KSÜ Tarım ve Doğa Derg 25 (2): 282-291, 2022
KSU J. Agric Nat 25 (2): 282-291, 2022
DOI:10.18016/ksutarimdoga.vi.887744

Vertical Distribution of Root Lesion Nematodes (*Pratylenchus thornei* (Sher et Allen) *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans Stekhoven (Tylenchida: Pratylenchidae) and Stem and Bulb Nematode *Ditylenchus dipsaci* (Kühn, 1857) (Tylenchida: Anguinidae) in Two Chickpea Growing Areas in Turkey

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ABSTRACT
Investigation of the vertical distribution of three plant-parasitic nematodes was conducted in two chickpea fields, one in southeastern (Şanlıurfa) and the other in central Anatolia (Ankara) Turkey during 2015/2016 and 2016/2017 growing seasons. Twelve accessions of Turkish domesticated and wild *Cicer* species including 3 *Cicer arietinum*, 4 *C. echinospermum*, and 5 *C. reticulatum* were used in the experiments..Soil samples were collected around the plant roots at a 10-20 cm and 20-30 cm depth by using an auger at each site. Maximum population densities of the root-lesion nematodes (*Pratylenchus thornei* (Sher et Allen) and (*Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans) were observed at the depth of 20-30 cm, during the pod filling stage and harvest time. Also, the population density of root-lesion nematodes was higher than *Ditylenchus dipsaci* (Kühn, 1857) (Tylenchida: Anguinidae) at the depths of 20-30 cm. Population density of root-lesion nematodes was positively correlated with the site, time of sampling, chickpeas species, and there was statistically significant difference between soil depth and population density of nematodes in both sites.

Research Article

Article History
Received : 08.04.2021
Accepted : 11.06.2021

Keywords
Chickpea
Depth distribution
Root-lesion nematodes
Ditylenchus dipsaci

Kök Lezyon Nematodlarının (*Pratylenchus thornei* (Sher et Allen) *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans Stekhoven (Tylenchida: Pratylenchidae) ve Soğan-Sak Nematodu *Ditylenchus dipsaci* (Kühn, 1857) (Tyleneida) 'nın Nohut Yetiştirilen Alanlarda Dikey Dağılımı

ÖZET
Türkiye'de, 2015/2016 ve 2016/2017 yetiştirme sezonunda, biri Güneydoğu Anadolu (Şanlıurfa) ve diğeri İç Anadolu'da (Ankara) bölgesinde bulunan iki nohut arazisinde üç bitki-paraziti nematodun dikey dağılımının incelenmiştir. On iki yerli ve yabani Cicer hattı (3 *Cicer arietinum,* 4 *C. echinospermum,* ve 5 *C. reticulatum* dahil) denemelerde kullanılmıştır. Toprak örnekleri, bitki kökleri çevresi 10-20 cm ve 20-30 cm derinliğinden burguyla toplanmıştır. Kök lezyon nematodları, *Pratylenchus thornei* (Sher et Allen) ve *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans!un en yüksek popülasyon yoğunlukları, 20-30 cm derinlikte, bakla doldurma aşaması ve hasat zamanında gözlenmiştir. Ayrıca, nohut arazisinde 20-30 cm derinliğindeki kök lezyon nematodlarının popülasyon yoğunluğu *Ditylenchus dipsaci*' (Kühn, 1857) (Tylenchida: Anguinidae)'den daha fazla bulunmuştur. Kök lezyon nematodlarının (*P. thornei* ve *P. neglectus*) popülasyon yoğunluğu, deneme arazisi, örnekleme zamanı, nohut türleri ile pozitif korelasyon göstermiştir ve her iki arazideki nematodların popülasyon yoğunlukları ve toprak derinliği arasında istatistiki olarak anlamlı farklar bulunmuştur.

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 08.04.2021
Kabul Tarihi : 11.06.2021

Anahtar Kelimeler
Nohut
Derinlik dağılımı
Kök lezyon nematodları
Ditylenchus dipsaci

To Cite: Behmand T, Kasapoğlu Uludamar EB, Elekçioğlu İH 2022. Vertical distribution of Root Lesion Nematodes (*Pratylenchus thornei* (Sher et Allen) *Pratylenchus neglectus* (Rensch) Filipjev & Schuurmans Stekhoven (Tylenchida: Pratylenchidae) and Stem and Bulb Nematode *Ditylenchus dipsaci* (Kühn, 1857) (Tylenchida: Anguinidae) in two Chickpea Growing Areas in Turkey. KSU J. Agric Nat 25 (2): 282-291. DOI: 10.18016/ ksutarimdoga.vi.887744.

