and have been attributed to either improvement in soil condition resulting in greater root growth, thereby enhancing the usage of soil nutrients of the plants. These therefore alter the host-parasite relationship thereby reducing nematode damage.

Finding from the current study provided results on the bionematicidal potential of chicken litter, cattle dung, Goat dung, Neem leaf powder, Eucalyptus leaf powder and Moringa leaf powder in the management of plant-parasitic nematodes population in rice field. All the soil organic amendments led to reduction in population of *Pratylenchus zeae*, *Helicotylenchus multicinctus*, *Hirschmaniella oryza*, *Hoplolaimus clarissimus, Rotylenchus* sp., *Xiphinema index*, *Trichodorus* sp. and *Criconemoides* sp. *Meloidogyne incognita* and *Tylenchus* sp. Neem leaf powder and chicken litter suppressed nematode populations the most, of all genera recovered. This finding agrees with the report of Olabiyi and Oladeji (2014) who stated that the use of neem compost reduced the population of nematode associated with okra. In a similar work Agu (2008) also stated that the use of chicken litter significantly suppressed plant-parasitic nematodes associated with pineapple. Daramola *et al* (2013) also reported that chicken litter suppressed plant-parasitic nematode populations associated with pineapples. (Gonzalez and Canto-saenz, 1993). Chindo and Khan (1990) reported a significant reduction of root-knot nematode population and root gall index following the application of chicken manure on tomato. Akhtar (1998) reported the effect of two neem-based as they significantly decrease the number of phyto-parasitic nematodes in tomato. Neem contains various compounds that are toxic to many groups of insects, arthropods, as well as nematodes. Among these toxic compounds, azadirachtin, a triterpenoid of the limonoid class, is the most active compound for the inhibition of nematode development (Mordue *et al*., 2005).

Table 1a: Effect of organic amendments on plant-parasitic nematodes population associated with rice field in Makurdi

Treatment	*Criconemoides*		*Helicotylenchus multicinctus*		*Hirschmaniella oryzaea*		*Hoplolamimus clarissimus*		*Pratylenchus zeae*	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Cattle Dung	48.00^{a}	118.99^{a}	268.00^{c}	773.30^{b}	1203.30^{b}	2625.00^{b}	53.00^{c}	538.00^{c}	998.90^{b}	1847.00^{b}
Chicken Litter	39.67^{a}	113.70^{a}	163.30^{d}	648.70^{c}	667.00^{e}	1398.00^{bc}	148.00^{b}	500.00^{d}	403.09^{c}	1265.00^{d}
Neem Leaf Powder	26.67^{b}	34.00^{b}	134.70^{d}	96.70^{e}	83.30^{g}	1252.00^{c}	32.30^{cd}	118.70^{f}	215.00^{d}	1118.00^{d}
Eucalyptus Leaf Powder	38.33^{a}	119.70^{a}	292.00^{c}	536.30^{d}	992.30^{c}	2155.00^{bc}	100.00^{bc}	640.00^{a}	889.80^{b}	1982.00^{b}
Goat dropping	48.67^{a}	120.00^{a}	167.30^{d}	780.00^{b}	900.00^{d}	2465.00^{bc}	185.00^{b}	262.00^{e}	999.06^{b}	1629.00^{c}
Moringa Leaf Powder	40.00^{a}	121.70^{a}	611.30^{a}	692.00^{bc}	600.70^{f}	2217.00^{bc}	103.70^{bc}	183.70^{g}	941.20^{b}	1655.00^{c}
Check	17.30^{c}	9.30^{c}	35.00^{e}	41.30^{f}	34.70^{h}	61.00^{d}	17.30^{d}	25.70^{h}	22.40^{e}	51.00^{e}
Control	44.33^{a}	119.30^{a}	507.30^{b}	1135.00^{a}	1438.00^{a}	4561.00^{a}	450.70^{a}	664.00^{a}	1785.00^{a}	3750.00^{a}
F.Pr ($p \leq 0.05$)	0.01	0.043	0.03	0.028	0.001	0.01	0.01	0.013	0.001	0.041
Grand Mean	37.87	94.59	272.36	587.91	739.91	2091.75	136.25	366.51	781.81	1662.13
CV (%)	26.69	45.05	67.29	57.93	63.11	58.19	95.57	63.43	66.76	58.43

