RESEARCH ARTICLE Agricultural Science Digest, Volume 41 Special Issue: 151-156 (April 2021)

Prevalence of Nematodes in Rhizosphere of Kiwi Plants (*Actinidia deliciosa* Chev., 1984) in International Centre for Integrated Mountain Development (ICIMOD), Knowledge Park, Godawari, Lalitpur, Nepal

B. Chhetri, J.R. Subedi

10.18805/ag.D-291

ABSTRACT

Background: Plants harbor many trophic groups of nematodes in them. The plant production is also determined by the occurrence of nematodes adjacent to the rhizosphere of plants, such as parasitic, free-living etc.

Method: Altogether 60 samples (30 from 20 cm depth and 30 from 30 cm depth) were examined from the Kiwi plants to detect the nematode distribution in Kiwi plants in ICIMOD, Godawari, Lalitpur, Nepal. Overall, 1510 individuals of 10 nematodes genera (both free living/beneficial and parasitic) belonging to four orders were found to be associated with Kiwi plants, among them the highest report was of order Mononchida (44.04%) which was followed by Rhabditida (33.44%), Dorylaimida (17.88%) and Tylenchida (4.64%). The number of nematodes were higher at 20 cm depth than at 30 cm depth. *Iotonchus* spp. was highest (32.68%) and the number of *Helichotylenchus* spp. (3.93%) and *Mesorhabditis* spp. (3.92) were lowest at 20 cm depth. Similarly, *Iotonchus* spp. was highest (20.13%) and the number of *Discolaimus* spp. (4.03%) was lowest at 30 cm depth.

Key words: Community analysis, Kiwi, Nematode distribution, Nematodes, Rhizosphere.

INTRODUCTION

Kiwi (*Actinidia deliciosa*) belongs to the order Ericales and family Actinidiaceae, which normally ripens within 25 weeks after the appearance of first flowers (Wilson *et al*., 2020). The Kiwi fruits are beneficial to the human health because it contains vitamin A, B, C, E and K, copper, potassium, fiber and folate (Beutel, 1990). The demand of Kiwi in the worldwide market is hiking due to these nutrients available in Kiwi fruit, which is mainly beneficial for the treatment of many diseases like cancer and heart disease, children and pregnant women (Beutel, 1990). Some beneficial soil nematodes increase the plant production by increasing soil fertility, whereas some lower the production by causing harm to the plants (Yeates and Coleman, 1982). Harmful nematodes are more disadvantageous to the crop production and cause massive loss to the farmers (Singha *et al*., 2015). About 100-157 US$ crop production is lost worldwide per year from the nematodes (Nicol *et al*., 2011). The crop rotation techniques are being practiced by farmers to lower the crop loss from disease and parasites (Curl, 1963; Nusbaum and Ferris, 1973). However, this technique won't be conceivable to perennial plants like Kiwi. Plant parasitic nematodes constitute one of the most important groups of organism inhabiting the soil and in and around the roots of plants. Plant parasitic nematodes lower the plant production by damaging crops. The most abundant plant parasitic nematodes fall under the orders like Tylenchida, Dorylaimida and Aphelenchida (Ingham and Detling, 1984). Furthermore, *Rhabditis* spp., *Mesorhabditis* spp., *Cephalobus* spp. and *Eucephalobus* spp., etc. are the free-living nematodes, which are common in the plants and benefit plants by providing nutrients through decaying organic matters (Yeates *et al*., 1993). Likewise, *Aphelenchus* spp. is one of the fungivorous nematodes, which also turn organic matters into inorganic form (Ingham and Detling, 1984). However, despite of being least abundant predatory nematode in most of the soil contents, *Mononchus* spp. feeds indiscriminately both free-living and plant parasitic nematodes (Yeates *et al*., 1993).

