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Eco-friendly management of maize cyst nematode, *Heterodera zeae* on sweet corn (*Zea mays* L. *saccharata*)

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Abstract
An integrated trial was carried out for the management of *Heterodera zeae* on sweet corn (variety-Madhuri). Bio-agent (*Paecilomyces lilacinus, Pochonia chlamydosporia* and *Trichoderma viride* at 2 % w/w as seed treatment) and botanicals (neem, karanj and lantana leaves powder at 2 g/plant as soil application) were used in combination for the management of maize cyst nematode, *H. zeae* on sweet corn. A trial was conducted in naturally infested soil having an initial nematode population of 600 larvae/100 cc soil. A standard chemical check (acephate 1 % as seed treatment + phorate 1 kg a.i./ha as soil application) and an untreated check were also maintained for comparison of the experimental findings. Observations on shoot weight (g), root weight (g), cyst per 100 cc soil, cyst per plant and final larvae per 100 cc soil, were recorded. Results exhibited that among bio-agent and botanical combinations, *Paecilomyces lilacinus at* 2% w/w coupled with neem leaves powder at 2 g/plant was found most effective for the management of maize cyst nematode followed by *Pochonia chlamydosporia* + neem leaves powder and *Paecilomyces lilacinus* + karanj leaves powder.

Keywords: Ecofriendly, management, bio-agents, botanicals, *Heterodera zeae*, sweet corn

1. Introduction

Maize (*Zea mays* L.) is, globally a top ranking cereal in productivity and has great significance as a food, animal and poultry feed and as a source of industrial products. In India, it ranks third place after rice and wheat with an area of 9.43 million hectares, production of 24.35 million tonnes and productivity of 2583 kg/ha [1]. Among cereals, maize is rich in starch, proteins, minerals, vitamins, oil, fat and sucrose and maize as a versatile crop has different types of varieties like normal maize, starch maize, sweet corn, baby corn, pop corn, quality protein maize, high oil maize and fodder maize etc. Among them in recent years the sweet corn usage is increasing very rapidly in cities and their periphery areas all over India. It is very delicious and nutritious crop and used as fresh or in boiled form. Sweet corn is one of the most popular vegetable in the USA, Europe and other advanced countries of the world and its consumption is increasing extensively in Eastern Asia [16]. The ears picked at the young stage are used for canning and table purpose. In India, it is gaining importance, particularly in star hotels of urban areas for the preparations of soups, jams, cream pastries and other delicious products. Madhuri is a sweet corn variety first of its kind in India and this variety has become popular in Andhra Pradesh and in many northern and southern states of India. It contains about 9% total sugars on dried seed basis while up to 33% on milky or fresh grain basis along with 16% fat and 15% protein.

Maize production in India and abroad is greatly affected by several biotic factors i.e. fungi, bacteria, insect pests and nematodes. Among them, plant parasitic nematodes are responsible to cause 10.2% losses on maize [14]. Plant parasitic nematodes *viz*., cyst nematodes (*Heterodera* spp.), lesion nematodes (*Pratylenchus* spp.), root knot nematodes (*Meloidogyne* spp.), stunt nematode (*Tylenchorhynchus* spp.) and spiral nematode (*Helicotylenchus* spp.) have been found to be associated with maize [9]. These nematodes apart from causing losses by themselves interact with other disease causing agents and adversely affect the quality and quantity of maize production. However, the maize cyst nematode, *Heterodera zeae* is considered as one of the most important nematode pests of maize in India and abroad [15].

Maize cyst nematode, *Heterodera zeae* was first reported [6] from Chhapli village of Rajsamand district of Rajasthan and widely distributed in maize growing areas of Rajasthan,

Delhi, Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh, Gujrat, Tamil Nadu, Karanataka, Andhra Pradesh and Maharashtra [5]. The severity of losses caused by *Heterodera zeae* on maize is higher in Rajasthan due to favourable soil condition, monocropping of maize and ignorance of management practices [13]. observed the distribution of maize cyst nematode, *H. zeae* from Banswara, Bhilwara, Chittorgarh, Dungarpur, Rajsamand and Udaipur district of Rajasthan. Highest occurrence (74.70%) and maximum nematode population were observed from Udaipur followed by Rajsamand and Bhilwara districts. The lowest occurrence (13.00%) was noted in Banswara.

