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Integrated management of major nematode pests of banana in *Gangetic* plains of West Bengal

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ABSTRACT

Banana (Musa AAB) is a widely grown fruit crop of India. Intensive cultivation of banana facilitates the nematode disease complex comprising Meloidogyne spp., Rotylenchulus reniformis and Hoplolaimus indicus that often inflict appreciable amount crop loss. An approach was undertaken to manage the nematode disease complex in banana cv. Martaman by integrating cultural practices, biological control agents and chemical nematicide during 2009-11 in nematode-sick plot at BCKV, Nadia, West Bengal, India. Results of two years' experiments showed that paring + hot water treatment of suckers at 55^{0}C for 10 minutes + carbofuran 3G @ 0.5g a.i. plant^{-1} + neem cake @ 1 kg plant^{-1} (at the time of planting) improved yield attributes (fingers hand^{-1}, hands bunch^{-1}) and fruit yield of banana by 30% over untreated control and noticeably reduced the soil populations of Meloidogyne incognita, M. javanica, Rotylenchulus reniformis and Hoplolaimus indicus. Root knot index due to infestation of Meloidogyne spp. was also found lowest in this treatment. Other treatments e.g. Pseudomonas fluorescens @ 20g m^{-2}, Trichoderma viride @ 20g m^{-2} and carbofuran 3G @ 0.3g a.i. m^{-2} also provided higher fruit yield of banana over untreated control and reduced the soil population of nematodes as well as root-knot index. The return per rupee expense for treatment was maximum of ₹ 3.65 in carbofuran 3G @ 0.3g a.i. m^{-2}.

Keywords: Carbofuran, *Hoplolaimus,* hot water treatment, integrated nematode management, *Meloidogyne,* paring, *Pseudomonas fluorescens, Rotylenchulus, Trichoderma viride*

Banana, *Musa* (AAB) (family Musaceae) is usually cultivated for food and sometimes for the production of fibre used in the textile industry. India has emerged as a largest producer of banana in the world with 29.67 million tons of banana production from 8.17 lakh ha area of plantations in 2011(FAO Stat, 2011). In contrast, the world production of banana in 2011 was 106.54 million tons from 51.57 lakh ha of cultivated area (FAO Stat, 2011). As per the estimates of FAO, the contribution of India to the world banana production was approximately 27.8 %. The average yield of banana in India is about 363.2 q ha^{-1} which is much lower than other countries of the world, such as Nicaragua (511.5 q ha^{-1}), Costa Rica (461.0 q ha^{-1}), Surinam (417.9 q ha^{-1}), Guatemala (416.9 q ha^{-1}) and Ecuador (386.9 q ha^{-1}). This low productivity may be attributed due to several reasons such as erratic weather conditions, non availability of quality planting material, poor agronomic practices and prevalence of pest and diseases.

In India, Tamil Nadu has the largest area followed by Maharashtra and Karnataka. Tamil Nadu also ranked first in production, followed by Maharashtra. However, the highest productivity was recorded in Maharashtra followed by Gujarat, Tamil Nadu and Madhya Pradesh. The acreage under banana crop in West Bengal is 7.8 lakh hectares with an annual production of 26.5 million tonnes in 2012-13 (http://nhb.gov.in).

Intensive cultivation of banana facilitates the infestation of insect pests and diseases including plant parasitic nematodes. Depending on soil type, varieties and management practices, avoidable yield loss due to nematodes could be to the tune of 12% in banana (Jain *et al.,* 2007). Sasser and Freckman (1987) estimated that the plant parasitic nematodes cause an annual yield loss of 12.3 % on global basis. In our country, annual monetary crop loss due nematode is around 21 thousand million rupees (Jain *et al*., 2007). Among the plant parasitic nematodes, root-knot nematodes (*Meloidogyne* spp.) are global menace to crop production. Out of these, *Meloidogyne incognita*, *M. javanica* and *M. arenaria* were reported to infect banana and plantain (De Waele and Davide, 1998; Namabase, 2010). Nematode disease complex comprising *Meloidogyne incognita*, *M. javanica*, *Rotylenchulus reniformis* and *Hoplolaimus indicus* often cause economic loss to the growers in several banana growing areas of West Bengal. Unlike insects, mites and other disease causing agents, nematode population increase rather slowly and the infestations caused by them generally do not appear as sudden epidemics destroying crops over vast areas in a matter of days, but cause slow decline in yield spreading

