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Correlation Between the Distribution of Nematodes and Soil Physicochemical Characteristics in Coffee Rejuvenation Areas

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Abstract

This study investigated the relationship between physicochemical characteristics of soil and the distribution of nematodes in coffee rejuvenation areas in Krong Pak and Krong Nang Districts of Daklak Province, one of the main coffee-growing regions of Vietnam. Thirty soil samples were collected at the top soil layer in each district for soil properties analysis and nematode analysis, and Pearson Correlation was used to determine the correlation between nematode distribution and soil physiochemical properties. It was found that after a coffee production cycle, clay content in topsoil layer was still quite high at 39.40% and 50.48% in Krong Pak and Krong Nang respectively. Chemical properties such as acidity (pHKCl) was 4.42 and 4.12; magnesium was 1.2 and 1.36 me/100 g soil; organic content was 3.71% and 2.42%. Total nitrogen was 0.18% and 0.15%. Bio-available phosphorus content was 27.11 and 32.9 mg/100 g soil. 10 species of harmful nematodes were found in the study area, of which 6 species were present in both districts. The density of nematodes including *Pratylenchus* spp, *Meloidogyne exigua* and *Rotylenchulus reniformis* was negatively correlated with the content of organic matter and Magnesium. *Meloidogyne exigua* also had a negative correlation with the contents of sand and clay. The other seven nematode species were found to not significantly correlate with any of the soil physiochemical properties investigated. The finding of this study could be useful for farmers as well as policy makers in designing appropriate cultivation methods in order to reduce the nematode-caused diseases of coffee and to maintain soil quality and health of agricultural ecosystem.

Keywords: coffee rejuvenation; correlation; nematodes; soil physicochemical characteristics

1. Introduction

It is estimated that annually the global cost of yield losses of agricultural crops due to plant parasitic nematodes is more than $120 billion (Chitwood, 2011). According to Jones et al. (2013) and Bebber et al. (2014), root knot nematode (*Meloidogyne* spp) is the most economically damaging to plants due to its capability of rapidly spreading to and colonizing new localities. Nematode entry and feeding within roots disrupts plant growth processes and causes growth decline. Root knot nematode's damage can also allow secondary infection when other disease-causing organisms enter. Plants with root knot nematode often grow slowly and weakly, suffer moisture stress more readily, and often turn yellow or even consequently die (Serracin et al., 1999). Besides root knot nematode, *Pratylenchus* (root lesion nematode) is also widely distributed in agricultural crops, causing substantial economic losses.

In Vietnam, coffee is one of the most economically valuable crops, importantly contributing to the country's economy. First introduced by the French in the mid 19th century, coffee production in Vietnam has been developing rapidly, becoming a major agricultural product for export. Presently, Vietnam is the world's second largest coffee producer (after Brazil), with an annual production of over 27 million 60 kg bags, accounting for 20% of the world coffee production (Chapman, 2014; Romei, 2015). However, this nationally important industry is facing with the problem of decreasing coffee yield as coffee trees are aging above the average productive period (about 20 years). It is estimated that the area with ageing coffee trees is about 150,000 ha, and up to 200,000 ha in 2020, accounting for about 30% of total coffee cultivation area. Most of the ageing coffee areas are located in the Central Highlands region, the home of Vietnamese coffee. Dak Lak, a province in the Central Highland region, and is the largest coffee production province of Vietnam, has more than 100,000 ha (about 50% of its total coffee plantation area) over the average productive period required to be rejuvenated in the next 5 to 10 years in order to maintain the current coffee yield and productivity, otherwise Vietnam's coffee production will decline dramatically. A large-scale rejuvenation is also an opportunity to improve coffee yield and quality, towards a sustainable production through planting improved varieties and applying latest rejuvenation technology. However, experience from the rejuvenation conducted in recent years (20,000 ha as of 2014) shows that there are numerous obstacles to successful rejuvenation in practice, of which the major concern is the prevailing problem of root system damaging due to harmful nematodes (Chapman, 2014). Nematode damage to coffee is typically characterized by the destruction of the cortical parenchyma cells of the tap, secondary and feeder roots, and causing roots rot. Without a full root system, coffee plants cannot properly take in water and nutrients, failing to respond to fertilizer inputs and cultural practices, and they can easily be dislodged due to poor anchorage. Typically older leaves shed as with drought symptoms. These symptoms are typically found in Vietnamese coffee plants in varying degrees. The major problem is that when old coffees are replanted, collapse of plants with nematode

infestations occurs within the first 3 years of replanting (Chapman, 2014).

