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STUDIES ON THE VERTICAL DISTRIBUTION AND SEASONAL FLUCTUATION OF THE CITRUS NEMATODE IN IRAQ

by

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Several surveys in Iraq have shown that the citrus nematode, *Tylenchulus semipenetrans* Cobb, is widespread in its occurrence and responsible for considerable reduction in yield (Natour *et al.*, 1965 and 1975; Maggenti, 1966; Villardebo, 1969, 1971; Al-Hakim, 1975; Stephan *et al.*, 1977). However, so far there have been no comprehensive studies on the seasonal fluctuations of populations.

It is generally recognised that a nematode species causes economic damage when its population density exceeds the particular tolerance level of the crop plant. Moreover, this tolerance level varies between climatic regions. A study was therefore undertaken to examine the effect of several soil and weather factors on the vertical distribution and seasonal fluctuations of the citrus nematode in four different localities in Iraq as a basis for predicting damage and identifying the need for control measures.

Materials and methods

The study was undertaken in four citrus (*Citrus aurantium* L.) orchards, two located at Hammam Al-Alil and Mosul in the province of Ninevah and the other two, at Jaafer and Abbas Al-Kazum, in the province of Diyala, about 400 miles SE of Ninevah. The four orchards contained trees of three different age groups: 3-10; 15-20; and 40-80 years. Soil and root samples were collected using a soil auger from three trees selected at random for each age group, each sample being

taken at 30 cm distance from the tree trunk and about 1 Kg soil collected at 0-15, 16-30, 31-45, 46-60 and 61-75 cm depths, with about 5 g roots collected only at 16-30 cm. Samples were taken at monthly intervals from mid-July, 1977 until mid-June, 1978. The samples were stored at 10 °C in a refrigerator until required for extraction, which was done within 15 days of collection.

Nematodes were extracted from soil samples using a combination of Oostenbrink's elutriator and the cotton-wool filter technique and a Peter's 1 ml counting slide was used for estimating the numbers of larvae and males of the citrus nematode in each sample. Root samples were stained with Acid Fuchsin in lactophenol and the number of mature females counted.

The textural composition of the soil and $CaCO_3$ content were estimated at each sampling depth (Table I). Soil temperature and moisture were also recorded at the different depths and pH at 16-30 cm depth.

Results

The highest populations of larvae and males were found in the top 30 cm at Hammam Al-Alil; between 16 and 45 cm at Mosul; between 16 and 60 cm at Jaafer; and in the top 45 cm at Abbas Al-Kazum. Soil populations peaked during November-December and were at the lowest during July-August, except at Hammam Al-Alil where nematodes were fewest in March-April (Figs. 1-4). The numbers of mature females per g of root were greatest during April-May and fewest during July-August at all locations (Fig. 5).

Regression analysis was used to determine the effect of various soil physical and chemical factors on the vertical distribution and population fluctuations of larvae and males in the soil.

At Hammam Al-Alil all the independent variables except soil depth and the percentage of clay and sand had highly significant effects (Overall F = 128.724) (Table II). The regression equation

$$Y_1 = 5215.1843 + 67.655 \text{ X } (CaCO_3) - 103.424 \text{ X (months)} + 26.1789 \text{ X (temp.)} - 36.6931 \text{ X (moisture)} + 315.43 \text{ X (pH)} + 27.659 \text{ X (silt)}$$

can be used for estimating the population to a substantially high degree of reliability because the independent variables explain 81.7%

