Asian Journal of Biology

Volume 20, Issue 3, Page 15-24, 2024; Article no.AJOB.112659
ISSN: 2456-7124

Influence of Seasonal Variations on Population Dynamics of Phyto-Parasitic Nematodes in Soil and Roots of Bell Pepper (*Capsicum annuum* L.) in Otari, Rivers State, Nigeria

Ekine Emmanuel Green [a*] and Ezenwaka Chinonye Oluchi [a]

[a] Department of Biology, Federal University Otuoke, Bayelsa State, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author EEG designed the study protocol. Both authors ECO and EEG performed the field samples collection, laboratory analyses, analyzed and interpreted the data. Author EEG managed literature search and wrote the initial manuscript. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJOB/2024/v20i3392

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/112659

Original Research Article

Received: 09/12/2023
Accepted: 14/02/2024
Published: 19/02/2024

ABSTRACT

Weather instability affects nematode proliferation in soil, affecting plant growth. Identifying endemic species and favourable seasons can guide farmers in cultivating crops during specific seasons, minimizing infections and improving yield. A survey to evaluate the influence of seasonal disparity on plant parasitic nematodes population in soil and roots of bell pepper (*Capsicum annuum* L.) was carried out during dry and rainy seasons in Otari, Abua/Odual Local Government Area of Rivers State, Nigeria. Five bell pepper cultivated fields were randomly selected and a total of 300 soil samples were collected and assayed for soil nematodes. The soil samples were collected using a

**Corresponding author: E-mail: emmanuelgreen95@gmail.com;*

soil auger at 0-15 cm depth, and roots were collected by the use of sterilized kitchen knife simultaneously for the isolation of nematode. The modified sieve plate method was employed for the extraction of nematodes. Nematode identification was carried out using a pictorial key. A total of 2,220 nematodes from 11 genera were reported in this study, among which 1,290 (58.1%) were recovered during the rainy season while the dry season showed 930 (41.9%) nematodes. Nematode population vary significantly between seasons in soil (P = .13) and roots of bell pepper (P = 3.90), with *Heterodera* species having higher density (1.44 and 1.03) during the rainy and dry seasons respectively in the soil. High density of *Meloidogyne* (0.97) was recorded during the rainy season and *Radopholus* spp (1.40) during the dry season in the root of bell pepper plant. The study showed that seasonal variations impacted on nematode population abundance in fields, establishing that nematodes are responsive to every unsteady condition of the soil environment resulting from seasonal disparity, and only species who adapt rapidly survive. Farmers should increase crop cultivation during the rainy season to boost yield, as nematodes population decline as rainfall increases.

Keywords: Bell pepper; nematodes; population dynamics; seasonal disparity; soil.

ABBREVIATIONS

1. F_1 = *Farm 1*
2. F_2 = *Farm 2*
3. F_3 = *Farm 3*
4. F_4 = *Farm 4*
5. F_5 = *Farm 5*

1. INTRODUCTION

Generally, nematodes have been implicated as crop pests in every cultivated field in Nigeria. Nematodes are versatile [1,2], inflicting plants with a variety of injuries [3,4]; yet understanding its community compositions with regards to season is not clear. However, the rate of survival for certain nematode species may be predicted depending on the stability of soil factors which are directly or partially regulated by seasonal disparity. Cedergreen *et al.* [5] reported that the proliferation of nematodes in the soil can be influenced by weather instability. This is because changes in weather may propel a change in soil water content as well as temperature and pH which could inhibit nematode development or incites propagation.

Since nematode survival chance is high in plant tissue, understanding on seasonal variations and nematode abundance in soil may aid suitable control measure and guide farmers on the best time to plant to be able to mitigate severe infections and increases yield. Reports have shown that nematodes display host preference [6,7,4], therefore, limited vegetations in certain fields propel by change in season may result to low populations of nematodes and affect composition at a given time and season. This is because not every plant will be available all season for active parasitism with species of specificity. Renco et al. [8] and [9] opined that fluctuations in season impact on soil factors and influences soil organisms including phyto-parasitic nematodes. Hassan *et al.* [10] stated that nematodes manifest high populations in soil between June and August (rainy season) and showcase a steady decline from October (dry season). Renco *et al.* [8] reported gradual increase of nematodes in continuous cropping system and more stable seasonal dynamics of nematode species.