Research shows that the physiochemical characteristics of soil are important relative to occurrence and density of nematodes (Fajardo et al., 2011). Majors of these are pH (Van Gundy et al., 1964), soil texture and type (Seinhorst, 1956), organic matter (Morgan et al., 1964), and Magnesium. Finding the relationship between the occurrence of nematodes and characteristics of soil can provide useful information for farmers as well as policy makers to implement appropriate soil management practices in order to control harmful nematodes to plants. The objective of this study was to therefore determine the physiochemical characteristics of soil which may have driven the occurrence and distribution of parasitic nematodes associated with rejuvenated coffee in Dak Lak, Vietnam.

2. Materials and Methods

The study was conducted in Krong Pak and Krong Nang Districts of Dak Lak Province in the Central Highlands region of Vietnam (Figure 1).

Secondary data on the total area of coffee plantation, area of coffee rejuvenation and area of coffee having symptoms of yellowed leaves and root rot in the two districts was collected from governmental agencies, including Ministry of Agriculture and Rural Development, Department of Agriculture and Rural Development of Dak Lak Province and that of Krong Pak and Krong Nang Districts. In each district, we selected five or six communes with many rejuvenated coffee farms having the above symptoms ranging from minor to severe levels as classified by the Ministry of Agriculture and Rural Development including: Severe level: over 50% of the trees in the farm having disease; Medium level: 25-50% of the trees in the farm having disease; and Minor level: less than 25% of the trees in the farm having disease. Thirty soil samples were collected in each district for soil properties analysis and nematode analysis. Soil samples were collected at the top layer (0-20 cm deep), and 0.5-1 m around the tree foot. 1 kg of soil was collected for each sample, then the sample was divided into halves (500 g for soil properties analysis and 500g for nematode analysis). Soil texture was determined using Particle Size Analysis (PSA) (Bowman and Hutka, 2002). In this method, the soil sample was treated with sodium hexametaphosphate to complex Ca^{++}, Al^{3+}, Fe^{3+}, and other cations that bind clay and silt particles into aggregates. Organic matter was suspended in this solution. The density of the soil suspension was determined with a hydrometer calibrated to read in grams of solids per liter after the sand settles out and again after the silt settles. The nematodes species were identified based on the morphological characteristics using centrifugal flotation method (Barker, 1985) and light microscope. The frequency of nematodes was determined as the percentage of samples in which the species was found. The methods used for soil chemical properties and nematode analysis are presented in Table 1. Data obtained was then analyzed using Statistical Package for the Social Sciences and Pearson Correlation in order to find the correlation of nematodes and soil physiochemical properties.