Mean values with the same alphabet in a column are not significantly different from each other at p.> 0.05; CV = Coefficient of variation

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Treatment	*Rotylenchus* sp.		*Trichodorus* sp.		*Tylenchus* sp.		*M. incognita*		*X. index*	
	2021	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**	**2021**	**2022**
Cattle Dung	425.30[b]	512.53[b]	142.33[d]	180.26[b]	133.70[b]	85.11[b]	3769.00[b]	2506.20[c]	280.30[a]	199.80[a]
Chicken Litter	519.30[a]	422.10[c]	263.67[b]	172.26[bc]	244.00[a]	79.94[b]	1382.00[e]	2123.06[d]	225.30[b]	126.09[ab]
Neem Leaf Powder	65.70[c]	218.60[e]	29.33[f]	89.33[e]	27.00[e]	30.80[c]	2336.00[d]	2000.31[d]	165.70[c]	98.03[c]
Eucalyptus Leaf Powder	195.30[d]	331.05[d]	137.33[d]	153.00[c]	43.30[d]	27.30[c]	3008.00[c]	2890.04[bc]	83.00[d]	171.00[b]
Goat dropping	224.30[c]	314.00[d]	53.67[e]	182.24[b]	99.70[c]	89.82[b]	3562.00[bc]	3793.33[b]	56.70[e]	110.70[b]
Moringa Leaf Powder	277.30[c]	343.11[f]	171.67[c]	101.08[d]	109.00[c]	80.40[b]	3061.00[c]	2889.50[bc]	214.70[b]	181.22[ab]
Check	38.30[d]	69.06[g]	21.20[g]	14.00[f]	26.70[e]	7.08[d]	67.00[f]	481.90[e]	21.00[f]	21.00[d]
Control	441.00[b]	621.00[a]	332.00[a]	276.00[a]	258.30[a]	103.27[a]	6809.00[a]	4601.00[a]	275.70[a]	121.04[ab]
F.Pr ($p \leq 0.05$)	0.014	0.037	0.021	0.012	0.025	0.015	0.031	0.001	0.003	0.023
Grand Mean	273.31	353.93	143.90	146.02	117.71	62.97	2999.25	2660.67	165.30	128.61
CV (%)	60.48	44.99	72.41	50.08	72.59	52.85	61.34	43.36	56.93	41.27

Table 1b: Effect of organic amendments on plant-parasitic nematodes population associated with rice field in Makurdi

Mean values with the same alphabet in a column are not significantly different from each other at p.> 0.05; CV = Coefficient of variation