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over years. Once established in the field, nematodes are very difficult to eradicate. In most of the cases, nematode injury invites other concomitant pathogenic problems and may together develop a complex syndrome. Infection of root-knot nematodes to banana induce galls on root (Fig. 1) as well as produce some above ground symptoms like yellowing, stunting, mid day wilting and premature shedding of leaves. Therefore, an integrated approach was undertaken to manage the nematode disease complex in banana (*Musa*) cv. *Martaman* (AAB) by incorporating cultural practices, biological control agent and chemical nematicide during 2009-2011 in nematodes infested sick plot of Bidhan Chandra Krishi Viswavidyalaya, Nadia West Bengal, India.

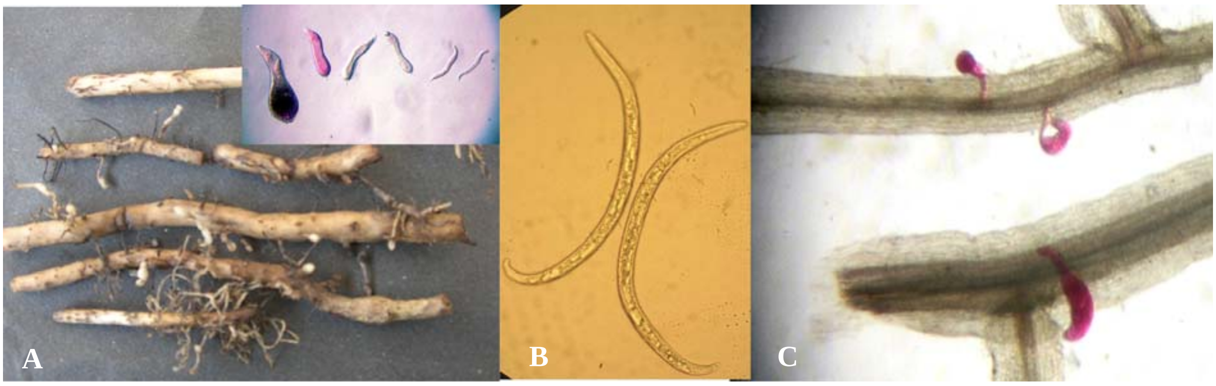

Fig. 1: Banana roots showing (a) galls due to infestation of *Meloidogyne* spp, developmental stages of *Meloidogyne* (inset) (b) young infective females and (c) adult females of *R. reniformis*

MATERIALS AND METHODS

An experiment on integrated management of nematode pests of banana was carried out for two consecutive years commencing from November, 2009 in an established sick plot at Central Research Farm of Bidhan Chandra Krishi Viswaviidyalaya, Gayeshpur, Nadia, West Bengal. The experimental site was geographically located at $22^{0}58^{\times}15.08^{Ø}$ N latitude and $88^{0}29^{\times}49.18^{Ø}$ E longitude with 40 ft elevation from mean sea level. The soil of the experimental field was typically *Gangetic* alluvial soil (Entisol) having sandy clay loam texture with good drainage facility, neutral in reaction and moderate in fertility. Weather condition during the period of experimentation revealed 22.4^{0}C minimum and 32.0 ^{0}C maximum mean temperatures, 62.7-93.2% mean RH and 1504.3 mm total rainfall during November, 2009 to October 2010 and 21.8^{0}C minimum and 32.3^{0}C maximum mean temperatures, 58.9-92.8% mean RH and 1292.3 mm total rainfall during November, 2010 to October, 2011. Randomized Complete Block Design was adopted for the experiment. Five treatments (Table 1) comprising cultural and physical tactics, bioagents, organic cake and chemical nematicide were replicated four times. The inputs were procured from local market. All the treatments were delivered at the time of planting. The sword suckers of banana cultivar *Martaman* were planted at a spacing of 2×2m in a plot size of 8m ´ 6m. The crop was fertilized with N:P:K @ 200:50:250 g plant^{-1} and raised following standard recommended package of practices.

