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Relationship of soil abiotic factors with population abundance and vertical distribution of root lesion nematode in robusta coffee plantation

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Abstract

This research was undertaken with the aim to know the abundance and vertical distribution of *Pratylenchus* sp. influenced by soil abiotic factors and coffee plant varieties in three fields. The research was conducted in Malangsari, Getas and Candiroto feilds. Samples of soil and roots were collected and various parameters of soil abiotic factors (pH, soil moisture, soil temperature, soil texture and organic matter) were obtained from each of the three fields. Vertical distribution was assessed using two soil sample depths (30 cm and 50 cm). This research showed that the highest population abundance of *Pratylenchus* sp. both from soil and roots was in Candiroto field with BP 42 variety i.e. 27 nematodes per 100 ml of soil and 60 nematodes per 10 g of roots, respectively. Relationship between pH and soil temperature with population abundance was negative correlation whereas soil moisture and organic matter had positive correlation. Vertical distribution of *Pratylenchus* sp. in all fields on Excelsa coffee, BP 308 and BP 42 variety were detected in < 30 cm depth, whereas in 50 cm depth only detected on BP 308 variety in Malangsari Field. The abundance of *Pratylenchus* sp. was mostly influenced by soil moisture, soil texture and variety.

Keywords: Abundance, coffee, *Pratylenchus*, soil abiotic factors, vertical distribution.

Plant parasitic nematodes are regarded as severe constraints to coffee production in Indonesia. Root lesion nematodes (*Pratylenchus* sp.) are considered as the most destructive plant parasitic nematodes of coffee plantation. The most important species that infects coffee in North Sumatera, Lampung, Central Java, East Java, Bali, South Sulawesi, and NTT (Nusa Tenggara Timur) is *Pratylenchus coffeae* (Wiryadiputra & Tran, 2008).

In East Java, *Pratylenchus* sp. caused yield losses up to 78% (Wiryadiputra, 1995 *cit.* Wiryadiputra & Tran, 2008). There were some lesion in the roots of coffee that were infected by *Pratylenchus* sp., yellowish leaves, and the growth was poor due to the retardation of water and nutrition uptake (Hulupi, 2008). *P. coffeae* is responsible for the death of plants that are younger than 5 years old (Trinh *et al*., 2011). *Pratylenchus* sp. lives in the soil then penetrates the roots.These nematodes develop and migrate within the roots.

Soil abiotic factors is one of the factor that influence the severity damage and vertical distribution of *Pratylenchus* sp. Soil abiotic factor such as soil texture, soil temperature, and soil moisture was could influence the population abundance (Castillo & Vovlas, 2007; Ornat *et al*., 1999).

Pudasaini *et al*., (2006) observed the vertical distribution of *P. penetrans* to be predominantly determined by the host. Earlier researchers also reported that vertical distribution of nematodes in soil depends on the nematode species (Davis *et al*., 1994), distribution of the hosts root system (Mac Guidwin & Forage, 1991) and the soil type and environmental conditions (Trinh *et al*., 2011).

Variety of the plant also influenced the vertical distribution and penetration of *Pratylenchus* sp. The main factor that influenced vertical distribution of *Pratylenchus* sp. was the roots system distribution and the climate fluctuation that play an important secondary role (Ravichandra, 2008).

Distribution pattern of nematode in soil depended on the cultivation, plant cover, extent of feeder roots, soil moisture and temperature (Montasser *et al*., 2015). Another factor, the soil organic composition, influenced vertical distribution of the nematode (Nzeako *et al*., 2014).

The major coffee type (about almost 93%) that is planted in Indonesia is robusta coffee (Wiryadiputra & Tran, 2008). In Indonesia, the most robusta coffee plantation is in Sumatera (about 69.53%) and in Java about 14.8%. In Java, coffee plantations are dominant in East and Central Java 60.27% and 24.22%, respectively. Total area of robusta coffee plantation in East Java is 63,770 ha and in Central Java is 25,636 ha (Nurbahar *et al*., 2014).

There were several varieties of robusta coffee that would be adapted by the altitude and climate type (Scmidd and Fergussons) such as variety BP 358, BP 436, BP 534, BP 920, BP 936 adapted in > 400 masl with climate type A and B. Variety BP 42, BP 234, BP 409, BP 939, BP 936, BP 534, SA 237, SA 203 adapted in > 400 masl (meter above sea level) with climate type C and D. Variety BP 42, BP 234, BP 358, BP 436, BP 920, BP 936, BP 534 adapted400 masl with climate type A and B. Variety BP 42, BP 234, BP 288, BP 409, BP 939, BP 936, BP 534, SA 237, and SA 203 adapted in < 400 masl with climate C and D. Variety BP 308 as a rootstock that adapted in all condition that resistant to nematode (Kementan, 2014). In Indonesia information about the relationship of soil abiotic factor and variety of robusta coffee that influenced the population abundance and the vertical distribution of *Pratylenchus* sp. is lacking. Therefore this study was conducted to observe the abundance of *Pratylenchus* sp. in some areas of robusta coffee plantation. The objective of this research was to know the relationship between the soil abiotic factor with the abundance of *Pratyenchus* sp. and the vertical distribution of *Pratylenchus* sp. in several varietys and fields of robusta coffee.

