BIO AGENTS USED AS AN ECO-FRIENDLY MODULE FOR ROOT KNOT NEMATODE *MELOIDOGYNE INCOGNITA* MANAGEMENT IN BETELVINE (*PIPER BETLE*)

JAYAKUMAR, J.[1] – SENTHILKUMAR, T.[2*] – RAVICHANDRAN, V.[3] – GANAPATHY, S.[4] – SHANMUGAPRIYA, M.[5] – SENTHILKUMAR, P.[6] – MALATHI, G.[7*]

[1]*Krishi Vigyan Kendra, TNAU, Vriddhachalam, Cuddalore 606001, Tamil Nadu, India*

[2]*Krishi Vigyan Kendra, TNAU, Paupparpatti, Dharmapuri 636809, Tamil Nadu, India*

[3]*Regional Research Station, TNAU, Vridhachalam, Cuddalore 606001, Tamil Nadu, India*

[4]*Krishi Vigyan Kendra, TNAU, Tindivanam, Villupuram 604002, Tamil Nadu, India*

[5]*Dr. M. S. Swaminathan Agricultural College and Research Institute, TNAU, Eachangkottai, Thanjavur 614902, Tamil Nadu, India*

[6]*Horticultural College and Research Institute, TNAU, Paiyur, Krishnagiri 635115, Tamil Nadu, India*

[7]*Horticultural Research Station, TNAU, Yercaud, Salem 636809, Tamil Nadu, India*

**Corresponding authors*
e-mail: senthilkumar.t@tnau.ac.in; malathihort@tnau.ac.in

(Received 17th Aug 2024; accepted 18th Dec 2024)

Abstract. Betelvine is a commercially significant plantation crop in India. The consumption of betelvine leaves is a deeply rooted and widely practiced tradition in India. Numerous pests and diseases pose significant threats to betelvine production, including root knot disease caused by *Meloidogyne incognita*. Identifying suitable environmentally friendly bio-agents for nematode control has become essential for growers to ensure successful betelvine cultivation. Hence, field experiments were conducted to evaluate bioagents such as *Trichoderma viride, Bacillus subtilis, Pochonia chlamydosporia, Purpureocillium lilacinum* and Arbuscular Mychorhizae Fungi (AMF) against the root knot nematode under field conditions. The results revealed that all tested bioagents suppressed the population density of nematode in soil and roots. Application of *P. lilacinum* at 30 g/vine significantly minimized final nematode population and enhanced the plant growth. A second field experiment was conducted to optimize the effectiveness of the promising bioagent *P. lilacinum* (30 g/vine) along with organic amendments such as farmyard manure (FYM), press mud, neem cake, vermicompost, and *Calotropis* leaves with standard chemical check against nematode. The results indicated that application of *P. lilacinum* (30 g/vine) combined with neem cake (1 t/ha) significantly reduced the final nematode population in soil, roots. and improved the plant growth, yield, and leaf shelf life.
Keywords: *Purpureocillium lilacinum, Vettilai, organic amendments, nematode, neem cake*

Introduction

Betelvine (*Piper betel* L.) is one of the most important commercial plantation crops grown in India. It belongs to the family Piperaceae, commonly known as the Black Pepper family. It is a perennial, dioecious, evergreen climber, grown in tropical and subtropical regions for its leaves, which are used as a chewing stimulant. Betelvine is cultivated in many parts of the world for its leaves, which are often chewed with areca nut for their aromatic and stimulating taste. Betel leaves are also fetching high demand

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

in many other countries around the world. In India, the crop is extensively cultivated for its young leaves, which are consumed by approximately 15-20 million people nationwide. The betel leaf remains unique and uncompared even today (Guha, 2006). The crop is grown on about 55,000 ha, with an annual production valued at around 9000 million rupees (Kaleeswari and Sridhar, 2013). Additionally, betel leaves worth 30-40 million rupees are exported to other countries, contributing significantly to foreign exchange earnings. In India, Tamil Nadu ranks fourth in the total area under betel vine cultivation. The betelvine plant known as Pan, Nagaballi, Nagurvel, Saptaseera, Sompatra, Tamalapaku, Tambul, Tambuli, VakshaPatra, Vettilai, Voojangalata, etc., in different parts of the country (Guha and Jain, 1997). Betel leaves are also known for their medicinal attributes, as they contain vitamins, enzymes, thiamine, riboflavin, tannin, iodine, iron, calcium, minerals, protein, essential oil, and medicine for liver, brain, and heart diseases. Its leaves also contain anti-oxidant properties due to the presence of phenols; particularly hydroxychavicol. Betel leaves possess immune-boosting and anticancer properties.