The Kiwi fruit production is declining, which may be due to the effects of nematodes such as *Xiphinema* spp., *Pratylenchus* spp., *Meloidogyne* spp., *Helicotylenchus* spp., *Paratylenchus* spp., *Psilenchus* spp. *Heterodera* spp., *Tylenchus* spp. and *Paratrichodorus* spp. (Watson *et al*., 1992). In Nepal, till date very less research specified the occurrences/ distribution of soil nematodes in kiwi plants. Therefore, the present study aims to lessen this research gap.

Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu, Bagmati Province, Nepal.

Corresponding Author: J.R. Subedi, Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu, Bagmati Province, Nepal. Email: janzoology@gmail.com

How to cite this article: Chhetri, B. and Subedi, J.R. (2021). Prevalence of Nematodes in Rhizosphere of Kiwi Plants (*Actinidia deliciosa* Chev., 1984) in International Centre for Integrated Mountain Development (ICIMOD), Knowledge Park, Godawari, Lalitpur, Nepal. Agricultural Science Digest. 41 (Special Issue): 151-156. DOI: 10.18805/ag.D-291.

Submitted: 29-06-2020 **Accepted:** 25-08-2020 **Online:** 10-11-2020

MATERIALS AND METHODS

The ICIMOD Knowledge Park at Godavari, on the southern slopes of the Kathmandu Valley, was set up in March 1993, following the generous provision of 30 hectares of land with loamy type soil. Its coordinates are: - Latitude: 27° 35′19″-27° 35′4″N, longitude: 85° 23′16″- 85° 23′44″E, altitude: 1540 - 1800 masl and slope gradient: 50-600 (North-facing) (Nepal Census, 2001). Study area has 35 Kiwi plants in Knowledge Park at Godawari.

Preliminary survey was done to acquire general information about study area. Interaction with concerned person was done to collect information about Kiwi plants farming in ICIMOD. The present study was carried out on July-September, 2019. Total 60 Kiwi plants randomly selected to collect Kiwi plants related soil nematodes. About 20 cm and 30 cm was dug on the side of kiwi plants. Five sub-samples collected randomly from a depth of 15-20 cm (for 20 cm depth) and 25-30cm (for 30 cm depth) from each rhizosphere of kiwi were mixed to make a composite sample. The soil was kept in plastic bags and tagged and brought to the lab of Central Department of Zoology for further processing. In laboratory, the chunks were smashed and pebbles were removed from soil samples by hand picking method. A 100cc of soil sample from collected sample was processed by Cobb's sieving (Cobb, 1918) (mesh size: 53µm and 200 mm) and decantation and modified Baermann's funnel technique (Staniland, 1954) for extraction of nematodes. Total 10 ml of nematode suspension was prepared and 1 ml out of 10 ml suspension was taken into a counting disc for counting of nematodes and result obtained was multiplied by 10. The killing and fixing of nematodes were done by Seinhorst's process (Seinhorst, 1966) by using 4% formaldehyde heated at 60-70°C. Dehydration of nematodes was done by keeping them in a desiccator for about 1 week (Seinhorst, 1959). The slides of nematodes were prepared by using glycerin, purified wax and hot plate. The slides were then observed under the low power and high power magnification. i.e. 10× (eye piece) and 10×, 20× and 40× (nose piece) from left to right side of the slide. The nematodes were identified up to genus level by comparing the characters of observed nematodes with available taxonomic keys (Smart and Nguyen, 1988).

Statistical Analysis

Parameters for community analysis of various nematode genera were calculated using formulae by Beals (1960) and Norton (1978).

Frequency (N): Frequency of nematode genus (*i.e.* the number of samples in which the genus was present).

$$\text{Absolute Frequency (AF \%)} = \frac{\text{Frequency of the genus} \times 100}{\text{Total number of sample counted}}$$

$$\text{Density (D)} = \frac{\text{Number of nematode specimens of the genus counted in all sample}}{\text{Total number of sample collected}}$$

$$\text{Relative Density (RD \%)} = \frac{\text{Mean density of the genus} \times 100}{\text{Sum of mean density of all nematode genera}}$$

$$\text{Prominence Value (PV)} = \text{Density}\sqrt{\text{Frequency}}$$

$$\text{Mean Density (MD)} = \frac{\text{Total no specimens of a genera}}{\text{Total number of sample}}$$

The distribution of Kiwi nematodes was analyzed in R Program 3.4.1 version (R Core Team, 2020).