Bell pepper, a vegetable crop widely used in Nigeria, thrives well in Otari, yet, quality yield is impaired by the activities of plant parasitic nematodes [2]. Studies on seasonal adaptation of nematodes and severity of infection in relation to bell pepper yield is lacking in Otari and constitute a major set-back in the control of pests. Therefore, a good understanding on nematode propagation and affluence in soil with regards to seasonal disparity will be beneficial to the rural farmers. Also since nematodes are host specific, identification of endemic species and the most favourable season of abundance can help with the most appropriate information regarding the most suitable crop for cultivation against specific season of the year to minimise infections and ameliorate yield. Therefore, this survey is aimed at evaluating the influence of seasonal variations on the population abundance of soil nematodes in rhizosphere and root tissues of bell pepper.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Otari. Otari is made up of 7 communities in Abua/Odual Local

Government Area of Rivers State and lies between latitude 4°50'13''N and longitude 6°39'24''E.The average rain fall in Otari is about 2000-2500mm and temperature range of 25°C – 32°C. The vegetation is typical of tropical rain forest. The indigenes are commercial farmers that concentrate mostly on cassava and vegetable crops. The area experiences two seasons, dry season (November to April) and rainy season (May to October).

2.2 Experimental Design

The random sampling design was employed for the study. Five bell pepper monoculture farms were randomly selected and sampled during the dry and rainy seasons. Soil and root sampling was done between December, 2020 to February, 2021 for dry season while rainy season sampling was done between June – August, 2021.The farms were designated F_1, F_2, F_3, F_4 and F_5

2.3 Sampling

2.3.1 Collection of soil and roots

Soil samples were collected randomly from the rhizosphere of ten stands of bell pepper at 0-15 cm depth per farm. These samples were collected once per month between December 2020– February, 2021 and June – August, 2021. The soil samples were collected using a soil auger and a total of fifty soil samples were collected in each month (ten samples in each farm) of sampling per season making a total of one hundred and fifty samples with a Grand total soil samples of three hundred. The soil samples were packed into properly labelled white waterproof bags and subsequently transported to the laboratory for nematode extraction.

At each time of soil sampling, ten randomly selected bell pepper stands were uprooted from each farm, and the roots taken at the same time as for soil with the aid of sterilized kitchen knife. The samples, placed into properly labelled polythene bags, were transported to the laboratory for nematodes extraction.

2.3.2 Nematode extraction procedure

Nematodes were extracted using the modified sieve plate technique as described in Imafidor and Ekine [1]. The soil samples in each water proof sampling bag were examined and detected debris removed. The soil samples from each water proof bag were spread evenly on tissue paper supported on a plastic sieve placed on plastic plates. Water was added to the side of the plates until the soil become wet but not immerse. After 48 hours, the soil samples were removed and the nematode suspensions emptied into a clean specimen bottles fixed with 5% for viewing using the microscope. The bell pepper roots collected were rinsed with Eva water to remove soil particles. The roots were chopped using a kitchen knife and macerated in an electric blender (BLG 450) for 15 seconds at low speed. Thirty (30) sub-samples were derived from the standardized samples and set up for extraction at each sampling time. The macerated root suspensions were spread evenly on tissue paper supported on a plastic sieve placed on a plastic plate. Water was added to the side of the plates until the root suspensions became wet but not immersed. The extraction set-up was left undisturbed for 48 hours at room temperature. The plate sieve containing the macerate roots was discarded appropriately. The nematode suspensions in the plastic plates were poured into clean specimen bottles and were subsequently fixed with 5% formalin and stored.

2.3.3 Identification of nematodes

Aliquot of 0.1ml of the nematode suspension extracted from soil and roots samples were taken with pipette and then dispensed on slides. The slides with the nematode suspension were observed using x4 and x10 objective of light microscope for identification and counting of nematodes. Identification of nematodes was done using pictorial keys according to Southey [11] and [12].

2.4 Data Analysis

The analysis of data among farms within season to ascertain nematode frequency and density was done using simple percentage (n x 100/N) while independent t-test was used to test the significant influence of season on nematodes population abundance.

3. RESULTS

3.1 Nematodes Population during Dry and Rainy Seasons in Soil Grown with Bell Pepper

Examination of soil during the dry and rainy seasons revealed a total of 1,652 nematodes belonging to 12 genera. Among the 1,652

nematodes recovered in soil cultivated with bell pepper, 1079 (65.3%) were extracted from soil samples collected during the rainy season while the dry season yielded a total of 573 (34.7%) nematodes.