Various means of nematode management *viz.* cultural, physical, biological and chemical methods of control have been tested, but all the methods have their own merits and demerits. Recently awareness about environmental and health problems associated with the use of nematicides/pesticides has triggered the search for alternative methods. Therefore, it is necessary to develop such control measures that are effective, economical and least environmentally disruptive. With this view, in the present investigation, efficacy of bio-agent and botanicals were tested in combination for the management of maize cyst nematode, *H. zeae* on sweet corn.

2. Materials and methods

All methods of nematode management have their own advantages and disadvantages. Therefore, recently in India and abroad, more attention is being paid towards the development of location specific integrated nematode management modules. Keeping this in view, an integrated nematode management trial was planned in the present investigation. Various bio-agents and plant products were used as seed and soil treatment for the management of maize cyst nematode, *H. zeae* on sweet corn. Seed treatment was done with *Paecilomyces lilacinus, Pochonia chlamydosporia* and *Trichoderma viride* at 2% w/w along with soil application of Neem (*Azadirachta indica*), Lantana (*Lantana camara*) and Karanj (*Pongamia pinnata*) leaves powder at 2g/plant. A standard chemical check (Acephate 1% w/w + Phorate at 1 kg a.i. /ha) and the untreated check were also maintained. The methodology for seed and soil treatment was adopted as described earlier. The soil samples were collected before sowing to determine initial nematode population. Experiment was carried out in completely randomized design with four replications. All practices *viz*., weeding, hoeing, irrigation etc. were employed during the course of an investigation. Observations on shoot weight (g), root weight (g), number of cyst per 100 cc soil, cyst per plant and final larval population/100 cc soil were recorded for comparison of treatments. Data were analyzed for interpretation of experimental findings and results have been presented in Table-1 and illustrated through Fig-1 and 2.

3. Results and discussion

Integrated nematode management consists of the development, use and evaluation of nematode management strategies that result in favourable socio-economic and environmental consequences. It is a system approach to reduce nematode damage to tolerable levels by integration of different management practices. It is recognized as a most desirable approach for the management of nematodes. It involves the design of an appropriate blend of technologies to meet out the needs of the farmers. Therefore, in present investigation bio-agents (*Paecilomyces lilacinus, Pochonia chlamydosporia* and *Trichoderma viride* at 2% w/w as seed treatment) and plant products (neem, karanj and lantana leaves powder at 2 g/plant as soil application) have been tried in combination for the management of maize cyst nematode, *H. zeae* on sweet corn.

Experimental findings revealed that all the treatments significantly increased shoot weight of sweet corn over untreated control. Among bio-agent and botanical combinations, maximum shoot weight (38.50 g) was obtained with *Paecilomyces lilacinus* + neem leaves powder followed by *Pochonia chlamydosporia* + neem leaves powder (37.00 g) and *Paecilomyces lilacinus* + karanj leaves powder (36.00 g). However, highest shoot weight (40.25 g) was obtained with the chemical combination (Acephate 1 % as seed treatment + phorate 1 kg a.i./ha as soil application). It was observed minimum (25.50 g) in untreated control followed by *Trichoderma viride* + lantana leaves powder (32.50 g) and *Pochonia chlamydosporia* + lantana leaves powder (32.75 g). Per cent increase in shoot weight was also calculated with different treatments over untreated control. Among bio-agent + botanical combination, maximum increase in shoot weight (50.98 %) was recorded with *Paecilomyces lilacinus* + neem leaves powder followed by *Pochonia chlamydosporia* + neem leaves powder (45.10%) and *Paecilomyces lilacinus* + karanj leaves powder (41.18%). Highest increase in shoot weight (57.84%) was recorded in chemical combination and lowest increase was observed with *Trichoderma viride* + lantana leaves powder (27.45%) over untreated control. Almost similar trend was noticed with respect to root weight of maize. All results are also showed in table-1 and illustrated through fig. 1 and 2.