Table I - *Soil texture and $CaCO_3$ content of the orchards under study.*

Soil Particles	Depths in cm	Hammam Al-Alil	Mosul orchard	Jaafers orchard	Nursery
	0 - 15	45.28	62.06	34.22	36.00
	16 - 30	38.06	56.22	38.22	43.28
SILT %	31 - 45	40.06	52.00	40.72	44.00
	46 - 60	38.22	53.28	36.00	50.24
	61 - 75	38.36	60.22	38.22	40.22
	0 - 15	29.12	6.62	31.12	30.40
	16 - 30	28.62	11.12	23.12	29.12
SAND %	31 - 45	14.62	14.76	21.68	21.12
	46 - 60	3.84	13.12	29.12	12.76
	61 - 75	6.04	11.12	32 04	21.84
	0 - 15	25.60	31.32	34.66	33.60
	16 - 30	33.32	32.66	38.66	27.60
CLAY %	31 - 45	45.32	33.24	37.60	34.88
	46 - 60	57.94	33.60	34.88	37.00
	61 - 75	55.60	28.66	29.74	37.94
	0 - 15	Loam	Silty-Clay-Loam	Clay-Loam	Clay-Loam
	16 - 30	Clay-Loam	Silty-Clay-Loam	Clay-Loam	Loam
SOIL TYPE	31 - 45	Silty-Clay	Silty-Clay-Loam	Clay-Loam	Clay-Loam
	46 - 60	Clay	Silty-Clay-Loam	Clay-Loam	Silty-Clay-Loam
	61 - 75	Clay	Silty-Clay-Loam	Clay-Loam	Clay-Loam
	0 - 15	17.46	15.02	26.39	32.88
	16 - 30	20.70	14.61	28.82	29.23
$CaCO_3$	31 - 45	27.60	15.02	30.46	33.29
	46 - 60	32.48	15.02	26.39	33.69
	61 - 75	34.51	13.80	31.26	34.91

of the total variations in nematode population; SE of the equation is 40.77% of the mean nematode population of 670.40.

The regression analysis (Table III) shows that only two of the four variables had a highly significant effect on the population fluctuation of mature females per g of root. The soil pH had comparatively more significant effect than the months.

The regression equation

$$Y_2 = 272.45 + 25.60 \text{ X (pH)} + 1.4 \text{ X (months)}$$

can be used for predicting mature female populations on citrus roots at Hammam Al-Alil. The independent variables explain 50.19% of the

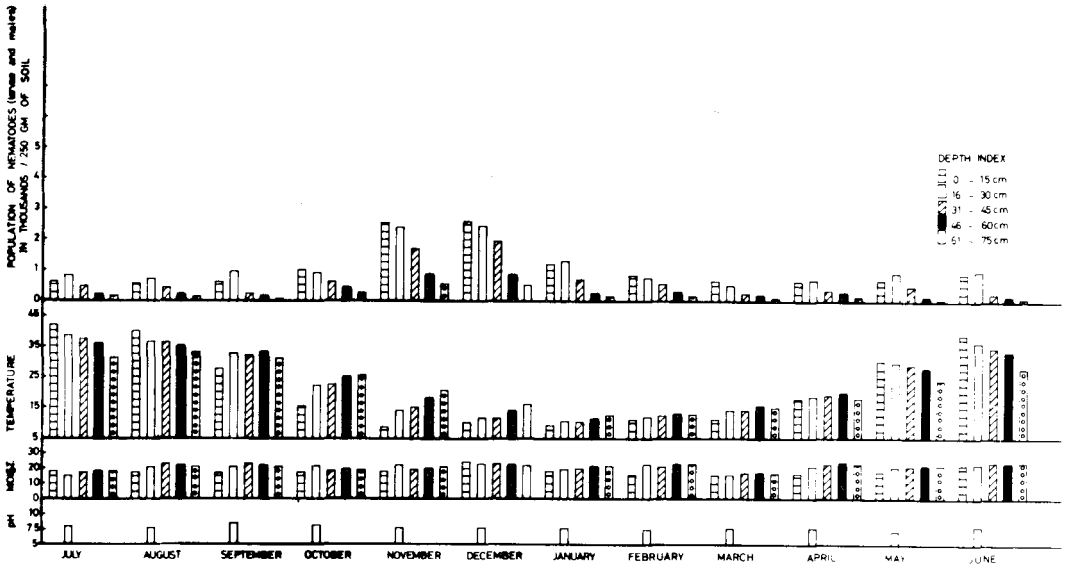

Fig. 1 - Vertical distribution and seasonal fluctuation in population of citrus nematode (larvae and males) in the soil at College of Agriculture orchard, Hammam, Al-Alil - Ninevah.