Materials and Methods

Experimental Field: The observations were taken in 3 different area of robusta coffee plantation, i.e. PTPN XII Malangsari Field (East Java), PTPN IX Getas Field (Central Java) and Candiroto Field (Central Java). The observation was taken from August to November 2016. In both PTPN XII and PTPN IX, the planted varieties were Excelsa coffee and BP 308, whereas in Candiroto Field, it was BP 42. Soil abiotic factors observed in this study were pH, soil moisture, soil temperature, organic matter, and soil texture. Soil moisture and soil temperature were observed on the field with RH meter and soil thermometer, whereas pH, organic matter and soil texture were analyzed in the laboratory.

Soil Sampling: Soil samples were taken with purposive technique sampling on the coffee plants that were severely damaged by *Pratylenchus* sp. At each field 5 – 7 plants per variety were sampled depending on the severity and each consisted of 3 soil cores. Each core was divided into two depths (< 30 cm and 30- 50 cm) for vertical distribution analyses.

Analyses of Nematode Population: Soil sample on each area was thoroughly mixed and a 100 ml subsample was taken. Each subsample had 5 replications for soil sample and 2 replications for roots sample. Nematodes were extracted from the mineral soil fraction used Whitehead tray method (Bezooijen, 2006), whereas, for extraction of nematodes from roots the Mistifier method (Bezooijen, 2006) was used before sieving and decanting (Cobb, 1918) through a 40 µm sieve. Number of *Pratylenchus* sp. was counted in a counting dish under the stereo microscope. Population abundance was counted by multiplying the average number of *Pratylenchus* sp. from 5 ml in 50 nematode suspensions (Rahman *et al*., 2014).

Statistical Analysis: Number of *Pratylenchus* sp. from each extracted soil and root samples in all fields were statistically analyzed using ANOVA. Relationship between soil abiotic factor and *Pratylenchus* sp. abundance (soil + roots) were analyzed by correlation and linier regression analyses. Vertical distribution of *Pratylenchus* sp. used from extracted soil sample on 2 depths (< 30 and 50 cm). Total numbers of *Pratylenchus* sp. from extracted soil on 2 depths for each variety were analyzed to determine the effect of variety and depth with the population in each field. The data was analyzed by multifactor analyses of variance (ANOVA). In this work, 5 x 2 factorial study was used. The first factor consisted of a variety from each location i.e. Excelsa_A, BP 308_A (A: Malangsari Field), Excelsa_B, BP 308_B (B: Getas Field), BP 42 (Candiroto Field). The second factor is depth i.e. < 30 cm and 50 cm. For statistical analyses used R verse 3.3.1.

Results and Discussion

Malangsari Field was in 659 masl (meter above sea level) with the value of pH, soil moisture, soil temperature and organic matter at 6.02; 56%; 27°C; 3.62%, respectively. Getas Field was in 480 masl with the value of pH, soil moisture, soil temperature, and organic matter, respectively at 5.42; 58.5%; 28.3°C; 3.32%. Candiroto Field was in 783 masl with the value of pH, soil moisture, soil temperature, and organic matter, respectively 4.70; 67.5%; 25.4°C; 3.74% (Table 1). All fields had same soil texture, i.e. clay loam but there had been a different percentage of soil fraction (Table 2).

Relationship between soil abiotic factor and *Pratylenchus* sp.: Habitat of plant parasitic nematode was mostly on the soil and the roots. *Pratylenchus* sp. is endoparasite migratory nematode that mostly living on the roots. Soil abiotic factors can influence the abundance of *Pratylenchus* sp. both in the soil and the roots. Soil abiotic factor such as soil temperature, soil moisture, organic matter, and pH can influence the population of plant parasitic nematodes directly and indirectly (Fig.1a, b).

Pratylenchus sp. abundance in the soil and roots of 3 fields was significantly different both on the soil and roots. Population abundance in Candiroto Field was significantly different from other fields, whereas population abundance in Malangsari and Getas Field were not significantly different in both soil and roots. The highest population in the soil and the roots was in Candiroto Field, 27 nematodes per 100 g of soil and 60 nematodes per 10 g of roots, respectively. In Malangsari Field, population abundance both on the roots and soil was not significantly different on each variety. From Excelsa coffee, nematode abundance was 13 nematodes per 100 g of soil and 15 nematodes per 10 g of roots, respectively. From BP 308 variety, nematode abundance was 2 nematodes per 100 g of soil and 10 nematodes per 10 g of roots, respectively (Table 3).