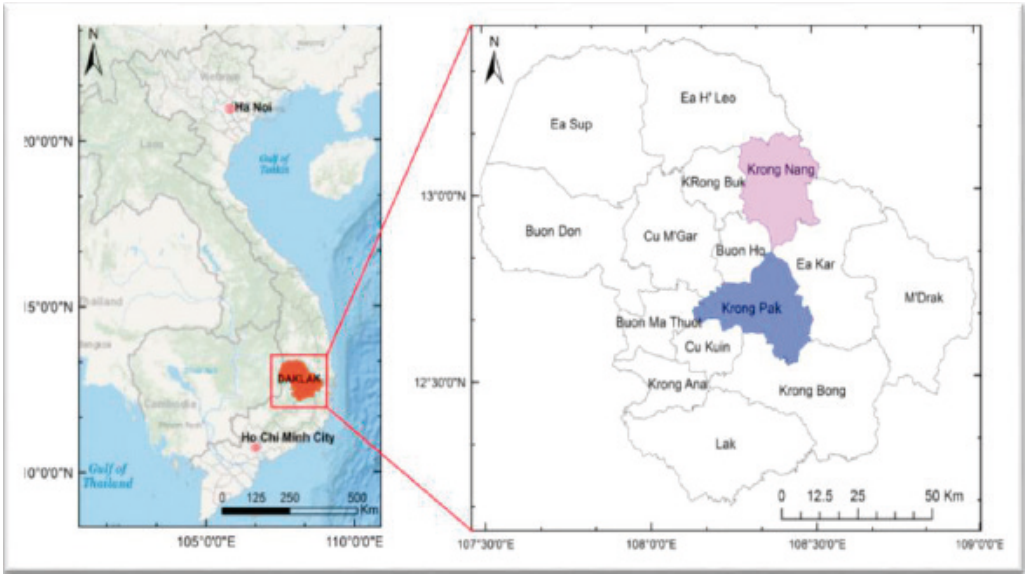

Figure 1. Geographic location of the study area

Table 1. Methodology for analyzing soil properties and nematodes

Properties	Methods
pHKCl	Measured by pH- meter
OM (%)	Walkley-Black method (Walkley and Black, 1934)
TN (%)	Kjeldahl digestion (Kjeldahl, 1883)
Bioavailable phosphorus (mg/100g soil)	Bray I (Bray and Kurtz, 1945)
Bioavailable potassium (mg/100g soil)	Flame Photometer
Magnesium Mg^{2+} (meq/100g soil)	Complexometric titration
Aluminum Al^{3+} (meq/100g soil)	Sokolov method (Sokolov, 1939)
Nematode analysis	Centrifugal flotation (Barker, 1985) and Microscope

3. Results and discussion

3.1. Situation of coffee rejuvenation in the study area

Figure 2 and Figure 3 present the distribution of coffee rejuvenation area in Krong Pak and Krong Nang Districts. The total coffee area of the two districts is 43,140 ha, of which 17,950 ha is in Krong Pak and 25,190 ha is in Krong Nang. According to statistics of the districts, the area of coffee required to be rejuvenated from 2013 to 2020 in Krong Pak district is around 4,249 ha,

accounting for 23.7% of the existing total coffee area of the district. As for Krong Nang District, around 2,084 ha of coffee area required to be rejuvenated during 2016-2020, excluding 661 ha of coffee area which was rejuvenated from 2013 to 2015.

3.3. Density and frequency of nematode species in coffee

In Krong Pak District, Hoa Dong commune has the largest area of coffee rejuvenation with 690 ha, followed by Ea Yong commune with 628 ha, then Ea Kenh commune with 377 ha. Ea Yieng commune has the smallest area of rejuvenation with 42 ha. In Krong Nang District, the commune with the largest area of rejuvenation is Dlie Ya with 447 ha, followed by Ea Tan with 380 ha and Cu Klong stands the last with 35.5 ha.

3.2. Distribution of nematode species in the study area

Results from Analyses of species and density of nematodes in soil and in the roots of re-planted coffee in 2014 in Krong Nang and Krong Pak districts showed that there were 10 species of harmful nematodes (Table 2), of which 6 species presented in both districts, including *Pratylenchus coffeae, Rotylenchulus reniformis, Helicotylenchus dihystera, Helicotylenchus dihystera, Xiphinema diffusum and Criconemella magnifica.* Out of the six species that occurred in both districts, *Pratylenchus coffeae, Meloidogyne incognita, and R. Reniformis* are the major pests to coffee. *Pratylenchus zeaes* were only found in Krong Nang, while *Pratylenchus neglectus*, M. *exigua* and *Meloidogyne* sp. only occurred in Krong Pak.

Compared with other regions in Vietnam (Nguyen and Nguyen, 2000), the presence of parasitic nematode species on coffee in the study area is less diversified as only the main species such as *Pratylenchus, Meloidogyne, Radopholus, and Rotylenchulus reniformis* were found. This shows that the ecological conditions of the different coffee growing regions produce different species of nematode. Also, compared with previous studies (Trinh et al., 2009; Trinh et al., 2013), the number of ectoparasitic nematode species (such as *Helicotylenchus*) has decreased and some other species appear such as those of *Meloidogyne* family (adding two species) and *Pratylenchus* (adding one species). In Trinh et al. (2013), two species of root-knot nematode were additionally found in the Central Highlands, including *M. exigua* and *M. coffeicola*, which parasitise on coffee together with *M. incognita*. Thus, the main harmful nematode species to coffee are present in the Central Highlands. Two species of *M. exigua* and *M. coffeicola* are known to be the major pests in South American coffee growing countries (Campos , 2005) but have not been reported in Asia (Souza, 2008). Density and frequency of occurrence of nematode species on coffee is a major indicator to assess their potential damage. Survey results on harmful nematodes on coffee rejuvenation in pre-matured phase in two districts of Dak Lak province indicated that there were 7 nematode species in Krong Nang district and 9 nematode species in Krong Pak district. However, there