Observations were recorded on initial nematode population (Table 2), final nematode

Table 1: Treatment details

Notation	Treatments
T_1:	*Pseudomonas fluorescens* @ 20 g m^{-2} area
T_2:	*Trichoderma viride* @ 20 g m^{-2} area
T_3:	Carbofuran (Furadan) 3G @ 0.3 g *a.i.* m^{-2} area
T_4:	Paring + Hot Water Treatment (HWT) at 55^{0}C for 20 mins +carbofuran 3G @ 0.5 g *a.i.* plant^{-1} + neem cake @ 1 kg plant^{-1}
T_5:	Untreated control

population, root-knot index and yield attributes of plant. One composite soil sample of 250cc from each plot was collected once before planting and again at the time of harvest from 30 cm depth 'V' shaped core. One composite soil sample was collected from three such cores. An aliquot of 200cc soil from each composite sample was processed by using Cobb's sieving and decanting technique followed by modified Baermann funnel method (Christie and Perry, 1951). Afterwards, the nematode suspension was killed by heating at 65ºC temperature and fixed in 4:1 formalin glacial acetic acid fixative. The estimation of nematode population was done by multi-chambered counting dish under stereoscopic binocular microscope (Olympus SZ 11).

Table 2: Initial nematode population (INP) of the experimental field

	Population/200 cc of soil							
	Meloidogyne **spp. (J2)**		***R. reniformis***		***H. indicus***		**Saprozoic Nematodes**	
	2009-10	**2010-11**	**2009-10**	**2010-11**	**2009-10**	**2010-11**	**2009-10**	**2010-11**
INP	367.9	142.9	1276.6	248.8	79.2	143.5	480.2	1749.1

Functional roots of banana at near harvest of the crop were collected from a standard-size excavation of 20 × 20 × 20 cm extending outward from the corm of the banana plant to work out root-knot index. Five root samples per plot were examined to work out the root-knot index in 1-5 scale [1=No gall or egg mass/ plant, 2=1-10, 3=11-30, 4=31-100, 5=>100]. The data recorded during experimentation were analyzed statistically using software MSTATC.

RESULTS AND DISCUSSION

Pooled data of two years experiments revealed that paring + hot water treatment of suckers at 55^{0}C for 10 minutes + carbofuran 3G @ 0.5 g *a.i.* plant^{-1} + neem cake @ 1 kg plant^{-1} (T_4) produced significantly maximum of 7.78 hands bunch^{-1} and 14.6 fingers hand^{-1} indicating 30% higher fruit yield of banana over untreated control (Table 3). Performance of carbofuran 3G @ 0.3g *a.i.* m^{-2} (T_3) was also found satisfactory next to T_4 with regard to the yield attributes of banana (Table 3). Root-knot index due to infestation of *M. incognita* and *M. javanica* was also found lowest in T_4, being 2.25 and 2.73 during 2009-10 and 2010-11, respectively (Fig. 2).

All the treatments were found to reduce phytonematode (*Meloidoyne incognita*, *M. javanica*, *Rotylenchulus reniformis* and *Hoplolaimus indicus*) population but T_4 and T_3 were observed as more promising to manage the nematode population (Fig. 3, 4). In spite of significant effect of treatments, none of the treatments kept the population of *R. reniformis* below threshold level in both the years of experimentation. An inoculum density of 1000 nematodes of *R. reniformis* per 500cc of soil is considered as pathogenic to brinjal (Roy *et al*., 2008).