Population abundance of both on the roots and soil was not significantly different on each variety. From Excelsa coffee, nematode abundance was 12.7 nematodes per 100 g of soil and 15 nematodes per 10 g of roots, respectively. From BP 308 variety, nematode abundance was 2 nematodes per 100 ml of soil and 10 nematodes per 10 g of roots, respectively (Table 3). Population abundance of *Pratylenchus* sp. was influenced by the soil abiotic factors such as pH, soil moisture, temperature and organic matter. Based on correlation coefficient, all soil abiotic factors were significantly different ($\alpha = 0.05$). pH and soil temperature have negative correlation whereas soil moisture and organic matter have positive correlation with the population abundance of *Pratylenchus* sp. (Table 4).

Population abundance of *Pratylenchus* sp. was mostly influenced by soil moisture that showed the highest R^2 value than other soil abiotic factors i.e. 0.43 (Table 5) thus it was the key factor that influenced the population abundance. Based on coefficient correlation (Table 4), both soil moisture and soil temperature were influenced by pH and organic matter whereas pH and organic matter were not influenced by each other (Fig. 2, 3).

Vertical Distribution Analysis of *Pratylenchus* spp.: Number of *Pratylenchus* sp. from the soil of all field was significantly influenced by the variety ($F = 5.072$; $df = 4$; $P < 0.05$), depth ($F = 42.959$; $df = 1$; $P < 0.05$) and interaction of variety and depth ($F = 5.473$; $df = 4$; $P < 0.05$). The lowest population of *Pratylenchus* sp. was from the layer of 50 cm depth of all varietys in 3 fields that there was not detected *Pratylenchus* sp. except on BP 308 variety in Malangsari Field as much as 2 nematodes per 100 ml of soil. The highest population of *Pratylenchus* sp. was from the < 30 cm depth on BP 42 variety in Candiroto as much as 27 nematodes per 100 ml of soil.

Vertical distribution of *Pratylenchus* sp. was observed on both < 30 and 50 cm depth in each variety for 3 fields (Fig. 3). Abundance of *Pratylenchus* sp. in Malangsari Field were not significantly difference for both variety, whereas in the layer of < 30 and 50 depth there was significantly difference in Excelsa coffee but not significantly difference on BP 308 variety. In Getas Field, there were significantly different for both variety and both depth < 30 and 50 cm on Excelsa coffee but not significantly different on BP 308 variety. Both Excelsa coffee in Malangsari and Getas Field were not significantly different in the layer of < 30 cm depth and also with BP 308 variety in Malangsari Field. BP 308 variety in Malangsari and Getas Field were not significantly different.

In Candiroto Field with BP 42 variety was significantly different with both Excelsa coffee and BP 308 variety in both < 30 cm and 50 cm depth and also significantly different with the layer of 50 cm depth on its variety. Both Excelsa coffee (Malangsari & Getas Field) and BP 42 variety were significantly different in both < 30 cm and 50 cm depth whereas BP 308 variety was not significantly different at both 30 cm and 50 cm depths (Fig. 3).

Plant parasitic nematode live in the roots and in the soil thus the population of nematode was influenced by environment. *Pratylenchus* sp. is endoparasite migratory nematode and generally spent life in the roots (Tuyet, 2010). Environmental factor including edaphic factor and climate such as soil texture and structure, soil temperature, soil pH, and soil moisture influenced the biology of *Pratylenchus* sp. so that it could be influenced the nematode population (Inomoto & Olivieira, 2008).

Soil abiotic factor which generally used as an estimate parameter, that influenced the population abundance of nematode i.e. pH, soil moisture, soil temperature, and soil texture. pH and soil texture directly influenced the population, whereas soil moisture and soil temperature were critically influenced along the reproduction stage (Norton, 1989).

The population abundance data demonstrated that the highest population of *Pratylenchus* sp. was in Candiroto Field both on the soil and the roots. Based on the soil abiotic factor that observed in this study, Candiroto Field have the highest RH (67.5 %) and the lowest pH (4.70). This data showed that *Pratylenchus* sp. was well developed in the high RH and low pH, whereas the soil temperature was following the soil moisture and have negative correlation with it.

Castillo & Vovlas (2007) reported that the optimum soil moisture for *Pratylenchus* sp. growth and development was 70 – 80%.*Pratylenchus* sp. has wide optimum pH range and it depends on its species. *P. brachyurus* was in 5 – 7.3; *P. penetrans* was in 5.2 – 6.4 and for both species decreasing pH value followed by decreasing population (Castillo & Vovlas, 2007; Melakeberhan *et al*., 2000).

Besides the soil abiotic factor, damage caused by plant parasitic nematode was influenced by the host susceptibility (Kandel *et al*., 2013). In this research, there were 3 varietys that planted in the field i.e. Excelsa coffee, BP 308 and BP 42. Each variety has differences in either morphology or physiology. BP 42 variety was recommended by the government since has good adaptations with the climate and altitude, whereas BP 308 variety was recommended as a plant resistant of nematode (Purwanto *et al*., 2015).