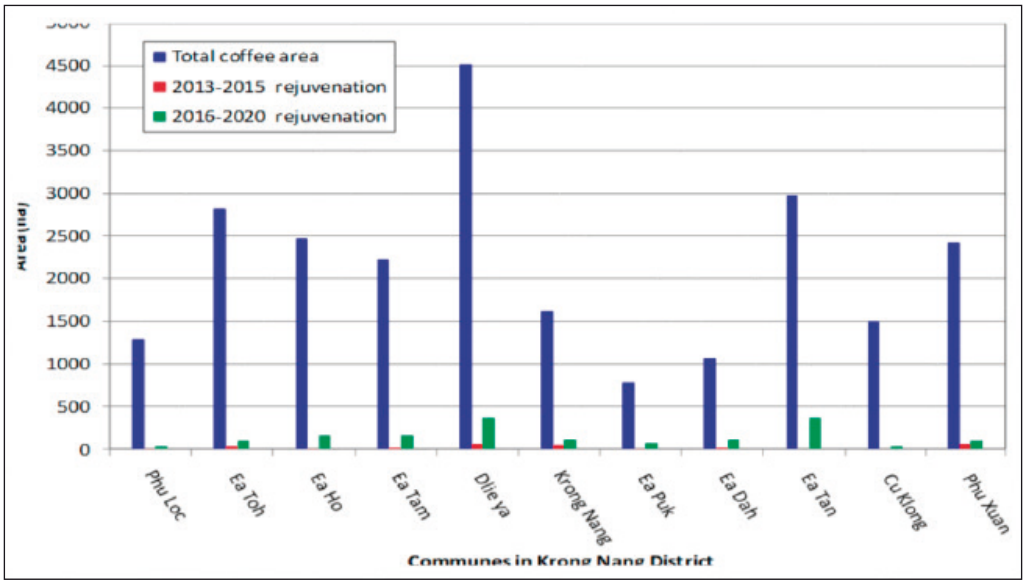

Figure 3. Distribution of coffee rejuvenation area in Krong Nang District

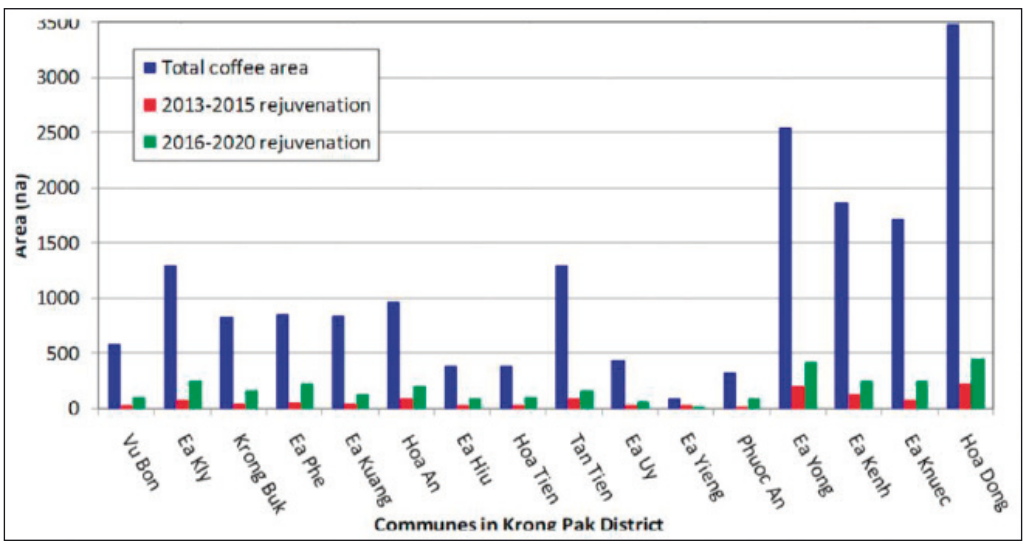

Figure 2. Distribution of coffee rejuvenation area in Krong Pak District

Table 2. The presence of nematode species in soil of coffee rejuvenation

No	Nematode species	Krong Nang	Krong Pak
1	*Pratylenchus coffeae*	+	+
2	*Pratylenchus zeae*	+	-
3	*Pratylenchus neglectus*	-	+
4	*Meloidogyne incognita*	+	+
5	*Meloidogyne exigua*	-	+
6	*Meloidogyne sp.*	-	+
7	*Rotylenchulus reniformis*	+	+
8	*Helicotylenchus dihystera*	+	+
9	*Xiphinema diffusum*	+	+
10	*Criconemella magnifica*	+	+