Prominent nematodes recovered during the rainy season were *Gracilachus, Helicotylenchus, Ditylenchus, Heterodera, Hoplolaimus, Meloidogyne, Radopholus, Rotylenchus, Scutellonema, and Tylenchorhynchus* species. Some plant parasitic nematodes were reported in all the five farm sites where samples were collected, while some were missing in certain farms. For instance, *Gracilachus* spp, *Helicotylenchus* spp, *Heterodera* spp*, Meloidogyne* spp*, Scutellonema* spp, were found in all the sampled farms while *Rotylenchus* spp, *Radopholus* spp, *Hoplolaimus* spp and *Ditylenchus* spp were missing in farm F_2, F_3, F_4 and F_5 respectively (Table 1).

The dry season showcased nematodes such as *Heterodera, Meloidogyne, Pratylenchus, Radopholus, Rotylenchus, Scutellonema* and *Tylenchus*. *Rotylenchus* spp was missing in Farm F_1 and F_2, while *Scutellonmea*, *Pratylenchus* and *Tylenchus* were not found in F_1, F_3, F_4 and F_5 respectively. Nematode population showed a significant difference between seasons in soil (*P* = .13) with *Heterodera* species displaying higher density (1.44 and 1.03) during the rainy and dry seasons respectively (Table 1).

3.2 Population of Plant Parasitic Nematodes of Bell Pepper Root in Otari during Rainy and Dry Seasons

From the root tissue of bell pepper, 568 nematodes belonging to 7 genera were recovered during the rainy and dry seasons. Among the 568 nematodes recovered, the rainy season yielded 211 (37.1%) while the dry season reported 358 (62.9%) nematodes. Important phyto-parasitic nematodes extracted were *Helicotylenchus* spp, *Pratylenchus spp*, *Radopholus* spp, *Rotylenchus* spp, *Tylenchus* spp, *Scutellonema* spp and *Meloidogyne* species. *Tylenchus* and *Scutellonema* species were peculiar to dry season and were not found during the rainy season. However, during the rainy season, *Rotylenchus* spp was missing in farm F_2 and F_5 while *Helicotylenchus* and *Radopholus* spp were not reported from farm F_1 and F_4 respectively. In the root of bell pepper plant, high density of *Meloidogyne* (0.97) was recorded during the rainy season; while *Radopholus* spp showed higher density (1.40) during the dry season. Nematode population showed a significant difference between seasons in roots of bell pepper (*P* = 3.90) (Table 2).

3.3 Actual Incidence of Nematodes in the Soil and Roots of Bell Pepper in Relation to Month of Occurrence in Otari

Soil sampling recorded high assemblage of nematodes in the month of June (25.3%), July had 15.6 %; while 7.7%, 13.8%, 6.8% and 9.7% of the total population of nematodes occurred in August, December, January and February respectively (Fig. 1). The occurrence in the root tissues of bell pepper was 1.8%, 3.1%, 4.6%, 2.6%, 4.4% and 4.6% for the June, July, August, December, January and February respectively (Fig. 2).

3.4 Nematode Dynamics in Soil and Roots of Bell Pepper during Dry and Rainy Season in Otari, Rivers State

Total assemblage of phyto-parasitic nematodes during rainy and dry seasons was 2,220. Among the 2,220 nematodes recovered from soil and roots of bell pepper in Otari, 1,290 (58.1%) occurred during rainy season and 930 (41.9%) were extracted at dry season.

There was disparity in the occurrence of nematodes during the sampling seasons. For instance, *Helicotylenchus* spp*, Heterodera* spp, *Meloidogyne* spp*, Scutellonema* spp*, Rotylenchus* spp, *Pratylenchus* spp and *Radopholus* spp occurred during dry and rainy season. However, *Gracilachus* spp, *Hoplolaimus* spp and *Tylenchorhynchus* spp were reported only during rainy season and *Tylenchus* spp was found during dry season only. The abundance of soil nematodes between seasons was statistically significant (*P* = .87). Nematode with most prevalence occurrence during the rainy season was *Meloidogyne* spp (17.8%), closely followed by *Heterodera* spp (16.7%). Significant occurrence was also observed from *Radopholus* spp (12.9%), *Helicotylenchus* spp (11.5%), *Gracilachus* spp (7.4%), *Hoplolaimus* spp (7.4%) and *Scutellonema* spp (7.2%), with *Pratylecnhus* spp (2.4%) showing the least appearance. *Radopholus* spp had the highest frequency of abundance at dry season followed by *Heterodera* spp and *Meloidogyne* species 16.6%.