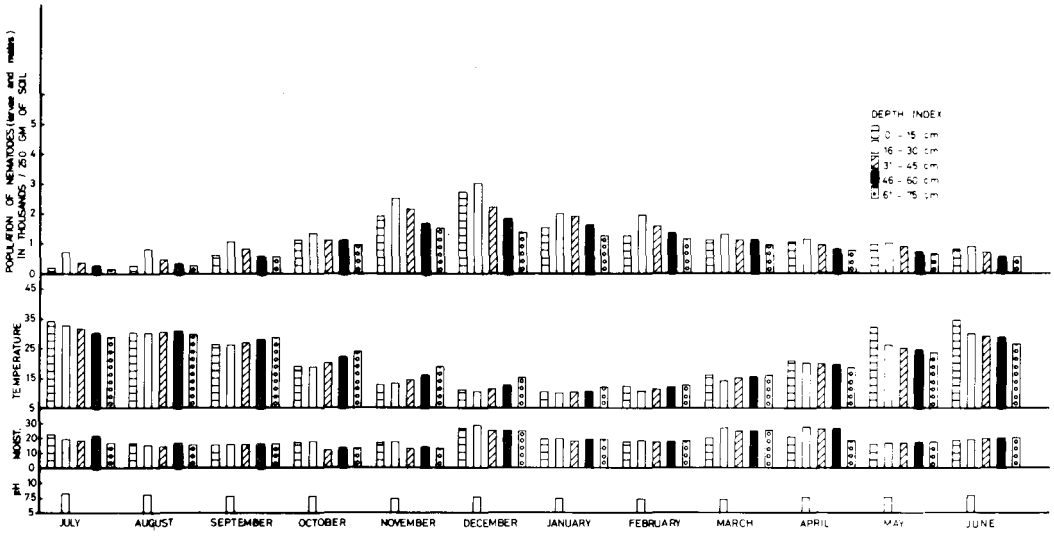

Fig. 2 - Vertical distribution and seasonal fluctuation in population of citrus nematode (larvae and males) in the soil at Horticulture Department Station orchard, Mosul - Ninevah.

