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Sustainable Management of Nematodes Infestation of Paddy Cultivation in Sri Lanka

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***Abstract*—**The rice root-nematode Hirschmanniella oryzae, and rice root-knot nematode, Meloidogyne graminicola have emerged as a major threat to rice cultivation. Therefore, the management of nematodes is highly essential for reducing severe damages in rice cultivation. A pre-tested questionnaire survey was conducted in five selected districts. Farmers were selected from farmer communities in each site by using a simple random sampling method (n=150) and, evaluated the effectiveness of new molecules of nematicide and non-chemical management package against nematode in a field experiment. The treatments were Abamectin 0.5% GR with three different dosages, poultry manure, paddy husk, and untreated control with three replicates. Area of 50 m2 each plot arranged in a Randomized Complete Block Design. The number of nematodes in soil, root-knot percentage, and yield data were recorded. The survey revealed that farmers in Mahaweli Systems B and C suffered from yield loss due to nematode attacks. The experiment results indicated that Abamectin 0.5% GR is effective for managing nematodes irrespectively of the dosage. Moreover, the application of poultry manure and paddy husk reduced nematodes from21/20g soil to 6/20g. The pilot trial indicated that there was no significant difference among Abemactin and organic manure applied fields in both nematode count and final yield. Therefore, it can be suggested, the application of poultry manure and paddy husk is a cost-effective, environmentally friendly method for controlling nematodes in the rice field. However, further large scale adaptive trials are needed to confirm and develop the well-adapted, non-chemical package against nematodes in rice fields.

***Keywords*—**Abamectin 0.5% GR, Hirschmanniella oryzae, Meloidogyne graminicola, nematicide, Non-chemical package

I. Introduction

Rice (*Oryza sativa* L.) is a staple food crop for most of the world's population with an estimated 480 million tons currently produced (Childs and Nathan, 2017). Plant-parasitic nematodes rank as one of the most important soil-borne pests of rice and may account for annual yield losses of 10 – 25 % worldwide. Nematodes are a fascinating, biologically diverse group of organisms and over 100 species of nematodes affect rice production. Their ability to adapt to a wide variety of habitats including; marine, soil, and aquatic, provides an evolutionary advantage for species longevity. Root-knot nametodes (*Meloidogyne* spp.) are distributed worldwide and are significant pathogens of rice and other crops cultivated in temperate and tropical areas (Trudgill and Blok, 2001). In Sri Lanka, it was estimated that rice yield loss can be reached up to 72 % due to root-knot nematode, *Meloidogyne graminicola* L. (Nugaliyadde *et al.* 2001).

The rice root-nematode *Hirschmanniella oryzae* is another species commonly found in irrigated rice production systems (Kyndt, *et al.,* 2014) and is well adapted to live in marshes and flooded paddy fields and multiply on some sedges and grasses. The role of such nematode is facultative, when the paddy is dry, the nematode becomes quiescent until the next rainy season (Throne, 1961). In the absence of host plants they could live in soil for 10 weeks and the minimum time of development from egg to adult is about one month. The multiplication factor per generation being as high as 13 (Vecht and Bergmen, 1952).

Meloidogyne spp., the root-knot nematodes are obligate endo-parasites and perfect examples of highly adapted root parasites (Siddiqi, 1986). From those, *Meloidogyne graminicola* is the major species attacking both upland (rainfed) and lowland (irrigated) rice. It is well adapted to flooded conditions and yield losses of up to 87 % have been reported (Lilley*et al.,* 2011). In India, *M. graminicola* is the dominant species infecting rice. *M. triticoryzae* infecting both rice and wheat including some monocot weeds is also reported from India (Gaur *et al.*, 1993) and its occurrence is restricted to a few areas.

The root-knot nematode is making its importance felt in almost all the rice-growing areas. The high initial population of *M. graminicola* causes seedling wilt along with the severe reduction in growth parameters, whereas, low population causes the only reduction in growth parameters. The main symptoms caused by *M. graminicola* are yellowing, stunting, and gall formation on the roots of rice plants. The degree of symptom manifestation varies with inoculums load, time of infection, age of the plants, etc. (Plowright and Bridge., 1990).