Boiling water treatment of pared suckers for at least 20 seconds and up to 30 seconds was highly efficient for disinfesting banana and plantain planting material. It reduced combined nematode densities of

Table 3: Effect of treatments on yield attributes of banana cv. Martaman

Treatments	**Fingers hand^{-1}**			**Hands bunch^{-1}**			**Yield (q ha^{-1})**			**IBCR***
	2009-10	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**	**2009-10**	**2010-11**	**Pooled**	
T_1 : *P. fluorescens* @ 20 g m^{-2}	14.43	13.98	14.20	7.63	7.39	7.50	204.9	135.5	170.2	1: 0.62
T_2 : *T. viride* @ 20 g m^{-2}	14.20	13.92	14.06	7.54	7.27	7.39	198.9	129.0	164.0	1: 0.76
T_3 : Carbofuran 3G @ 0.3 g *a.i.* m^{-2}	14.56	14.45	14.50	7.68	7.64	7.68	223.2	146.7	185.0	1: 3.65
T_4: Paring + HWT+ carbofuran 3G @ 0.5 g a.i. plant^{-1} + neem cake @ 1 kg plant^{-1}	14.67	14.52	14.60	7.70	7.85	7.78	234.9	167.7	201.3	1: 0.22
T_5 : Untreated Control	13.97	13.61	13.80	7.51	7.18	7.35	187.3	123.1	155.2	-
SEm (±)	**0.25**	**0.13**	**0.14**	**0.16**	**0.07**	**0.09**	**10.7**	**8.3**	**6.8**	
LSD (0.05)	**NS**	**0.41**	**0.41**	**NS**	**0.22**	**0.25**	**33.1**	**25.6**	**19.8**	

Note:* *Calculation is based on pooled yield data, ₹ 1000 q^{-1} was the market price of banana*

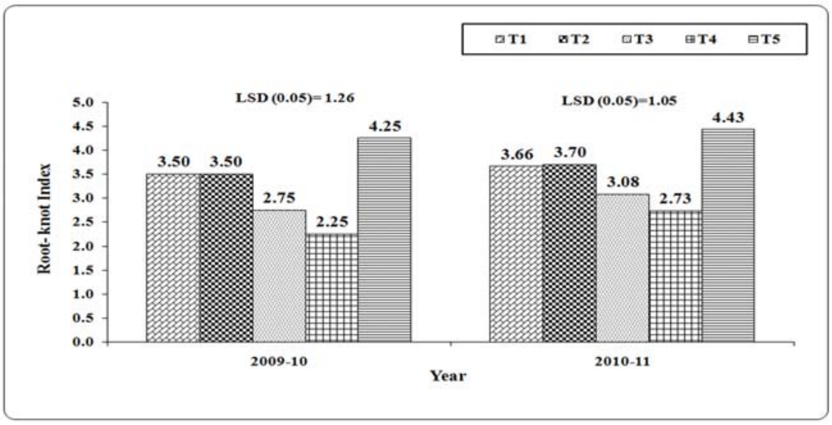

Fig. 2: Effect of treatments on root-knot index in banana cv. Martaman

Helicotylenchus multicinctus, *Radopholus similis* and *Meloidogyne* spp. to 0.7% of over controls (Coyne *et al*., 2010). A method to remove nematode pests of banana and plantain (*Musa* spp.) by simply immersing the peeled or unpeeled suckers in boiling water for 20-30 seconds has proven to be friendly to small-scale farmers and is better than the hot water treatment at 50°C as the time taken to treat a sucker is reduced and the measurement of the temperature and timing is simplified. It effectively disinfects suckers of various sizes without affecting their germination (Hauser and Coyne, 2010). The treatment comprised of paring + hot water treatment of suckers at 55˚C for 10 minutes also showed its superiority over others in managing predominant phytonematode population of banana at the experimental site. This observation was found at par with earlier information made by Coyne *et al*., 2010.

In vitro studies of native strains of *Pseudomonas fluorescens*, PfB 13 @100% concentration showed significant mortality of adult female of *R. similis.* Glasshouse grown plants revealed significant reduction of nematode population and lesion index along with simultaneous improvement in plant growth parameters when treated with the isolate PfB13 (Senthilkumar *et al*., 2008). Field study with native isolates of *P. fluorescens*, PfB 13 @ 10 g plant^{-1} significantly reduced the infestation of *R. similis*. Treated banana plants increased plant height, pseudostem girth, leaf area, number of leaves and fruit yield. The effectiveness of the native isolate PfB13 was comparable with that of the chemical carbofuran. The treatment PfB13 also enhanced the activity of defense enzymes responsible for induction of systemic resistance *viz*., peroxidase, polyphenol oxidase [catechol oxidase] and phenylalanine ammonia lyase (Kumar *et al*., 2008). *P. fluorescens* did not exhibit any promising result here with regard to the enhancement of growth and yield attributes of banana cv. *Martaman* as well as reduction of parasitic nematodes population in the crop.