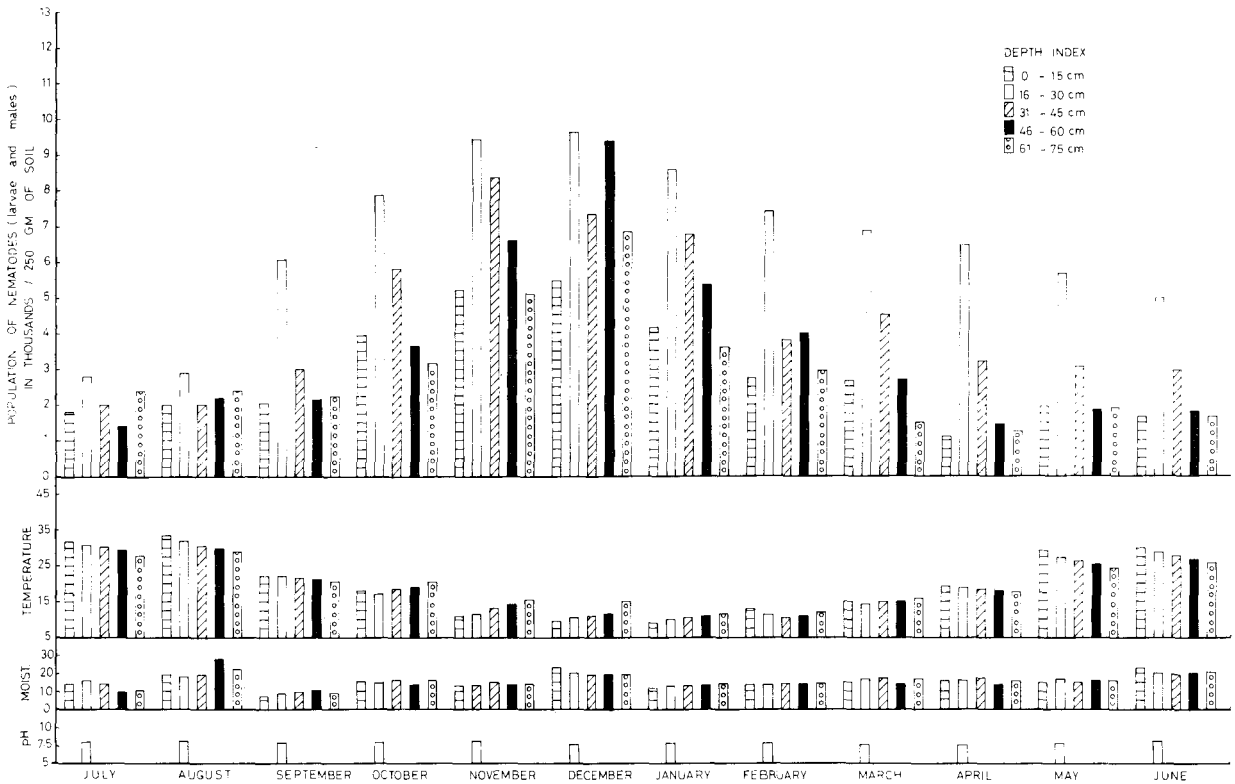

Fig. 3 - Vertical distribution and seasonal fluctuation in population of citrus nematode (larvae and males) in the soil at Jaafer's orchard, Howaider - Diyala.