INTRODUCTION

Chickpea is one of the most important legume crops in the world. The most important chickpea-producing countries are India, Australia, Myanmar, Ethiopia, Turkey, Pakistan, Russia, Iran, Mexico, USA, and Canada. Turkey is ranked fifth in the world for chickpea production (FAO, 2019). Nematode distribution in the soil is dependent on the physical and chemical properties of the medium (Marissônia et al., 2020). The vertical movement in the soil, and their association with different hosts, of the root-lesion nematodes (*Pratylenchus thornei* (Sher et Allen) and *P. neglectus* (Rensch) Filipjev & Schuurmans), *Helicotylenchus* and of the smaller stem endoparasite *Ditylenchus dipsaci* (Kühn, 1857) (Tylenchida: Anguinidae) were investigated experimentally, to compare their rates of distribution (Behmand et al., 2019). The study on relationships between depth use for crop plants and soil organisms is important for adaptive ecosystem management and better understanding the soil ecosystem process. Wu et al. (2000) indicated that the distribution of nematode can change because of growing plants in different depths of soil and the structure and function of the soil. Work (Lo pez and Bello, 1995; Liang et al., 1999) has shown that different vertical distribution of nematode species releases to a variety of biological, physical, and chemical variables in soil. Also, the distribution and population density of nematodes can be decreased with increasing soil depths because of the limited nutrient group composition (Yeates, 1980; Yeates et al., 2000; Lazarova et al., 2004). Information about the vertical distribution of nematodes and how they change at different depths of the soil is important for controlling population density below a threshold level.

Chickpea (*Cicer arietinum* L.) is an important grain legume that is grown in most parts of Turkey. The plant-parasitic nematodes are one of the important factors limiting chickpea productivity. It is often grown in rotation with wheat (Triticum aestivum) respectively, in intolerant cultivars attributed to *P. thornei* (Thompson et al., 2000; Reen et al., 2014). The attention of nematologist is now focused on alternative control methods. Knowing about the vertical distribution of plant-parasitic nematodes in different crop fields can be helpful to reduce the population densities of plant-parasitic nematodes. The aim of this research was to determine the effects of different depths of the growth of chickpea in a field with the presence of the nematodes. The biggest number of plant-parasitic nematodes was observed in the top 15-20 cm of soil (Norton, 1978; McSorley, 1987; Rickard and Barker, 1982). Also, the maximum densities of some nematode species were in the deeper depths of 30 cm soil (Bouyoucos, 1936; Barker and Campbell, 1981).

Many abiotic and biotic stress factors can cause yield loss in chickpea. Root-lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) are one of the most important biotic factors to limit chickpea production in the world. The best strategy for management to control these nematodes is to use resistant chickpea cultivars. Although, the strategy of the breeding program is not easy for resistance to root-lesion nematodes because of the reaction of different varieties and little diversity of chickpea to nematodes (Thompson et al., 2000).

Usually, there is not a standard definition method of deep sampling for plant-parasitic nematodes, but it is usually suggested at sampling depth of 15-20 cm for plant-parasitic nematodes (Lehman, 1980; Dunn, 1984). The objective of this study was to compare nematode distribution in different depths of soil (10-20 and 20-30 cm) under cultivation of chickpea in South-eastern (Şanlıurfa province) and Central Anatolia Turkey (Ankara province).

MATERIALS and METHODS

Experimental Area

This study was conducted during 2015/2016 and 2016/2017 at the Field Research Facility of the Faculty of Agriculture at Harran University in Şanlıurfa and Haymana region in Ankara, Turkey. The investigational field was located on the Harran Plain (altitude: 465 m; 37o 08 N and 38o 46 E) where the climate change from arid to semi-arid and the weather was hot and dry from May to September when temperatures can reach up to 46°C, and was usually warm during the winter. There was a an average of 460 mm of rain falls each year and the relative humidity averages was about 49%. The second site of the experiment was located on the Haymana plain. It is located at the intersection South part of Ankara and side in a position that could be considered the canter of 39 degrees north latitude and 32 degrees east longitude, where chickpea planted in March/April and harvested in June/July. Experiments were established at the beginning of March during the 2015/2016 and 2016/2017 chickpea growing seasons. At the beginning of the experiment, the land was plowed and cultivated, then prepared for planting with a single pass of a disk-harrow.

