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Effect of Neem Sawdust on Eggplant (*Solanum melongena* L.) Yield with Root-Knot Nematode Populace

Asgar Ali*[1] and Kamal Singh[2]

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ABSTRACT

Sawdust is an important industrial waste product derived from neem (*Azadirachta indica*) wood that has environmental consequences along with economic viability, so it can be intricately used to boost crop growth and yield by boosting some of the physico-chemical properties of the soil with moisture and nutrient pool reversal. Because of the production of so many organic chemicals with nematicidal potential, the presence of neem sawdust (NSD) also mitigates the root-knot nematode populace. All eggplant yield parameters (number and weight of flowers, fruits, and seeds) were increased by up to 30% decomposed NSD levels. Decomposed NSD has been proven to be hazardous to eggplant yield at concentrations of more than 30%. All of them, meanwhile, is significantly inhibited by the existence of the root-knot nematode. Regrettably, subsequent sawdust additions drastically decreased yields, since no flowering or fruiting was seen with NSD amendments comprising 80 to 100% NSD. As compared to the control or the 3500 and 4000 inoculum levels, the 3000 nematode inoculum level showed the greatest suppression of yield. Apparently, nematode inhibitory effects on yield have always been steadily mitigated; up to a 30% degraded NSD concentration. Varying degraded NSD levels must affect the nematode population. The population of nematodes in roots, soil, and total nematode population flourished up to 3000 nematode levels and even declined, although somewhat insignificantly, at 3500 and 4000 levels. All of the NSD additions reflected such a population boom. Throughout all NSD additions, the number of eggs per egg mass (i.e., fecundity) was dramatically decreased. It must have been likewise boosted to 3500 nematode levels before being diminished in successive nematode inoculums. The reproduction factor had already been steadily decreasing across both directions. That seems to be either immense sawdust additions or perhaps even nematode inoculum levels. As a consequence, we may still infer that the NSD amendments boost yield by up to 30% based on observed yield trends. But from another aspect, it has been demonstrated that its addition is harmful to the nematode population. As somewhat of a result, overall implementation of NSD addition was indeed feasible since it limited the pest populace even while boosting yield.

***Key words*:** Fecundity, Neem, Population, Root-knot nematodes, Reproduction factor, Sawdust, Yield

Neem sawdust is a diverse economic byproduct with far too much environmental friendliness, including potential adverse effects on existent flora and fauna within the vicinity. Growing crops are also much more likely to be influenced by growth and yield characteristics as a result of their stresses, which may have been mitigated while also optimizing soil physico-chemical status, as well as possibly some moisture and nutrient pool boosting [1-2]. The acquisition of decomposing sawdust serves as an external reservoir of organic matter in the soil, consequently sustaining soil structure and fertility. Its decomposition produces compost inside the soil, boosts cation exchange capacity, and diminishes the leaching of nutrients through the subsoil [3-4]. Decomposed sawdust diminishes bulk density while boosting the porous structure, pH, water retention characteristics of the soil such as hydraulic conductivity, plant usable water, and water-holding capacity [5]. Reports on its (NSD) nematicidal action are almost always attainable owing to the presence of far too many organic chemicals, something which assists in the control of the nematode population [6-10]. Apart from the nematicidal consequences, the triterpene compounds contained in NSD hamper the nitrification process, increasing the supply of nitrogen to developed plants by the same amount [11]. Even significant reduction with neem sawdust has previously been found to be beneficial in facilitating the root-knot nematode elsewhere in the field or a pot [12].

Vegetables play a vital role in every day's human diet as they are an important source of vitamins, minerals and proteins. Among the vegetables, eggplant (*Solanum melongena* L.) is the second most important vegetable crop, next to potatoes, in

* **Asgar Ali**
✉ aliasgar5383@gmail.com

[1-2] Department of Botany, D. S. College (Dr. Bhim Rao Ambedkar University), Aligarh - 202 001, Uttar Pradesh, India

respect of grown acreage and production. Under natural and greenhouse circumstances, it is a commercially significant and widely farmed crop throughout most of the world's subtropical and tropical zones [13]. In 2012, China, India, Iran, Egypt, and Turkey produced 90% of all eggplant [14]. It's yearly harvesting of eggplant was indeed 1,864,556 acres, putting the country tenth in vegetable production globally in 2018 [13]. Whenever the fruit matures, it should always be plucked as early as possible since any time delay enhances the bitterness of the seeds therein, resulting in inferior fruits. Apart from its use as a vegetable, it is also useful in the prevention and treatment of so many diseases [15-16]. Its anti-oxidant potential inhibits cancerous growth [17], protects against cardiovascular disease, and prevents respiratory infections [18] along with traditional nutrient content and perhaps other health-promoting bioactive compounds [17-19], they seem to have a high concentration of phenolic acids [20-21], that are beneficial to human health [22-23]. Eggplant is rich in carbohydrates, dietary fibers, including minerals, low in calories, does indeed have moderate protein content, and includes various vitamins [24]. Even with its non-starchy nature or even high fibre content, its fruit has therefore been suggested by different governmental organisations that help prevent possible type 2 diabetes [25-26]. Because although functional components of eggplant, nasunin [27], aminobutyric acid [28], and chlorogenic acid [29-30] have previously been demonstrated, nasunin, an eggplant purple pigment, possesses antioxidant properties [31]. GABA possesses antihypertensive as well as relaxing actions [32]. CA is by far the most prominent polyphenol ingredient, possessing anti-diabetic, anti-hyperlipidemic [33], as well as hepatoprotective [34] instincts.