Excelsa coffee was the old coffee plant in both Malangsari & Getas Field that predicted as a resistant variety against nematode, whereas Excelsa coffee was more susceptible than BP 308 variety. BP 42 variety was susceptible to *Pratylenchus coffeae*, whereas BP 308 was highly resistant. However, the resistance of BP 308 variety depends on the source of planting material. Clonal source was more resistant than propelegitim source (Mawardi *et al*., 2004). Data showed that *Pratylenchus* sp. was found from roots of variety BP 308 in both Malangsari and Getas Field. The presence of *Pratylenchus* sp. in variety BP 308 showed that the resistant variety could be attacked by the *Pratylenchus* sp. in different area that have different condition of soil.

Interaction between host susceptibility and soil abiotic factor influenced the vertical distribution of *Pratylenchus* sp. The data was demonstrated that *Pratylenchus* sp. was highly abundance in < 30 cm depth and *Pratylenchus* sp. was not detected in 50 cm depth except on BP 308 variety in Malangsari Field. Studies on vertical distribution of *Pratylenchus* sp. on coffee showed that *P. coffeae* was dominant in the layer 10 - 40 cm, about 70 - 90% of total nematode (Trinh *et al*., 2011).

Vertical distribution of *Pratylenchus* sp. on turf was highly abundant in the layer of 0.5 - 10 cm depth, then decrease till 20 cm depth. It might be due to the roots exudates of the turf; it means that vertical distribution of *Pratylenchus* sp. was highly influenced by the roots system of the host (Nzeako *et al.*, 2016).Generally, about 70% of roots system of robusta coffee was in above 30 cm (Hulupi & Mulyadi, 2007). Every variety has different roots system distribution. It was reported by Mawardi *et al*., (2004) where

Table 1. Soil abiotic factor in 3 Robusta coffee plantation.

Field	Altitude (masl)*	Parameter of Soil Abiotic Factor				
		pH	Soil Moisture (%)	Temperature (^{0}C)	Organic Matter (%)	Texture
Malangsari	659	6.02	56	27	3.62	clay loam
Getas	480	5.42	58.5	28.3	3.32	clay loam
Candiroto	783	4.70	67.5	25.4	3.74	clay loam

*= Meter above sea level

Table 2. Percentage of soil fraction in 3 Robusta coffee plantation.

Field	Soil Fraction (%)		
	Clay	Dust	Sand
Malangsari	28.76	39.89	31.34
Getas	32.38	40.74	26.89
Candiroto	33.71	40.8	25.49

Table 3. Population of *Pratylenchus* sp. in three fields.

Field	Population of *Pratylenchus* spp.	
	Soil (100 g)	Roots (10 g)
Malangsari_Excelsa	14 b	2 b
Malangsari_BP308	6 b	5 b
Getas_Excelsa	13 b	15 b
Getas_BP 308	2 b	10 b
Candiroto_BP42	27 a	60 a

The different letters in number of population showed significant differences according to Duncan's multiple range test ($P < 0.05$).

Table 4. Correlation coefficient of *Pratylenchus* sp. abundance and soil abiotic factor.

Abiotic factors	Population	pH	Soil moisture	Soil temperature	Organic matter
Population	1				
pH	-0.6*	1			
Soil moisture	0.66*	-0.97*	1		
Soil temperature	-0.6*	0.59*	-0.78*	1	
Organic matter	0.48*	-0.33	0.56*	0.95*	1

*= showed significant differences P < 0.05

Table 5. Regression analysis of population abundance of *Pratylenchus* sp. on soil abiotic factors.

Parameters	Intercept	Prob.	R^2
pH	0.0009*	0.0037*	0.36
Soil moisture	0.0039*	0.0011*	0.43
Soil temperature	0.0023*	0.0043*	0.35
Organic matter	0.0517	0.029*	0.22