RESULTS AND DISCUSSION

General prevalence of nematodes

Out of 60 soil samples, all soil samples were positive (100%)

Table 1: Population structure of soil inhabiting nematodes of Kiwi plants of ICIMOD, Lalitpur, Nepal.

Nematodes	N	AF %	Density	RD	Total no. of each genus of nematode	PV	MD	*p*- value
Helichotylenchus spp.	30	50.00	1.17	4.65	70	6.41	1.17	
Iotonchus spp.	60	100.00	6.67	26.50	400	51.67	6.67	
Dorylaimus spp.	60	100.00	3.33	13.23	200	25.79	3.33	
Parahadronchus spp.	30	50.00	2.75	10.93	165	11.89	2.75	
Mononchus spp.	27	45.00	1.67	6.63	100	8.68	1.67	
Rhabditis spp.	23	38.33	3.50	13.90	210	16.79	3.50	2.2×10^{-16}
Cephalobus spp.	24	40.00	1.58	6.28	95	7.74	1.58	
Eucephalobus spp.	24	40.00	2.00	7.95	120	9.80	2.00	
Mesorhabditis spp.	20	33.33	1.33	5.28	80	5.95	1.33	
Discolaimus spp.	15	25.00	1.16	4.65	70	4.53	1.17	
Total	313	521.66	25.16	100.00	1510	149.25	25.17	

N (Frequency) = No. of samples in which the genus was present; AF% = Frequency of genus x 100 / total no. of sample; MD = Total no. of specimens of a genera / No. of samples; RD % = Mean density of a genus x100/ sum of mean density of all nematode genera and Prominence value (PV) = Density.$\sqrt{\text{Frequency}}$. There was significant difference ($\chi^2_{cal} > \chi^2_{tab}$) between the total number of nematode species in samples studied in ICIMOD Education Park study area ($P < 0.05$).

Table 2: Nematodes identified at 20 cm depth of rhizosphere soil of Kiwi plant.

Nematodes	20 cm depth		
	Frequency (N)	No. of each genus of nematode	*p*- value
Helichotylenchus spp.	15	30	
Iotonchus spp.	30	250	
Dorylaimus spp.	30	90	
Parahadronchus spp.	15	65	
Mononchus spp.	14	60	
Rhabditis spp.	13	100	2.2×10^{-16}
Cephalobus spp.	12	50	
Eucephalobus spp.	12	50	
MesoRhabditis spp.	10	30	
Discolaimus spp.	5	40	
Total		765	

There was significant difference ($\chi^2_{cal} > \chi^2_{tab}$) between the total number of nematode species in samples studied at 20 cm depth of rhizosphere soil of Kiwi plants in ICIMOD Education Park study area ($P < 0.05$).

Table 3: Nematodes identified at 30 cm depth of rhizosphere soil of Kiwi plant.

Nematodes	30 cm depth		
	Frequency (N)	No. of each genus of nematode	*p*- value
Helichotylenchus spp.	15	40	
Iotonchus spp.	30	150	
Dorylaimus spp.	30	110	
Parahadronchus spp.	15	100	
Mononchus spp.	13	40	
Rhabditis spp.	10	110	2.2×10^{-16}
Cephalobus spp.	12	45	
Eucephalobus spp.	12	70	
MesoRhabditis spp.	10	50	
Discolaimus spp.	10	30	
Total		745	

There was significant difference ($\chi^2_{cal} > \chi^2_{tab}$) between the total number of nematode species in samples studied at 30 cm depth of rhizosphere soil of Kiwi plants in ICIMOD Education Park study area ($P < 0.05$).

for the prevalence of plant non-parasitic nematodes. However, plant parasitic nematodes were documented only from 50% soil samples. There was high prevalence of *Iotonchus* spp (26.49%) and low prevalence of *Helicotylenchus* Spp. and *Discolaimus* Spp. (4.64%) (Fig 1).

