Türk. entomol. derg., 2020, 44 (1): 3-12
DOI: http://dx.doi.org/10.16970/entoted.597606

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Nematode damage and management in banana in Turkey[1]

Türkiye muz alanlarında nematod zararı ve mücadelesi

Adem ÖZARSLANDAN[2*] **Dilek DİNÇER[3]** **Mustafa ÜNLÜ[4]**

Abstract

Banana is grown in tropical and subtropical regions of the world, and they are also cultivated in the coastal regions of the Mediterranean Region in Turkey. The present study aimed to determine the losses induced by the plant-parasitic nematodes in Anamur and Erdemli districts of Mersin Province, Turkey. Spiral nematode, *Helicotylenchus multicinctus* Cobb, 1893 (Tylenchida: Hoplolaimidae); root-knot nematodes, *Meloidogyne incognita* (Kofoid & White, 1919) and *Meloidogyne javanica* (Treub, 1885) (Tylenchida: Meloidogynidae) were detected in the study greenhouses. Three nematicides, oxamyl, fenamiphos and ethoprophos, were used with two or four application against these nematodes. The experiments were conducted in three replicates in four greenhouses each with nematicide treated and untreated plots. In the study, yield for each treatment was calculated for 15 plants (5 plants/replicate). Nematodes were isolated from soil and root samples with a modified Baermann funnel method and nematode counting was performed under a microscope. In banana plantations with nematode management, the yield was between 28.6 and 53.1 kg/plant and the yield increase ranged between 34 and 117%. The results suggested that use of a single control method would not be effective against these nematodes and additional control methods in integrated management should be used to control nematodes in banana plantations.

Keywords: Banana, integrated management, nematicides, nematodes

Öz

Muz, dünyanın tropikal ve subtropikal bölgelerinde yetişir ve ayrıca Türkiye'nin Akdeniz Bölgesi'nin sahil şeridinde yetiştirilir. Bu çalışmada, Türkiye'nin Mersin İli, Anamur ve Erdemli ilçelerinde bulunan bitki paraziti nematodlarının neden olduğu kayıpların belirlenmesi amaçlanmıştır. Çalışma seralarında Spiral nematodu, *Helicotylenchus multicinctus* Cobb, 1893 (Tylenchida: Hoplolaimidae); kök ur nematodları, *Meloidogyne incognita* (Kofoid & White, 1919) ve *Meloidogyne javanica* (Treub, 1885) (Tylenchida: Meloidogynidae) tespit edilmiştir. Bu nematodlara karşı üç nematisid, Oxamyl, Fenamiphos ve Ethoprophos iki veya dört uygulama olarak kullanılmıştır. Denemeler her biri nematisid uygulanmış ve uygulama yapılmamış parsellere sahip dört serada üç tekerrürlü olarak yürütülmüştür. Bu çalışmada, her uygulama için verim 15 bitki (5 bitki / tekerrür) üzerinden hesaplanmıştır. Nematodlar, Geliştirilmiş Baermann Huni yöntemiyle toprak ve kök örneklerinden izole edilmiş ve nematodların sayımı mikroskop altında yapılmıştır. Muz alanlarında nematod mücadelesi ile verim 28.6 ile 53.1 kg /bitki ve verim artışı % 34 ile 117 arasında değişmiştir. Sonuçlar muz alanlarında bu nematodlara karşı tek bir mücadele yönteminin kullanılmasının etkili olmayacağını ve entegre mücadele yöntemleri içerisinde ilave mücadele yöntemlerini kullanımı ile kontrol edilebileceğini önerilmiştir.

Anahtar sözcükler: Muz, entegre mücadele, nematisid, nematodlar

[1] This study is a part of project financially supported by The Scientific and Technological Research Council of Turkey (TUBITAK TOVAG project number 1130473).
[2] Mersin University, Applied Technology and Management School of Silifke, 33940, Mersin, Turkey
[3] Biological Control Research Institute, 01321, Adana, Turkey
[4] Alata Horticultural Research Institute, 33740, Erdemli, Mersin, Turkey
* Corresponding author (Sorumlu yazar) e-mail: aozarslandan@mersin.edu.tr
Received (Alınış): 27.07.2019 Accepted (Kabul ediliş): 17.10.2019 Published Online (Çevrimiçi Yayın Tarihi): 17.12.2019

Introduction

Banana cultivation has great economic value in subtropical and tropical regions around the world. In Turkey, banana is cultivated in microclimates protected by Taurus Mountains around Gazipaşa, Alanya, Anamur, Bozyazı, Silifke, Erdemli, and İskenderun Districts with 499 kt of bananas produced on 7.6 kha in 2018 (TUİK, 2019).