Betel vine leaf production is affected by various biotic and abiotic stresses. Among the biotic stresses, plant-parasitic nematodes have been reported to be a significant concern for betel vine (Sandip et al., 2018). The root knot nematode *Meloidogyne incognita* and the reniform nematode *Rotylenchulus reniformis* are the most destructive nematodes in betelvine-growing areas (Jonathan et al., 1997; Jayant and Indira, 2004). In Tamil Nadu, the root knot nematode is particularly dominant (Maiti and Shivshankara, 1998) and commonly infests betelvine crop, leading to significant yield reduction (Sivakumar and Marimuthu, 1984; Acharaya and Padhi, 1988). These nematode damages the feeder roots, impairing the plant’s ability to absorb water and nutrients from the soil. Consequently, infected plants produce fewer leaves that are smaller in size. The yield losses due to the diseases caused by nematodes were estimated to be 3.9 to 40.28 percent (Maiti and Shivshankara, 1998) depending on severity of infestation. Root knot nematode *M. incognita* alone has been reported to cause 26 - 38 percent yield losses (Jonathan, 1990; Nakat, 1997) in betelvine.

Due to perennial nature of the crop, the roots are exposed to a wide array of micro-organisms like fungi, bacteria viruses and nematodes. The disease complex, interaction studies between *M. incognita* and *Phytophthora palmivora* revealed that root rot index was significantly high in the presence of nematode and fungus (Sitaramaiah and Devi, 1994; Jonathan et al., 1996). There was a reduction in plant height, root length, shoot and root weight, and the number of leaves per vine. It was observed that the nematode makes the vine more susceptible to the fungus *P. palmivora*, which infects through wounds caused by *M. incognita* (Marimuthu, 1991; Jonathan et al., 1996). Several studies have suggested using host resistance as an eco-friendly strategy to control nematode populations in betelvine. However, the effectiveness of varietal resistance may be compromised by new biotypes of *M. incognita*. Replacing susceptible cultivars with genetically resistant ones appears to be the most viable approach for nematode management. Unfortunately, no cultivars have been found to be resistant to root knot nematodes (Acharya and Padhi, 1988; Nakat and Madne, 1993). Pre-plant soil fumigation with methyl bromide or metham sodium is one of the most commonly used methods for managing nematode *M. incognita* in betelvine gardens. The main advantage of chemical control is its ability to reduce nematode populations to very low levels after application (Murthi and Rao, 1994; Nakat and Madne, 1993). However, the use of chemicals is restricted in betelvine gardens because the leaves are directly consumed as

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

fresh leaves. As a result, nowadays eco-friendly alternative strategies, such as applying nematode-antagonistic biocontrol agents, are becoming increasingly popular. Therefore, field studies were conducted to evaluate the effectiveness of biocontrol agents in managing *M. incognita* in betelvine gardens.

Materials and methods

Effect of bio control agents for the management of M. incognita in betelvine

Field experiment was conducted during 2021-2022 in root knot nematode, *M. incognita* sick field at Sugarcane Research Station, Tamil Nadu Agricultural University (TNAU), Sirugamani, Tamil Nadu, India. The biocontrol agents *Trichoderma viride*, and *Bacillus subtilis* used in this study obtained from Department of Plant Pathology, TNAU, Coimbatore, *Pochonia chlamydosporia* and *Purpureocillium lilacinum* received from Department of Nematology, TNAU, Coimbatore and Arbuscular Mychorhizae Fungi (AM fungi) was received from Department of Agricultural Microbiology, TNAU, Coimbatore. Each plot consisted of 50 vines arranged in a paired row system, covering an area of 5 square meters. Betel vine variety SGM1 cuttings were planted after treating with biocontrol agents as per the treatment schedule consisted of T_1-*T. viride*-10 g/vine, T_2-*T. viride*-20 g/vine, T_3-*T. viride*-30 g/vine, T_4-*B. subtilis*-10 g/vine, T_5-*B. subtilis*-20 g/vine, T_6-*B. subtilis*-30 g/vine, T_7-*P. chlamydosporia*-10 g/vine, T_8-*P. chlamydosporia*-20 g/vine, T_9-*P. chlamydosporia*-30 g/vine, T_{10}-*P. lilacinum*-10 g/vine, T_{11}-*P. lilacinum*-20 g/vine, T_{12}-*P. lilacinum*-30 g/vine, T_{13}-AM Fungi -10 g/vine, T_{14}-AM Fungi-20 g/vine, T_{15}- AM Fungi -30 g/vine, T_{16}-Standard check (Fluensulphone) and T_{17}-Untreated control. Nematode population in each plots were assessed before planting of bioagents treated cuttings. The cuttings were trained on Sesbania grandiflora, which provided support and shade for the betel vine. The experiment was conducted using a Randomized Block Design with seventeen treatments, each replicated three times.