Note: + Available, - Not available

are differences in the frequency and density of nematodes between the two districts (Table 3). In Krong Nang district, the frequency of occurrence of P. *coffeae* is 64.3% with an average density of 61 and the highest density of 265 individuals / 250g soil. The frequencyof *M. incognita* is 57.1% with an average density of 132 and the highest density of 1113 individuals / 250g soil. For *R. reniformis* species, the frequency is 50%, average density is 39, and the highest density is 182 individuals/250g soil. Compared with Krong Nang in term of frequency and density of the main harmful nematodes, the figures in Krong Pak are higher, the highest is *Meloidogyne incognita species* with 2410 individuals /250g soil, followed by *R. reniformis* with 2120 individuals/250g soil, and *P. coffeae* with 263 individuals/250g soil.

3.4. Physicochemical characteristics of soil in yellow leaf and rot root coffee area.

a. Soil texture

Many studies have confirmed that the physical properties of the soil play a special role in the growth and development of coffee, especially in the second cycle of cultivation because the first cycle of cultivation has changed physical properties following unfavorable trends such as increased density, reduced porosity, lower moisture retention. Meanwhile, these are indicators related to soil texture (Vu et al., 2014). The results of soil analysis presented in Table4show that, after the first cycle of coffee plantation, basaltic soil still has high clay content with average values of 38.5% and 41.52% for Krong Pak and Krong Nang, respectively. The range between the highest value and the lowest

Table 3. Density and frequency of parasitic nematode species on rejuvenated coffee area

TT	Nematode species	Soil		Root	
		Density	Frequency (%)	Density	Frequency (%)
	Krong Nang District				
1	Pratylenchus spp.	61 ± 88 (0-265)	64, 3	164 ± 261 (0-750)	64, 3
2	Meloidogyne incognita	132 ± 318 (0-1113)	57, 1	70 ± 204 (0-765)	35, 7
3	Rotylenchulus reniformis	39 ± 67 (0-182)	50, 0	2 ± 5 (0-19)	7, 1
4	Helicotylenchus dihystera	3 ± 8 (0-40)	21, 2	-	-
5	Xiphinema diffusum	1 ± 1.3 (0-5)	21, 2	-	-
6	Criconemella magnifica	1 ± 0.4 (0-2)	9, 1	-	-
	Krong Pak District				
1	Pratylenchus spp.	104 ± 205 (0-263)	60, 0	136 ± 229 (0-780)	60, 0
2	Meloidogyne spp.	391 ± 805 (0-2410)	53, 3	55 ± 96, 7 (0-256)	33, 3
3	Rotylenchulus reniformis	535 ± 845 (0-2120)	60, 0	3 ± 7 (0-24)	26, 0
4	Helicotylenchus dihystera	0.1 ± 0, 2 (0-1)	6, 7	-	-
5	Xiphinema diffusum	1 ± 1, 6 (0-5)	20, 0	-	-
6	Criconemella magnifica	0, 1 ± 0, 3 (0-1)	6, 7	-	-

Note: Density is the number of nematodes found in 250g of soil. Density was shown as average ± STDEV (min - max)

value of clay content indicates the development trend of the soil. Sampling sites with high content of clay indicate the nature of the soil derived from the parenteral basaltic rock. In contrast, sampling sites with under-average clay content, especially the samples with the minimum value, reflect the effects of coffee cultivation on soil degradation and on the

change of soil texture.

b. Chemical properties

Chemical properties of soil reflect the ability of the soil to provide nutrients to plants, but this ability also depends on many factors such as soil moisture, soil acidity and plants and their growing stage. In principle, the soil developed on basalt rock is rich soil, in terms of both physical properties and chemical properties, except for some factors arising from parent rock such as low content of total potassium and sulfur. However, after long cycles of coffee cultivation, properties of soil may significantly change, and thus the trend of chemical behavior and whether it is related to the emergence of nematodes need to be considered. In the present study, we investigated a number of chemical properties of coffee-growing soil at the sites where coffee was yellowed or dead. The results are as follows:

- Soil acidity:

Soil acidity is among the important environmental factors influencing plant growth. Initially, each type of soil has a certain level of acidity and pH depending on its composition, native vegetation, and rainfall amounts; however, a variety of factors cause changes in soil pH. Leaching, erosion, and plant uptake of basic cations (calcium, Ca^{2+}; magnesium, Mg^{2+}; and potassium, K^{+}), decay of plant residues, and plant root exudates are all means by which the soil pH is increased (Weil and Brady, 2016). Results of exchangeable soil pH (pHKCl) analysis of 60 soil samples in the study area show that after the first coffee growing cycle, for Krong Pak district, pHKCl had the minimum value of 3.36 and the maximum value of 5.66 with an average value of 4.42 and standard deviation of 0.63.