Plant Material

In this study, Twelve accessions of Turkish domesticated and wild *Cicer* species including 3 *Cicer arietinum*, 4 *C. echinospermum*, and 5 *C. reticulatum* were used to identify the vertical distribution of nematodes at different depths of soil.

Identification of Nematodes

Root lesion nematodes (*P. thornei* and *P. neglectus*)

were identified based on morphological (Handoo and Golden, 1989) and Molecular (Behmand et al., 2019). *Ditylenchus dipsaci* species have been developed based on species specific DdpS2/rDNA2 and DdpS1/rDNA2 primers (Subbotin et al., 2005).

Experimental Design

The experiment was set up in split plots in a randomized complete block design (RCBD) with four replications. Main plots consisted of distribution depth (10-20 and 20-30 cm) and subplots consisted of *Cicer* genotypes. Each plot consisted of single rows with 2 m long and distances between the rows were 60 cm and intra-row spacing was 5 cm. The seeds were sown at a 5-6 cm depth. The experiment was repeated in 2017 using a similar pattern and procedures. All the treatments were irrigated by using a sprinkler irrigation system. A total of 480 (12 line×4 replication×2 depth×2 times of sowing) soil samples were collected from the 0-20 cm and 20-30 cm depth of soil during early spring (March) and mid-summer (July) by using an auger from the plots of each field (eight plots).

Soil Structure

The soil texture was very similar at all depths and all of the plots had a similar position. Also, soil moisture was under 10% at all depths, and all of the plots in the field had a sand content lower than 90%.

Data Collecting

Soil samples were collected at 30-day intervals from early spring (March) 2015/2016 until mid-summer July 2016/2017 from eight plots (7.2 m wide x 2 m long =14 m2) per field.

Data analysis

The data was analysed using ANOVA according to the standard analysis of variance procedure with Gen Stat (Statistical and Mathematical Software) discovery edition. The significance level of differences between treatments and replications of data were calculated at P<0.001. In addition, distribution of data was checked using the above software program.

Twelve accessions of *Cicer* species (3 *Cicer arietinum*, 5 *C. reticulatum* and 4 *C. echinospermum*) were planted during winter and spring growing season to evaluate the vertical distribution of nematodes between *Cicer* species. The soil samples were collected monthly from 96 subsamples (12 accessions x 4 replicated with 2 cultivations in spring and autumn = 96). The nematodes were extracted from soil by using a 'Modified Baermann Funnel' method (Hooper, 1986). All the plant parasitic nematodes from the subsample were counted directly, avoiding dilution that could result in counting error (Mcsorley, 1987). For each plot on each sampling date, the abundance percentage of each nematode species present at each depth was calculated by the formula.

$$Present\ of\ species\ at\ depth = \frac{Density\ of\ species\ at\ depth}{Total\ density\ of\ species\ at\ two\ depths}$$

as reported in previous nematological studies (Hijink and Kuiper, 1966; Sinclair et al., 1982). The percentage of abundance by depth was subjected to analysis of variance to determine if significant (P<0.001) difference occurred with depth.

RESULTS and DISCUSSION

The analysis of the data showed that the population density of both root-lesion nematodes (*P. thornei* and *P. neglectus*) at the depth of 20-30 cm of soil was higher (P <0.001) than 10-20 cm depth during the 2015/2016 and 2016/2017 growing seasons (Table 1, 2, 3 and 4). At the final soil sampling in June and July of 2015/2016 and 2016/2017 in both sites (Şanlıurfa and Ankara), more than 50% population density of *Pratylenchus thornei* and *P. neglectus* each year was found in the upper 20-30 cm of soil, a higher (P<0.001) proportion than in either of the depth examined (Table 1 and 3). Additionally, as the season progressed, nematodes became more distributed through the soil layer in increasing numbers. There was a trend toward the maximum level of the population at 20-30 cm deep, particularly in 2015/2016, the distribution density of nematode in the upper layers (20-30 cm) was Similar (P <0.001) in the 2016/2017 year, but it was different in each field. The highest population density of nematodes usually was presented at the 20-30 cm depth mid-summer (July) in the Ankara field (Table 2 and 4). The percentage of all sampling dates was greater (P <0.001) than 10-20 cm depth (Figure 1 and 2). Similar studies in Şanlıurfa indicated that the distribution density of nematode was similar among the two layers of soil just a few slight differences (P<0.001) were given (Table 1, 3 and Figure 1, 2).