Optimization of promising bio agents P. lilacinum for the management of M. incognita in betelvine

Second field experiment was conducted during 2022-23 to optimize the effectiveness of the biocontrol agent *P. lilacinum* (30 g/vine) selected from first field experiment for root knot nematode management in betelvine. The field experiment was carried out at Sugarcane Research Station, Tamil Nadu Agricultural University, Sirugamani, Taml Nadu, India. Field was selected in such a way that the field was naturally infested with *M. incognita* and planted with SGM 1 variety treated with T_1- *P. lilacinum* (30 g/vine), T_2- T_1 + FYM (12.5 t/ha), T_3- T_1 + Pressmud (1 t/ha), T_4- T_1 + Neem cake (1 t/ha), T_5- T_1 + Vermicompost (1 t/ha), T_6- T_1 + Calotrophis leaves (2.5 t/ha), T_7-Carbofuran (1 kg a.i/ha), T_8- T_1 + Soil drench with Velum prime (0.75 ml/litre of water), T_9-Untreated control. The initial nematode population of *M. incognita* in soil and root were assessed before imposing treatment. Every treatment in the trial experiment was replicated three times and it was set up in the randomised block design.

Nematode population

The plants were carefully uprooted 250 days after imposing the treatment. The decanting and sieving method (Cobb, 1918) was used to extract nematodes from soil

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

samples. A modified version of Baermann's funnel method (Schindler, 1961) was then used to extract juvenile second stages. Nematode population in the soil and root were recorded in pre-treatment and post treatment of both field experiments. The root gall index was estimated as 0-5 scale basis. Observations on nematode population were recorded in each replication. Data on nematode population in 250 ml soil, No. of females/g of root, No. of egg masses/g of root, No. of eggs/egg mass, Gall index (0-5 scale) were recorded.

Plant growth and yield parameters

Plant growth parameters were measured by assessing shoot length (cm), shoot weight (g), root length (cm), and root weight (g). Yield parameters observed were the number of leaves per vine per year, the weight of 100 leaves (g), leaf yield per hectare (lakhs), and shelf life (days).

Data analysis

All collected data were subjected to analysis of variance (ANOVA). Using IRRISTAT software version 92, developed by the Biometric Unit of the International Rice Research Institute in the Philippines, the means were separated using Duncan's multiple range test (Panse and Sukhatme, 1989).

Results and discussion

Effect of bio control agents for the management of M. incognita in betelvine

The results revealed that all tested biocontrol agents effectively reduced the population density of the root knot nematode *M. incognita* in both soil and roots. Among the biocontrol agents, *P. lilacinum* applied at 30 g per vine significantly decreased the nematode population compared to the pre-treatment levels, as assessed during the layout of the field experiment. The results indicated that the application of *P. lilacinum* (30 g/vine) minimized post treatment nematode infestation in soil significantly which was expressed by number of females/g of root, number of egg masses/g of root, number of eggs/egg mass and gall index over to control (*Table 1*). The same treatment *P. lilacinum* (30 g/vine) increase the plant growth parameters such as shoot length, shoot weight, root length, root weight, number of leaves/vine/year, weight of 100 leaves, leaf yield/ha and shelf life (*Table 2*) of betelvine leaves. Application of *P. lilacinum* in betelvine field also proved its effectiveness in reducing the nematode population and increases the leaf yield as reported earlier by Jonathan et al. (2000) and Everlon et al. (2024). The application of *P. lilacinum* in tomato and black pepper cultivation effectively reduced the nematode population and increased crop yield, since this bio agents target the nematode eggs leads to premature death (Dahlin et al., 2019; Girardi et al., 2022; Senthilkumar and Jaya Jasmine, 2021).