*= showed significant differences P < 0.05

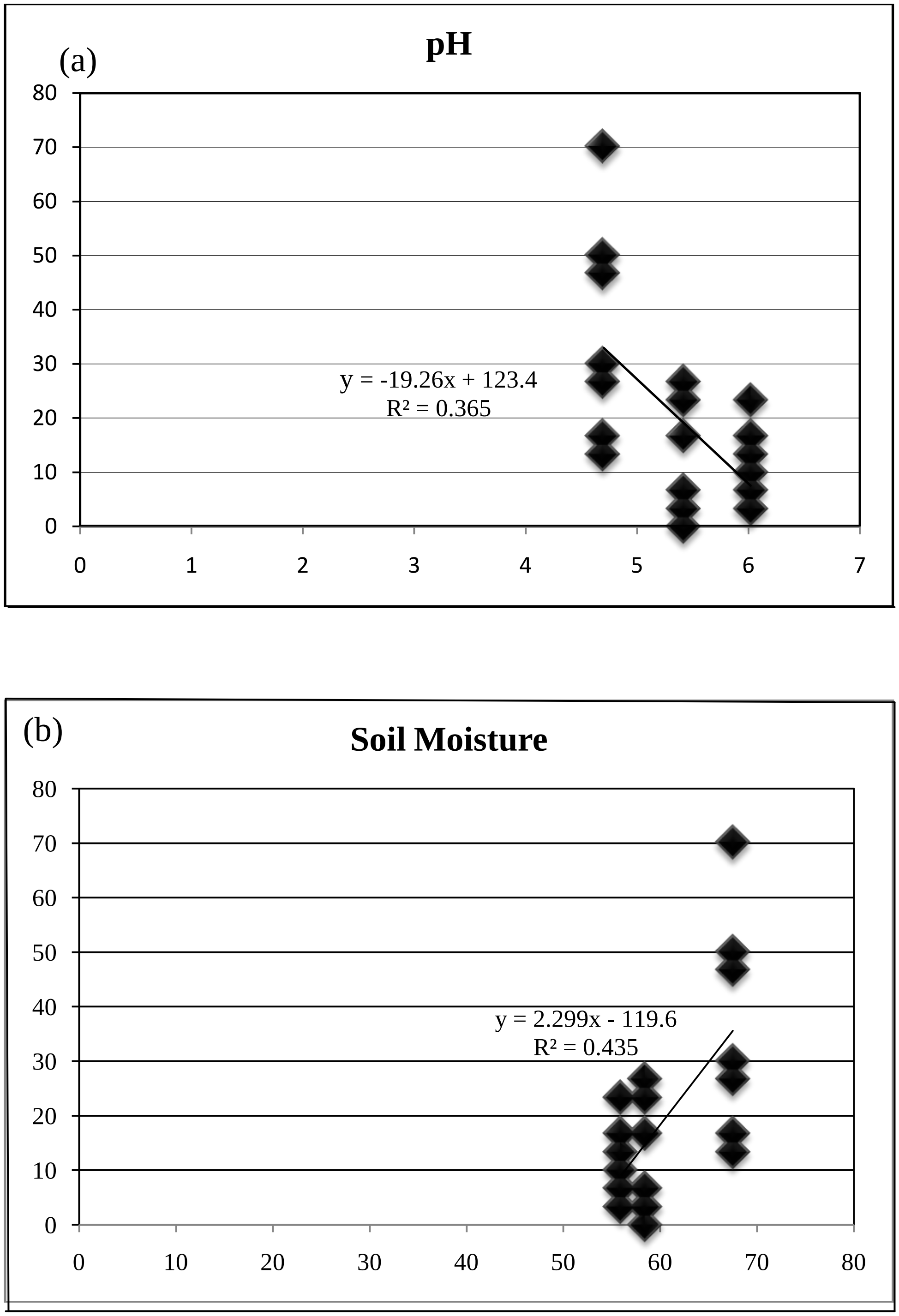
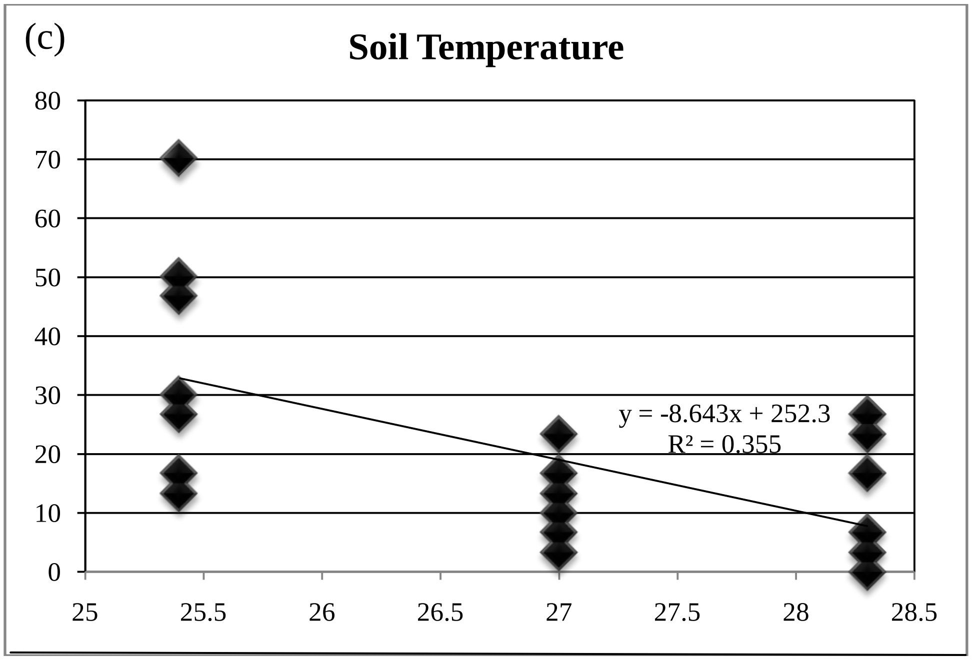


Fig. 1a. Regression between soil abiotic factors and abundance of *Pratylenchus* sp. factor: (a) pH; (b) Soil moisture.