The root-knot nematode (*Meloidogyne* spp.) is by far the most economically valuable parasitic genus amongst plant-parasitic nematodes. These seem to be obligatory root parasite microorganisms with something like a wide geographic range of risks that could potentially infect virtually most crop species as well as damage mainly horticultural commercial field crops [35]. *Meloidogyne* spp. infested over 97 percent of the fields, and 100 percent frequency of occurrences of them was also quantified in the suburb of Aligarh [36-37]. Under the appropriate circumstances, nematode populations in the soil might dramatically multiply [38]. This genus has over 100 species that have been identified [39]. *Meloidogyne incognita*, *M. javanica* and *M. arenaria* seem to be three of them which have always been ubiquitous in Aligarh and pose a significant threat to crop growers [37]. The root-knot nematode potentially causes yield losses of up to 60% to 90% in potatoes, tomatoes and eggplants [40]. Moreover, in India, root-knot nematode caused an annual loss of around 10%–42% of eggplants [10]. *M. arenaria* might just cause yield losses of up to 100% across infected crops [41])]. Following are the main four major species (*M. arenaria*, *M. incognita*, *M. hapla* and *M. javanica*) that cause severe yield losses in numerous crops [42].

The root-knot nematode reportedly causes a global loss exceeding $100 billion each year [43]. Despite their rapid mobility and even the possession of a stylet, their second-stage juvenile (J2s) seems to be the infectious stage (Fig 4b). They established feeding sites after piercing the root vascular cylinder [44], eventually penetrating the cortical cells and metamorphosing into J_3+J_4 stage juveniles. Own future growth has now become dependent on the quality and amount of food available to produce either as a male or female. Because whenever juveniles mature into males, they will migrate into the soil and eventually die [35]. They transform into females (Fig 3b) and establish in a site in the host root to get nutrients and carbohydrates, enabling subsequent good establishment. Because of their permanent establishment, the cortex cells maintain an intimate relationship mostly with the host plant, and so, as a result of the re-differentiation, these cortical cells are becoming syncytial as well as hypertrophied giant cells. More such cells seem to be the nematode's primary source of carbohydrates as well as nutrition and therefore are required for growth and reproduction [45]. As a consequence, hyperplasia of nearby root cells results in the formation of the gall (root-knot) as a below-ground symptom (Fig 2a) on host roots and easily recognised above-ground symptoms such as wilting, stunted growth, yellowing (Fig 2b-c) through patches, reduced flower and fruit sizes on host plant shoots [46-47].

Root-knot nematode seems to be a challenging issue affecting global agricultural production, causing yield, quality and quantity losses. In consideration of all this, the present research work was conducted to determine potential efficiency using botanicals in the management of root-knot nematode. Regrettably, because of their broad host range, their self owns control through other means is restricted. As something of a consequence, alternative management tasks focused even more on environmentally resilient and sustainable food production must always be developed and implemented. Organic amendments, something that mitigates yield losses, boost profitability, as well as results in more sustainable food production, are often the most environmentally friendly, sustainable and cost-effective strategy for controlling the root-knot nematode disease. Apart from organic amendments, there are some other environmentally safe effective ways to reduce nematodes, including weed eradication, summertime ploughing, soil solarization, and hence the implementation of resistant cultivars. There are already several publications regarding effective management of the root-knot nematodes employing the neem parts [48- 53]. NSD has since been proven to be an important industrial byproduct of wood processing. Amongst some of the aforementioned plants, neem parts are extensively employed to combat root-knot nematodes. As somewhat of a consequence, NSD substrates seem to have the potential to be a unique alternative to peat-growing media for greenhouse production profitability. Hours are usually required to complete its own (NSD) usability test against all of the various crops.

This work discusses the findings of our research experiment during which sawdust derived from neem (*Azadirachta indica*) was used to manage *Meloidogyne arenaria* race 1 infected eggplant. As a result, it will then be evaluated as an efficient and environmentally friendly organic matter possessing nematicidal properties. The use of synthetic nematicides contains the following limitations regarding nematode management; hence any safe and sustainable approach for management should be investigated. Managing nematode losses to crops can make NSD more relevant. The present work's main objectives are just to evaluate eggplant yield and root-knot population under NSD stress.

MATERIALS AND METHODS

The study was conducted in the Botanical Garden, Department of Botany, Faculty of Life Science, D. S. College, Aligarh, which is affiliated with Dr. Bhim Rao Ambedkar University Agra, Uttar Pradesh, India.

Collection and Sterilization of soil

Soil for this experiment was acquired from an uncontaminated agricultural field at approximately 20 cm depth, following the elimination of the top of the litter existent. This soil is subsequently delivered into the research lab in plastic bags. The soil was subsequently hydrated before being placed in a cut drum, sealed, and heated to a temperature of 80°C, which was maintained for approximately 20 minutes. After it has cooled, the soil is placed inside uncontaminated clay pots with perforated bottom. The soil comprised sandy loam with a pH of 6.7, 66% sand, 25% silt, 8% clay, and 2% organic matter.

Fig 1 (a) Closed flowers on eggplant, (b) Open flower on eggplant, (c) Fruting on eggplant

Fig 2 (a) Galls on root sytem of eggplant, (b) Stunting of eggplant shoot with curly leaves, (c) Yellowing of eggplant leaves