Optimization of promising bio agents P. lilacinum for the management of M. incognita in betelvine

The application of *P. lilacinum* in betel vine has been shown to effectively reduce the nematode population when compare to initial nematode population as well as untreated control and increase leaf yield in earlier field experiments. To enhance the efficacy of

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

the identified fungal antagonist *P. lilacinum* against the root-knot nematode *M. incognita*, a second experiment was conducted to evaluate its effectiveness when combined with organic materials such as neem cake, press mud, farmyard manure, vermicompost, and *Calotropis* leaves. The effects of these various combinations were compared with the standard application of commercial nematicides such as carbofuran and velum prime to assess their effectiveness against betel vine nematodes.

There were significant increases in vine growth as measured by estimates of shoot length (cm), shoot weight (g), root length (cm), root weight (g), number of leaves/vine/year, weight of 100 leaves (g) and shelf life (days) recorded 37.57%, 31.80%, 36.97%, 47.57%, 50.33%, 47.38%, 45.63% respectively in the vines treated with *P. lilacinum* (30 g/vine) + Neem cake (1 t/ha) (*Table 3*) compared to untreated control. Similarly, application of *P. lilacinum* (30 g/vine) + Neem cake (1 t/ha) minimized final nematode population in soil and root compared to untreated control (*Table 4*). The present study validated the beneficial effect of *P. lilacinum* bioagents in the betelvine garden under field conditions.

The results clearly indicated that the population of *M. incognita* was get reduced after imposing the treatments. The efficient decrease of root knot nematode *M. incognita* population in soil and consequent rise in the betelvine crop's yield parameters in field conditions after application of fungal antagonists *P. lilacinum* along with Neem cake registered in the present study supports the utilization of eco-friendly natural supplements to control the nematodes in betelvine. The neem cake effectively reduced the root knot nematode, since, neem cake having the bio-substance and its derivatives results toxicity on plant parasitic nematode (Singh et al., 1996; Javed, 2008; Madhushri et al., 2020). The earlier reports also indicated that the efficacy of *P. lilacinum* against *M. incognita* in betelvine was most successful in lowering the number of nematode population and increase the leaf yield (Jonathan et al., 1995, 1997; Dahlin et al., 2019; Girardi et al., 2022). Similarly, application of egg parasitic fungi increase the nematode mortality and improve growth and yield in black pepper (Senthilkumar and Jaya Jasmine, 2021). According to Jayant et al. (2002) soil application of *T. viride* gradually increase the betelvine plant growth parameters, yield and decreased the rate of *M. incognita* multiplication as indicated by reproduction factor. The root-knot index and number of egg masses were significantly reduced by applications of *T. viride* (Senthilkumar and Ramakrishnan, 2004; Kiriga et al., 2018; Girardi et al., 2022).

The addition of organic amendments, such as pressmud, neam cake, vermicompost, calotrophis leaves and farm yard manure, promotes the growth of *P. lilacinum*, that are antagonistic to nematodes, thereby inhibiting the growth of *M. incognita* (Rao et al., 1999). There are several ways in which the organic amendments combat nematodes that parasitize plants. The breakdown of microorganisms or organic amendments releases organic acids into the soil, including butric, propionic, acetic, and formic acids. Decomposition of soil releases gases such as ammonia and hydrogen sulphide. Nematodes are poisoned by these organic gases and acids. Microbes that are antagonistic to nematodes grow quickly when organic matter is included. Organic fertilisers enhance soil quality and promote plant growth by providing several components of nutrition for the crop plants (Sahoo and Sahu, 1994). The present finding on the influence of application of fungal antagonist, *P. lilacinum* along with neem cake against betlevine nematode with enhanced yield and quality of leaf was well strengthened by the reports of Jonathan (1995, 2000) and Everlon et al. (2024).