The nematode can cause economic yield losses in upland and deep-water rice (Ibrahim et al., 1972). The impact of *M. graminicola* on rice yield has been well established, with yield losses up to 20% to 90% (Soriano *et al.,* 2000). On upland rice, *M. graminicola* causes a 16-32 % loss in grain yield due to incomplete filling of kernels (Biswas and Rao, 1971). Yields can decrease to 72 % when 4000 eggs and juveniles of *M. graminicola* or plant occur in deepwater rice plants by drowning out (Bridge and Page, 1982). The beneficial effects of organic wastes are both direct and indirect. They affect the nematodes directly by releasing toxic products (after decomposition) that kill or inactivate the nematodes (Bello *et al.,* 2006). They indirectly control nematode effects by increasing soil fertility to the advantage of the crop (Boehm *et al.,* 1993). In addition to soil fertility, soil amendment with the organic matter may also alter the soil physical and chemical properties, and thereby affecting soil microflora (Huang and Huang, 1993). Therefore, this study was aimed to assess the nematode damage at field levels, evaluate new chemical nematicide and organic amendments against nematodes in Sri Lanka. Thereby develop a non-chemical management package for controlling nematodes damage in rice cultivation.

II. Material and Methods

A. Field Survey

The field survey was conducted to collect basic information related to the nematode damage situation in Sri Lanka during the 2018/19 *Maha* and 2019 *Yala* seasons. The areas i.e. Kurunegala, Moneragala, Gampaha representing rain-fed cultivation, and Mahaweli systems B, C, comprised of major irrigation systems were assessed. The data were collected from 175 farmers comprising 35 farmers from each selected area. The survey study was carried out by following the simple random sampling method and data were analyzed using descriptive statistics.

B. Extraction of nematodes from the soil sample

Soil samples were collected from each experiment field (n = 150) to count the nematode population. Each sample, 20g of soil was taken to nematode extraction and nematodes were extracted from the soil by applying the sieve method and the Baermann funnel technique (Agrios, 2005; EPPO. 2013).

C. Evaluation of Organic amendments and different doses of Abamectin for Management of Nematodes

Two field experiments were conducted at the farmer fields located in the locations of Sandagalathenna, Dehiaththakandiya during 2018/19 *Maha* and Thuwaragala, Dehiaththakandiya during the 2019 *Yala* cultivation seasons. Each experiment was laid down following Randomized Complete block Design (RCBD) with three replicates. Application of Abamectin 0.5% GR (40 kg/ha) (T1), Abamectin 0.5% GR (50 kg/ha) (T2), Abamectin 0.5% GR (60 kg/ha) (T3), Poultry manure and Paddy husk (2000 kg + 1000 kg per ha)(T4) and Untreated control (T5) were used as the treatments of both trials. In each experiment, the number of nematodes in 20g of soil sample (n = 10) was extracted and counted before the treatment and 10 and 20 days after the application of treatments. Finally, the root-knot percentage was determined by randomly collected 20 rice plants per block. In each block, the final yield was recorded after harvesting. The collected data was compared and analyzed following the ANOVA procedure using SAS statistical package.

D. Pilot-scale trial for selected treatments

Based on the results of the above field experiments in two different locations and two seasons, a pilot-scale field trial was conducted to confirm the effective dose of Abamectin and organic amendments at Nagasawa, Dehiaththakandiya during 2019 *Yala*. The research field was divided into 9 equal plots with each having approximately100m2 area. The experiment was laid down by following RCBD with three replicates. Abamectin 0.5% GR (50 kg/ha)(T1), Poultry manure and Paddy husk (2000 kg + 1000 kg per ha) (T2) and Untreated control (T3) were the treatments. In each plot, a number of nematodes in 20g of soil sample (n = 10) was extracted and counted before the treatment and, at 10 and 20 days after the treatments. Finally, the root-knot percentage was determined by randomly collected 20 rice plants per block. In each block, the final yield was recorded after harvesting. The collected data was compared and analyzed following ANOVA procedure using SAS statistical package.

III. Results and discussion

A. Field Survey

The majority of the farmers in Mahaweli system B and C have more experience in rice cultivation practices than in Kurunegala, Gampaha, and Moneragala paddy farming.

The major livelihood of the farmers in the area is dependent on farming as well those areas are considered as agricultural potential areas. Therefore, the people in the area have lifetime farming experience compared to other agricultural communities within this study.

Land preparation in rice cultivation having an important precautionary benefit to avoid after-ward pest attacks including nematodes. However, the majority of the farmers in selected areas have used a rotavator (Table 1) as the ploughing equipment compared to the disc plough and Mould board plough from selected sampling areas. However, the Mahaweli system's community has a light increment on land preparation by using disc plough compared to Kurunegala, Gampaha, and Moneragala under the rain-fed and minor irrigation system category. Usage of disc plough is an important land preparation practice for mange nematodes and several

Table I: Summary data on basic farm practices, nematodes damage and their management in rice cultivation in selected areas in Sri Lanka.