Robertson et al. (1979) reported that the majority of legume roots grow in the upper 15 cm in sandy soil. A proportional decrease in plant size and root distribution throughout the profile could leave relatively few roots available for feeding below 30 cm. Mc Sorley and Dickson (1990) indicated that the number of lesion nematode in the soil increased in the upper level 15 cm in sandy soil under soybean growing field. The result of the study indicated that the population density of *Pratylenchus thornei* and *P. neglectus* at depths of 10-20 cm soil was lower than the density at depths of 20-30 cm in growing soil chickpea (Table 1, 2, 3, and 4). In other words, when depths started to increase from 10 to 30 cm population density of this nematode species increased showing a positive correlation with population

densities of root-lesion nematodes (*P. thornei* and *P. neglectus*) (P<0.001). The highest population densities of root lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) on chickpea were concentrated at soil depths 20-30 cm (Figure 1-2).

Table 1. ANOVA summary for the vertical distribution of *Pratylenchus thornei* nematode in both sites during 2015 to 2017 years.

Çizelge 1. 2015-2017 yılları arasında her iki bölgedeki Pratylenchus thornei nematodunun dikey dağılımı için ANOVA özeti.

Source of variation Site.Reps stratum	d.f.	s.s	m.s	v.r	F pr
Site	1	2674.	2674.	0.27	0.622
Residual	6	59486.	9914.	7.41	
Site.Reps.*Units* stratum					
Time	3	1856044.	618681.	462.57	<.001
Depth	1	51680.	51680.	38.64	<.001
Sp	2	1847913.	923956.	690.82	<.001
Site.Time	3	19093.	6364.	4.76	0.003
Site.Depth	1	2626.	2626.	1.96	0.162
Time.Deoth	3	786.	262.	0.20	0.899
Site.Sp	2	16763.	8382.	6.27	0.002
Time.Sp	6	494253.	82376.	61.59	<.001
Depth.Sp	2	502.	251.	0.19	0.829
Sp.line	9	312163.	34685.	25.93	<.001
Site.Time.Depth	3	401.	134.	0.10	0.960
Site.Time.sp	6	4034.	672.	0.50	0.807
Site.Depth.Sp	2	916.	458.	0.34	0.710
Time.Depth.Sp	6	1670.	278.	0.21	0.974
Site.Sp.Line	9	14552.	1617.	1.21	0.287
Time.Sp.Line	27	246488.	9129.	6.83	<.001
Depth.Sp.Line	9	3274.	364.	0.27	0.982
Site.Time.Depth.Sp	6	248.	41.	0.03	1.000
Site.Time.Sp.Line	27	41179.	1525.	1.14	0.286
Site.Depth.Sp.Line	9	908.	101.	0.08	1.000
Time.Depth.Sp.Line	27	3237.	120.	0.09	1.000
Site.Time.Depth.Sp.Line	27	4001.	148.	0.11	1.000
Residual	568	759686.	1337		
Total	765	5738434			

* df: contains degree of freedom which are measure of how much information is contained in each variance;
s.s: Means squares, which are calculated by multiplying the mean square and degree of freedom in the same row;
ms (Means squares): The variance between treatment;
v.r: The ratio of the between treatment variance to the within treatment variance;
F pr or P value: Significance value P < 0.001.

Table 2. Modification of the number of *Pratylenchus thornei* nematode at a depth of 10-20 and 20-30 cm.

Çizelge 2. 10-20 ve 20-30 cm derinlikte Pratylenchus thornei nematodu sayısının modifikasyonu.

Site sample	Time sample	Depth (cm)	
		10-20	20-30
Ankara	Flowering	75	88.8
	Harvest	169.7	180.6
	Poding filling	129	138.3
	sowing	52.3	69.2
Şanlıurfa	Flowering	58.5	75.8
	Harvest	170.4	190
	Poding filling	130.6	151.5
	sowing	36.7	59.6
	LSD	25	

Table 3. ANOVA summary for vertical distribution of *Pratylenchus neglectus* nematode in both sites during 2015 to 2017 years.

Çizelge 3. 2015-2017 yılları arasında her iki bölgedeki Pratylenchus neglectus nematodunun dikey dağılımı için ANOVA özeti.