Investigations on the management of *R. similis*, infesting banana cv. Dwarf Cavendish, revealed combined application of neem cake @ 500g plant^{-1}, carbofuran 3G @ 40 g plant^{-1} and *Trichoderma viride* @ 10 g plant^{-1} was most effective in reducing the nematode population and improving plant growth and yield attributes of banana with a cost-benefit ratio of 1:2.9 (Harish and Gowda, 2001). Soil applications of powdered neem seed or neem cake @100 g plant^{-1} at planting and, subsequently, at 3-month intervals, reduced the populations of *Pratylenchus goodeyi* and *Meloidogyne* spp. of banana (Musabyimana and Saxena, 1999). It was observed that application of poultry refuse @ 2.5 kg plant^{-1} combined with carbofuran 5G @ 15 g plant^{-1} reduced root-knot nematodes population and gall index and improved plant growth of banana (Sadat *et al*., 2007). Carbofuran 3G @ of 60 g plant^{-1} was found effective in containing the population of *Radopholus similis* on banana cv. Dwarf Cavendish (Khan, 2008). Two consecutive applications of terbufos, carbofuran, ethoprophos and cadusafos at 4 months interval commencing from 3 months after planting were evaluated on banana cv. Grande Naine to manage the nematode problems. The nematicides evaluated decreased *Radopholus similis*, *Helicotylenchus* spp. and *Meloidogyne* spp. populations in functional roots compared with the untreated plots. No difference in nematode control was found among nematicides. The nematicides improved significantly the total root and functional root weights (Araya and Cheves, 1997). Single application of a treatment is not an effective practice for managing nematode problems of a perennial crop like banana (Araya and Cheves, 1997; Musabyimana and Saxena, 1999; Sadat *et al*., 2007). In the present experiment, the treatment comprised of paring + hot water treatment (HWT) at 55^{0}C for 20 mins + carbofuran 3G @ 0.5 g *a.i.* plant^{-1} + neem cake @ 1 kg plant^{-1} performed better over others where single application of a nematicide or bioagent was used.