Collected Data		Kurunegala	Moneragala	Gampaha	Mahaweli B	Mahaweli C
Used plough equipments for land preparation	Disc plough	11%	6%	11%	17%	14%
	Rotary plough	86%	74%	80%	80%	83%
	Mould board	3%	20%	9%	3%	3%
Identification of nematode damage in the rice field	Yellowing and Browning of leaf tips	6%	17%	20%	8%	17%
	Yellowing the rice plant	34%	29%	37%	20%	26%
	Reduction of plant growth	40%	37%	29%	29%	23%
	By inspection of Agriculture extension officers	20%	17%	14%	43%	34%
Actions taken to control the Nematodes damage	Chemical application	71%	63%	74%	83%	80%
	Not taken any action	29%	37%	26%	17%	20%
Used chemicals	Carbofuran	11%	14%	11%	17%	17%
	Diazinone	17%	11%	23%	11%	11%
	Fipronil	23%	20%	17%	23%	23%
	Diazinone + Fipronil	29%	26%	29%	32%	29%
	Carbosulfan	11%	18%	11%	14%	11%
	Other	9%	11%	9%	3%	9%
Yield loss % due to nematode attack		12%	12%	10%	20%	18%

other rice pests as it cuts and opens the soil up to 15 to 20 cm depth by breaking the hard layers present in the soil system (Table 1).

The survey revealed that the majority of farmers had identified nematode damage in the rice field after reduction of plant growth and the majority of them applied chemicals as an action for controlling nematodes damage in the rice field. In addition, survey analysis reveals that the majority tended to use chemical application practice for controlling nematodes. Out of the total survey sample from five districts, Diazinone + Fipronil has been used by the majority of farmers at the initial stage of nematode control (Table 1).

According to the survey data analysis, farmers in Mahaweli systems B and C suffered a lot from yield loss due to the nematode attack than other major rice-growing areas (Table 1). Yield loss percentage was calculated with the comparison of previous yields (before confirming the nematode attack) in those fields.

B. Evaluation of Organic amendments and different doses of Abamectin for Management of Nematodes

Sandagalathenna-Dehiaththakandiya in 2018/19 Maha season The experimental data reveal that there was a significant difference among the treatments. Both abamectin applied treatment and poultry manure applied plots were recorded a lower number of nematodes than the control. It was observed that the plants treated with abamectin 0.5% GR (60 kg/ha) had a significantly lower number of nematodes than those in the untreated control (Table 2).

The experimental data reveal that there was a significant difference among the treatments. Both Abamectin applied treatment and poultry manure observed that the plants treated with abamectin 0.5% GR (60 kg/ha) had a significantly lower number of nematodes than those in the untreated control (Table 2)

Abamectin 0.5% GR (60 kg/ha) treated field had shown significantly higher yield (6559.3 kg/ha) than the untreated control. Poultry manure and paddy husk treated field had

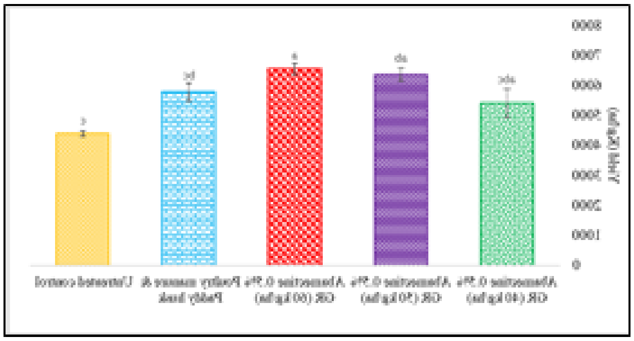

Figure 1: Yield variation under chemical and non-chemical treatments against nematodes. **The bars indicate the mean (± SE) yield of paddy under different treatments. The different letters above the bars indicated the significant differences among the treatments at p >0.05.**

experienced 5791 kg/ha yield. It was higher than the lower dose of Abamectin 0.5% GR treated field (Figure 1).