Pratylenchus spp was 15.5% while frequency of abundance of *Helicotylenchus* spp was 3.1%. The most prevalent nematode during rainy and dry season was *Meloidogyne* spp (17.3%), closely followed by *Heterodera* spp (16.7%) and *Radopholus* spp (15.9%); while the least occurred nematode was *Tylenchorhynchus* spp (3.2%) (Fig. 3).

4. DISCUSSION

The result of this study recorded overall occurrence of 2,220 nematodes from 11 genera unlike the result of Cerevkova and Cagnan [13] and [8] which reported 6 and 9 nematode genera in their respective studies on effects of seasonal fluctuations on nematodes population in the field. However, the result suggests that nematode propagation in Otari occur all through the year not minding season.

The abundance of plant parasitic nematodes in the soil during the dry season (34.7%) was low compare to the recovered population during the rainy season. The low nematode population observed in bell pepper-cultivated soil during the dry season may be attributed to insufficient water in the soil due to the absence of rain as observed in the study area (Otari) during the period under review. The limited water noticed in the soil may have impacted negatively on the propagation and profusion of soil nematodes and have encouraged hypobiosis. However, the high population of nematodes observed during the rainy season could be attributed to nematodes trophic affiliation. This result agrees with Talwana eta l. [9] who reported low nematode occurrence in their research on occurrence of plant parasitic nematodes and factors that enhance population build up in cereal-based cropping system in Uganda. However, it is in contrast with Hassan et al. [10] and [13].

In this study, nematodes were unevenly distributed in soil across the seasons during soil sampling. This scenario is indicative that seasonal fluctuations influence population abundance of plant parasitic nematodes in fields. This result suggests that changes in season directly impact on nematodes abundance in the soil. This is because at each time of switch (from dry season to rainy season), the soil ecosystem is altered and significantly dictate nematode survival chances in the soil [14].

The abundance of nematodes in relation to the month of sampling showed that during the rainy season, the month of June (25.3%) recorded the highest prevalence of soil nematodes and showed a steady decline in July (15.6%) and August (7.7%). The high population of soil nematodes observed in June could be attributed to activeness of nematodes due to rain. The rain, during the rainy season in the month of June, impacted on the amount of water present in the soil and may have improved its optimum level, enhancing nematode survival strategies. It also stirred up important soil microbes for active associations in the soil, hence, made more food available for nematodes and improve propagation and abundance. Elsewhere, Daramola et al. [15] recorded a peak nematode

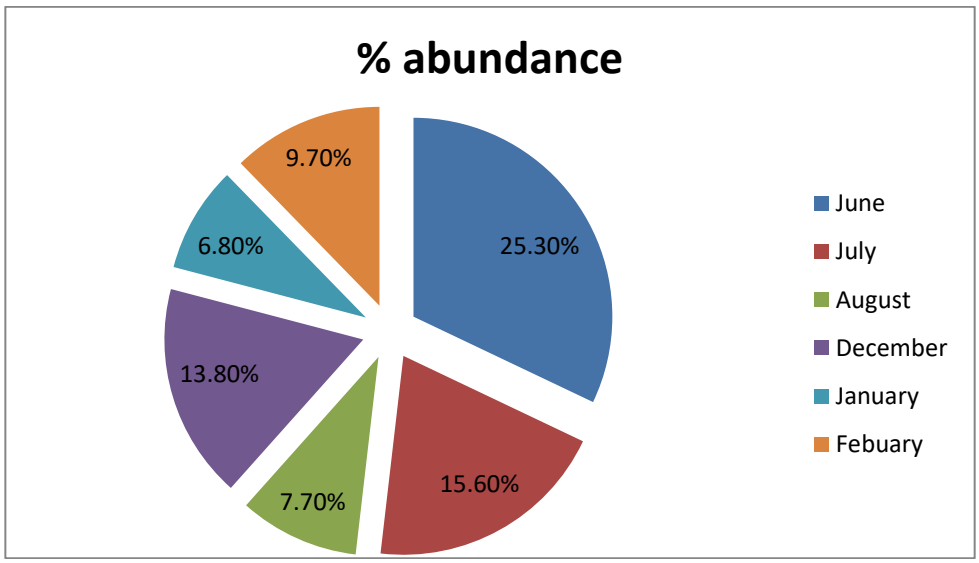

Fig. 1. Actual incidence of nematodes in the soil of bell pepper in relation to month of occurrence