Source of variation Site.Reps stratum	d.f.	s.s	m.s	v.r	F pr
Site	1	589.2	589.2	0.56	0.482
Residual	6	6307.4	1051.2	1.49	
Site.Reps.*Units* stratum					
Time	3	418518.0	139506.0	197.62	<.001
Depth	1	146945.9	146945.9	208.16	<.001
Sp	2	46350.3	23175.2	32.83	<.001
Site.Time	3	28358.1	9452.7	13.39	<.001
Site.Depth	1	9.9	9.9	0.01	0.906
Time.Deoth	3	5829.3	1943.1	2.75	0.042
Site.Sp	2	2626.1	1313.0	1.86	0.157
Time.Sp	6	48894.1	8149.0	11.54	<.001
Depth.Sp	2	9118.9	4559.4	6.46	0.002
Sp.line	9	80158.6	8906.5	12.62	<.001
Site.Time.Depth	3	838.7	279.6	0.40	0.756
Site.Time.sp	6	1112.5	185.4	0.26	0.954
Site.Depth.Sp	2	3867.8	1933.9	2.74	0.065
Time.Depth.Sp	6	4018.9	669.8	0.95	0.459
Site.Sp.Line	9	9396.0	1044.0	1.48	0.152
Time.Sp.Line	27	49190.3	1821.9	2.58	<.001
Depth.Sp.Line	9	4612.3	512.5	0.73	0.685
Site.Time.Depth.Sp	6	2767.2	461.2	0.65	0.687
Site.Time.Sp.Line	27	27666.1	1024.7	1.45	0.067
Site.Depth.Sp.Line	9	5298.0	588.7	0.83	0.585
Time.Depth.Sp.Line	27	9376.6	347.3	0.49	0.986
Site.Time.Depth.Sp.Line	27	6346.0	235.0	0.33	0.999
Residual	569	401677.1	705.9		
Total	766	1318108.4			

* df: contains degree of freedom which are measure of how much information is contained in each variance;
s.s: Means squares, which are calculated by multiplying the mean square and degree of freedom in the same row;
ms (Means squares): The variance between treatment;
v.r: The ratio of the between treatment variance to the within treatment variance;
F pr or P value: Significance value P < 0.001.
***p-value:** (typically ≤ .001) indicates strong evidence against the null hypothesis, so you reject the null hypothesis. A large **p-value** (>.001) indicates weak evidence against the null hypothesis, so you fail to reject the null hypothesis

Table 4. Modification of the number of *Pratylenchus neglectus* nematode at a depth of 10-20and 20-30 cm.

Çizelge 4. 10-20 ve 20-30 cm derinlikte Pratylenchus neglectus nematodu sayısının modifikasyonu.

Site sample	Time sample	Depth (cm)	
		10-20	20-30
	Flowering	40.42	63.75
Ankara	Harvest	75.83	110.42
	Pod filling	35.46	83.54
	sowing	56.67	60.42
	Flowering	33.54	53.75
Şanlıurfa	Harvest	88.33	124.58
	Pod filling	25.00	101.25
	sowing	67.60	46.46

The analysis of the data indicated that there was a significant difference between the population density of *D. dipsaci* at the depth of 10-20 and 20-30 cm of soil (Table 5), whereas the population density of distribution of *D. dipsaci* nematode in the soil in an *Ditylenchus dipsaci* was more concentrated at below 15 cm soil depths (Figure 3, Table 6). The vertical infested chickpea plot was a marked increase in numbers of *D. dipsaci* at the surface upper 5 cm (10-20 cm) (Figure 3).

Similarly, Wallace (1962) reported thatnumbers of *D. dipsaci* nematode in the soil in an infested oat plot

were increased at the surface 10-20 cm during the rainy season. *D. dipsaci* was more abundant between 10-20 cm (Figure 3), while lesion nematodes (*Pratylenchus thornei* and *P. neglectus*) were more numerous between 20 and 30 cm (Figure 1 and 2). Vertical distribution of nematodes is regulated by the development and growth of plant root system, thus, the highest population of them found in depths where the maximum root densities occur.