For Krong Pak, pH KCl ranged between 3.43 and 5.15 with an average of 4.12 and standard deviation of 0.29. Thus, values of pH KCl in the two districts were slightly different but ranged within the same level of acidity. Possible causes may be due to the effects of alkali metals and alkaline earth metals washaway. This is evidenced by the analysis of magnesium content. Mg^{2+} ranged between 0.29-5.4 me/100g of soil in Krong Pak and between 0.32-3.12 me/100g of soil in Krong Nang with average values of 1.2 and 1.36 for the two districts respectively (Table 5).

- Contents of Organic Matter (OM) and Total Nitrogen (TN)

According to Soane (1990) organic matter in the soil is a source of nutrients that correlates very closely with the fertility of the soil, especially in the hot and humid climate of tropical regions, including Vietnam. Under the influence of high temperatures and humidity, organic matter is rapidly decomposed and-washed away gradually. Forest land after cleared and changed to cultivated land, the index of cultivation (expressed by the contents of humus) is only equal to 18 - 26% of that of the original forest land. In the study area, after a cycle of coffee plantation, organic matter of the soil has average values of 2.76 and 2.42 for Krong Pak and Krong Nang respectively. These values are below the average range of most of productive agricultural soils (which is 3-6%) (Fenton et al., 2008). Total nitrogen content also tends to be similar to that of OM in soils. Analysis results of 60 soil samples from coffee areas with symptoms of yellowed leaves, root rot or death shows that TN ranges between 0.14% and 0.34% in Krong Pak and between 0.11% and 0.35% in Krong Nang with averages of 0.18% and 0.15% for the two district, respectively (Table 6).

Table 4. Texture of soil in yellow leaf and rot root coffee area

District	Statistics	Percentage (%)		
		Sand	Silt	Clay
Krong Pak (n=30)	Mean	18.61	42.89	38.50
	Max	39.40	49.36	48.56
	Min	7.90	32.77	18.17
	STDEV	*7.43*	*3.71*	*8.31*
Krong Nang (n=30)	Mean	14.51	43.98	41.52
	Max	22.43	49.17	50.14
	Min	9.50	30.58	29.02
	STDEV	*3.76*	*5.01*	*4.28*
Two districts (n=60)	Mean	16.56	43.43	40.01
	Max	39.40	49.36	50.14
	Min	7.90	30.58	18.17
	STDEV	*6.20*	*4.41*	*6.73*

Table 5. Chemical properties of soil in yellow leaf and rot root coffee sites

District	**Statistics**	**pHKCl**	**Al^{3+}**	**Mg^{2+}**
			(me/100g)	
Krong Pak (n=30)	Mean	4.42	0.43*	1.20
	Max	5.66	0.84	5.40
	Min	3.36	0.24	0.29
	STDEV	*0.63*	*0.14*	*1.24*
Krong Nang (n=30)	Mean	4.12	0.35**	1.36
	Max	5.15	1.68	3.12
	Min	3.43	0.04	0.32
	STDEV	*0.29*	*9.45*	*0.79*
Two districts (n=60)	Mean	4.27	0.41***	1.28
	Max	5.66	1.68	5.40
	Min	3.36	0.04	0.29
	STDEV	*0.51*	*0.34*	*1.03*

(*): Average of 19 samples; (**): Average of 27 samples; (***): Average of 46 samples

- Contents of bioavailable phosphorus and potassium

According to Weil and Brady (2016), phosphorus is an indicator of soil fertility, and according to Peuke et al. (2002), after nitrogen and phosphorus, potassium is the third most important nutrient element for plants in general and coffee in particular. Studies show

that phosphorus and potassium are the precursors of soil: which developed on rocks containing rich phosphorus and potassium minerals are rich in phosphorus and potassium. Soils developed on weathering products of basalt are usually rich in total phosphate but poor in bioavailable phosphate and potassium. Table 7 presents the content of bioavailable phosphorus (as P_2O_5) and potassium (as K_2O) in basaltic soil in the study area. P_2O_5 was found to range between 9.68-46.99 mg/100g soil (average of 27.16) in Krong Pak and 20.56-32.79 mg/100g soil (average of 44.06) in Krong Nang. As for K_2O, the average values were found to be 56.26 and 64.43 mg/100g soil for Krong Pak and Krong Nang respectively. The contents of bioavailable phosphorus and potassium found in the present study are much higher than that investigated previously by another study conducted in the same area (SCP, 2014). However, this is attributed to phosphorus and potassium fertilized by farmers in the early phase of re-cultivation.