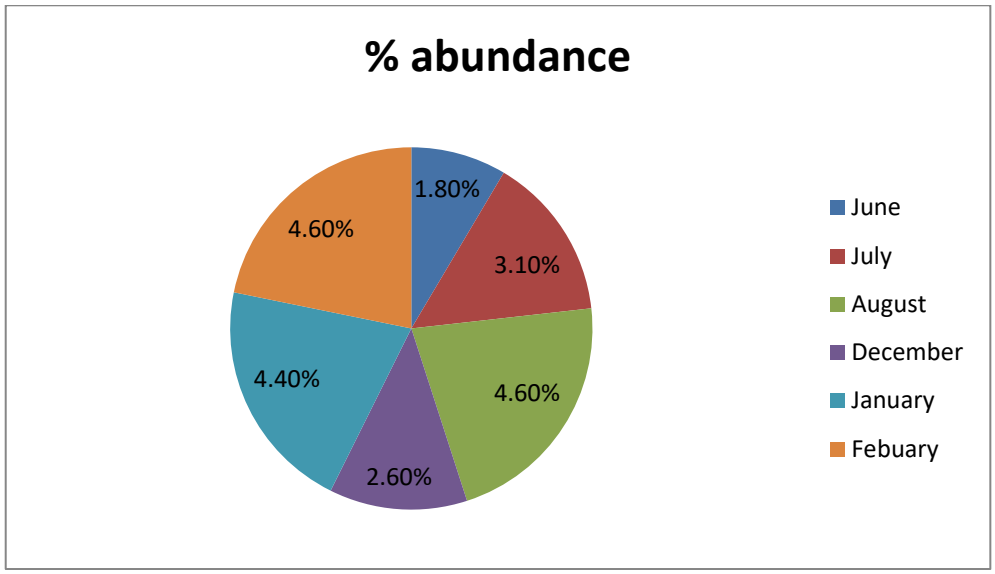

Fig. 2. Nematode assemblage in roots of bell pepper and month of occurrence

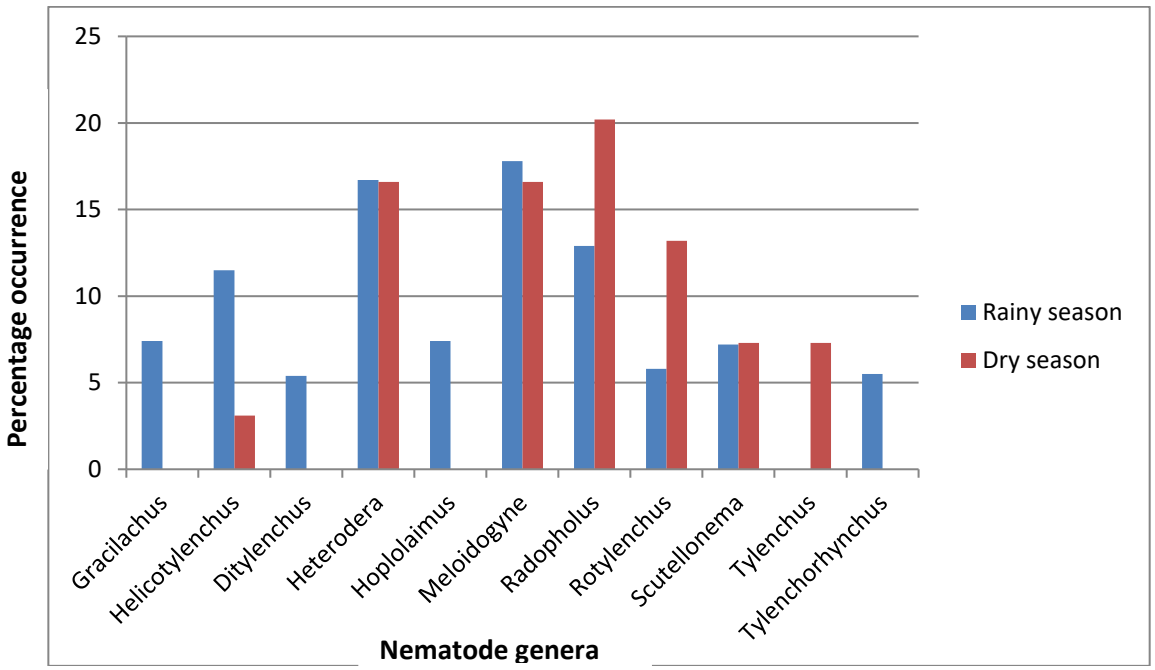

Fig. 3. Nematode dynamics in soil and roots of bell pepper during dry and rainy season in Otari