Many nematodes endeavor Kiwi plants for getting nutrition and for reproduction, such as *Pratylenchus vulnus* (walnut root lesion nematode) and *Meloidogyne* spp. (root knot nematode), both belonging to order Tylenchida is the main pest to Kiwi plants (UC IPM, 2019). Among four orders

Table 4: Plant parasitic and plant non-parasitic nematodes at various depths of rhizosphere.

20 cm depth		
Plant Parasitic Nematodes	Plant Non-Parasitic Nematodes	*P*- value
30	735	2.2×10^{-16}
30 cm depth		
Plant Parasitic Nematodes	Plant Non-Parasitic Nematodes	*P*- value
40	705	2.2×10^{-16}

There was significant difference ($\chi^2_{cal} > \chi^2_{tab}$) between the plant parasitic and plant non-parasitic nematodes at 20 cm and 30 cm depth of rhizosphere of Kiwi plants in ICIMOD Education Park study area ($P < 0.05$).

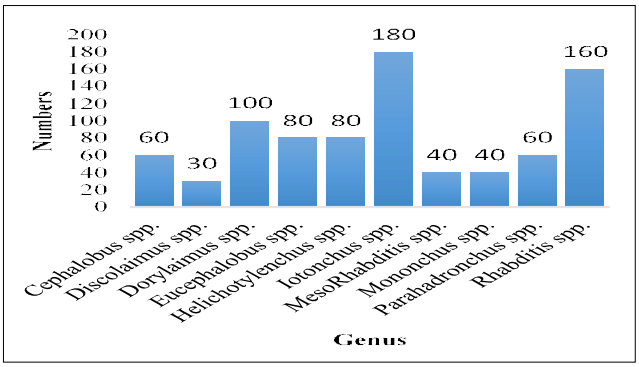

Fig 1: Prevalence of nematodes in ICIMOD, Godawari, lalitpur.

of nematodes, order Mononchida (*Iotonchus* spp., *Parahadronchus* spp. and *Mononchus* spp.) and order Tylenchida (*Helicotylenchus* spp.) was least found, probably due to the regular supplying of organic matters to the Kiwi plants. This assumption can be supported by the occurrence of nematodes belonging to orders Dorylaimida, Mononchida, Rhabditida and Tylenchida in Central Horticulture Centre, Kirtipur (Chhetri and Subedi, 2019) and Machchhegaun (Chhetri, 2019), Kathmandu.

Order Wise Nematodes Identification

In study, the number of Mononchida order was the highest (44.04%) which was followed by Rhabditida (33.44%), Dorylaimida (17.88%) and Tylenchida (4.64%) (Fig 2).

Genus Wise Nematodes Identification

The number of *Iotonchus* spp. was highest the (26.49%) followed by *Rhabditis* spp. (13.91%), *Dorylaimus* spp. (13.25%), *Parahadronchus* spp. (10.93%), *Eucephalobus* spp. (7.95%), *Mononchus* spp. (6.62%), *Cephalobus* spp. (6.29%), *Mesorhabditis* spp. (5.30%) *Helichotylenchus* spp. (4.64%) and *Discolaimus* spp. (4.64%) (Table 1) (Fig 3).

Depth Wise Nematodes Identified

The number of nematodes were higher at 20 cm depth than at 30 cm depth. *Iotonchus* spp. was highest (32.68%) and the number of *Helichotylenchus* spp. (3.93%) and

Mesorhabditis spp. (3.92) were lowest at 20 cm depth. Similarly, *Iotonchus* spp. was highest (20.13%) and the number of *Discolaimus* spp. (4.03%) was lowest at 30 cm depth (Table 2) (Table 3) (Table 4).