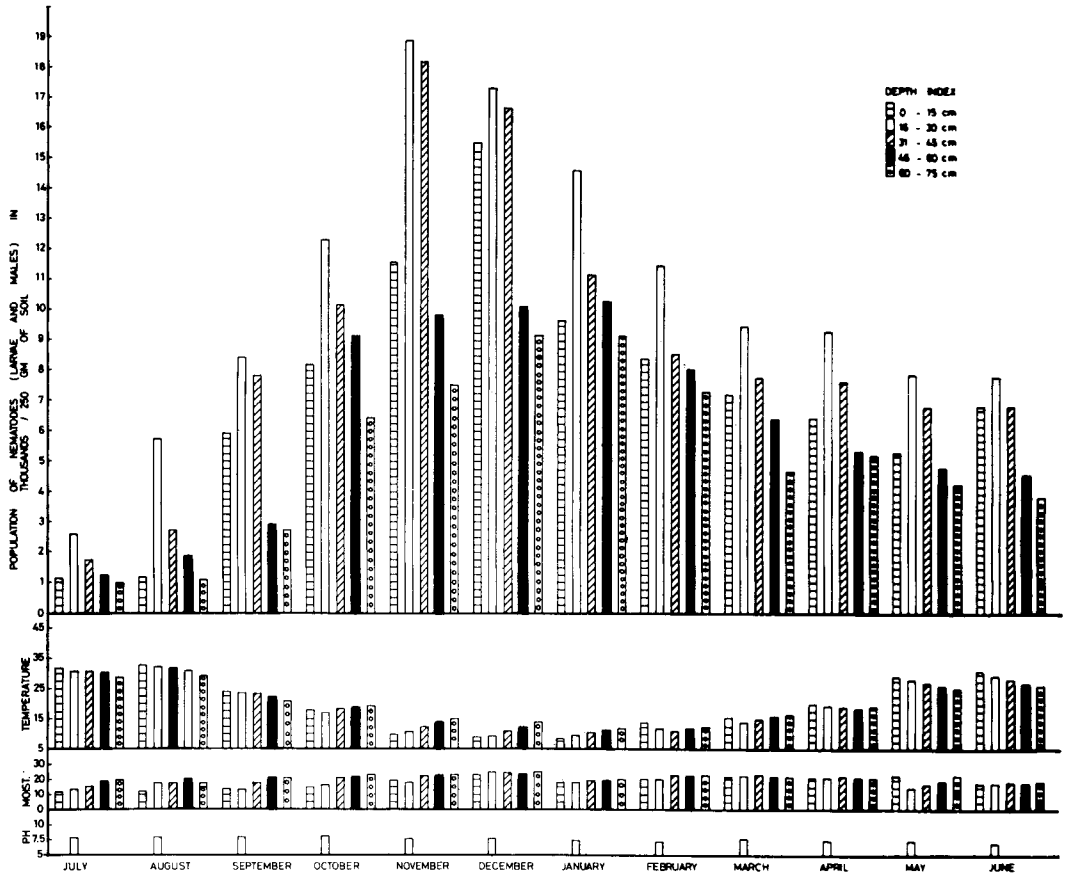

Fig. 4 - Vertical distribution and seasonal fluctuation in population of citrus nematode (larvae and males) in the soil at Abbas Al-Kazum's nursery, Howaider - Diyala.

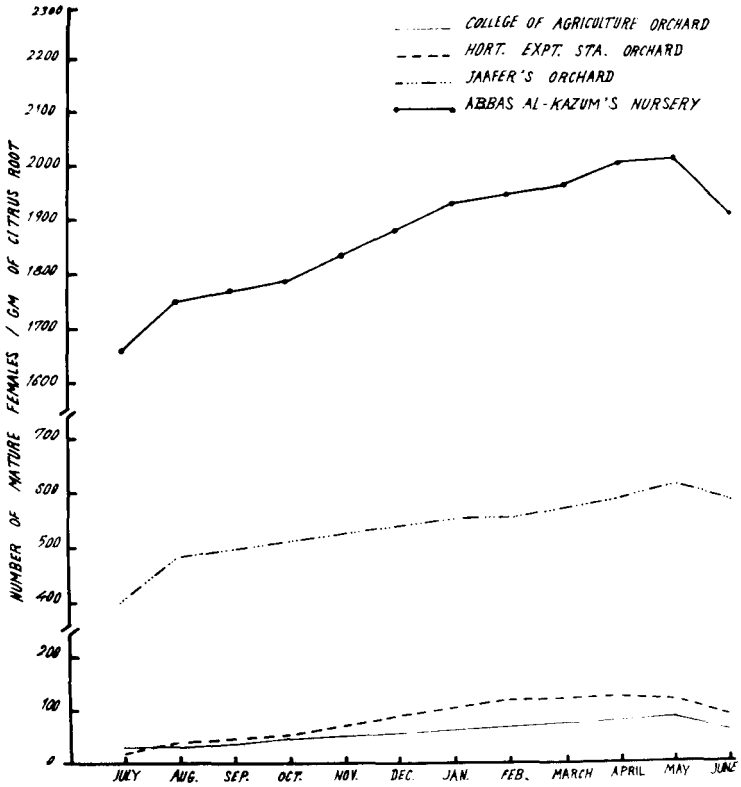

Fig. 5 - Seasonal fluctuation in the population of mature females/g citrus root at different localities.

total variation; SE of the equation is 18.37% of the mean population of 63.66.

Table II - *Effect of different variables on the soil population of the citrus nematode at Hammam Al-Alil.*

Independent Variables	Partial F value
$CaCO_3$	262.837**
Months	242.185**
Soil temperature	121.587**
Soil moisture	15.951**
Soil pH	15.734**
Silt	7.1225**

** P = 0.01.

Table III - *Effect of different variables on the root population of the citrus nematode at Hammam Al-Alil.*

Independent variables	Partial F values
Soil pH	15.0**
Months	5.06**

** P = 0.01.

At Mosul, all the variables except pH and percentage silt and clay had highly significant effects on the soil populations of the nematode (Overall F = 141.55) (Table IV). For this locality the regression equation proposed is

$$Y_1 = 2738.98 + 82.64 \text{ X (temp.)} - 74.2 \text{ X (months)} + 14.55 \text{ X (depth)} - 65.37 \text{ X (sand)} + 28.87 \text{ X } (CaCO_3) + 15.16 \text{ X (moisture)}.$$

The independent variables account for 83.08% of the total variation in nematode population; SE of the equation is 23.63% of the mean nematode population of 1115.97.