population for all plant-parasitic nematodes in the summer. The progressive decline in nematodes population observed in July and August could be attributed to increased water in the soil due to frequent downpour experienced in the study area during the study period. This result opined that changes in season, alongside fluctuations in rainfall could result to irregular pattern in the occurrence of nematodes in the soil as suggested by Daramola et al. [15]. However, [14], [16-17] reported disparity in nematodes frequency of occurrence with respect to variable water content in soil resulting from different amount of rain fall. Nematodes experience less stress for sustainable amplification at rainy season. This is because moderate rainfall could raise soil water to optimum level and improve nutrient for the sustainability of nematodes span [18]. The hydrological conditions of soil during the rainy season can ease nematode migratory ability [19] and facilitate food search and enhances their opportunity to stay alive.

Table 1. Nematodes population during dry and rainy seasons in soil grown with bell pepper in Otari, Rivers State, Nigeria

		Farms grown with bell pepper					Total	Pop.
Season	**Nematode genera**	**F_1 (%)**	**F_2 (%)**	**F_3 (%)**	**F_4 (%)**	**F_5 (%)**	**(%)**	**density**
Rainy season	*Gracilachus*	37 (14.8)	16 (11.9)	10 (5.4)	19 (6.3)	13 (6.3)	95 (8.8)	0.63
	Helicotylenchus	27 (10.8)	14 (10.4)	30 (16.1)	24 (7.9)	40 (19.3)	135(12.5)	0.90
	Ditylenchus	17 (6.8)	31 (23.1)	22 (17.8)	0	0	70 (6.4)	0.46
	Heterodera	50 (20.0)	27 (20.1)	62 (33.3)	44 (14.5)	33 (15.9)	216(20.0)	1.44
	Hoplolaimus	31 (12.4)	9 (6.7)	13 (7.0)	43 (14.2)	0	96 (8.9)	0.64
	Meloidogyne	33 (13.3)	17 (12.7)	12 (6.5)	37 (12.2)	41 (19.8)	140(12.9)	0.93
	Radopholus	21 (8.4)	9 (6.7)	0	49 (16.2)	30 (14.5)	109(10.1)	0.72
	Rotylenchus	4 (1.6)	0	17 (9.1)	23 (7.6)	9 (4.3)	53 (4.9)	0.35
	Scutellonema	14 (5.6)	5 (3.7)	20 (10.8)	37 (12.2)	17 (8.2)	93 (8.6)	0.62
	Tylenchorhynchus	15 (6.0)	6 (4.5)	0	27 (8.9)	24 (11.6)	72 (6.8)	0.48
	Total	249(23.1)	134(27.4)	186(17.2)	303(28.1)	207(19.2)	1,079	7.17
Dry season	*Heterodera*	41 (39.4)	32 (27.6)	28 (17.4)	17 (28.8)	37 (27.8)	155(27.1)	1.03
	Meloidogyne	14 (3.5)	24 (20.7)	31 (19.3)	5 (8.5)	12 (9.0)	86 (15.0)	0.57
	Pratylenchus	14 (15.5)	24 (20.7)	31 (19.3)	0	32 (24.0)	96 (16.8)	0.64
	Radopholus	4 (3.8)	17 (14.6)	28 (17.4)	15 (25.4)	23 (17.3)	62 (10.8)	0.41
	Rotylenchus	0	0	27 (16.7)	12 (20.3)	22 (16.5)	91 (15.9)	0.60
	Scutellonema	0	13 (11.2)	16 (9.9)	3 (5.0)	7 (5.3)	39 (6.8)	0.26
	Tylenchus	31 (29.8)	6 (5.2)	0	7 (11.9)	0	44(7.7)	0.29
	Total	104(18.2)	116(20.2)	161(28.0)	59 (10.3)	133(23.2)	573	3.8