Plant-parasitic nematodes are common in banana plantations and these are among the most damaging pests in all banana cultivars, leading to severe crop losses in commercial export banana plantations, and also significantly limiting the production and viability of other banana species. Many studies have been conducted on nematodes in bananas (Wardlaw, 1961; Gowen, 1995; Sarah & Fallas, 1996; Gowen et al., 2005; Wang & Hooks, 2009).

The first evidence of nematode damage leading to yield loss in banana was in the Jordan Valley (Minz et al., 1960). Several studies reported that important plant-parasitic nematodes, such as burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949 (Tylenchida: Pratylenchidae); spiral nematode, *Helicotylenchus multicinctus* (Cobb, 1893) (Tylenchida: Hoplolaimidae); lesion nematode, *Pratylenchus* spp. (Tylenchida: Pratylenchidae) and root-knot nematode, *Meloidogyne* spp. (Tylenchida: Meloidogynidae), lead to economic losses in banana plantations (Mant & Hinai, 1996; Brooks, 2004; Chavez & Araya, 2010). In studies conducted in banana plantations in Turkey, *H. multicinctus, Helicotylenchus dihystera* (Cobb, 1893) (Tylenchida: Hoplolaimidae), *Meloidogyne incognita* (Kofoid & White, 1919) and *Meloidogyne javanica* (Treub, 1885) (Tylenchida: Meloidogynidae) were identified (Elekcioğlu, 1992; Elekçioğlu & Uygun, 1994; Özarslandan & Elekcioglu, 2010; Özarslandan & Dinçer, 2015). It has been reported that *H. multicinctus* populations were higher in banana greenhouses in Bozyazı District of Mersin Province than *Meloidogyne incognita* and *M. javanica* populations (Kasapoğlu et al., 2015). It has also been found that spiral nematodes were more prevalent in banana plantations in Turkey than root-knot nematodes (Özarslandan & Dinçer, 2015).

In Florida, *H. multicinctus* can cause severe root damage resulting in the toppling of mature plants (McSorley & Parrado, 1986; Gowen, 1995). According to McSorley & Parrado (1986), this nematode is highly prevalent in subtropical banana plantations. In Lebanon, *H. multicinctus* was considered as the most important root parasite of banana (Sikora & Schloesser, 1973). Since the spiral nematode feeds on the cortical cells close to the epidermis, it often forms superficial reddish brown and black lesions. Purple-black lesions can be observed in the root or rhizome, and the root lesions can merge and expand, and finally kill the entire root. Root-knot nematodes form galls in the main and secondary roots and the symptoms are observed frequently in the form of irregular bulges. However, knot formation is not observed in thick primary roots. In addition to the direct damages caused by the nematodes, they can also indirectly enable pathogenic fungal infection. Fungal pathogens (*Fusarium* spp. and *Rhizoctonia* spp.) can infect and kill the roots. Nematodes inhibit nutrient and water intake due to root damage in banana. Thus, the plant collapses due to the loss in root strength and also plants exhibit retarded growth, trunk shrinkage, yellow leaves, decreased in leaf count and size, delayed flowering, delayed harvest, decreased bunch weight, and decreased fruit size and weight (McSorley & Parrado, 1986; Bridge, 1988; Fogain & Gowen, 1997; Araya et al., 1999). As a result of nematode damage, the leaves grow on top of each other and the plant buckles. These plants either do not produce flowers or the yield is reduced. Thus, the market value of the fruit is impacted.

The density of soil and root nematodes has been reported to be important for decision-making (Moens et al., 2001; Pattison et al., 2002). The number of nematodes per gram of root is used to determine the economic threshold for nematicide application. Greater then 1 nematode/g soil in banana plantations has been reported to be the damage threshold (Rajendran et al., 1980). Many studies have also found that when the number of nematodes per 100 g banana roots exceeds 2000, economic losses are likely to occur

(Gowen & Quénéhervé, 1990; Sarah & Dallas, 1996; Wang & Hooks, 2009). There is no universal threshold for economic damage to nematodes in banana plantations around the world.