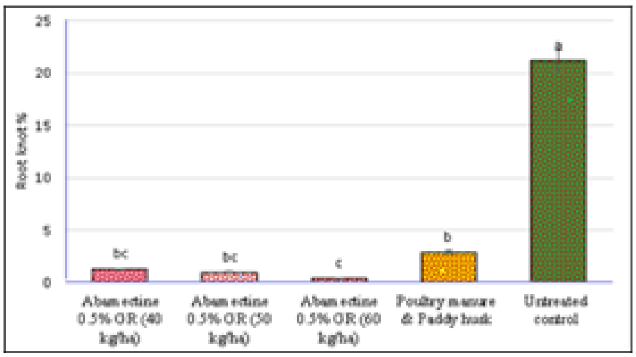

Figure 2: Root-knot percentage on rice plants cultivated under chemical and non-chemical treatment applied plots. **The bars indicate the mean (± SE) number of the root-knot percentage under different treatments. The different letters above the bars indicated the significant differences among the treatments at p >0.05.**

It was observed that the plants treated with abamectin 0.5% GR (60 kg/ha) had significantly lower per cent root knots (0.3%) than those in the untreated control. Poultry manure and paddy husk treated field had experienced 2.9% root knots however, abamectin treated all plots having lower percentage root knots than organic amendments (Figure 2).

Thuwaragala, Dehiaththakandiya in 2019 Yala season

Field Experiment 2 further indicated that the plants treated with Abamectin 0.5% GR (60 kg/ha) had a significantly lower number of nematodes than those in the untreated control. The yield and the root-knot percentage of Abamectin and poultry manure applied plots having significantly low numbers than untreated control (Figure 3 and 4). The same trend was observed as in experiment 1.

Further, Abamectin 0.5% GR applied field had a higher yield (6214 kg/ha) and lower root-knot percentage (0.46 %) than others. Poultry manure and paddy husk treated field had shown 5584 kg/ha yield and 3.8 % root-knot %. Which was significantly lower than the control and the reduction of root-knot and increment of the yield is in an acceptable amount.

It was observed that the plants treated with Abamectin 0.5% GR 50 kg/ha (250 g ai/ha) had a significantly lower

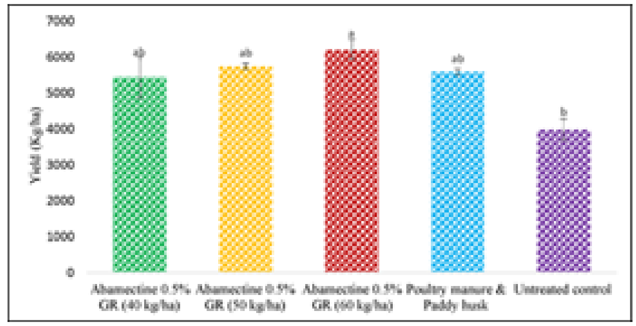

Figure 3: Yield variation under chemical and non-chemical treatments against nematodes with untreated control. **The bars indicate the mean (± SE) yield of paddy under different treatments. The different letters above the bars indicated the significant differences among the treatments at p >0.05.**

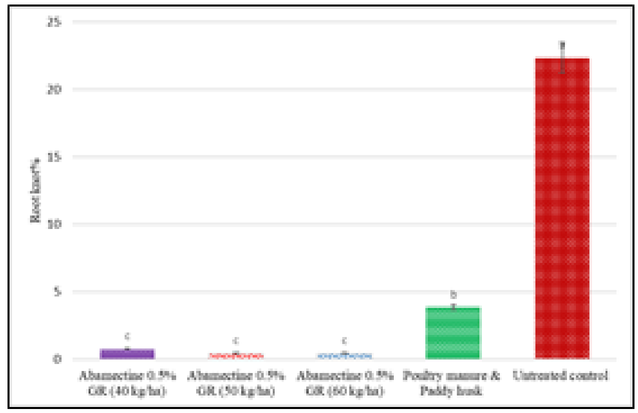

Figure 4: Root-knot % of chemical and non-chemical treated plots against nematodes with untreated control. **The bars indicate the mean (± SE) number of the root-knot percentage under different treatments. The different letters above the bars indicated the significant differences among the treatments at p >0.05.**

number of Nematodes than those in the untreated control (Table 4).