Results of present findings are similar to the investigations of [12, 8, 7, 2, 3] reported that integration of bio-agent and botanicals enhanced plant growth and provide good protection to crops against plant parasitic nematodes [12]. Reported that the integration of *P. lilacinus* with neem leaf aqueous suspension effectively manage root-knot nematode on brinjal [8]. Studied the effect of *T. harzianum* and neem cake (10 q/ha) alone and in combination to manage root-knot nematode, *M. incognita* in chickpea cv. Type-3. The organic amendment and *T. harziianum* increased the chickpea growth over the control However; reduction of root-knot nematode was registered maximum with neem cake + *T. harzianum* treatment followed by neem cake and *T. harzianum* alone [7]. reported that seed treatment with biopesticides (neem seed powder, latex of *Calotropis procera* and Neemark) and bio-agents (*Trichoderma viride, Aspergillus niger* and *Paecilomyces lilacinus*) effectively control root-knot nematode infestation and increased plant growth and yield of chickpea [2]. Applied fungal bio-agents *i.e. Paecilomyces lilacinus, Pochonia chlamydosporia* and *Trichoderma viride* at 1, 2, 4 % as seed treatment to manage maize cyst nematode, *H. zeae* on sweet corn. Results revealed that *Paecilomyces lilacinus* at 4 per cent was found to be the best followed by *Pochonia chlamydosporia* at 4 per cent and *Paecilomyces lilacinus* at 2 per cent to enhanced plant growth of sweet corn and to reduced the infection of *H. zeae*.

These findings shows that integration of bio-agents and botanicals significantly enhanced plant growth characters infested with nematodes and provide an effective alternative of chemicals for management of phytonematodes in agricultural crops including maize.

Experimental results revealed that cyst per 100 cc soil decreased significantly in all the treatments as compared to untreated control. Among bioagent + botanical combinations, minimum cyst per 100 cc soil (8.50) was recorded in

Paecilomyces lilacinus + neem leaves powder followed by *Pochonia chlamydosporia* + neem leaves powder (10.50) and *Paecilomyces lilacinus* + karanj leaves powder (11.00). Seed dressing with *Paecilomyces lilacinus* followed by soil amendment with neem leaves powder was found significantly better over rest of the combinations. Among all the treatments, minimum cyst per 100 cc soil (6.00) was obtained in chemical combination (acephate + phorate) and was found significantly better over other treatments. Maximum cyst population was observed in untreated control (23.00 cyst/100cc soil) followed by *Trichoderma viride* + lantana leaves powder (14.00). All the treatments significantly decreased cyst population over untreated control. Per cent reduction in cyst per 100 cc soil was also calculated with different treatments over untreated control. Maximum reduction (63.04%) was observed with *Paecilomyces lilacinus* + neem leaves powder followed by *Pochonia chlamydosporia* + neem leaves powder (54.35%) and *Paecilomyces lilacinus* + karanj leaves powder (52.17%). Minimum reduction (39.13%) was obtained with *Trichoderma viride* + lantana leaves powder over untreated check.