It is known that root plant nematodes and spiral nematodes, which are important plant-parasitic nematodes in banana areas of Turkey, are widespread. The aim of this study was to determine the damage conditions of nematodes in banana plantations and to determine the methods of combating them.

Materials and Methods

Experiments were conducted in four greenhouses in Erdemli (Greenhouse 1 and 2) and Anamur (Greenhouse 3 and 4) Districts in Turkey. In these greenhouses, the experiments had four treatments: oxamyl 15 ml/plant), fenamiphos 20 ml/plant, ethoprophos 15 ml/plant and untreated control in three replicates. Five plants were selected for each replicate and each treatment was applied to 15 plants and plant yields recorded. Five soil samples were collected from five locations up to 30 cm from the trunk and near the roots of each plant. The soil samples (2 kg) were collected into plastic bags. Root samples were collected from the same locations and placed plastic bags (Mant & Hınai, 1996; Wang & Hooks, 2009). Nematodes were extracted from soil samples (100 g) in a Petri-dish method; a modified Baermann funnel method (Barker, 1985; Southey, 1986). Root samples were washed with water to remove the soil and cut into 5-25 mm long pieces and the nematodes were extracted with a modified Baermann funnel method (Barker, 1985; Southey, 1986). Thus, the nematode number in 100 g of fresh root was determined. Nematicide application dates,13 March, 29 April, 19 June and 12 August 2014. Only two application were treated with nematicide on the first and second dates.

The effect (%) of treatments on yield was determined with Abbott's formula. The yield, root and soil nematode counts were analyzed by variance analysis using SPSS 23.0 (IBM Corporation, Armonk, NY, USA) and the means were compared using the Duncan’s test at 0.05 significance level.

Result and Discussion

Root-knot and spiral nematodes were found in mixed populations in experimental sample and spiral nematode, *H. multicinctus*, *M. incognita* and *M. javanica* were also present. Nematodes were active for 12 months in the greenhouse. In winter, the root-knot nematode population decreased. In Greenhouse 1, the highest yield (31.9 kg/plant) was with four ethoprophos applications (15 ml/plant), an increase of 49.8%. The yields with two and four oxamyl applications, four ethoprophos applications, and four fenamiphos applications were 28.6, 30.1, 31.9, 30.5 and 31.3 kg/plant, respectively, i.e., increases of 34.3, 41.3, 49.8, 43.2 and 46.9% over the control (Table 1). In Greenhouse 2, the highest yield was with four oxamyl 15 ml/plant applications (53.1 kg/plant), an increase of 71.9%. The yield increases with two and four oxamyl applications, and two and four fenamiphos applications were 47.6, 53.1, 44.1 and 48.2 kg/plant, respectively, i,e., increases of 54.1, 71.9, 42.7 and 55.9% over the control (Table 1). In Greenhouse 3 the highest yield was observed with four oxamyl 15 ml/plant applications (49.5 kg/plant), an increase of 117%. The yields with four oxamyl applications, and four ethoprophos applications were 49.5 and 44.4 kg/plant, respectively, i.e. increases of 117 and 94.7% over the control (Table 2). In Greenhouse 4, the highest yield (41.9 kg/plant) was with four oxamyl applications (15 ml/plant), an increase of 63%. The yields obtained with four applications of fenamiphos and ethoprophos were 37.1 and 36.4 kg/plant, respectively, i.e., increases of 44.4 and 41.6% over the control (Table 2). These results show that overall yield in the experiment areas was from 28.6 to 53.1 kg/plant with the nematode management, with yield increases between 34 and 117%.

Table 1. Nematode numbers in root (100 g) and soil (100 g) after 1 and 12 months, banana yield (kg/plant) and effect relative to the control (%) in Erdemli, Mersin Province, Turkey