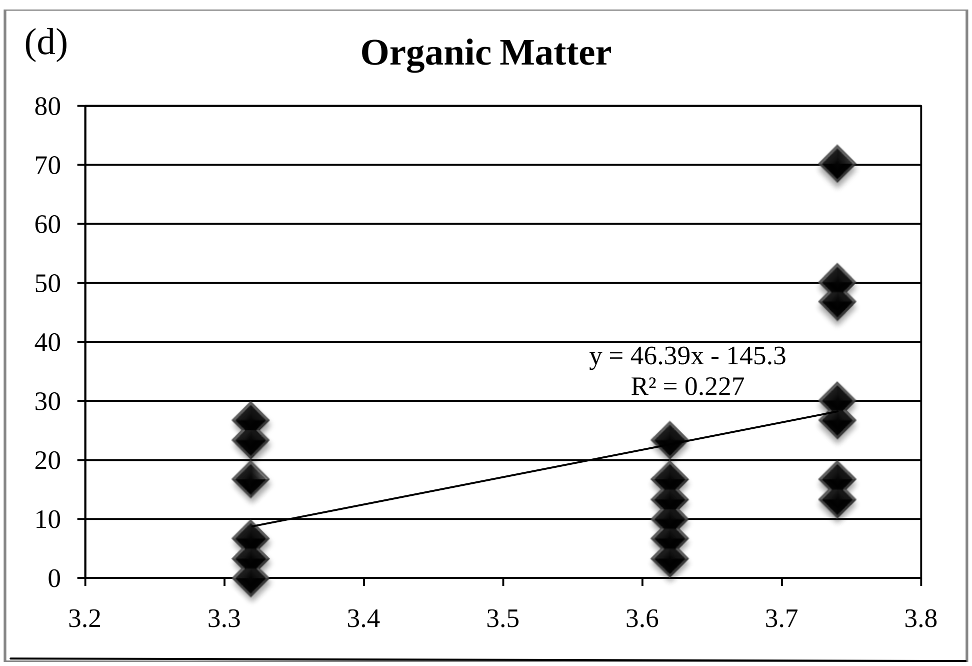


Fig. 1b. Regression between soil abiotic factors and abundance of *Pratylenchus* sp. factor: (c) Soil temperature factor; (d) Organic matter factor.

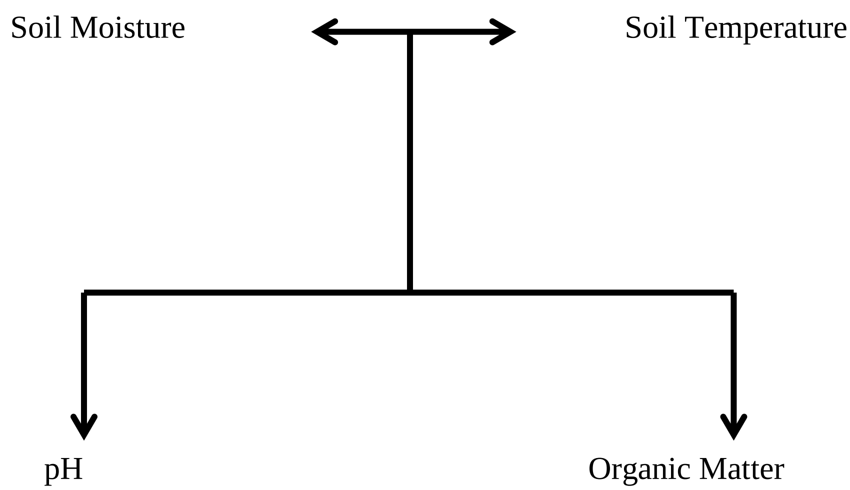


Fig. 2.Relationship between soil abiotic factors.