The results obtained in present investigation are also in accordance with the findings of [10, 11, 4, 2, 3] who reported that integration of bio-agent and botanicals effectively reduced plant parasitic nematodes [10]. reported that *Trichoderma viride* alone and in combination with either neem or castor cake was most effective in parasitizing egg masses of the root-knot nematode, *M. incognita* infecting tomato [11] studied the bio-efficacy and compatibility of formulations of *P. chlamydosporia* and *P. lilacinus* on root-knot nematode, *M. javanica*, infecting nursery seedlings of acid lime. Application of 5 or 10 g of each biological agent formulation per kg of soil significantly reduced root-gall index and number of nematodes in the roots. The combined use of *P. lilacinus and P. Chlamydosporia* each at 10g/kg significantly reduced rhizosphere colonization [4]. observed that maximum reduction in nematode multiplication including final soil population was recorded in treatment that received soil application at 3g/plot at sowing time coupled with seed treatment at 3% w/w with *P. Chlamydosporia* over control [2]. tested the efficacy of neem, karanj and lantana leaves powder as soil application at 1, 2 and 4 g/plant for the management of *Heterodera zeae* on sweet corn (cv. Madhuri). Results revealed that neem leaves powder at 4 g/plant was found most effective in improving plant growth characters of sweet corn and to reduced the infection of *H. zeae*.

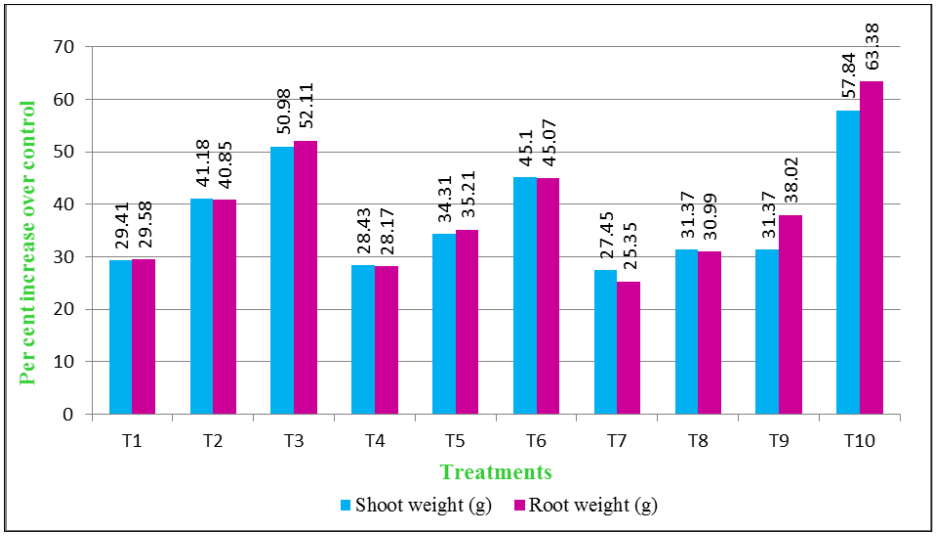

Fig 1: Effect of integrated approaches on plant growth of sweet corn infested with *Heterodera zeae*