© 2025, ALÖKI Kft., Budapest, Hungary

Table 1. *Effect of bio control agents on growth and leaf yield of betelvine*

Treatments	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	No. of leaves/vine/year	Weight of 100 leaves (g)	Leaf yield/ha (lakh)	Shelf life (days)
T_1-*T. viride* (10 g/vine)	203.3	97.6	24.3	12.6	1922.1	215.3	38.3	13.6
T_2-*T. viride* (20 g/vine)	210.6	101.4	25.7	14.6	2150.4	227.6	39.5	15.0
T_3-*T. viride* (30 g/vine)	211.4	103.2	26.8	15.2	2364.6	239.2	40.3	15.2
T_4-*B. subtilis* (10 g/vine)	207.2	103.3	24.3	13.0	1991.3	217.3	39.3	12.8
T_5-*B. subtilis* (20 g/vine)	212.6	108.3	26.4	15.6	2112.6	230.6	41.6	15.3
T_6-*B. subtilis* (30 g/vine)	214.2	110.5	27.5	15.3	2412.3	242.3	42.3	15.8
T_7-*P. chlamydosporia*-(10 g/vine)	198.5	93.6	22.3	13.6	1869.2	212.2	35.6	12.3
T_8-*P. chlamydosporia*-(20 g/vine)	206.4	98.3	24.1	14.7	2067.7	225.3	37.6	14.3
T_9-*P. chlamydosporia*-(30 g/vine)	208.2	100.2	25.8	15.8	2296.3	236.2	39.6	15.0
T_{10}-*P. lilacinum* (10 g/vine)	210.3	105.6	25.9	13.2	2004.4	220.4	41.3	13.2
T_{11}-*P.* lilacinum (20 g/vine)	217.3	110.4	27.3	14.3	2194.6	232.6	42.4	15.7
T_{12}-*P. lilacinum* (30 g/vine)	219.2	113.3	29.6	16.6	2516.5	248.8	44.2	16.1
T_{13}- AM Fungi (10 g/vine)	203.6	87.3	20.4	12.3	1812.9	210.3	35.5	13.2
T_{14}- AM Fungi (20 g/vine)	208.4	94.2	21.8	14.2	2033.6	223.6	37.0	14.1
T_{15}- AM Fungi (30 g/vine)	210.3	97.2	23.6	15.3	2214.3	235.2	39.2	14.8
T_{16}-Standard check (Fluensulphone)	224.3	117.7	31.3	17.3	2584.2	252.6	45.7	16.3
T_{17}-Untreated control	158.1	69.3	14.6	8.3	1197.3	198.4	30.3	12.2
SEd	2.7	2.1	0.3	0.2	44	1.7	1.42	0.47
CD at 5%	8.3	6.3	1.5	0.6	132	4.8	4.72	NS

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

Table 2. *Effect of bio control agents on an infestation of M. incognita in betelvine*

Treatments	Pre-treatment nematode infestation					Final nematode infestation					
	Soil population (250 g)	**No. of females/g of root**	**No. of egg masses/g of root**	**No. of eggs/egg mass**	**Gall index (0-5 scale)**	**Soil population (250 ml)**	**Percent decrease over pre-treatment soil population**	**No. of females/g of root**	**No. of egg masses/g of root**	**No. of eggs/egg mass**	**Gall index (0-5 scale)**
T_1-*T. viride* (10 g/vine)	456.4	44.31	23.62	124.32	4.9	257.65	43.5	30.50	15.72	111.33	3.2
T_2-*T. viride* (20 g/vine)	423.3	42.36	22.31	162.33	4.6	228.56	46.0	27.32	11.50	104.25	3.1
T_3-*T. viride* (30 g/vine)	472.6	65.32	33.62	174.21	4.8	178.32	62.3	20.33	7.50	75.65	2.8
T_4-*B. subtilis* (10 g/vine)	453.5	52.31	29.65	156.47	4.9	252.32	44.4	28.66	15.30	108.22	3.2
T_5-*B. subtilis* (20 g/vine)	486.3	46.38	22.32	178.25	5.0	214.65	55.9	22.65	11.0	102.63	3.0
T_6-*B. subtilis* (30 g/vine)	421.3	72.36	31.65	210.65	4.8	164.24	61.0	17.25	7.15	66.15	2.6
T_7-*P. chlamydosporia*- (10 g/vine)	466.6	65.66	38.32	225.74	4.6	262.55	43.7	37.55	16.12	115.35	3.3
T_8-*P. chlamydosporia*- (20 g/vine)	475.3	72.35	30.65	284.32	4.7	241.35	49.2	34.32	12.13	108.75	3.2
T_9-*P. chlamydosporia*- (30 g/vine)	431.3	87.46	28.16	278.14	4.9	186.32	56.8	24.22	7.75	85.33	2.9
T_{10}-*P. lilacinum* (10 g/vine)	444.3	95.32	25.12	296.35	4.5	248.32	44.1	32.33	14.20	72.32	2.9
T_{11}-*P. lilacinum* (20 g/vine)	422.6	76.88	27.65	189.65	4.8	202.45	52.1	20.12	10.52	66.35	2.7
T_{12}-*P. lilacinum* (30 g/vine)	475.6	81.24	25.68	225.54	4.9	152.33	68.0	14.42	6.20	54.33	2.4
T_{13}- AM Fungi (10 g/vine)	482.3	92.67	31.32	241.32	4.6	266.32	44.8	42.25	17.25	122.33	3.8