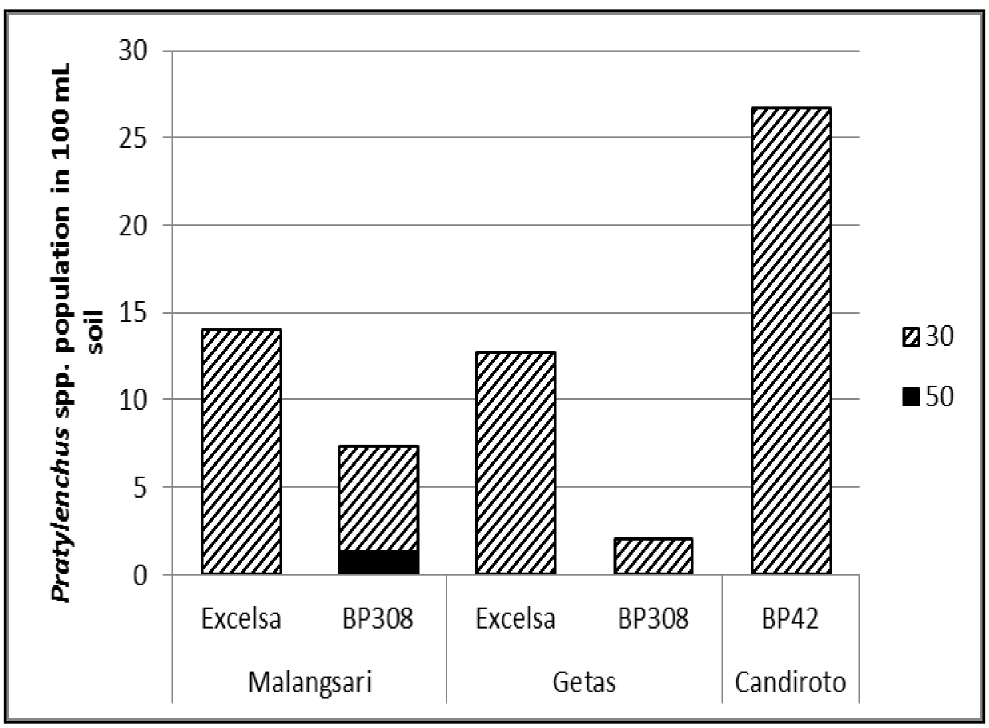


Fig. 3. Total population of *Pratylenchus* sp. (mean of 5 replications) in each depth (< 30 and 50 cm) of each variety in 3 Robusta Coffee plantations. The different letters in column show significant differences according to Duncan's multiple range test (P < 0.05).

BP 308 variety have more tap and lateral roots than BP 42 variety. Number of lateral roots of BP 308 was more than BP 42 variety, i.e. 17 and 10.7, respectively. Likewise the length of the roots of BP 308 was longer than BP 42 variety, i.e. 76 cm and 50 cm, respectively. The vertical distribution of *Pratylenchus* sp. was mostly in < 30 cm depth, except on BP 308 variety in Malangsari where *Pratylenchus* sp. also detected in 50 cm depth.

The presence of *Pratylenchus* sp. on BP 308 variety in 50 cm depth was caused by the deeper roots system. However, there was no *Pratylenchus* sp. detected on BP 308 variety in Getas Field. It caused by the soil moisture and soil texture. Soil moisture in Malangsari was lower than in Getas Field, and it facilitated the deeper movement of nematode. It was reported by Castillo & Vovlas (2007), when soil moisture was high, *Pratylenchus* sp. mostly exist in 15-30 cm, whereas when soil moisture was low, nematode will move deeper.

Sand fraction in Malangsari was greater than in Getas Field (Table 2), it was supported the movement of nematode easier. Study on cereal crop determines that population of *Meloidogyne* spp., *P. zeae* and *Scutellonema* spp. was higher in sandy soil than in loamy soil (Talwana *et al.*, 2008). Sand fraction supported the development of *Pratylenchus* sp. Since it is provides lots of oxygen (Castillo & Vovlas, 2007).

This is the first report on the interaction impacts of soil conditions and coffee varietys on the vertical distribution of *Pratylenchus* sp. There are two kinds of response toward the abundance of *Pratylenchus* sp., i.e. direct and indirect. Direct response happened when soil condition as directly influenced the abundance, whereas indirect response happened when soil condition through the coffee variety including morphological roots and resistance influenced the abundance.

High soil moisture, low pH value, high sand fraction, and roots system was influenced by highly abundance of *Pratylenchus* sp. From this result, it is important in order to anticipate the damaged by *Pratylenchus* sp. on coffee plantation based on ecological control. Besides that, knowing the vertical distribution could gain an accurately application when controlling nematode by nematicide or other biological control agents.

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References

Bezooijen, J. (2006). *Methods and Techniques for Nematology*.Wageningen.

Castillo, P. & Vovlas, N. (2007). *Pratylenchus* (Nematoda: Pratylenchidae) : Diagnosis, Biology, Pathogenicity and Management. Brill. USA.

Cobb, N. A. (1918). Estimating the Nema Population of the Soil. *Agricultural Technical Circular Bureau of Plant Industries*, United States Department of Agriculture.

Davis, R. F., Wilkinson, H. T. & Noel, G. R. (1994).Vertical distribution of three nematode genera in a Bent grass putting green in central Illinois. *Journal of Nematology*, 26, 8-521.

Hulupi, R. & Mulyadi (2007). Sebaran populasi nematode *Radopholus similis* dan *Pratylenchus coffeae* pada lahan perkebunan kopi. *Pelita Perkebunan*, 23, 177-181.

Hulupi, R. (2008). Pemuliaanketahanantanaman kopi terhadap nematode parasit. *Review Penelitian Kopi danKakao*, 24, 21.

Inomoto, M. M. & Oliveira, C. M. G. (2008). Plant-Parasitic Nematodes of Coffee: Coffee-Associated *Pratylenchus* spp.- Ecology and Interactions with Plants. Springer, USA.