- Correlation between physiochemicalproperties of soil and the density of nematod species

The correlation between physical and chemical properties of soil and the distribution of nematodes in coffee rejuvenation areas wasexamined (Table 8). Data was analyzed using Statistical Package for the Social Sciences and Pearson Correlation was employed. Theresults show that among nine physical and chemical properties investigated, OM, and Mg^{2+} were closely negatively correlated with the density of three nematode species including *Pratylenchus* spp, *Meloidogyne exigua* and *Rotylenchulus reniformis*. Specifically, OM has Pearson Correlation coefficient (r value) of -0.372 (with *Pratylenchus spp*), -0.5 (with *Meloidogyne exigua*), and -0.456 (with *Rotylenchulus reniformis*). For Mg^{2+}, the r values are -0.255; -0.285, and -0.337 for the three nematode species, respectively. For soil texture, only *Meloidogyne exigua* has a negative correlation with sand content and clay content with r values of -0.297 and -0.313, respectively. These mean that after a cycle of coffee plantation and the above mentioned properties of soil were degraded, *Pratylenchus* spp, *Meloidogyne exigua* and *Rotylenchulus reniformis* are likely to occur more densely. The density of the other nematode species was not correlated with the physical and chemical properties of the soil investigated. Research shows that among soil conditions, soil texture, which determines soil compactness and porosity (thereby availability of moisture and aeration for the nematodes) is one of the most important soil characteristics related to density of nematode in crop fields (Moore and Lawrence, 2013). Generally light sandy soils are more favorable to large populations of nematodes than heavy clay soils owing to more adequate aeration provided in soils consisting of coarse particles (Dropkin, 1980). However, other factors such as weather conditions, soil moisture, cultivation methods, etc. would also affect the occurrence and density of nematodes. Therefore, it is understandable if the correlations between density of nematodes and soil properties do not always exist.

Table 6. Organic matter and nitrogen contents of the soil in yellowed leaves and rot root coffee sites

District	Statistics	OM (%)	TN (%)
Krong Pak (n=30)	Mean	2.76	0.18
	Max	5.17	0.34
	Min	1.36	0.14
	STDEV	*0.84*	*0.04*
Krong Nang (n=30)	Mean	2.42	0.15
	Max	3.13	0.35
	Min	1.77	0.11
	STDEV	*0.36*	*0.04*
Two districts (n=60)	Mean	2.59	0.17
	Max	5.17	0.35
	Min	1.36	0.11
	STDEV	*0.66*	*0.04*

Table 7. Contents of phosphorus and potassium at yellowed leaves and rot root coffee sites

District	Statistics	P_2O_5	K_2O
		(mg/100g soil)	
Krong Pak (n=30)	Mean	27.16	29.83
	Max	46.99	56.26
	Min	9.68	16.44
	STDEV	*10.70*	*11.10*
Krong Nang (n=30)	Mean	32.79	40.19
	Max	44.06	64.43
	Min	20.56	9.44
	STDEV	*6.30*	*12.90*
Two districts (n=60)	Mean	29.98	35.01
	Max	46.99	64.43
	Min	9.68	9.44
	STDEV	*9.15*	*13.03*