Regression analysis with respect to the number of mature females per g root indicate that all the variables had a highly significant effect (Overall F = 101.061) (Table V)

$$Y_2 = 307.0 + 32.73 \text{ X (pH)} - 3.102 \text{ X (moisture)} + 2.32 \text{ X (months)} + 1.187 \text{ X (temp.)}.$$

The independent variables account for 92.88% of the total variation in population fluctuation; SE of the equation is 10.56% of the mean population of 88.03 females on the roots.

Table IV - *Effect of different variables on the soil population of the citrus nematode at Mosul.*

Independent variables	Partial F values
Soil temperature	708.353**
Months	149.848**
Depths	66.043**
Sand	34.444**
$CaCO_3$	19.652**
Soil moisture	10.365**

** P = 0.01.

Table V - *Effect of different variables on the root population of the citrus nematode at Mosul.*

Independent variables	Partial F values
Soil pH	11.592**
Soil moisture	82.387**
Months	16.302**
Soil temperature	9.22**

** P = 0.01.

At the Jaafer orchard each of the independent variables had a highly significant effect on the nematode population in the soil (Overall F = 106.284) (Table VI). The regression equation in respect of soil populations is

$$Y_1 = 7872.3 + 231.337 \text{ X (temp.)} + 1263.462 \text{ X } (CaCO_3) + 307.87 \text{ X (depth)} - 210.826 \text{ X (months)} - 1692.5 \text{ X (silt)} + 930.474 \text{ X (clay)} - 2405.603 \text{ (pH)} - 60.11 \text{ X (moisture)} - 552.692 \text{ X (sand).}$$

The independent variables account for 84.91% of the total variation in the nematode population; SE of the equation is 23.21% of the mean nematode population of 4054.87.

Only soil moisture and months showed a significant effect (Overall F = 4.613) on the fluctuations in numbers of mature females per g of

Table VI - *Effect of different variables on the soil population of the citrus nematode at Jaafer.*

Independent variables	Partial F values
Soil temperature	406.683**
$CaCO_3$	121.190**
Depth	112.629**
Months	77.701**
Silt	32.916**
Clay	13.003**
Soil pH	11.637**
Soil moisture	10.435**
Sand	4.888**

** P = 0.01.

root (Table VII). The regression equation for estimating numbers of mature females per g root is

$$Y_2 = 482.44 - 5.98 \text{ X (moisture)} + 5.922 \text{ X (months)}$$

The variables account for only 37.31% of the total variation; SE of the equation is 9.13% of the mean population of 537.83 mature females.

Table VII - *Effect of different variables on the root population of the citrus nematode at Jaafer.*

Independent variables	Partial F values
Soil moisture	4.850**
Months	4.3122**

** P = 0.01.

At Abbas Al-Kazum, all the independent variables except moisture, depth and sand had a highly significant (Overall F = 150.83) effect on the numbers of nematodes in the soil (Table VIII). The regression equation is

$$Y_1 = 8248.07 + 394.99 \text{ X (temp.)} - 476.97 \text{ X (months)} + 5042.247 \text{ X (pH)} + 2000.675 \text{ X (clay)} - 278.534 \text{ X (silt)} - 3024.886 \text{ X } (CaCO_3).$$

The independent variables account for 85.99% of the total variation of nematode populations; SE of the equation is 21.41% for the mean nematode population of 7641.43.

Soil pH, months and moisture showed a highly significant effect (Overall F = 23.05) on the numbers of mature females per g root (Table IX). The regression equation for estimating the population of females per g root is

$$Y_2 = 3660.7 + 243.75 \text{ X (pH)} + 14.92 \text{ X (months)} - 12.24 \text{ (moisture)}.$$

The independent variable account for 68.36% of the total variation in the population fluctuations; SE for equation is 4.50% of the mean nematode population of 1918.88.