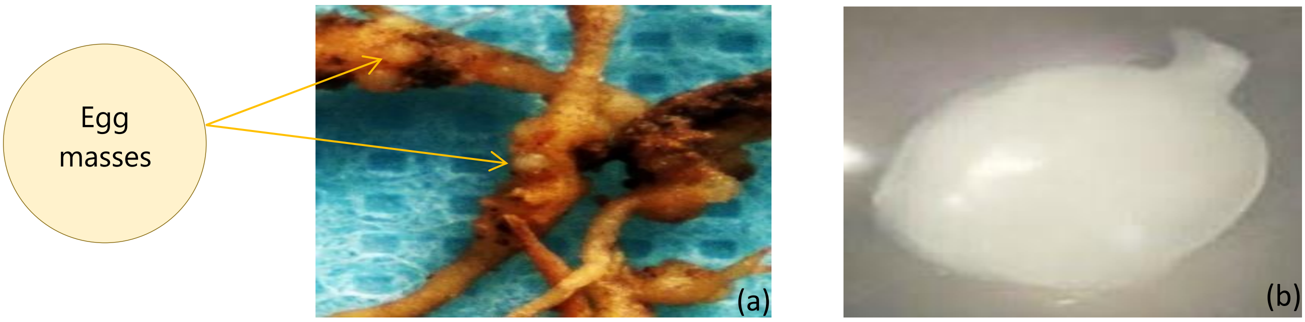

Fig 3 (a) RKN egg masses withgalls on dameged roots of eggplant, (b) Excised female

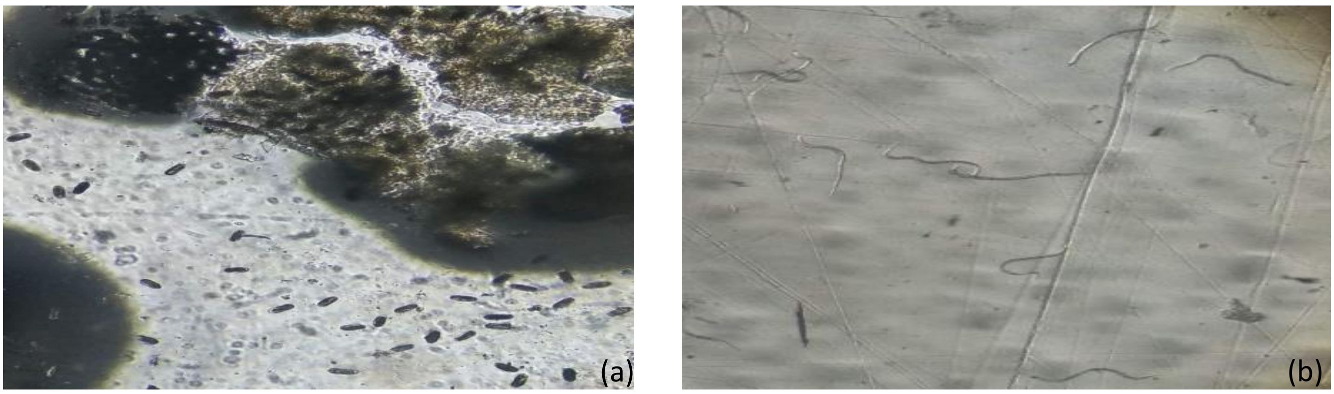

Fig 4 (a) Excised eggs with ruptured egg mass of RKN, (b) Second stage juveniles of RKN

NSD collection

The NSD used in this experiment was obtained from a sawmill in Sikandra Rao, Tehsil of Hathras district, Uttar Pradesh, India. NSD was retrieved and left to decompose in an elevated excavation for three months. Following decomposition, the sawdust was compiled and blended with sterile agricultural field soil. Ingredients are subsequently blended throughout the proper proportions to attain their varying concentrations (0%, 10%... 100% w/w). For at least a week, this mixture was left to dry in direct sunshine.

Preparation of the Pot

The clay pots used to fill the mixture were 25cm in height × 30cm in diameter. To maintain adequate circulation of water as well as air during the peak of plant growth, an aperture was created in the centre of the basal area of each pot. Taking into account the entire amount of sterilized soil and NSD mixture, this is again 3kg per pot. Pots containing all levels of the combination were autoclaved for 12-19 minutes at 20 lbs of pressure in an autoclave heated to 120 degrees Celsius.

Host plant and seedling preparation

As a test plant, an eggplant was adopted (*Solanum melongena* L. var. Pusa Kranti). Its seeds were acquired from the National Seed Corporation (NSC), IARI, (PUSA) Campus New Delhi, India. Before seeding, they were surface sterilized for two minutes with 0.01% $HgCl_2$. In the greenhouse, botanical garden of the department of botany, D. S. College, Aligarh (U.P.), India, sterilized seeds are sown in autoclaved soil stuffed clay pots. At the three-leaved stage, seedlings were grown in autoclaved soil in clay pots for fifteen days.

Pure culture and inoculation of the root-knot nematode

After surveying the infested regions, a root-knot nematode must have been handpicked as the test pathogen among severely infected roots of eggplant selected from the suburbs of Aligarh (U.P.), India. A single egg mass (Fig 3a) was placed in a petri dish, and the same female from the galls was excised and identified as *Meloidogyne* species, considering the morphological features of the perennial pattern underneath the stereo-microscope. After the confirmation of *Meloidogyne arenaria* race 1, egg masses were retrieved from the severely diseased root and allowed to rest in a tiny coarse sieve (1 mm hole size) covered in tissue paper before hatching in a 10 cm diameter petri dish with double distilled water. After hatching in a petri dish, the second-stage juveniles (J2) were inserted into newly developed eggplant seedlings (*Solanum melongena* L.). After 45 days, the egg masses are subsequently sub-cultured in just the same manner to achieve the needed number. To obtain adequate inoculum, they were once again inoculated onto fresh eggplant roots. The roots have always been uprooted, cleaned up, and cleansed using tap water before even being trimmed down to the 2cm portion size for even further testing. Their eggs (Fig 4a) were retrieved using sodium hypochlorite. These eggs were subsequently induced to hatch in the distilled water petri dish. *Meloidogyne arenaria* second juveniles (J2) were retrieved after approximately 24 hours and will be used for future studies. Previously grown 15-day-old or three-leaf stage eggplant seedlings were transplanted into clay pots containing varying percentages of sterile soil containing decomposed NSD after two weeks into the bouts of depression (1.5 cm × 3 cm × 4 cm) formed in the soil. To ensure optimal growth, these seedlings were irrigated just on alternate days. After one week of treatment, seedlings were allowed to be treated with root-knot nematodes. The suspension was placed in a pipette subsequently inoculated around the bases of eggplant seedlings in sterile clay pots containing NSD amended soil according to the treatments. Similarly, different amounts of suspension were pipetted up into different clay pots containing a mixture of agricultural field soil and NSD to make different nematode inoculation treatments of 0, 500, 1000, 1500, 2000, 2500, 3000, 3500, and 4000 inoculum levels as designated.