Among the identified nematodes in the kiwi plants the free-living species such as *Iotonchus* Spp. *Rhabditis* spp., *Dorylaimus* spp., *Eucephalobus* Spp., *Parahdronchus* spp., *Cephalobus* spp., *Mononchus* spp., *Mesorhabditis* Spp. and *Discolaimus* spp. were more dominant at 20 cm depth than 30 cm depth of rhizosphere. It is probably due to the regular supplying of organic matters at less depth (10-20 cm) in the rhizosphere of the kiwi plants in study area. This assumption can be supported by the occurrence of free-living nematodes *Iotonchus* Spp. and *Rhabditis* Spp. in Central Horticulture Centre, Kirtipur and Machchhegaun, Kathmandu (Chhetri, 2017).

Trophic Group Wise Nematodes

Overall Predatory nematodes (*Mononchus* spp., *Parahadronchus* spp., *Iotonchus* spp., *Discolaimus* spp. and *Dorylaimus* spp.) comprised more than half of the soil nematode community (61.92%) in study area, but bacterivores (*Rhabditis* spp., *Mesorhabditis* spp., *Cephalobus* spp. and *Eucephalobus* spp.) (33.44%) and herbivores (*Helicotylenchus* spp.) (4.64%) were also represented (Fig 2). The dominance of predatory nematodes in study area may be due to the use of organic manure like cattle dung and plant leaves in 20:80 ratio on the rhizosphere soil of Kiwi plants. The composition of the soil nematode community depends on the vegetation present, as well as on soil type, season, soil moisture level, amount of soil organic matter and many other factors. Because they are responsive to so many different factors, it is believed that nematodes may be useful bio-indicators of the condition of the soil environment (El-Borai and Fahiem, 2005).

Kiwi plants harbor several trophic groups of nematodes, namely, bacterivorous (*Rhabditis* spp., *Mesorhabditis* spp., *etc*.) and different stages of insects and animal parasites like *Deladinus* female, *Eudiplogaster* larva, *Sphaerularia* spp. and *Mermis* spp., *etc*. (Chhetri, 2019). Among the identified nematodes in the Kiwi plants the free-living species such as *Iotonchus* spp. *Rhabditis* spp., *Dorylaimus* spp., *Eucephalobus* spp., *Parahdronchus* spp., *Cephalobus* spp., *Mononchus* spp., *Mesorhabditis* spp. and *Discolaimus* spp. were dominant, probably due to the regular supplying of organic matters to the Kiwi plants. This assumption can be supported by the occurrence of free-living nematodes *Iotonchus* spp. and *Rhabditis* spp. in Central Horticulture Centre, Kirtipur (Chhetri and Subedi, 2019), Machchhegaun (Chhetri, 2019) Kathmandu and established grasslands (Freckman, 1982; Reyes and Domingo, 1991; Èerevková, 2011). The occurrence of predatory nematodes (*Mononchus* spp., *Parahadronchus* spp., *Iotonchus* spp., *Discolaimus* spp. and *Dorylaimus* spp.), were probably supported by the occurrence of numerous free-living nematodes. The dominance of predatory nematodes in study area may be due to the use of organic manure like cattle dung and plant leaves in 20:80 ratio on the rhizosphere soil of Kiwi plants. The composition of the soil nematode community depends on the vegetation present, as well as on soil type, season, soil moisture level, amount of soil organic matter and many other factors. Because they are responsive to so many different factors, it is believed that nematodes may be useful bio-indicators of the condition of the soil environment (El-Borai and Fahiem, 2005).