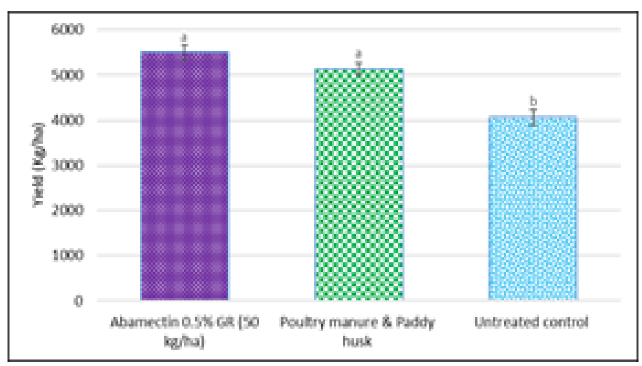

Figure 5: Yield variation under chemical and non-chemical treatments against nematodes with untreated control. **The bars indicate the mean (± SE) yield of paddy under different treatments. The different letters above the bars indicated the significant differences among the treatments at p >0.05.**

Abamectin 0.5% GR (60 kg/ha) treated field and poultry manure and paddy husk treated field had shown significant difference from untreated control field. Abamectin 0.5% GR (60 kg/ha) treated field had higher yield (5500 kg/ha) than others. Poultry manure and paddy husk treated field had

Table II: Effect of different treatment on Nematodes population at Thuwaragala, Dehiaththakandiya – 2019 Yala.

Treatment (product)	Dose g/ha or ml/ ha	No. of Nematodes / 20 g of soil sample)		
		Before treatment	10 days after treatment	20 days after treatment
Abamectin 0.5% GR	40 kg/ha	21.66[a]	9.33[bc]	3.66[b]
Abamectin 0.5% GR	50 kg/ha	17.66[a]	7.33[dc]	1.33[c]
Abamectin 0.5% GR	60 kg/ha	20.00[a]	5.00[d]	0.66[c]
Poultry manure and Paddy husk	2000 kg/ha & 1000 kg/ha	18.00[a]	11.33[b]	5.33[b]
Untreated control	-	19.33[a]	23.00[a]	28.66[a]
CV	-	7.17	13.83	13.57

*The number of nematodes indicated the total number of plant-parasitic nematodes per 20 g of soil sample. The different letters above the values within the columns indicated the significant differences at p>0.05.

Field Trial 3: Pilot-scale trial: Nagaswewa, Dehiaththakandiya 2019 Yala season

Table III: Effect of different treatment on Nematodes population at Nagaswewa, Dehiaththakandiya in 2019 Yala season.

Treatment (product)	Dose g/ha or ml/ ha	No. of Nematodes / 20 g of soil sample		
		Before treatment	10 days after treatment	20 days after treatment
Abamectin 0.5% GR	50 kg/ha	20.66[a]	5.66[c]	0.66[c]
Poultry manure & Paddy husk	2000 kg/ha & 1000 kg/ha	19.33[a]	9.33[b]	5.33[b]
Untreated control	-	21.00[a]	23.00[a]	29.33[a]
CV	-	5.98	9.45	12.13

*The number of nematodes indicated the total number of plant-parasitic nematodes per 20 g of soil sample. The different letters above the values within the columns indicated the significant differences at p>0.05.

experienced 5133 kg/ha yield however, there is no significant difference between abamectin treatment and poultry manure treatment (Figure 5).

It was observed that the plants treated with Abamectin 0.5% GR (60 kg/ha) had a significantly lower root-knot percentage (0.56%) than those in the untreated control. Poultry manure and paddy husk treated field had experienced 2.96% of root-knot percentage (Figure 6).

There is substantial evidence that the addition of organic matter in the form of compost or manure will decrease nematode populations and associated damage to crops (Walker, 2004). Therefore, poultry manure and paddy husk also can

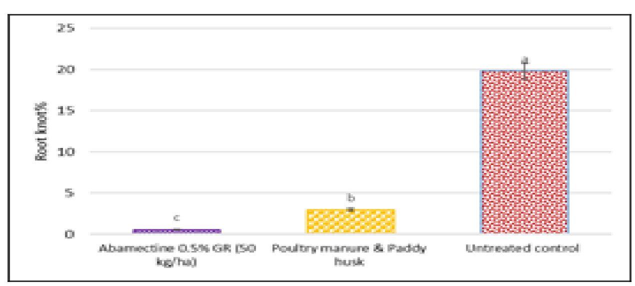

Figure 6: Root-knot percentage on rice plants cultivated under chemical and non-chemical treatment applied plots. **The bars indicate the mean (± SE) number of root-knot percentages under different treatments. The different letters above the bars indicated the significant differences among the treatments at p >0.05.**

be taken as the effective nematode management package.

IV. Conclusion

The survey revealed that farmers in Mahaweli systems B and C suffered a lot from yield loss due to nematode attacks. Application of Abamectin 0.5% GR and Poultry manure and paddy husks are equally effective for controlling nematodes in the rice field. Therefore, it can be used as an environmentally friendly method. However, further research is needed to confirm the research findings and develop the well adapt non-chemical package against nematodes presence in rice fields.

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