Experimental design

All experimentally sown pots were spread on greenhouse benches at (30±2°C) at botanical garden D. S. College, Aligarh. The experiments were carried out in completely randomized blocks. Their randomized complete block design (CRBD) was used. Each treatment got five repetitions, with or without the NSD and/or nematode. These treatments were just as follows: decomposed neem sawdust was thoroughly mingled with sterilized agricultural field soil @ 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% to require a total quantity of soil of 3 kg at a height of 25 × 25 cm in diameter, and the height of clay pots, respectively. Every soil and NSD mixture treatment was inoculated with different inoculum levels (i.e., 0, 500, 1000, 1500, 2000, 2500, 3000, 3500 and 4000). Without neem sawdust and nematode amendments, pots were kept as a control. All the pots were arranged on the benches in the greenhouse, where an averaged optimum temperature was maintained.

Watering, weeding and harvesting

The pots were irrigated on a regular schedule in the evening to maintain a conducive environment for growth. Carefully thinning the weeds with our hands, we managed to retain enough to keep all the pots weed-free. To get rid of undesired plants, pots were thinned every week regularly. After 91 days of growth, eggplants were harvested and evaluated for a range of characteristics.

Yield parameters

Number of flowers, fruits and seeds

Plants were carefully uprooted for harvesting, taking good care not to damage the fibrous roots. Visual observations, as well as measurements of either the plants in each pot, were obtained, as well as yield data were recorded. The number of flowers and fruits (Fig 1a-c) were counted five times in the final two days at a 13-day interval for each duplicate independently, and an average yield was computed for each treatment. The number of seeds was quantified after the crop harvest using the wet seed extraction method [54].

Fruit and seed weight determination

A standard technique was also used to determine the fruit weight. Since the crop plants were terminated, the weight of the fruits was expressed in grams per plant. Following seed extraction from the subsamples of each treatment, one hundred extracted seeds from each fruit were taken into account for seed weight determination. Seeds were dried at room temperature in the shade and weighed using an electronic scale, with their mean findings represented in grams.

Parameters of root-knot nematode (RKN)

RKN populace in soil

At the end of the experiment, the roots of the uprooted plants have indeed been thoroughly rinsed with wash water from the tap, and now the whole root system is being viewed again with the naked eye. A modified version of Cobb's decanting and sieving procedure, followed by Baermann's funnel technique, was used to determine the population of *M. arenaria* [55]. The soil was collected from each of the five duplicate root zones. The sample of soil from each pot was mixed as well as sifted through a coarse sieve, as well as 1 kg was housed in a plastic bucket containing 10L of water. The soil and water mixture were stirred and allowed to remain for approximately 1-2 minutes. This suspension was decanted through three sieves with meshes of 60, 200 and 400 mesh, as well as the collection from the fine nesting sieve was gently cleaned and passed to a beaker. In a Baermann funnel filled with water, a small coarse sieve comprising two layers of wet paper towels was stored. The beaker's nematode suspension was gently placed onto the sieve as well as allowed to stand overnight. The nematode juveniles migrated through the paper holes into the water and subsequently settled at the bottom of the funnel's rubber tubing as just a consequence of their wriggling motions. The nematode suspension retrieved from the Baermann funnel was subsequently added to the beaker as well as counted under a stereomicroscope in a counting dish.

RKN populace in roots

Again, for measurement of nematode populations in roots, roots were properly cleaned to eliminate them from adherent soil. One gram of root samples was collected from different nematode-treated plants, were macerated with the appropriate amount of water, subsequently stained with acid fuchsin as well as destained with lactophenol, a routinely used procedure [58]. Under a stereomicroscope, the stained roots were squeezed between two glass slides, as well as the diverse development stages of the nematode (J_2 and J_3+J_4) were viewed and enumerated. The total number of J_2 and J_3+J_4 throughout the whole root system of the replicate was computed and afterward summed. One gram containing root pieces was placed to 5% HNO_3 and incubated at 25ºC to quantify the number of females. The females were gently teased out from the root pieces after 72 hours. The overall number of females was counted per grams of the root, as well as the overall number of females for the whole root system was computed. The repetitions' average has also been computed.

Fecundity

Fecundity is defined as the total number of eggs in a particular egg mass. It was computed by vigorously shaking 10 egg masses in a solution of 5.25 percent NaOCl (sodium hypochlorite). These eggs are subsequently extracted from the egg mass as well as passed through a 5,000 mesh sieve. The eggs were poured into a beaker with 100 mL of water from the sieve as well as dyed with 0.35% acid fuchsin (in 25% lactic acid), having 20 to 25mL of suspension heated for 1 minute to stain the eggs. Following cooling, 1mL of the solution was then transferred to a counting dish, and now all types of eggs (healthy, fungus-invaded, or damaged), as well as eggs per egg masses, were counted underneath a stereomicroscope to quantify fecundity [56].

Total nematode population

The total population of nematodes across all samples was computed by adding the population in soil and root by its number of eggs, as well as an average of the counting including all stages of multiplication was computed.

Reproduction factor

The reproduction factor of root-knot nematodes was estimated using the formula RF = pf/pi, where pf, as well as pi, indicate the final and beginning populations of nematodes implemented (inoculum levels of J_2), respectively [57].