Application	Root/ Soil	M/H*	Greenhouse 1				Greenhouse 2			
			1 months	12 months	Yield	Effect (%)	1 months	12 months	Yield	Effect (%)
Oxamyl 15ml 4 Application	root	M	1040±301	0±0	30.1±1.6 a	41.3	0±0	1200±427	53.1 ±1.8 a	71.9
		H	2000±415	1600±369			640±138	2400±565		
	soil	M	100±46	40±23			0±0	40±23		
		H	20±20	600±80			400±173	1500±427		
Oxamyl 15ml 2 Application	root	M	0±0	100±46	28.6±1.6 a	34.3	0±0	1700±496	47.6±2.5 ab	54.1
		H	640±80	2700±438			440±138	4500±773		
	soil	M	220±69	200±69			0±0	20±11		
		H	600±127	1580±219			240±69	1520±554		
Ethoprophos15ml 4 Application	root	M	2800±323	0±0	31.9±2.4 a	49.8				
		H	1840±369	400±69						
	soil	M	20±11	20±11						
		H	120±23	440±184						
Fenamiphos 20ml 4 Application	root	M	880±103	0±0	31.3±1.6 a	46.9	0±0	100±46	48.2±1.3 ab	55.9
		H	720±138	2100±254			320±69	1400±334		
	soil	M	280±80	20±11			0±0	0±0		
		H	260±46	240±80			0±0	100±46		
Fenamiphos 20ml 2 Application	root	M	0±0	100±46	30.5±3.2 a	43.2	0±0	200±69	44.1±0.9 b	42.7
		H	400±80	700±173			200±57	2600±450		
	soil	M	160±34	60±23			20±11	0±0		
		H	180±92	780±150			160±34	1400±219		
Control	root	M	60±23	300±103	21.3±3.0 b		160±57	0±0	30.9±4.7 c	
		H	1300±334	4400±542			480±173	2600±496		
	soil	M	20±11	0±0			20±11	0±0		
		H	12034	1820± 323			180±57	400±161		

* H, spiral nematode, *Helicotylenchus multicinctus*; M, root-knot nematodes, *Meloidogyne* spp.

The per plant yield differences between the greenhouses demonstrated that nematicide application alone was not sufficient to increase the yield. In order to increase per plant yield, it is necessary to use integrated nematode management methods. Since banana is monoculture production, nematode populations are advantaged by continuous development. After the nematicide application, spiral nematode population did not decrease, the life cycle was completed, and the nematode population increased. However, the plant trunk thickened, the leaf count and the distances between the leaves increased and the overall plant development improved after the nematicide applications.

Table 2. Nematode numbers in root (100 g) and soil (100 g) after 1 and 12 months, banana yield (kg/plant) and effect relative to the control (%) in Anamur, Mersin Province, Turkey

Application	Root/ Soil	M/H*	Greenhouse 3				Greenhouse 4			
			1 months	12 months	Yield	Effect (%)	1 months	12 months	Yield	Effect (%)
Oxamyl 15 ml 4 Application	root	M	200±103	6900±773	49.5±2.7 a	117.1	0±0	100±46	41.9±1.5 a	63
		H	0±0	0±0			2800±427	900±300		
	soil	M	20±11	2970±271			0±0	240±115		
		H	0±0	0±0			160±34	800±230		
Ethoprophos15 ml 4 Application	root	M	640±98	800±207	44.4±2.1 a	94.7	60±23	100±34	36.4±0.9 b	41.6
		H	0±0	0±0			1040±196	5000±329		
	soil	M	20±11	280±80			40±23	40±23		
		H	0±0	0±0			180±23	1900±334		
Fenamiphos 20 ml 4 Application	root	M					0±0	100±46	37.1±1.5 b	44.4
		H					2400±334	1000±230		
	soil	M					0±0	0±0		
		H					20±11	120±23		
Control	root	M	480±161	120±57	22.8±4.0 b		0±0	0±0	25.7±0.9 c	
		H	0±0	0±0			640±138	1800±323		
	soil	M	120±46	120±23			0±0	0±0		
		H	0±0	0±0			80±23	2000±323		

* H, spiral nematode, *Helicotylenchus multicinctus*; M, root-knot nematodes, *Meloidogyne* spp.