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

T_{14}- AM Fungi (20 g/vine)	471.3	79.64	29.33	195.32	4.5	244.21	48.2	36.33	13.33	110.35	3.4
T_{15}- AM Fungi (30 g/vine)	459.3	85.61	32.67	258.87	4.8	193.21	57.9	28.32	9.24	96.55	3.0
T_{16}-Standard check (Fluensulphone)	465.6	69.23	28.33	250.62	4.7	141.62	69.6	12.48	5.46	52.22	2.2
T_{17}-Untreated control	458.5	73.33	24.21	236.25	4.8	686.32	-49.7	60.32	36.24	294.33	5.2
SEd	-	-	-	-	-	3.21		1.21	0.62	2.96	1.3
CD at 5%	-	-	-	-	-	7.32		2.92	1.92	6.20	0.3

Table 3. *Effect of Purpureocillium lilacinum on growth and leaf yield in betelvine*

Treatments	Shoot length (cm)	Shoot weight (g)	Root length (cm)	Root weight (g)	No. of leaves/vine/ year	Weight of 100 leaves (g)	Leaf yield/ha (lakh)	Shelf life (days)
T_1- *Purpureocillium lilacinum* (30 g/vine)	199.6	108.3	21.7	13.0	2233.5	227.6	34.3	12.7
T_2- T_1 + FYM (12.5 t/ha)	210.6	113.3	24.2	13.7	2327.6	236.3	38.2	13.6
T_3- T_1 + Pressmud (1 t/ha)	204.5	110.6	22.2	13.2	2287.3	230.7	36.6	13.1
T_4- T_1 + Neem cake (1 t/ha)	220.4	115.2	26.3	15.2	2455.3	242.3	41.3	15.0
T_5- T_1 + Vermicompost (1 t/ha)	197.3	105.3	19.4	12.6	2153.7	220.3	31.6	12.2
T_6- T_1 + Calotrophis leaves (2.5 t/ha)	195.3	101.5	19.3	11.5	2086.4	215.2	30.7	12.0
T_7-Carbofuran (1 kg a.i/ha)	225.3	118.3	28.6	15.7	2423.6	245.6	39.4	15.3
T_8- T_1 + Soil drench with Velum prime (0.75 mL/L of water)	226.6	121.6	30.8	16.2	2435.3	250.3	40.3	16.0
T_9-Untreated control	160.2	87.4	19.2	10.3	1633.2	164.4	29.3	10.3
SEd	2.9	2.0	0.4	0.3	42	1.8	1.29	0.45
CD at 5%	8.6	6.5	0.7	0.7	130	4.6	4.51	NS

Table 4. *Effect of Purpureocillium lilacinum on an infestation of M. incognita in betelvine*

Treatments	Pre-treatment nematode population					Final nematode population					
	Soil population (250 g)	No. of females/g of root	No. of egg masses/g of root	No. of eggs/egg mass	Gall index (0-5 scale)	Soil population (250 ml)	Percent decrease over Pre-treatment soil population	No. of females/g of root	No. of egg masses/g of root	No. of eggs/egg mass	Gall index (0-5 scale)
T_1- *Purpureocillium lilacinum* (30 g/vine)	475.3	41.32	21.52	184.12	4.5	197.09	58.5	31.15	13.91	99.73	3.2
T_2- T_1 + FYM (12.5 t/ha)	482.5	64.26	32.44	172.32	4.8	181.42	62.4	23.66	11.22	77.33	2.8
T_3- T_1 + Pressmud (1 t/ha)	468.6	44.63	23.22	180.20	5.0	190.22	59.4	27.18	13.32	88.14	3.0
T_4- T_1 + Neem cake (1 t/ha)	434.3	60.32	36.41	220.14	4.7	167.13	61.5	20.32	10.88	66.25	2.7