Statistical analysis

By processing the data via Analysis of Variance, all enumerated data was subjected to two factorial least significant differences (LSD) analysis (ANOVA). R software was used to do this two-factorial and interactive analysis at 5% (P=0.05).

RESULTS AND DISCUSSION

Plant yields

Overall plant yield parameters (number of flowers, fruits, seeds, and weight of fruits and seeds) continued to rise to 30% decomposed neem sawdust (NSD) levels, as shown in (Table 1-3).

Table 1 Effect of neem sawdust and different inoculum levels of *M. arenaria* on number flowers and fruits of eggplant

Neem sawdust (%)	Numbers	Control	Inoculum levels								
			500	1000	1500	2000	2500	3000	3500	4000
0.0	Flower	15.00	13.00	11.00	10.00	9.00	8.00	7.00	9.00	8.00
	Fruit	13.00	11.00	10.00	9.00	8.00	7.00	6.00	8.00	7.00
10	Flower	16.00	14.00	13.00	11.00	10.00	9.00	8.00	10.00	9.00
	Fruit	14.00	12.00	11.00	10.00	9.00	8.00	7.00	9.00	8.00
20	Flower	18.00	16.00	14.00	13.00	12.00	10.00	9.00	11.00	10.00
	Fruit	15.00	14.00	12.00	11.00	10.00	9.00	8.00	10.00	8.00
30	Flower	20.00	18.00	16.00	14.00	13.00	12.00	11.00	12.00	10.00
	Fruit	17.00	16.00	14.00	12.00	11.00	10.00	9.00	11.00	10.00
40	Flower	14.00	12.00	10.00	9.00	8.00	7.00	5.00	7.00	6.00
	Fruit	12.00	10.00	8.00	7.00	6.00	5.00	4.00	6.00	5.00
50	Flower	13.00	11.00	9.00	8.00	7.00	6.00	4.00	6.00	5.00
	Fruit	11.00	9.00	7.00	6.00	5.00	4.00	3.00	5.00	4.00
60	Flower	11.00	10.00	8.00	7.00	6.00	5.00	4.00	5.00	4.00
	Fruit	10.00	8.00	6.00	5.00	4.00	3.00	3.00	4.00	2.00
70	Flower	9.00	8.00	7.00	6.00	5.00	4.00	3.00	4.00	3.00
	Fruit	8.00	7.00	5.00	4.00	3.00	2.00	0.00	1.00	0.00
80	Flower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	Flower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	Flower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD at 5%	Flower	Neem sawdust = 1.64			Nematodes = 1.44			Interaction = 3.83		
(P≤0.05)	Fruit	Neem sawdust = 1.13			Nematodes = 1.6			Interaction = 3.47		

Neem sawdust was demonstrated to be hazardous to plant yields at concentrations that exceed over 30% in all of the parameters mentioned above. Even from 40% to 100% NSD, these were detrimental in number as well as weight incrementally. Most such characteristics have the lowest value (zero) now for eggplant growing in pure decomposed NSD. Overall yield parameters must have been inhibited progressively because nematode density increased from zero (control) to the maximum level (4000 inoculums). Perhaps the highest suppression of blooming, blossoming, and seeding occurred at 3000 nematode inoculant levels, but it was substantially obscured at 3500 and 4000 nematode levels compared to 3000, but it was still higher than control. Both decomposing NSD-treated, as well as untreated eggplants, have substantially reduced eggplant yields. The nematode's suppression effects were significantly reduced as the level of decomposing NSD in the soil continued to increase. Decomposed NSD was shown to be hazardous for overall eggplant yields over more than a level of 30%. Subsequent sawdust amendments, on the other hand, reduced the yield considerably since no flowering as well as fruiting was documented in 80–100% of the NSD amendments. Regardless of the nematodes, their (flowering and fruiting) presence was completely missing in 80, 90 & 100% of the NSD amendments.

Table 2 Effect of neem sawdust and different inoculum levels of *M. arenaria* on weight of fruits and weight of 100seeds (g) of per eggplant

Neem sawdust (%)	Numbers	Control	Inoculum levels							
			500	1000	1500	2000	2500	3000	3500	4000
0.0	Fruit weight	1050.0	1010.0	1000.0	940.0	900.0	820.0	740.0	800.0	780.0
	Seed weight	4.50	4.12	3.80	3.55	3.05	2.35	2.00	2.22	2.05
10	Fruit weight	1100.0	1060.0	1040.0	1000.0	980.0	950.0	870.0	900.0	880.0
	Seed weight	4.60	4.50	4.30	3.75	3.58	2.70	2.50	2.65	2.58
20	Fruit weight	1260.0	1220.0	1200.0	1160.0	1100.0	1040.0	980.0	1030.0	1000.0
	Seed weight	4.90	4.80	4.70	4.15	3.86	3.60	3.08	3.25	3.10
30	Fruit weight	1600.0	1540.0	1470.0	1400.0	1370.0	1300.0	1200.0	1260.0	1220.0
	Seed weight	5.80	5.50	5.40	5.15	4.70	3.98	3.50	3.75	3.60
40	Fruit weight	1000.0	950.0	930.0	900.0	860.0	791.0	700.0	750.0	730.0
	Seed weight	4.01	3.78	3.29	2.98	2.50	2.25	1.91	2.10	2.05
50	Fruit weight	960.0	940.0	900.0	880.0	800.0	760.0	680.0	720.0	700.0
	Seed weight	3.20	3.10	2.92	2.70	2.41	2.06	1.70	1.82	1.73
60	Fruit weight	890.0	810.0	780.0	700.0	670.0	650.0	630.0	645.0	635.0
	Seed weight	2.90	2.59	2.30	2.20	2.10	1.70	1.30	1.50	1.41
70	Fruit weight	700.0	670.0	600.0	570.0	500.0	470.0	410.0	450.0	430.0
	Seed weight	2.10	2.06	1.95	1.75	1.50	1.30	1.00	1.20	1.10
80	Fruit weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Seed weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	Fruit weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Seed weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	Fruit weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Seed weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD at 5%	Fruit weight	Neem sawdust = 2.14			Nematodes = 2.04			Interaction = 3.43		
($P \leq 0.05$)	Seed weight	Neem sawdust = 1.83			Nematodes = 1.65			Interaction = 3.67		