Kandel, S. L., Smiley, R. W., Garland-Campbell, K., Elling, A. A., Abatzoglou, J., Huggins, J. D., Rupp, R. & Paulitz, T. C. (2013). Relationship between climatic factors and distributiom of *Pratylenchus* spp. in the dryland wheat-production areas of eastern Washington. *Plant Disease*, 97, 1448-1456.

Kementan (2014). KebunInduk, Kopi Arabika, Kopi Robusta, *PedomanTeknis*, 1827, 1-26.

Macguidwin, A. E. & Forge, T. A. (1991). Winter survival of *Pratylenchus scribneri*. *Journal of Nematology*, 23, 198-204.

Mawardi, S., Hulupi, R., Priyono, Suprijadji, G., Wiryadiputra, S., Nur Zaenudin, A. M., Hartobudoyo S., Suhartono, Sudarsianto, A. Soedarsan & Leupen, F. F. (2004). BP 308 klon kopi robusta tahan terhadap nematode parasit. *Warta Pusat Penelitan Kopi dan Kakao Indonesia*, 20, 1-20.

Melakeberhan, H., Jones, A. L. & Bird, G. W. (2000). Effects of soil pH and *Pratylenchus penetrans* on the mortality of 'Mazzard' cherry seedlings and their susceptibility to *Pseudomonas syringae* pv. syringae. *Canadian Journal of Plant Pathology*, 22, 31-137.

Montasser, S. A., Korayem, A. M., Youssef, M. M. A. & Mohammed, M. M. M. (2015). Vertical distribution of the root lesion nematode, *Pratylenchus zeae* infesting sugarcane in relation to soil type and growing season. *Scientia Agriculture*, 10, 95- 97.

Norton, D. C. (1989). Abiotic soil factors and plant-parasitic nematode communities. *Journal of Nematology*, 21, 299-307.

Nurbahar, I. R., Soependi, I. Y. & Arianto, Y. (2014). Statistik Perkebunan Indonesia-Kopi. Direktorat Jenderal Perkebunan. Jakarta.

Nzeako, S. O., Imafidor, H. O., Ogwumba, E. & Ezenweka, C. O. (2016). Vertical distribution of the lesion nematode: *Pratylenchus* species in selected turf fields in River State, Nigeria. *IOSR-Journal of Agriculture and Veterinary Science*, 9, 53-58.

Nzeako, S. O., Imafidor, H. O., Uche, A. O. & Ogufere, M. O. (2014). Agro-related anthropogenic activities on soil nematodes in the Niger Delta, Nigeria. IAASR, 32-40.

Ornat, C., Verdejo-Lucas, S., Sorribas, F. J. & Tzortzakakis, E. A. (1999). Effect of fallow and root destruction on survival of root-knot and root-lesion nematodes in intensive vegetable cropping systems. *Nematropica*, 29, 5-16.

Pudasaini, M. P., Schomaker, C. H., Been, T. H. & Moens, M. (2006). Vertical distribution of the plant-parasitic nematode, *Pratylenchus penetrans*, under four field crops. *Phytopathology*, 96, 226-233.

Purwanto, E. H., Rubiyo & Towaha, J. (2015). Karakteristik mutu dancita rasa kopi robusta klon BP 42, BP 358 dan BP 308 asal Bali dan Lampung.*Sirinov*, 3, 67 -74.

Rahman, S. A., Zain, S. N. M., Mat, M. Z. B., Sidam, A. K., Othman, R. Y. & Mohamed Z. (2014). Population distribution of plant parasitic nematodes of banana in Peninsular Malaysia. *Sains Malaysiana*, 43, 176-177.

Ravichandra, N. G. (2008). *Plant Nematology*. I. K. International Publishing House Pvt. Ltd. New Delhi, India, 718 pp.

Talwana, H. L., Butseya, M. M. & Tusiime, G. (2008). Occurrence of plant parasitic nematodes and factors that enhance population build-up in cereal-based cropping systems in Uganda. *African Crop Science Journal*, 16, 119-131. doi.org/10.4314/acsj.v16i2.54352.

Trinh, P. Q., Wesemael, W. M. L., Nguyen, C.N. & Moens, M. (2011). Decline of *Pratylenchus coffeae* and *Radopholus arabocoffeae* populations after death and removal of 5-year-old Arabica coffee (*Coffea Arabica* cv. Catimor) trees. *Nematology*, 13, 41-500 doi:10.1163/138855410X528505.

Tuyet, N. T. (2010). *A comparative polyphasic study of 10 Pratylenchus coffeae populations from Vietnam*. Ph. D. thesis, Katholieke Universiteit Leuven, Belgie, 141 pp.

Wiryadiputra, S. & Tran, L. K. (2008). Indonesia and Vietnam. In: Souza R. M. (Ed) *Plant-Parasitic Nematodes of Coffee* Springer, Dordrecht. DOI: 10.1007/978-1-4020-8720-2_15

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