The identified herbivorous nematode (*Helicotylenchus* spp.) in the Kiwi plants was less dominant, probably due to the presence of free-living nematodes like *Iotonchus* spp. *Rhabditis* spp., *Dorylaimus* spp., *Eucephalobus* spp., *Parahdronchus* spp., *Cephalobus* spp., *Mononchus* spp., *Mesorhabditis* spp. and *Discolaimus* spp. which graze on bacteria, fungi and other phyto-parasitic nematodes, thus they control the populations of harmful micro-organisms (Wallace, 1973; Chhetri, 2019; Chhetri and Subedi, 2019). Generally, plant parasitic nematodes can be found in less number in those plants where fungivorous *Eucephalobus* spp. are common are more common in homogeneous crop residues such as in maize (*Zea mays*) (FAO, 2005).

The predatory nematodes such as *Mononchus* spp., *Parahadronchus* spp., *Iotonchus* spp., *Discolaimus* spp. and *Dorylaimus* spp. were highest in kiwi plants of this study area which might be due to the high number of bacterivorous nematodes (*Rhabditis* spp., *Mesorhabditis* spp., *Cephalobus*

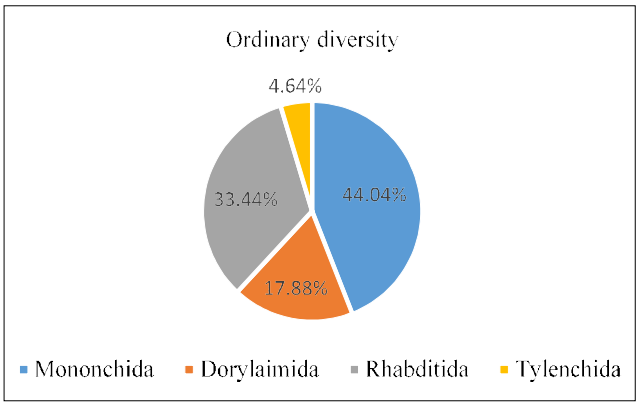

Fig 2: Orders of soil nematodes.

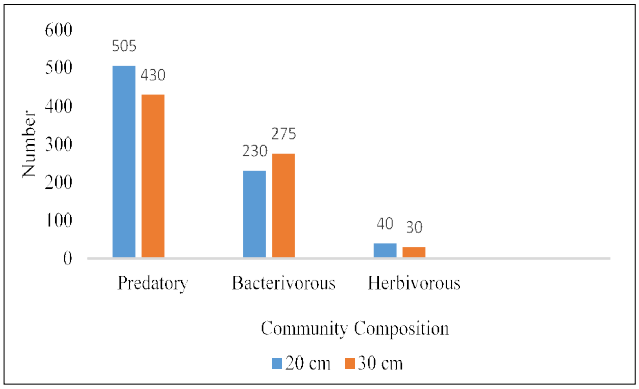

Fig 3: Trophic group of soil nematodes.

spp. and *Eucephalobus* spp.). These genera are supposed to be common food of the predatory nematodes. Increase of predatory nematodes cause declines in prey populations, which in turn prevents further increase of the predator population (MCSorley and Frederick, 1999; Djigal, 2004). Out of all identified nematodes from rhizosphere of kiwi plants, the bacterivorous nematodes like *Rhabditis* spp., *Mesorhabditis* spp., *Cephalobus* spp. and *Eucephalobus* spp. were dominant, probably due to the regular supplying of organic matters to the kiwi plants. Nematode occurrences can be supported by nematodes present in Central Horticulture Centre, Kirtipur, Kathmandu (Chhetri, 2019; Chhetri and Subedi, 2019) and litter present in the soil (Xue, 2013).

Community Analysis of Identified Nematodes

Total 10 genus of plant nematodes were encountered in the rhizospheres of Kiwi plants. *Iotonchus* and *Dorylaimus* genera were the most frequently encountered species with the absolute frequencies of 100% each and least frequent was *Discolaimus* (25%). Genus *Iotonchus* had the highest mean density of 400 nematodes and lowest mean density was possessed by *Helicotylenchus* and *Discolaimus* (each 70) per 250 ml soil. In this study, genus *Iotonchus* had the highest (51.67) and *Discolaimus* had lowest (4.53) prominence value.