Table 3 Effect of neem sawdust and different inoculum levels of *M. arenaria* on numbers and weight of 100seeds (g) of per eggplant

Neem sawdust (%)	Seed numbers	Control	Inoculum levels							
			500	1000	1500	2000	2500	3000	3500	4000
0.0	Seed number	1050.0	1010.0	1000.0	940.0	900.0	820.0	740.0	800.0	780.0
10	Seed number	1100.0	1060.0	1040.0	1000.0	980.0	950.0	870.0	900.0	880.0
20	Seed number	1260.0	1220.0	1200.0	1160.0	1100.0	1040.0	980.0	1030.0	1000.0
30	Seed number	1600.0	1540.0	1470.0	1400.0	1370.0	1300.0	1200.0	1260.0	1220.0
40	Seed number	1000.0	950.0	930.0	900.0	860.0	791.0	700.0	750.0	730.0
50	Seed number	960.0	940.0	900.0	880.0	800.0	760.0	680.0	720.0	700.0
60	Seed number	890.0	810.0	780.0	700.0	670.0	650.0	630.0	645.0	635.0
70	Seed number	700.0	670.0	600.0	570.0	500.0	470.0	410.0	450.0	430.0
80	Seed number	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	Seed number	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	Seed number	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD at 5% ($P \leq 0.05$)	Seed number	Neem sawdust = 3.14			Nematodes = 2.04			Interaction = 6.43		

Nematode populace

The nematode population was computed by averaging total counts of eggs, juveniles (J_2, J_3+J_4), males and females. Different concentrations of degraded NSD influenced them. The population of nematodes in the roots was substantially enhanced up to 30% NSD while still being suppressed under treatment of 40% – 60% NSD. Furthermore, the addition of NSD would prevent them from flourishing. But even though the population of nematodes inside the roots increased significantly up to 3000 nematode levels, it declined insignificantly at 3500 and 4000 levels. The population of nematodes in the soil as well as the total population of root-knot nematodes declined considerably as NSD levels increased. In 70% of such NSD treatments and no nematodes were found. The population of nematodes in the soil, as well as the total population of nematodes, steadily grew up to 3000 nematode inoculated treatments. Boosting the nematode inoculum dosage, on the other hand, minimized them (Table 4-5).

Table 4 Effect of neem sawdust and different inoculum levels of *M. arenaria* on fecundity and population of root–knot nematodes in roots (RNP) of eggplants

Neem sawdust (%)	RNP	Control	Inoculum levels							
			500	1000	1500	2000	2500	3000	3500	4000
0.0	RNP	0.0	1415.3	1998.4	2092.7	2455.1	2792.5	2966.6	2896.0	2817.2
10	RNP	0.00	1515.6	2068.7	2193.7	2560.3	2934.3	3085.3	3028.9	2975.0
20	RNP	0.00	1595.7	2156.5	2300.9	2648.1	3037.0	3205.9	3118.8	3061.9
30	RNP	0.00	1723.6	2270.5	2424.1	2756.7	3126.3	3309.3	3243.4	3148.9
40	RNP	0.00	1075.8	1310.9	1686.8	1737.7	1787.5	1955.8	1899.2	1864.1
50	RNP	0.00	760.9	862.8	1018.5	1218.8	1307.9	1490.8	1349.5	1323.3
60	RNP	0.00	553.2	624.0	705.4	780.3	885.4	1045.1	930.7	904.7
70	RNP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
80	RNP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90	RNP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	RNP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD at 5% ($P \leq 0.05$)	RNP	Neem sawdust = 2.03			Nematodes = 2.8			Interaction = 5.67		

Table 5 Effect of neem sawdust and different inoculums levels of *M. arenaria on* population of nematodes in soil and total population

Neem sawdust (%)	SNP TNP	Control	Inoculum levels							
			500	1000	1500	2000	2500	3000	3500	4000
0.0	SNP	0.000	1230.20	3490.20	4120.50	4995.80	5230.10	5310.30	5280.40	5240.30
	TNP	0.000	8977.00	16568.61	20137.24	24954.39	27230.56	28238.43	27981.88	27316.98
10	SNP	0.000	1156.00	2524.70	3465.70	3865.01	4040.05	4190.05	4105.05	4050.20
	TNP	0.000	7431.60	13591.17	17011.82	20789.96	22372.45	23411.09	22845.19	22513.27
20	SNP	0.000	1105.50	2090.40	2595.60	3129.10	3360.40	3530.80	3380.00	3415.30
	TNP	0.000	6412.62	9603.49	12166.88	13859.13	17328.83	18208.23	17783.62	17518.08
30	SNP	0.000	705.80	1410.60	1915.20	2511.60	2811.60	2915.30	2880.30	2740.30
	TNP	0.000	4610.58	7312.96	9533.30	12267.44	14205.06	14887.10	14578.51	14228.46
40	SNP	0.000	356.30	401.02	614.70	850.42	1010.50	1165.20	1110.30	1050.40
	TNP	0.000	2914.50	4038.48	5729.79	7218.18	8204.00	9107.35	8775.95	8486.80
50	SNP	0.000	110.20	228.30	318.40	435.80	580.30	609.85	595.21	582.54
	TNP	0.000	1801.82	2547.39	3700.7	4255.80	4760.11	5181.70	4900.97	4807.41
60	SNP	0.000	90.80	135.50	198.62	265.10	290.95	318.12	298.56	292.45
	TNP	0.000	1219.56	1614.49	2317.56	2722.32	3134.37	3526.94	3313.59	3178.41
70	SNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	SNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90	SNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100	SNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	TNP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LSD at 5%	SNP	Neem sawdust = 18.14			Nematodes = 11.04			Interaction = 32.43		
($P \leq 0.05$)	TNP	Neem sawdust = 20.03			Nematodes = 19.8			Interaction = 36.67		