Table 8. Correlation between physiochemical properties of soil and the density of nematod species

		pH	OM	TN	P2O5	K2O	Mg++	Al+++	Sand	Silt	Clay Pra	Meloi	Roty
pH	Pearson Correlation	1											
	Sig. (2-tailed)												
	N	60											
OM	Pearson Correlation	.068	1										
	Sig. (2-tailed)	.603											
	N	60	60										
TN	Pearson Correlation	.314*	.269*	1									
	Sig. (2-tailed)	.015	.038										
	N	60	60	60									
P2O5	Pearson Correlation	.129	-.153	-.090 1									
	Sig. (2-tailed)	.328	.242	.495									
	N	60	60	60	60								
K2O	Pearson Correlation	-.281*	-.012	.164	.162	1							
	Sig. (2-tailed)	.029	.930	.209	.216								
	N	60	60	60	60	60							
Mg++	Pearson Correlation	-.032	.643**	.101	.108	.271*	1						
	Sig. (2-tailed)	.810	.000	.443	.409	.036							
	N	60	60	60	60	60	60						
Al+++	Pearson Correlation	-.680**	.054	-.125	-.037	.014	-.048	1					
	Sig. (2-tailed)	.000	.681	.341	.778	.918	.713						
	N	60	60	60	60	60	60	60					

			pH	OM	TN	P2O5	K2O	Mg++	Al+++	Sand Silt	Clay	Pra	Meloi	Roty
Sand	Pearson Correlation	.726**	.029	.270*	.061	-.192	-.097	-.349**	1					
	Sig. (2-tailed)	.000	.826	.037	.643	.142	.459	.006						
	N	60	60	60	60	60	60	60	60					
Silt	Pearson Correlation	.197	.202	-.043	.237	-.009	.212	-.260*	-.229	1				
	Sig. (2-tailed)	.130	.121	.746	.068	.948	.105	.044	.078					
	N	60	60	60	60	60	60	60	60	60				
Clay	Pearson Correlation	-.798**	-.159	-.221	-.211	.182	-.049	.492**	-.770**	-.444**	1			
	Sig. (2-tailed)	.000	.225	.090	.105	.164	.710	.000	.000	.000				
	N	60	60	60	60	60	60	60	60	60	60			
Pra	Pearson Correlation	-.218	-.372**	-.077	.021	-.042	-.255*	.097	-.089	-.176	.197	1		
	Sig. (2-tailed)	.094	.003	.560	.876	.748	.049	.462	.497	.179	.131			
	N	60	60	60	60	60	60	60	60	60	60	60		
Meloi	Pearson Correlation	-.174	-.560**	-.240	.125	.073	-.285*	.020	-.297*	-.061	.313*	.012 1		
	Sig. (2-tailed)	.183	.000	.065	.342	.581	.027	.882	.021	.646	.015	.929		
	N	60	60	60	60	60	60	60	60	60	60	60	60	
Roty	Pearson Correlation	.185	-.456**	-.024	.058	-.051	-.337**	-.172	.175	-.005	-.158	-.093	.097	1
	Sig. (2-tailed	.156	.000	.858	.660	.701	.008	.189	.181	.973	.227	.481	.462	
	N	60	60	60	60	60	60	60	60	60	60	60	60	60

*. Correlation is significant at the 0.05 level (2- tailed).

**. Correlation is significant at the 0.01 level (2- tailed).

4. Conclusion

This study found that there were 10 species of harmful nematodes occurring in the soil or coffee roots in Krong Pak and Krong Nang districts of the Central Highlands region of Vietnam, of which 6 species presented in both districts, but with different frequency. The occurrence of nematodes including *Pratylenchus* spp, *Meloidogyne exigua* and *Rotylenchulus reniformis* was negatively correlated with the content of organic matter and Magnesium. *Meloidogyne exigua* also has a negative correlation with the contents of sand and clay. The other seven nematode species were found to not significantly correlate with any of the soil physiochemical properties investigated. From the negative correlations found in this study, it can be conclude that if the contents of organic matter and Magnesium in the soil are increased, the density of *Pratylenchus* spp, *Meloidogyne exigua* and *Rotylenchulus reniformis* may decrease, and if the contents of sand and clay are increased, the density of *Meloidogyne exigua may* decrease. Nematode control practices should therefore focus on the improvement of contents of organic matter, Magnesium, sand, and clay in the soil. In addition, in order to control the nematodes in soil and increase soil quality for more productive coffee cultivation, together with often-used chemical conter-measures, alternatives such as incorporation of organic residues, soil solarization, and use of legume cover crops are recommended. For nematode management of gardener, it is also important to note that nematodes are mainly spread through lack of sanitation and movement of infected soil and planting material. In order to limit a build-up of nematodes, planting tools should be properly cleaned. Furthermore, because once nematodes are introduced into a crop field they cannot be totally eradicated, so only soil and planting material free of nematodes should be used. After harvest, infected coffee trees should be destroyed to prevent the build-up of nematodes on the residues and therefore in the soil.

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