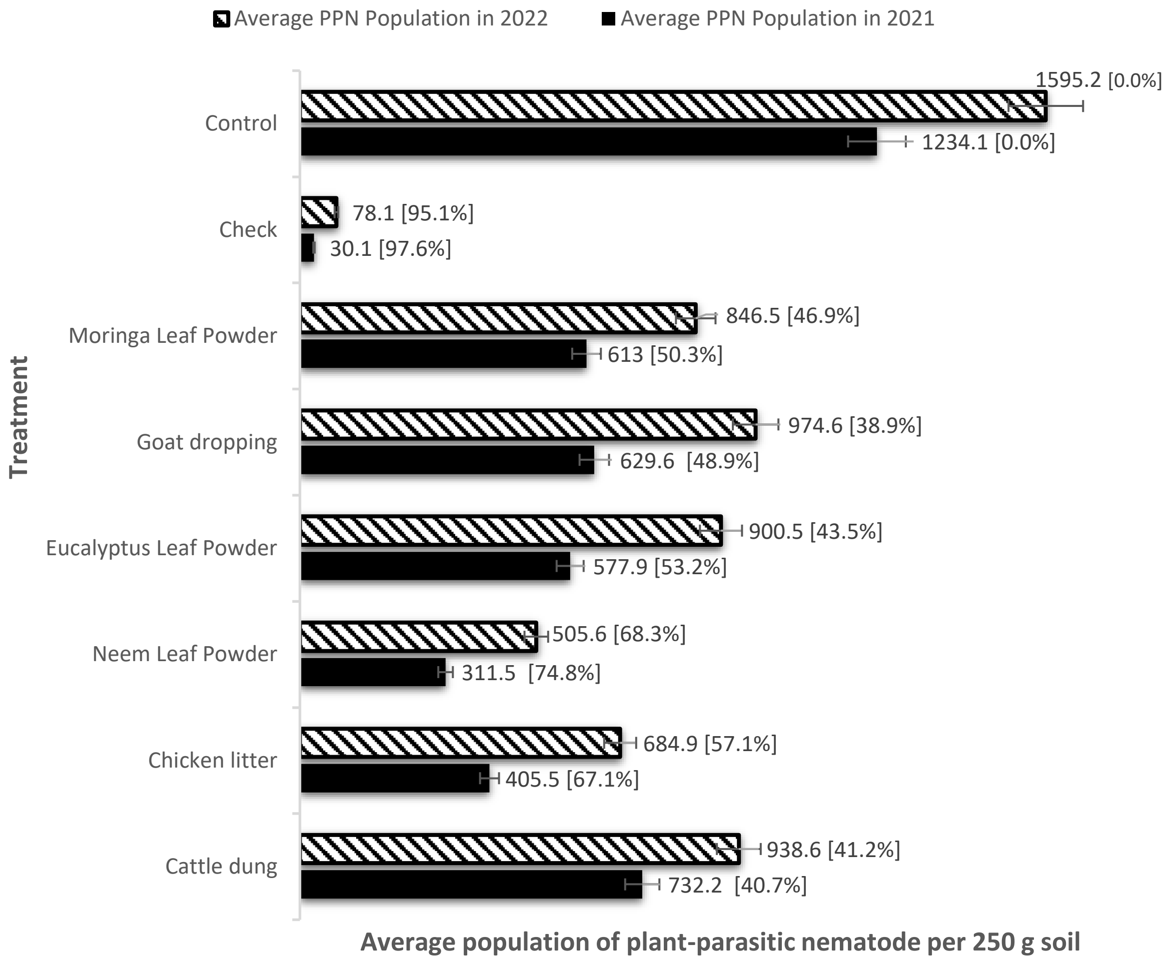

Figure 1: Effect of amendment on average plant-parasitic nematodes associated with rice

According to Nisa *et al*. (2021), population and diversity of nematode communities are affected by the addition of organic matter and also saprophytes increase as Riegel and Noe (2000) reported that suppression of nematodes by chicken litter is probably a combination of microbial activity and constituent toxicity to nematodes. Chicken manure contains a significant amount of nitrogen, the majority of which is in the form of uric acid that can be easily converted to ammonia, which is mortal to plant-parasitic nematodes. Amulu and Adekunle (2015) reported that addition of cow dung in *M. incognita* infested soil sown to okra reduced the population density of *M. incognita* and increased the yield of okra. Dushyant *et al.* (2017), reported suppression of root gall formation on rice root in field due to application of combination of neem cake + vermicompost.

In a previous study, eucalyptus leaf, leaves, stem, bark and fruit exerted lethal effects and resulted in mortality of *M. javanica* juveniles (Shahnaz *et al*, 2007) and this is in agreement with findings from this study even though eucalyptus leaf powder showed comparatively lower effectiveness in percentage mortality compared to neem leaf powder, chicken litter, moringa leaf powder and goat dropping that showed high percentage mortalities. A crude extract from fruits of *E. globulus* showed strong antimicrobial activities (Pereira *et al.* 2014). Results obtained in this current study are in line with the finding of Damjanovic-Vratnica *et al*. (2011) who reported a high antimicrobial potential for the of *E. globulus* in comparison with some used antibiotics (ceftriaxone, amykacine and tetracycline).

The nematicidal effect of organic manures on plant parasitic nematodes could be attributed to many factors. Among which is the direct effects of chemicals produced during manure decomposition such as ammonia, hydrogen sulphide, methane, fatty acids with low molecular weight like acetic, propionic, dimethylamine, trimethyamine and butric acids as well as phenols (Oka *et al*, 2000). Tanimola and Akarekor (2014) revealed that animal manures like poultry and goat manures have been successful tools for controlling root knot nematode, *M. incognita* and increase crop yield of cucumber plants therefore, may be used in place of oxamyl.

CONCLUSION

The current study has also established that Neem leaf powder and Chicken litter at a rate of 5 t/ha respectively reduced the activities and damaging effects of nematodes on the rice field. The use of this organic amendment could be incorporated into the management tools for nematode control. The use of Neem leaf powder and chicken litter has proven to be effective against PPNs and therefore be recommended for used in nematode management.

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