Looking at the different parameters used in this study, genera *Helicotylenchus*, with, its lowest value in all parameters, seems to be the least important nematode population in Kiwi plant and could not be the reason for decline of the plantation in the area. This is in contrary with the supposition of Norton (1978); Samathanam and Chawla (1982) and Keshari *et al*. (2018), that importance value (IV) of a nematode need not be confined to considerations based on frequency, density and biomass only but should be broad based to include facts reflecting its pathogenie abilities. Therefore, IV as applied now may not be sufficient to provide all informations about pathogenic potential of a parasite and needs consideration for either modification of the present formula or incorporation of a new one, for the analysis of community structure of nematodes.

CONCLUSION

The presence of predatory nematodes and bacterivore nematodes almost in equal number and also high number of herbivorous nematode species in ICIMOD study area may be due to the use of organic manure like cattle dung and plant leaves as fertilizer in the rhizosphere soil of Kiwi plants. Therefore, regular use of manures and treatment of Kiwi plants are recommended for increased yield of kiwi fruits.

ACKNOWLEDGEMENT

Authors thank Mr. Samden Lama Sherpa, Head of ICIMOD Knowledge Park and Mr. Jiwan Tamang, Assistant Manager of ICIMD knowledge park for assisting by providing the soil samples for research work. We also thank Central Departments of Zoology for providing lab for this research. Furthermore, we thank International Centre for Integrated Mountain Development, Knowledge Park, Godawari, Lalitpur, Nepal for research permission.

REFERENCES

Beals, E. (1960). Forest bird communities in the Apostle Islands of Wisconsin. Willson Bull. 72: 156-181.

Beutel, J.A. (1990). Kiwifruit production in California. Division of Agriculture and Natural Resources.

Čerevková, A. (2011). Diversity and distribution of nematode communities in grassland in relation to its establishment age and utilization. In: Nematodes morphology, functions and management strategies. Nova Science Publishers, pp. 1-15.

Chhetri, B. (2017). Comparative study of nematodes in rhizosphere soil of Kiwi plants in Central Horticulture Centre Kirtipur and Machchhegaun, Kathmandu, Nepal. M.Sc. Thesis. Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Chhetri, B. (2019). Nematode fauna associated with Kiwi (*Actinidia delicosa,* Chev.) plants in Machchhegaun, Kathmandu, Nepal. Nepal Journal of Biotechnology. 7(1): 50-62; doi: https://doi.org/10.3126/njb.v7i1.26951.

Chhetri, B. and Subedi, J.R. (2019). Nematodes associated with Kiwi Plants in Central Horticulture Centre Kirtipur, Kathmandu, Nepal. International Journal of Applied Agricultural Sciences. 5(3): 71-74; doi: 10.11648/j.ijaas.20190503.12.

Cobb, N.A. (1918). Estimating the nema population of soil. *U.S.* Department of Agricultural Technical Circular. 1: 48.

Curl, E.A. (1963). Control of plant disease by crop rotation. The Botanical Review. 29: 13-479.

Djigal, D., Brauman. A., Diop, T., Chotte, J.L. and Villenave, C. (2004). Influence of bacterial-feeding nematodes (Cephalobidae) on soil microbial communities during maize growth. Soil Biology and Biochemistry. 36: 323-331.

El-Borai, K.F. (2005). Plant parasitic nematodes in subtropical and tropical agriculture. 2nd Edition.

FAO. (2005). Food and Agriculture Organization of the United Nations. The importance of soil organic matter. Viale delle Terme di Caracalla, 00100 Rome, Italy. 64.

Freckman, D.W. (1982). Nematodes in soil ecosystems. University of Texas Press, Austin, TX.

Ingham, R.E. and Detling, J.K. (1984). Plant-herbivore interactions in a North American mixed-grass prairie. III. Soil nematode populations and root biomass on *Cynomys ludovicianus* colonies and adjacent uncolonized areas. Oecologia. 63: 307-313.