Fecundity and reproduction factor

The presence of eggs per egg mass is usually known as fecundity (Table 6). Because of physically interacting, it was influenced by the existence of just about any addition. The concentration of neem sawdust (NSD) was steadily increased, resulting in decreased fecundity. It was diminished at any and all NSD levels generally, as well as the reduction was level dependent. Despite increasing NSD levels, no eggs inside the egg masses emerged. It became a slow boost to 3500 nematode levels before being decreased in subsequent inoculums. Eggs were determined to be negligible in egg masses treated with 70%, 80%, 90% and 100% neem sawdust levels. The reproduction factor was steadily diminished, including both scenarios of boosting sawdust or nematode inoculum amounts. At whatever inoculum level, none of the nematode populations occur in the treatments beyond 70% NSD. As a result of the NSD enhancements, the reproduction factor was diminished (Table 6).

Sawdust is mostly composed of carbohydrates and lignin, with a small content of carbon, hydrogen, oxygen, and nitrogen [58]. The incorporation of sawdust might well have given adequate carbon to soil microbes (bacteria and fungus) to be adequately acted upon by soil biota, hence boosting humification as well as decomposition mechanisms. Increased microbial engagement in sawdust amended soil may be associated with increased soil fertility alteration via composting of organic materials within the soil [59]. The eggplants demonstrated a significant improvement in yield due to the enhanced fertility of the soil, with at least a 30% increase in sawdust amendments in this type of soil. Enhanced neem sawdust yield of approximately 30% also was conceivable since its addition influences the physicochemical characteristics of the soil, improving the possibilities of macro-and micronutrient availability to the plants' required nutritional engagement. The soil adaptations caused by increased physico-chemical characteristics and nutritional status were most likely optimal at 30% sawdust additions. Numerous researchers have revealed that the addition of sawdust to soil boosts the yields of both leguminous and non-leguminous plants [60-61]. There have also been accounts of enhanced fruit size in sawdust-amended soil [62].

Table 6 Effect of neem sawdust and different inoculum levels of *M. arenaria* on reproduction factor (Rf) and fecundity (Fec)

Neem sawdust (%)	RF Fecundity	Control	Inoculum levels							
			500	1000	1500	2000	2500	3000	3500	4000
0.0	RF	0.00	17.95	16.56	13.42	12.47	10.89	9.41	7.99	6.82
	Fecundity	0.00	301.50	356.04	372.10	395.21	410.42	415.00	423.60	411.01
10	RF	0.00	14.86	13.59	11.34	10.39	8.94	7.80	6.52	5.62
	Fecundity	0.00	295.02	342.12	358.12	372.14	380.20	385.10	393.20	381.01
20	RF	0.00	12.82	9.60	8.11	7.92	6.90	6.06	5.08	4.37
	Fecundity	0.00	265.10	280.45	301.8	328.40	335.32	340.40	358.40	336.10
30	RF	0.00	9.22	7.31	6.35	6.13	5.68	4.96	4.16	3.55
	Fecundity	0.00	242.08	259.23	270.52	290.18	309.40	315.00	322.10	310.01
40	RF	0.00	5.82	4.03	3.81	3.60	3.28	3.03	2.50	2.12
	Fecundity	0.00	211.7	228.09	242.28	251.36	270.30	273.10	282.00	270.50
50	RF	0.00	3.60	2.54	2.46	2.12	1.90	1.72	1.40	1.20
	Fecundity	0.00	185.4	205.10	225.06	230.60	235.40	237.00	246.50	235.90
60	RF	0.00	2.43	1.61	1.54	1.36	1.25	1.17	0.94	0.79
	Fecundity	0.00	142.09	169.80	185.51	190.12	195.60	196.7	202.10	190.50
70	RF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fecundity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	RF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fecundity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	RF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fecundity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	RF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Fecundity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD at 5%			Neem sawdust = 1.34			Nematodes = 1.24		Interaction = 3.39		
($P \leq 0.05$)			Neem sawdust = 1.38			Nematodes = 1.65		Interaction = 3.7		