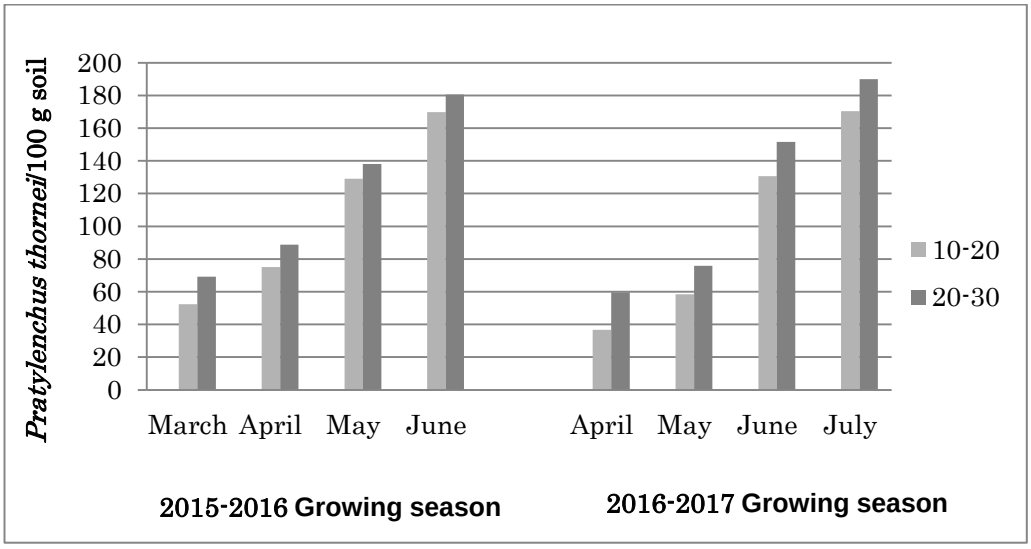

Figure 1. Distribution population density of *Pratylenchus thornei* at two different depths in Ankara and Sanliurfa province.

Şekil 1. Pratylenchus thornei'nin Ankara ve Şanlıurfa ilinde iki farklı derinlikteki dağılım nüfus yoğunluğu

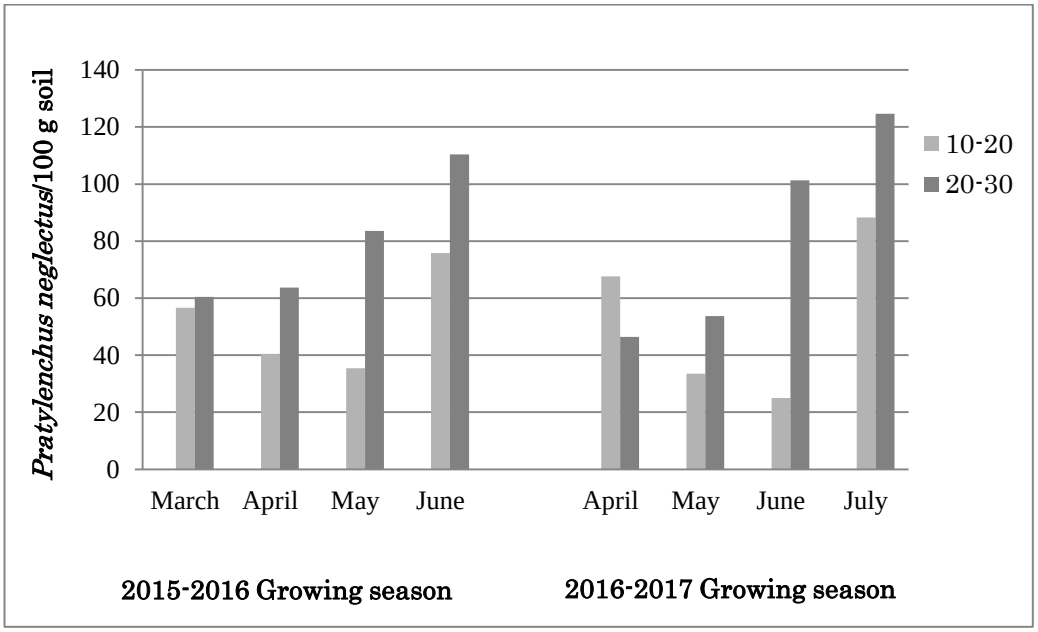

Figure 2. Distribution population density of *Pratylenchus neglectus* at two different depths in Ankara and Sanliurfa province.

Şekil 2. Pratylenchus neglectus'un Ankara ve Şanlıurfa ilinde iki farklı derinlikteki dağılım nüfus yoğunluğu.