Table VIII - *Effect of different variables on the soil population of the citrus nematode at Abbas Al-Kazum.*

Independent variables	Partial F values
Soil temperature	656.09362**
Months	125.854**
Soil pH	109.611**
Clay	28.548**
Silt	26.267**
$CaCO_3$	18.563**

** P = 0.01.

Table IX - *Effect of different variables on the root population of the citrus nematode at Abbas Al-Kazum.*

Independent variables	Partial F values
Soil pH	17.77**
Months	8.693**
Soil moisture	6.139**

** P = 0.01.

Discussion

Plant age, condition of the root system and depth of feeder roots were some of the more important factors which appeared to affect vertical distribution in the soil of larvae and males of citrus nematode. For example, 3-10 year old trees in the orchard at Hammam Al-Alil and Mosul had meagre root systems which supported fewer nematodes than in orchards with more mature trees. The few nematodes present suggest that they were brought into the nurseries in infested roots. In the nursery at Abbas Al-Kazum where the trees were very young, nematode populations were high but the land has been used for the previous 20 years for raising citrus nursery stocks. In the orchard at Jaafer where the trees were about 80 years old, severe decline symptoms were prevalent and only low populations of nematodes occurred, possibly because of the poor root systems.

In the Hammam Al-Alil orchard, the young trees provided little or no shade to the soil and therefore temperatures were high in the

root zone during the summer months which may explain the slow increase in the nematode population. In the Mosul orchard where the trees were older (about 10 years) and provided shade to the soil, nematode populations were higher.

Soil pH was found to be the second most important variable affecting the seasonal fluctuation of nematode populations. A pH range of 7.4-7.8 appeared to be the most favourable to the nematode and encouraged the production of high populations.

SUMMARY

Vertical distribution of the citrus nematode (*Tylenchulus semipenetrans* Cobb) was found correlated with the plant age, condition of root system and soil factors. Populations were higher at soil depths where more feeder roots were present. Plants of intermediate age (15-20 years) showed moderate decline symptoms but supported heavy populations whereas very old plants (80 years) showed severe decline symptoms but supported poor populations. Populations were very low around young plants (3-10 years). Highest populations of larvae and males, at all localities, were recorded during November-December and lowest during July-August except in Hammam Al-Alil orchard. Number of mature females/g of roots was highest during April-May and lowest during July-August. A pH range of 7.4-7.8 was found to support the highest populations. Soil type and percentage of $CaCO_3$ significantly affected vertical distribution and seasonal fluctuations. Since the effect of factors studied was so highly significant at all localitities a prediction equation is proposed for each locality separately to predict or estimate the nematode populations to a high degree of reliability which in turn can be fruitfully used for predicting damage or otherwise prescribing measures of control.

RIASSUNTO

Studi sulla distribuzione verticale e la fluttuazione stagionale del nematode degli agrumi in Iraq.

È stata notata una correlazione tra la distribuzione verticale del nematode degli agrumi (*Tylenchulus semipenetrans* Cobb) e l'età delle piante, le condizioni dell'apparato radicale e le caratteristiche del terreno. Le popolazioni erano più elevate alle profondità in cui vi era maggiore concentrazione di radici capillari. Piante di età intermedia (15-20 anni) mostravano sintomi modesti di declino, ma alimentavano alti livelli di popolazione, mentre piante molto vecchie (80 anni) mostravano sintomi severi di sofferenza, ma alimentavano livelli di popolazione molto bassi. Le popolazioni associate con piante giovani (3-10 anni) erano di livelli modesti. Le cariche più elevate di maschi e larve nel terreno sono state riscontrate in tutte e quattro le località oggetto di studio in novembre-dicembre e quelle più basse in luglio-agosto, ad eccezione dell'agrumeto di Hammam Al-Alil. Il numero più elevato di femmine sulle radici è stato osservato in aprile-maggio e quello più basso in luglio-agosto. Le cariche più elevate erano presenti ad un pH tra 7,4 e 7,8. Il tipo del terreno e la concentrazione di $CaCO_3$ hanno influenzato la distribuzione verticale e la fluttuazione stagionale delle popolazioni. Poiché l'effetto dei fattori studiati è altamente significativo in tutte le località viene proposta, per ognuna di esse, una equazione di previsione dei danni o che suggerisca l'opportunità di interventi nematocidi.

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