Overall, NSD from 30% onwards was shown to be inadequate for overall eggplant yields. The argument suggested for this inappropriateness would be that heavy metal accumulation may well have exceeded the threshold limit for eggplant growing in such NSD amended soil. Apart from that, the steady decline of eggplant yield may be correlated with an increase in alkalinity caused by the accumulation of some anions in NSD amended soil over the threshold range. For the aforementioned reasons, adverse effects on yield at higher NSD amendments can also be characterized by the development of toxicity leading to the incorporation of some phenolic compounds due to increased microbial activity [63-64]. Nitrogen impoundment at higher NSD levels might also be argued as one of the causes of poor yield allocations to eggplants. The microorganisms that decompose sawdust require food apart from carbohydrates, as well as substantial amounts of nitrogen [65] for energy requirements. However, because of the continual increase in sawdust amendments, the quantity of nitrogen has been gradually decreased. Soil micro-flora, as well as fauna, may not be enabled to perform to their full potential owing to the unavailability of nitrogen in the progressive NSD additions. And such nutrient-deficient soil is unsuitable for fostering healthy eggplant with a low yield. The disrupted photosynthetic system caused by a lack of adequate nitrogen for chlorophyll construction [66] in these kinds of NSD additions might also be stemmed from a legal cause other than the correct distribution of eggplants luxuriant yield. For tomatoes and eggplants, higher levels of NSD were observed to be phytotoxic [6]. In comparison to the control, the presence of root-knot nematodes considerably decreased the total assessed yield parameter. Previously, researchers [67] discovered root-knot nematode assault on many crops, resulting in a reduction in plant yield. Different plants of leguminous and non-leguminous crops were shown to have varying degrees of yield loss [67-69]. Nematode infections produce gall development as a result of hyperplasia and hypertrophy of adjacent cortical cells, which serve as transfer cells as well as provide food and resources to sedentary females. Sedentary females of root-knot nematodes sucked food continually from diseased roots with their stylets [46]. Consequently, food, as well as resources contained inside plants, might be channeled to nematode females, whereas the plants themselves could be allocated to declining health, resulting in much fewer flowers and fruits. Aside from that, nematodes cause extensive changes in the vascular tissues of plants, and the supply of water and nutrients has been reported to be greatly impaired [70]. Anatomical transformation, occurring due to nematode infection, also disrupts the continuity of xylem vessel elements [44]. Such plants appear to be incapable of transporting adequate minerals and nutrients to the areal portions of host plants, resulting in a considerable loss in yield. The metabolic alterations and altered host pathophysiology caused by the aforementioned anatomic modifications might potentially be accountable for decreased yield. Eggplant yield substantially declined up to 3000 inoculum levels but improved immensely at 3500 and 4000 inoculum levels. Ultimately, nematode destruction is extremely dependent on the nematode density levels adopted, with larger inoculum levels causing more harm. High nematode density levels may affect the water absorption capacity of the host plant. [71] was also reported that high root-knot nematode inoculation levels caused a sharp decline in net photosynthetic rate in tomato plants. At 3500 and 4000 inoculum levels, there may be the formation of an intraspecific competition amongst themselves for food and space and mating, to antagonize their damaging effect on the host plants which ultimately leads to some insignificant improvement in yield parameters.

In neem sawdust (NSD) mixed soil, the population of nematodes in roots, soil, as well as the total population of nematodes increased by approximately up to 30%. All of them, however, subsequently diminished under onward amendments. Improved water holding capacity [65] as well as soil porosity as a result of neem sawdust amendments might be argued as fascinating assumptions enabling free juvenile movement in the soil [72]. Even before compared to non-neem sawdust-supplemented soil, the unrestricted mobility of juveniles in porous and optimum water-content supplied 30% mixed neem sawdust soil would allow them to have a larger striking likelihood on roots. As a result of the facilitated mobility in such sawdust-amended soil, J2's interaction ability with the host root would most likely be multiplied. To successfully complete the life cycle, a higher number of ingressed second-stage juveniles (J_2) would be suddenly transformed into a greater number of J_3+J_4 juveniles, females and galls inside the host roots. All of these variables, separately or mutually, might be implicated again in the overall increase in the population of *M. arenaria* in roots. Due to a healthy interaction, three thousand inoculum levels are thought to be the best optimal threshold level for nematode proliferation in eggplant roots. These kinds of interactions were not most likely formed at increasing nematode inoculum levels (i.e., 3500 and 4000), and their populations were decreased dramatically in these treatments. The enrichment of macro-and micro-nutrients in minimal neem sawdust amended treatments [61] may well have led to better yield of the host plant. Plants in good health and status may have developed the ability to provide an appropriate and sufficient amount of food for the root-knot nematodes during their parasitic phase, leading to the latter growing healthier and multiplying conveniently. This seems to be evident from the data, as the aforementioned nematode parameters steadily increased by up to 30% neem sawdust.

However, fecundity, reproduction factor, and total nematode population were observed to be decreased in soil amended with any concentration of neem sawdust. Suppression of the aforementioned parameters, on the other hand, was neem sawdust concentration-dependent. Despite lower neem sawdust levels, suppression was lower than at higher neem sawdust levels. From 70-100% neem sawdust amendments, all of these variables were revealed to be zero. Of that kind, the nematode inhibiting effects of NSD can indeed be concerned with the production of phenolic compounds as a consequence of its degradation [63-64]. Because there is no exceeding of the threshold limit, these phenolic molecules may not be quite as harmful to nematode levels up to 60% amendment. This is why they have a presence of up to 60% NSD. Furthermore, they were all virtually nonexistent in subsequent NSD amendments, presumably because toxicity to nematodes might well have been enhanced, leading to the accumulation of these phenolic compounds in such treatments. Different phenolic compounds have been shown to dramatically diminish nematode egg-laying capability [64]. Additional consequences of such decreases might be the development and colonization of nematode natural enemies [73] in greater NSD amended soil. Steadily increasing nematophagous fungal colonisations, as well as reproduction, have been observed using NSD amended soil [74-76].

CONCLUSION

As a consequence of the above discussion, we might assume that neem sawdust (NSD) was extremely hazardous to the overall root-knot nematode disease here on the eggplant crop. According to the report, NSD increased the rate of overall improvement by up to 30%. As a result, the effects of NSD against root-knot nematode are conceivable if applied as a soil addendum at a lower dosage. Even though the disease was being controlled, reduced NSD levels boosted the growth. At higher levels, NSD reduced both eggplant yield and root-knot nematode population.

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Authors' contributions

AA and KS devised the experiment's goals and work strategy, as well as organized and authorized the necessary facilities. They also helped with the setup of the experiment. In the field and the lab, AA was in charge of all tabulation, computations, reviewing the data and writing the paper, as well as submitting and correcting it. KS provided helpful feedback and contributed to the development of the MS.

Conflicts of interest

The authors state that they have no conflicts of interest.

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