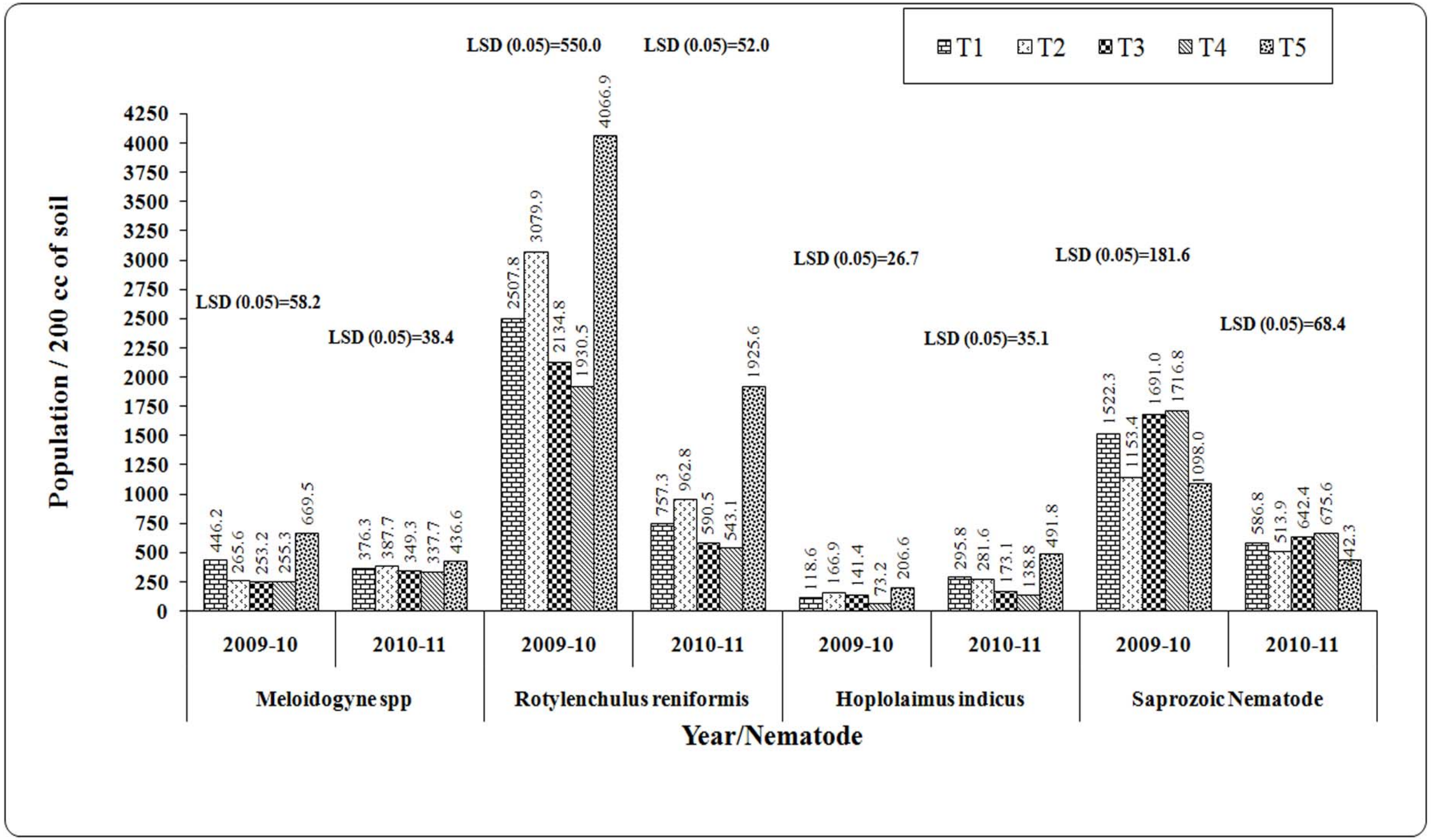

Fig. 3: Effect of treatments on final population of *Meloidogyne* spp., *R. reniformis*, *H. indicus* and saprozoic nematodes in banana field

Saprozoic nematodes comprising free living dorylaimids and rhabditids population were also affected by the treatments. Population of saprozoic nematodes in T_3 and T_4 was recorded comparatively more than remaining treatments including an untreated control. This signifies the non-existence of deleterious effect of carbofuran 3G and neem cake on saprophagous nematode fauna in soil after twelve months of treatment application as observed from final nematode population data (Fig. 3). On the contrary, saprophagous nematode population in *P. fluorescens*, *T. viride* and untreated control were low. That might be due to competition for space between phytophagous and saprozoic nematodes. Similar observation was earlier reported by Roy *et al*., 2014.

Application of biological control agent e.g. *P. fluorescens* @ 20 g m^{-2} (T_1) and *T. viride* @ 20 g m^{-2} (T_2) against nematode pest complex of banana was found uneconomic. The return per rupee expense for treatment was found maximum of ₹ 3.65 in carbofuran 3G @ 0.3g *a.i.* m^{-2} (Table 3).

The treatment comprised paring + hot water treatment (HWT) at 55^0C for 20 mins + carbofuran 3G @ 0.5 g *a.i.* $plant^{-1}$ + neem cake @ 1 kg $plant^{-1}$failed to achieve economic return because of high market price of neem cake but still the treatment has a prospect to adopt where nematode is a big threat to the banana crop. If farmer could procure neem cake of his own then the cost of treatment will be low and this will be the best choice for them to tackle the menacing effect of nematode in a crop like banana.

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