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

T_5- T_1 + Vermicompost (1 t/ha)	425.7	85.36	27.19	272.31	4.9	205.15	51.8	23.42	15.23	117.17	3.4
T_6- T_1 + Calotrophis leaves (2.5 t/ha)	454.3	90.37	34.32	239.47	4.8	218.20	52.0	25.17	17.51	124.54	3.1
T_7-Carbofuran (1 kg a.i/ha)	458.6	83.42	30.72	256.62	4.6	156.12	66.0	23.14	9.13	57.23	2.5
T_8- T_1 + Soil drench with Velum prime (0.75 ml/litre of water)	472.4	73.66	30.33	186.30	4.8	154.28	67.3	21.72	8.23	55.10	2.2
T_9-Untreated control	462.4	71.33	25.22	230.21	4.5	683.32	-47.8	63.27	39.87	298.32	5.0
SEd	-	-	-	-	-	2.26	-	1.12	0.82	2.72	1.1
CD at 5%	-	-	-	-	-	7.43	-	3.01	2.13	7.12	0.5

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

Conclusion

The application of the egg parasitic fungus *P. lilacinum* at 30 g per vine was successful in reducing nematode infestation in the soil when compare to pre-treatment nematode infestation as well as untreated control. This effective bioagents improve the plant growth parameters, including shoot length, shoot weight, root length, root weight, number of leaves, and shelf life. The performance of *P. lilacinum* along with organic materials recorded remarkable effect on nematode population. It is concluded that *P. lilacinum* can be effectively used for managing *M. incognita* in betelvine. These findings could be incorporated as a component of an integrated management strategy for nematodes in betelvine.

REFERENCES

[1] Acharaya, A., Padhi, N. N. (1988): Nematodes of betelvine and their management. – Indian Journal of Nematology 18: 109.
[2] Cobb, N. (1918): Estimating the nematode population of the soil. – Agric. Tech. Circ. U. S. Dept. Agriculture.
[3] Dahlin, P., Eder, R., Consoli, E., Krauss, J., Kiewnick, S. (2019): Integrated control of *Meloidogyne incognita* in tomatoes using fluopyram and *Purpureocillium lilacinum* strain 251. – Crop Protection 124: 104874.
[4] Everlon, C. R., Daniel, N., Olubukola, O. B., Nicolas, D. (2024): *Purpureocillium lilacinum* as an agent of nematode control and plant growth-promoting fungi. – Agronomy 14: 1225.
[5] Girardi, N. S., Sosa, A. L., Etcheverry, M. G., Passone, M. A. (2022): In vitro characterization bioassays of the nematophagous fungus *Purpureocillium lilacinum*: evaluation on growth, extracellular enzymes, mycotoxins and survival in the surrounding agroecosystem of tomato. – Fungal Biology 126: 300-307.
[6] Guha, P. (2006): Betel leaf: the neglected green gold of India. – Journal of Human Ecology 19(2): 87-93.
[7] Guha, P., Jain, R. K. (1997): Status Report on Production Processing and Marketing of Betel Leaf (*Piper betle* L). – Agricultural and Food Engineering Department, IIT, Kharagpur, India.
[8] Javed, N. (2008): Efficacy of neem (*Azadirachta indica*) formulations on biology of root-knot nematodes (*Meloidogyne javanica*) on tomato. – Crop Protection 27: 36-43.
[9] Jayant Bhatt, S. K., Sengupta, Chaurasia, R. K. (2002): Management of *Meloidogyne incognita* by *Trichoderma viride* in betelvine. – Indian Phytopathology 55(1): 97-98.
[10] Jayant, B., Indira, V. (2004): Nematodes of betelvine and their management—a review. – Agricultural Reviews 25(3): 231-234.
[11] Jonathan, E. (1990): International Nematology Network News 7: 26.
[12] Jonathan, E., Padmanabhan, D., Ayyamperumal, A. (1995): Biological control of root knot nematodeon betelvine, by *Paecilomyces lilacinus*. – Nematologia Mediterranea 23: 191-193.
[13] Jonathan, E., Sivakumar, M., Padmanabhan, D. (1996): Interaction of *Meloidogyne incognita* and *Phytophthora palmivora* on betelvine. – Nematologia Mediterranea 24: 341-343.
[14] Jonathan, E., Rajendran, G., Arulmozhiyan, R. (1997): Interaction of *Rotylenchulus reniformis* and *Phytophthora palmivora* on betelvine. – Nematologia Mediterranea 25(2): 191-193.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary

[15] Jonathan, E., Arulmozhiyan, R., Muthusamy, S., Manuel, W. W. (2000): Field application of *Paecilomyces lilacinus* for the control of *Meloidogyne incognita* on betelvine, *Piper betle*. – Nematologia Mediterranea 28: 131-133.
[16] Kaleeswari, V., Sridhar, T. (2013): A study on betel vine cultivation and market crisis in Karur District. – Indian Journal of Applied Research 3(10): 1-3.
[17] Kiriga, A. W., Haukeland, S., Kariuki, G. M., Coyne, D. L., Beek, N. V. (2018): Effect of *Trichoderma* spp. and *Purpureocillium lilacinum* on *Meloidogyne javanica* in commercial pineapple production in Kenya. – Biological Control 119: 27-32.
[18] Madhushri, K., Mesta, R. K., Kiran Kumar, K. C., Rudresh, D. L. (2020): Evaluation of nematicides and oil cakes against root knot nematode caused by *Meloidogyne incognita* in pomegranate. – International Journal of Current Microbiology and Applied Sciences 9(7): 1763-1775.
[19] Maiti, S., Shivshankara, K. S. (1998): Betelvine Research Highlights (1981-1998). – All India Coordinated Research Project on Betelvine, IIHR, Banglore, India.
[20] Marimuthu, T. (1991): Fungal nematode wilt complex in betelvine (*Piper* betle, L.). – Plant Disease Research 6(2): 85-88.
[21] Murthi, M. M. K., Rao, K. T. (1994): Chemical control of root knot nematode, *Meloidogyne incognita* in betelvine with non-volatile nematicides. – Indian Journal of Entomology 56(1): 44-50.
[22] Nakat, R. V. (1997): Proceedings of the First National Symposium on Pest Management in Horticultural Crops. Environmental Implications and Thrusts, Bangalore, 15-17 Oct 1997, pp. 308-311.
[23] Nakat, R. V., Madne, N. P. (1993): Proceedings of National Symposium on Betelvine Production Technology. JNKVV, Jabalpur 22-23 Sept 1993, pp. 66-67.
[24] Panse, V. G., Sukhatme, P. V. (1989): Statistical Methods for Agricultural Workers. – Indian Council of Agricultural Research, New Delhi.
[25] Rao, M. S., Reddy, P. P., Nagesh, M. (1999): Bare root dip treatment of Tomato seedlings in Calotropis or Castor leaf extracts mixed with *Paecilomyces lilacinus* spores for the management of *Meloidogyne incognita*. – Nematologia Mediterranea 27: 323-326.
[26] Sahoo, C. R., Sahu, S. C. (1994): Studies on the effect of different oilcakes and two nematicides in the control of lesion nematode, *Pratylenchus zeae* in rice. – Annals of Plant Protection Sciences 2: 30-32.
[27] Sandip, M., Prahlad, S., Amit, S., Matiyar Rahaman, K., Abhishek, M. (2018): Distribution and community structure of plant-parasitic nematodes and their relationship with some soil properties in betel vine-growing regions of West Bengal, India. – Nematology 21(6): 1-15.
[28] Schindler, A. F. (1961): A simple substitute for Baermann funnel. – Plant Disease Reporter 45: 747-748.
[29] Senthilkumar, T., Jaya Jasmine, A. (2021): Study the efficacy of fungal bioagents on root knot nematode, *Meloidogyne incognita* in black pepper (*Piper nigrum*) nursery. – International Journal of Current Microbiology and Applied Sciences 10(3): 1560-1562.
[30] Senthilkumar, T., Ramakrishnan, S. (2004): Studies on compatibility of Pseudomonas fluorescens, Trichoderma viride and carbofuran 3G and their influences on Meloidogyne incognita in okra. – Annals of Plant Protection Sciences 12(1): 140-142.
[31] Singh, K., Singh, A., Singh, D. K. (1996): Molluscicidal activity of neem (*Azadirachta indica*). – Journal of Ethnopharmacology 52: 35-40.
[32] Sitaramaiah, K., Devi, G. P. (1994): Nematodes, soil microorganisms in relation to phytophthora wilt disease in betelvine. – Indian Journal of Nematology 20: 230-231.
[33] Sivakumar, M., Marimuthu, T. (1984): Parasitic nematodes associated with betelvine (*Piper betle* L.) in Tamil Nadu. – Madras Agricultural Journal 71: 108-110.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2301_15151525
© 2025, ALÖKI Kft., Budapest, Hungary