The total number of nematodes (*Helicotylenchus* spp. + *Meloidogyne* spp.) obtained from the root and soil samples collected in August was higher than in May, and the nematode population was more than 2500/100 g in 62% of the root samples collected in August (Özarslandan & Dincer, 2015). Since spiral nematode attacks the root tissues of banana, causing degradation, it prevents the development and reproduction of root-knot nematodes (Araya & Moens, 2003). Thus, it was observed that the spiral nematode population was higher in banana plantations (Tables 1 & 2). Although, it is difficult to determine the damage caused by a specific nematode species in banana, nematicide application provided 61 to 98% yield increase with root-knot and spiral nematode infestation in Nigeria (Caveness & Badra, 1980; Badra & Caveness, 1983) and Ivory Coast (Adiko, 1988). Also, it was reported that nematicides gave 119% and higher yield increases in the banana plantations in Jamaica (Hutton & Chung, 1973) and in Puerto Rico, nematicides gave 207-275% yield increases for more than 3 years (Roman et al., 1977). A yield loss of 15-50% due to *R. similis* and *H. multicinctus* was reported in East Africa (Speijer & De Waele, 2001). In that study, *Azadirachta indica* A. Juss. (Rutales: Meliaceae) and *Allium sativum* L. (Asparagales: Alliaceae) extracts and ethoprophos were used three times at weekly intervals and Mocap application was determined as the most effective, and gave significant increases in plant growth in all applications (Bartholomew et al., 2014). In a study by Mant & Hinai (1996), oxamyl, fenamiphos and ethoprophos were used for nematode control in banana. They reported an increase in plant growth and 48.8% increase in with three nematicides applications of 2.5-3.5 g ai/plant (Quénéhervé et al., 1991b). It was reported that nematicide application increased the yield by 20-40% through nematode nematode management in banana plantations (Araya & Cheves, 1997). In a study by Araya & Lakhi (2004), 3 g ai/plant nematicide led to an average yield increase of 30.8%. Eissa et al. (2005) reported that 1-2 applications of certain biological agents and oxamyl (15 ml/plant; 240 ai/L) in banana plantations against *Meloidogyne incognita, Helicotylenchus exallus* and *Criconemoides* spp. increased bunch weight and finger count. Two or three non-fumigant applications led to 21-44% yield increase in Australia (Broadley, 1979), 50% yield increase in Cameron and 41% yield increase in Costa Rica (Araya & Cheves, 1997). Studies conducted on nematicide use in various banana producing countries found that yield responses varied significantly between 15 and 275% (Gowen & Quénéhervé, 1990). In the Philippines, yield reductions based on bunch weights that varied between 26.4 and 57.1% were observed after inoculation with the root-knot nematode *M. incognita* (Davide & Marasigan, 1985). In greenhouse experiments, significant reductions in plant growth (Jonathan & Rajendran, 2000) and alteration of the concentration of macro- and micronutrients in leaves (Cofcewicz et al., 2004) were observed after inoculation with root-knot nematodes. In the 1980s, only *H. multicinctus* and *Meloidogyne* spp. were considered important pests in Nigerian (Caveness & Badra, 1980) and Ivory Coast plantains (Adiko, 1988), and yield increases that ranged between 61 and 98% after established plantains infested with these nematode species had been treated with nematicide (Caveness & Badra, 1980; Badra & Caveness, 1983). Plantain yield losses that ranged between 25 and 64% for the first crop and 50-90% for the successive crop cycles were reported in Ghana (Coyne et al., 2005). In a field experiment conducted in Cameroon, the total production losses in the first and second cycles were 60 and 51%, respectively (Fogain, 2000). After chemical treatment, large yield improvements were observed in Jamaica with 119% in one cycle (Hutton & Chung, 1973). The present study findings on yield improvement in banana plantations with nematicide treatment is consistent with previous studies.

Injection of carbofuran and oxamyl in the harvested pseudostem did not suppress nematode numbers per 100 g fresh roots, but bunch weight increased significantly, compared to the untreated control (Araya, 1999). While nematicides are effective against stable endoparasitic root-knot nematodes, they are not effective against motile spiral nematodes in the root. Nematode populations did not decrease significantly after nematicide applications and spiral nematode population increased despite the treatment. Araya & Lakhi (2004) reported that nematicides affected the root-knot nematodes, while the nematodes were motile in the root completed their life cycle despite the nematicide treatment and the nematode population increased. It was reported that aldicarb, fenamiphos, isazophos, carbofuran and cadusaphos applications did not prevent the increase in nematode populations in the root in the banana plantations (Stanton & Pattison, 2000; Quénéhervé et al., 1991a, b).

The causes of the root death in banana plantations are biotic and abiotic factors, and it was reported that these not only included nematode damage but also by fungi, bacteria, soil type and poor drainage, pH, plant species, soil moisture, soil structure and mechanical damage (Kobenan et al., 1997). Due to monoculture of banana, the nematode populations continuously increase and there is a always nematodes present in the soil. The low nematode population in winter months adversely affect the development of banana suckers with increasing soil temperature in spring. It was reported that chemical control has been adopted in plant-parasitic nematode management in banana plantations since 1960, but yield loss due to plant-parasitic nematodes can be reduced through the application of integrated management approaches (Gowen et al, 2005; Stirling & Pattison, 2008; Roy et al., 2016; Shankar et al., 2016). Another study reported that fertilizer use after nematicide treatment would be beneficial in nematode-inoculated banana plantations (Smithson et al., 2001).