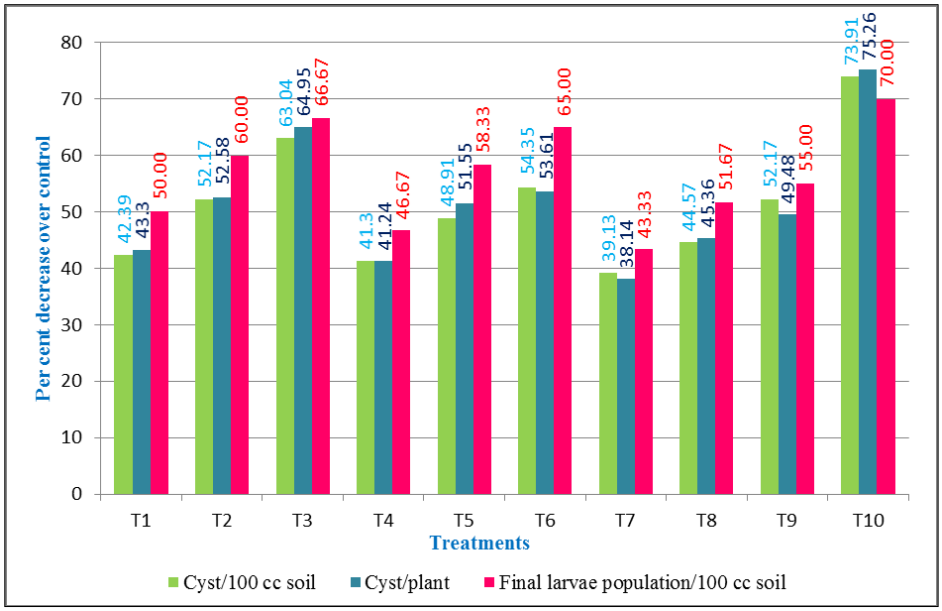

Fig 2: Effect of integrated approaches against maize cyst nematode, *Heterodera zeae* on sweet corn.

Table 1: Integrated management of maize cyst nematode, *Heterodera zeae* on sweet corn through bio-agents and botanicals.

Treatments		Plant growth characters		Nematode parameters		
		Shoot weight (g)	Root weight (g)	Cyst / 100 cc soil	Cyst/ plant	Final larvae population/ 100 cc soil
Paecilomyces lilacinus 2% w/w + Lantana leaves powder 2g/plant	(T_1)	33.00 (29.41)	23.00 (29.58)	13.25 (42.39)	13.75 (43.30)	300.00 (50.00)
Paecilomyces lilacinus 2% w/w + Karanj leaves powder 2g/plant	(T_2)	36.00 (41.18)	25.00 (40.85)	11.00 (52.17)	11.50 (52.58)	240.00 (60.00)
Paecilomyces lilacinus 2% w/w + Neem leaves powder 2g/plant	(T_3)	38.50 (50.98)	27.00 (52.11)	8.50 (63.04)	8.50 (64.95)	200.00 (66.67)
Pochonia chlaymydosporia 2% w/w + Lantana leaves powder 2g/plant	(T_4)	32.75 (28.43)	22.75 (28.17)	13.50 (41.30)	14.25 (41.24)	320.00 (46.67)
Pochonia chlaymydosporia 2% w/w + Karanj leaves powder 2g/plant	(T_5)	34.25 (34.31)	24.00 (35.21)	11.75 (48.91)	11.75 (51.55)	250.00 (58.33)
Pochonia chlaymydosporia 2% w/w + Neem leaves powder 2g/plant	(T_6)	37.00 (45.10)	25.75 (45.07)	10.50 (54.35)	11.25 (53.61)	210.00 (65.00)
Trichoderma viride 2% w/w + Lantana leaves powder 2g/plant	(T_7)	32.50 (27.45)	22.25 (25.35)	14.00 (39.13)	15.00 (38.14)	340.00 (43.33)
Trichoderma viride 2% w/w + Karanj leaves powder 2g/plant	(T_8)	33.50 (31.37)	23.25 (30.99)	12.75 (44.57)	13.25 (45.36)	290.00 (51.67)
Trichoderma viride 2% w/w + Neem leaves powder 2g/plant	(T_9)	35.00 (31.37)	24.50 (38.02)	11.00 (52.17)	12.25 (49.48)	270.00 (55.00)
Acephate 75 SP 1% w/w + Phorate 10 G 1 kg /ha	(T_{10})	40.25 (57.84)	29.00 (63.38)	6.00 (73.91)	6.00 (75.26)	180.00 (70.00)
Untreated check	(T_{11})	25.50	17.75	23.00	24.25	600.00
SEm ±		0.714	0.513	0.574	0.562	9.945
CD at 5 %		2.054	1.477	1.653	1.618	28.613

Initial nematode population: 600 larvae /100 cc soil, Data are the average of four replications

4. Conclusion

According to results it's proved that efficacy of bio-agents enhanced when used with organic material because organic matter provide suitable substrate for bio-agents for their growth and multiplication. It is logistic from these findings that botanicals and bio-agents when used in combination at reduced doses provide better protection to crops from phytonematodes as compared to their sole application at higher dose.

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