There seems to be a number of reasons why nematodes differ in their vertical distribution. It has been suggested that nematode populations are related to root distribution (Yeates, 1980; Brodie, 1976) but even for migratory and endoparasitic nematodes this relationship does not always apply (Froge and MacGuidwin 1998). However, there are many other factors affecting the vertical distribution of nematode in soil (Boag, 1981). Davis et al (1994) reported that the population density of *Helicotylenchus* spp. was more abundant in the upper 2.5 cm of the soil profile. A study carried out by (Yeates et al., 1983) has shown that population density of root-lesion nematodes (*Pratylenchus neglectus* and *P. penetrans*) was found in a deeper soil profile than other nematode species. Thompson (1990) indicated that the majority of population density of *P. thornei* was observed

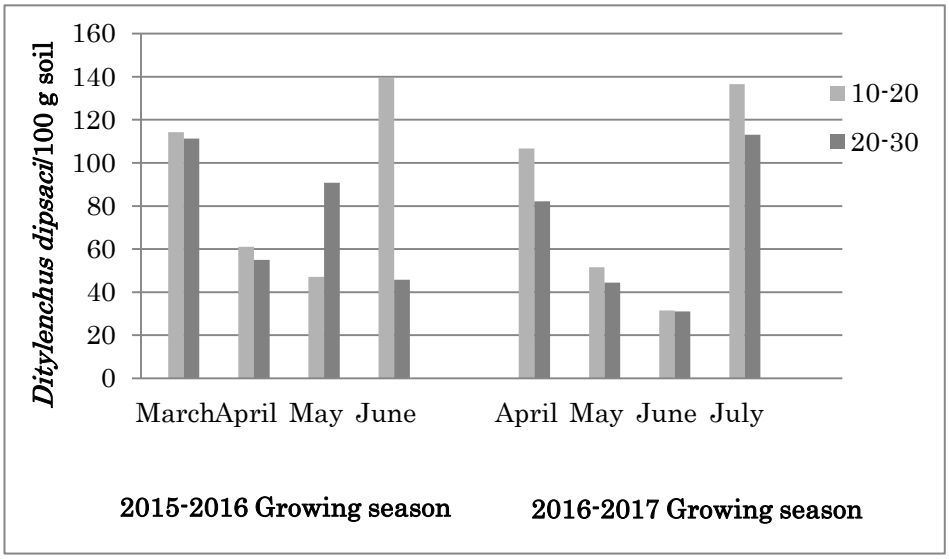

Figure 3. Distribution population density of *Ditylenchus dipsaci* at two different depths in Ankara and Sanliurfa province.

Şekil 3. Ditylenchus dipsaci'nin Ankara ve Şanlıurfa ilinde iki farklı derinlikteki dağılım nüfus yoğunluğu.

Table 5. ANOVA summary for vertical distribution of *Ditylenchus dipsaci* nematode in both sites during 2015 to 2017 years.

Çizelge 5. Ditylenchus dipsaci nematodunun 2015-2017 yılları arasında her iki bölgedeki dikey dağılımı için ANOVA özeti.

Source of variation (*Variyasyon kaynağı*) Site.Reps stratum	d.f.	s.s	m.s	v.r	F pr
Site	1	13730.2	13730.2	1.36	0.287
Residual	6	60464.7	10077.4	11.58	
Site.Reps.*Units* stratum					
Time	3	919685.7	306561.9	352.34	<.001
Depth	1	39168.0	39168.0	45.02	<.001
Sp	2	465236.3	232618.2	267.36	<.001
Site.Time	3	5448.4	1816.1	2.09	0.101
Site.Depth	1	28.2	28.2	0.03	0.857
Time.Deoth	3	22379.0	7459.7	8.57	<.001
Site.Sp	2	23797.5	11898.7	13.68	<.001
Time.Sp	6	262753.4	43792.2	50.33	<.001
Depth.Sp	2	16671.9	8336.0	9.58	<.001
Sp.line	9	109212.8	12134.8	13.95	<.001
Site.Time.Depth	3	257.7	85.9	0.10	0.961
Site.Time.sp	6	23184.3	3864.1	4.44	<.001
Site.Depth.Sp	2	2064.9	1032.5	1.19	0.306
Time.Depth.Sp	6	15503.2	2583.9	2.97	0.007
Site.Sp.Line	9	13291.9	1476.9	1.70	0.086
Time.Sp.Line	27	147107.9	5448.4	6.26	<.001
Depth.Sp.Line	9	13561.1	1506.8	1.73	0.079
Site.Time.Depth.Sp	6	1578.5	263.1	0.30	0.936
Site.Time.Sp.Line	27	49815.7	1845.0	2.12	<.001
Site.Depth.Sp.Line	9	2330.8	259.0	0.30	0.975
Time.Depth.Sp.Line	27	27918.2	1034.0	1.19	0.236
Site.Time.Depth.Sp.Line	27	4291.3	158.9	0.18	1.000
Residual	566	492456.8	870.1		
Total	763	2729841.2			