Table 2. Population of plant parasitic nematodes of bell pepper root in Otari

Season		Farms grown with bell pepper					Total (%)	Pop. density
	Nematode genera	**F_1 (%)**	**F_2 (%)**	**F_3 (%)**	**F_4 (%)**	**F_5 (%)**		
Rainy season	*Helicotylenchus*	0	4 (14.8)	1 (1.8)	2 (12.5)	6 (9.8)	13 (6.2)	0.14
	Meloidogyne	24(46.2)	11(40.7)	20(36.4)	7 (43.8)	26(42.6)	88 (41.7)	0.97
	Pratylenchus	6 (11.5)	3 (11.1)	9 (16.4)	3 (18.8)	10(16.4)	31 (14.7)	0.34
	Radopholus	12(23.1)	9 (33.3)	17(30.9)	0	19(31.1)	57 (27.0)	0.38
	Rotylenchus	10(19.2)	0	8 (14.5)	4 (25.0)	0	22 (10.4)	0.24
	Total	52(24.6)	27(12.8)	55(26.0)	16 (7.6)	61(28.9)	211(37.1)	2.07
Dry season	*Helicotylenchus*	16(16.6)	7 (5.8)	5 (7.9)	0	1 (1.2)	29 (8.1)	0.32
	Meloidogyne	21(21.9)	11(13.4)	7 (11.1)	6 (18.8)	24(28.6)	69 (19.3)	0.76
	Pratylenchus	6 (6.3)	12(14.6)	0	13(40.6)	17(20.7)	48 (13.4)	0.53
	Radopholus	32(33.3)	7 (5.8)	41(65.1)	7 (21.9)	39	126(35.3)	1.40
	Rotylenchus	4 (4.2)	20(24.4)	8 (12.7)	0	0	32 (9.0)	0.35
	Scutellonema	0	21(25.6)	2 (3.2)	6 (18.7)	0	29 (8.1)	0.32
	Tylenchus	17(17.7)	4 (4.9)	0	0	3 (3.7)	24 (6.7)	0.26
	Total	96(26.9)	82(23.0)	63(17.6)	32 (8.9)	84(23.5)	357(62.9)	3.94

From the roots of bell pepper, greater population of nematodes were isolated at dry season (62.9%) while the percentage abundance during the rainy season (37.1%) was relatively low compare to the results of Wang et al. [20]. This result implied that dryness of soil due to the absence of rain during the dry season presented unsafe environmental conditions for the survival of plant parasitic nematodes and they borrow into the roots tissues of bell pepper for survival. However, improved soil environment due to rain during the rainy season stir up active associations in the soil and increases nutrient concentration around the bell pepper plant and discourages root borrowing. This result also opined that bell pepper has less rigidity or resistance against plant parasitic nematodes at dry season. This observation agrees with Shokoohi et al. [21] which reported similar result, but disagree with Elele [22] who extracted higher number of nematode species in the root of eggplant. This disparity could be attributed to study location; crop under review and prevalence nematode genera endemic in the study area.

The nematodes population dynamics seen in this study suggests that seasonal disparity affects nematode propagation and profusion. *Meloidogyne* species had the highest prevalence in the study, followed by *Radopholus* species; while *Tylenchorhynchus* species had the least abundance in the study. This study's observation indicates that *Meloidogyne* was better adapted to seasonal fluctuations than any other species occurring in the study area. This study result also suggests that nematode species are sensitive to unsteady conditions of the soil ecosystem resulting from seasonal disparity and only species that are better adapted to survive. *Meloidogyne, Scutellonema, Hoplolaimus, Pratylenchus, Helicotylenchus, Rotylenchus and Radopholus* were reported at both dry and rainy seasons, while *Tylenchus* was found only during dry season and *Gracilachus, Ditylenchus, Hoplolaimus* and *Tylenchorhynchus* were peculiar to the rainy season only. This scenario could be attributed to nematode survival strategy and persistence environmental fluctuations in the soil due to seasonal variations. It also signifies that soil nematodes propagate and survive only in environments that they are betters supported. This observation agrees with Dabur and Bajaj [6] and [23].

5. CONCLUSION

Seasonal variations directly impact on nematodes population abundance in the soil as it impacts on soil factors which also influence nematode chances of survival. Soil nematodes are responsive to unsteady environmental conditions resulting from seasonal disparity and only species who adapt rapidly survive. Due to the fact that nematode populations decline as rainfall increases, farmers should make the most of the season by increasing crop cultivation throughout the rainy season in order to boost yield. Since Otari's endemic species population declines with frequent rainfall, farmers should try to expose agricultural area cleared for production to flooding by irrigation for at least 21 days before ploughing.