Keshari, A.K., Manjur Shah, M. and Gupta, R. (2018). Community analysis of soil nematodes in vegetable growing areas of Dhading District, a high hill of Nepal. Journal of Applied and Advanced Research. 3(5): 156-160. Doi: http://dx.doi.org/10.21839/jaar.2018.v3i 5.234.

McSorley, R. and Frederick, J.J. (1999). Nematode population fluctuations during decomposition of specific organic amendments. Journal of Nematology. 31(1): 37-44.

Nepal Census (2001). (2008 September 3). Nepal's village development committees. Digital Himalaya. Archived from the original on 2008-10-12.

Nicol, J.M., Turner, S.J., Coyne, D.L., den Nijs, L., Hockland, S. and Tahna Maafi, Z. (2011). Current nematode threats to agriculture. In: Genomics and molecular genetics of plant-nematode interactions. Heidelberg, Germany: Springer, pp. 21-43.

Norton, D.C. (1978). Ecology of plant parasitic nematodes. New York: John Willey and Sons. pp268.

Nusbaum, C.J. and Ferris, H. (1973). The role of cropping systems in nematode population management. Annual Review of Phytopathology. 11: 423-440.

R Core Team. R. 2020. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org.

Reyes, P.S. and Domingo, J. (1991). Mononchid nematodes from Spain. Description of *Iotonchus rotundicaudatus* sp. n. and observations on *I. zschokkei* (Menzel, 1913) Altherr, 1955. Review on Nematology. 14(3): 353-360.

Samathanam, G.J. and Chawla, M.L. (1982). Community analysis of soil and plant parasitic nematodes of hilly areas of Southern districts of Tamil Nadu. Indian Journal of Nemotology. 12: 60-64.

Seinhorst, J.W. (1959). A rapid method for the transfer of nematodes from fixative to anhydrous glycerin. Nematologica. 4: 67-69.

Seinhorst, J.W. (1966). Killing of nematodes for taxonomic study with hot F.A. 4:1. Nematologica. 12: 178.

Singha, S., Singh, B. and Singh, A.P. (2015). Nematodes: a threat to sustainability of agriculture. Proceeding of the Environment Science. 29: 215-216.

Smart, G.C. and Nguyen, K.B. (1988). Illustrated key for the identification of common nematodes in Florida. University of Florida Gainesville, Florida.

Staniland, L. (1954). A modification of the Baermann Funnel Technique for the collection of nematodes from plant material. Journal of Helminthology. 28(1-2): 115-118. DOI: 10.1017/S0022149X00032739.

UC IPM. (2019 November 2). UC pest management guidelines. http://ipm.ucanr.edu/PMG/r430200111.html.

Wallace, H.R. (1973). Nematode ecology and plant disease. pp. 1-228.

Watson, R.N., Wilson, E.A. and Marsden, R.S. (1992). Distribution of plant parasitic nematodes in the rhizosphere of Kiwi fruit. Acta Horticulturae. 297: 537-544; doi: 10.17660/ Acta Hortic. 1992.297.70.

Wilson, E.H., Yichang, A.R., Ferguson, E.H. (2020 February 17)**.** Wilson, Yichang and the Kiwifruit. http://arnoldia. arboretum. harvard.edu/pdf/articles/115 5.pdf.

Xue, Q. (2013). Nematode diversity of soil and litter in mount Hamiguitan, the Philippines, with morphological and phylogenetic analysis of selected species. M.Sc. Thesis. Department of Biology, Ghent University, Ghent, B-9000, Belgium.

Yeates, G.W., Bongers, T., de Goede, R.G.M., Freckman, D.W. and Georgieva, S.S. (1993). Feeding habits in soil nematode families and genera- an outline for soil ecologists. Journal of Nematology. 25: 315-331.

Yeates, G.W. and Coleman, D.C. (1982). Nematodes in decomposition, In: Nematodes in soil ecosystems, [D.W. Freckman (Ed.)], University of Texas Press, Austin. pp 55-80.