* df: contains degree of freedom which are measure of how much information is contained in each variance;
s.s: Means squares, which are calculated by multiplying the mean square and degree of freedom in the same row;
ms (Means squares): The variance between treatment;
v.r: The ratio of the between treatment variance to the within treatment variance;
F pr or P value: Significance value $P < 0.001$.

Table 6. Modification of the number of *Ditylenchus dipsaci* nematode at a depth of 10-20 and 20-30 cm.
Çizelge 6. 10-20 ve 20-30 cm derinlikte Ditylenchus dipsaci nematod sayısının modifikasyonu.

Site sample	Time sample	Depth (cm)	
		10-20	20-30
Ankara	Flowering	61.0	55.0
	Harvest	139.3	45.8
	Poding filling	47.1	90.8
	sowing	114.2	111.3
Şanlıurfa	Flowering	51.5	44.4
	Harvest	136.6	113.1
	Poding filling	31.5	31.0
	sowing	106.7	82.1

between 15 and 60 cm in the black clay soils of Queensland and the grey cracking clay in Victoria but nematodes were still found to a depth of 90 cm. The variations in the vertical distribution of the different feeding groups of nematodes are to some extent caused by differences in the vertical distribution of their food sources (Ferris and McKenry, 1976; Ingham et al., 1985). In another study, Mcsorley and Dickson (1990) indicated that the highest population density of nematode occurred in the top 15-20 cm of the soil profile and thus accept to be the most common sampling depth. However different factors can affect the vertical distribution of nematodes for example nematodes population is lower where food sources and oxygen decrease (Sohlenius and Sandor, 1987). Also, the vertical distribution of nematodes at various depths can change because of other abiotic factors over several years (Ferris and McKenry, 1974; Yeatest et al., 1983). However, the vertical distribution of nematodes can also be different because of nematode species (Davis et al., 1994). Analysis of variance data indicated that there were significant differences at all levels of organization: species, depth, time of sowing, collection sites within species, and accessions within collection sites within species P<0.001. The responses to *P. thornei* and *P. neglectus* were affected by species differences between *C. echinospermum* and *C. reticulatum* that become even more important in this study where these comparisons were more balanced.

It was noted that this was at odds with the consistent results coming from the field study of nematode population dynamics. However, because there was still significant remaining variation between collection sites within a depth of sampling at 10 and 20 cm for responses to root-lesion nematodes.

The depth of sampling level responses to *P. thornei* was much greater, which means the population density of nematode was increased when the depth of sampling increased from 10 cm to 20 cm.

Further, the results indicated that the response of different varieties to nematodes was different and there was a significant difference observed between *Cicer* species to nematode species (P<0.001) (Table 1, 3 and 5). Where the development population density of root-lesion and *D. dipsaci* nematodes at domesticated sp. (*C. arietinum*) was higher than wild *Cicer* sp. plots (*C. reticulatum* and *C. echinospermum*).

CONCLUSION

Findings of the study, after comparison of plant-parasitic species and the depth distribution patterns revealed some separation of community members by depth. Although the vertical distribution of the nematodes is different because of their food sources and host crop, the information provided by this research will be useful for sampling these nematodes under chickpea growing areas. Differences in the vertical distribution of lesion nematodes and *D. dipsaci* nematodes not only in chickpea growing areas also for other nematode species that provide a large amount of information is of big interest. In conclusion, the data presented here suggested that the best sampling depth under the chickpea for *Pratylenchus* genus was found in the top layer 20-30 cm, whereas for *D. dipcaci* was at 10-20 cm depth.

ACKNOWLEDGEMENT

This study was financially supported by the Grains Research and Development Corporation (GRDC) as part of the Australian Coordinated Chickpea Improvement Program (ACCIP).

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Author's Contributions

TB designed the study, conducted the experiments, and prepared the manuscript. IHE and EBKU provided technical guidance, and critically revised the manuscript for intellectual content. All authors read and approved the final manuscript.

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