ACKNOWLEDGEMENT

The authors immensely appreciate the farm owners in Otari, Rivers State, Nigeria, for their consent. The support of Laboratory Technologists in the Department of Biology, Ignatius Ajuru University of Education, Rivers State, is sincerely appreciated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Imafidor HO, Ekine EG. A survey of the nematode pests of the crop cassava (Manihot esculenta) in Rivers State, Nigeria. African Journal of Applied Zoology & Environmental Biology. 2016;18:17-18.
2. Gboeloh LB, Elele K, Ekine EG. Plant parasitic nematodes associated with cucumber (Cucumis sativa) cultivated in Abua/Odual local government area of Rivers State, Nigeria. International Journal of Science, Technology, Enginerring, Mathematics and Science Education. 2019;4(1):23-31.
3. Noling JW. Nematode management in tomato, pepper and eggplant. EN-032 Florida corporative extension service, University of Florida. 2009;492-520.
4. Orluoma CA, Ekine EG, Karibi EI. Populations of phyto-parasitic nematodes on groundnut (*Arachis hypoeal*) cultivated fields in Egbolom, Abual/Odual Local Government Area, Rivers State, Nigeria. FNAS Journal of Scientific Innovations. 2023;4(2):19-26.
5. Cedergreen N, Norhave NJ, Svendsen C, Spurgeon DJ. Variable Temperature

Stress in the Nematode Caenorhabditis elegans and its Implication for Sensitivity to an Additional Chemical Stressor. PLOS ONE. 2016;11 (1):10-17.
6. Dabur KR, Bajaj HK. Nematode trophic groups as affected by zero lillage in rice wheat cropping system. Jaipur. 2002;81-84.
7. Ekine EG, Gboeloh LB, Imafidor HO, Elele K. Nematode community composition and species diversity from pre-cropping to harvest of Cucumber (*Cucumis sativa*) in Abua, Rivers State. Nigeria Journal of Nematology. 2020;5:19-29.
8. Renco M, Liskova M, Cervkova A. Seasonal fluctuation on the nematode communities in a hop garden soil. Helminthologia. 2010;47(2):115-122.
9. Talwana HL, Butseya MM, Tusime G. Occurrence of plant parasitic nematodes and factors that enhance population build up in cereal-based cropping system in Uganda. African Crop Science Journal. 2008;16(2):119-131.
10. Hassan J, Chishti MZ, Ahmad I, Iqbal M, Lone BA. Seasonal nematode population density on maize and mustard. World Applied Science Journal. 2009;6(6):734-736.
11. Southey JF. Laboratory method for work with plant and soil nematodes. Her majesty's Stationery office, London. 1986; 201.
12. Mekete T, Dababa A, Sekora N, Akyazi F, Abebe E. Identification Key for agriculturally important plant-parasitic nematodes identification course. A manual for nematology. 2012;109.
13. Cerevkova A, Cagnan L. Seasonal effect on the population dynamics of soil nematodes in a maize field. Journal of Central European Agriculture. 2012;13 (4): 739-746.
14. Boland GJ, Melzer MS, Hopkin A, Higgins V, Nassuth A. Climate change and plant disease in Ontario. Canadian Journal of Plant Pathology. 2004;26(3):335-50.
15. Daramola FY, Malgas R, Malan AP. Occurrence and seasonal changes in the population of root-knot nematodes on honeybush (*Cyclopia sp*.). Helminthologia. 2021;58(2):202-212.
16. Arun KY. Soil moisture effect on the activity of three entomopathogenic nematodes (Steinernematidae and Heterorhabditidae) isolated from Maghalaya, India. Journal of Parasite Distribution. 2012;36(1):94-98.
17. Andrea C, Ludovit D. Seasonal effect of population dynamics of soil nematodes in a Maize Field. Journal of Central European Agriculture. 2012; 13(4):739-746.
18. Ekine EG. Impact of poultry manure on soil nematode dynamics and yield of bell pepper (Capsicum annuum) in Abua/Odual Local Government Area, Rivers State. PhD thesis, Ignatius Ajuru University of Education, Port Harcourt, Rivers State, Nigeria; 2020.
19. Wall JM, Virginia RA. Control on soil biodiversity sight from extreme Environment. Applied Soil Ecology. 2009; 13:137-145.
20. Wang KH, McSorley R, Fasilo TR. Foliar and root-knot nematodes as pest of ornamental plants. Bug. Tutorials, University of Florida Press. 2006;188.
21. Shokoohi E, Mashela PW, Iranpour F. Diversity and seasonal fluctuation of Tylenchid plant parasitic nematode in association with alfalfa in Kerman Province of Iran. Journal of Nematology. 2019;51:1-14.
22. Elele K. Influence of organic amendment on soil nematodes community composition and infectivity on eggplant (*Solanumm elongena* L.) in Rivers State. PhD Research Thesis, University of Calabar, Nigeria. 2016;67-68.
23. Deming L, Qi L, Fangming L, Young J, Wenju L. Vertical distribution of soil nematodes in an age sequence of Caragan microphylla plantation in the Horqin Sandy land. Ecological Research. 2006;22:49-56.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/112659