In banana monoculture in Turkey, it was observed that yield and quality decreases due to nematode damage, leaves concentrated on the top and banana cluster weight decreased. Continuous banana cultivation is conducted in certain locations either in fields or in greenhouses. Spiral and root-knot nematode populations in the mother plant prevent sucker root development, which is the basis of the next generation fruit production. The plants in the control plot were exposed to a high nematode population since they were adjacent to the mother plant. Thus, their yield and quality decreased. Banana suckers are exposed to a lower nematode population when they are further away from the mother plant. Therefore, plant growth, yield and quality increase (Özarslandan, 2019). In the present study, nematode damage awareness was observed among producers. Nematicide should be applied in April, May, June and August in infested greenhouses. In the present study, field observations were conducted and found that ethoprophos 20 L/ha and fenamiphos 40-43.5 L/ha applications led to good plants, and no leaf accumulation was observed. Rates of 150 ml/100 L ethoprophos and 150-200 ml/100 L fenamiphos were applied to the suckers. This treatment yielded 28.6-53.1 kg/plants. The difference between the yields demonstrated that production increases cannot be achieved with nematicides alone. In order to increase product growth in banana plantations, it was demonstrated that an integrated nematode management should be adopted. It is also important that the planted suckers are grown using tissue culture. Since the sucker roots produced by the farmers in greenhouses are infected with disease and nematodes, these suckers should not be planted, since the presence of disease and nematodes in roots will affect plant growth, which will subsequently lead to decreases in the yield and quality. Mycorrhiza treatment should be administered to the suckers before planting. Mycorrhizae are effective against soil-based fungi and nematodes and improve the nutrient uptake and root volume. The Increases in root volume and nutrient intake lead to an increase in the yield and quality. Burnt animal manure should be used. The animal manure decreases nematode motility and propagation, thus leading to good root development. Nematode population decreases due to the increases in beneficial microorganisms in the soil induced by the animal manure. Several benefits of animal manure are already known. Nematode population increases due to cultivation in the same location. Thus, when the mother plant is cut, the nematodes in the roots attack adjacent suckers. Since the development of suckers is negatively affected, they do not develop well. Therefore, an alternation system should be implemented by changing the row positions in the greenhouse frequently. When the suckers are planted adjacent or close to the mother plant, the nematodes in the mother plant attack the suckers and adversely affect their growth. We recommend replacing the suckers every three years due to yield and quality decreases observed after the third year of sucker plantation. In banana cultivation, the row spacing is 3 m and the suckers should be planted at a distance of 1.5 m from the rows. Since the nematode density is 0-40 cm around the plant (Özarslandan, 2019), plant development and yield quality are better when they are planted away from the mother plants. The locations of the rows should be changed frequently in greenhouses. Cut suckers or carved suckers should be used. The suckers planted next to the mother plant in April should be cut and carved between June and early July. A new sucker is obtained far from the mother plant. This sucker gives more yields when compared to the suckers adjacent to the mother plant. Shadow dust should be applied in early April, when the greenhouse temperature rises significantly above 40°C. The greenhouse should be checked at 2 pm when the highest temperatures are observed. The greenhouse temperature should be kept at 30°C. The temperature inside the greenhouse should not exceed 36°C. When temperatures exceed 40°C, plants close to greenhouse vents grow well, however the plants in the center of the greenhouse do not develop well at high temperatures. Since these plants cannot tolerate nematode and root diseases, yield and quality losses increase. Weeds increase nematode population and lead to yield and quality losses in banana. Nematode populations can be reduced by weed control. The nematicide treatment should be conducted in warm periods when the nematodes are active. The banana plant roots develop until flowering. To control the nematodes in these roots, nematicides are applied as two applications in April and May. In August, when decline symptoms are observed in nematode infected roots, the application is necessary if the roots are unhealthy that may cause poor bunches and delayed harvest. Plants with healthy roots form bunches in July and harvest is completed between September and December. Greenhouses should be irrigated in the morning. For plant growth, moisture should be kept around 80% in greenhouses. In certain greenhouses with integrated management, nematicides are used, while they are not required in other greenhouses. Banana could be cultivated without nematicide application. Farmers should utilize all management methods to grow healthy plants that could tolerate the nematodes.

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