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# OCCURRENCE, ABUNDANCE, AND DISTRIBUTION OF SOIL NEMATODES ASSOCIATED WITH GROUNDNUT FARMING IN KENYA

**Nyandiala A[1]*, Amakhobe T[2] and S Okoth[2]**

**Anne Nyandiala**

*Corresponding author email: anyandiala@gmail.com

[1]Zoology Department, National Museums of Kenya P.O Box 40658-00100 Nairobi, Kenya

[2]Department of Biology, University of Nairobi, P.O Box 30197- 00100 Nairobi, Kenya

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## ABSTRACT

Groundnut is a major cash crop grown in tropical and subtropical regions. In Kenya, groundnut is mostly grown in the Western and Nyanza regions and has been ranked the fourth cash crop of the Lake Victoria Basin (LVB). However, groundnut production in Kenya has continued to decline with farmers attaining less than 50 % of the yield potential of 700 to 1400 kg/ha. Yearly statistical reports by Agriculture and Food Authority (AFA), Nuts and Oil Crops Directorate for the last seven years, show the decline has been consistent. In 2019/2020 AFA reported there was a decrease of 216 Mt in Homa Bay and 30 Mt in Kisumu. Yield loss is attributed to lack of quality improved seed and pests' infestation during growth and storage. Plant parasitic nematodes (PPN) are the major pests of groundnut worldwide. This study sought to investigate the occurrence of nematode communities (PPN and non-parasitic nematodes (NPN) in soils cultivated with groundnuts in the LVB and to determine the effect of farmyard manure application on their presence. Six peanut varieties (4 improved and 2 local) were cultivated in Nyakach and Karachuonyo in March to August in 2021 and 2022. Soil samples, groundnut roots and pods were collected. A modified Baermann's, maceration methods and filtration technique was used to isolate nematodes from the soil, groundnut pods and roots. Multi-stage Analysis of variance (ANOVA) was used to determine any significant differences in abundance and richness while the Shannon index compared diversity of PPN and NPN among the farms in two seasons and regions. Eleven genera of PPN: *Aphelenchoides, Meloidogyne, Pratylenchus, Helicotylenchus, Tylenchus, Scutellonema, Trichodorus, Hemicycliophora, Tylenchorhynchus, Rotylenchulus* and *Criconema.* spp., and three genera of NPN; *Rhabdittes, Dorylaimus* spp. and Predators were categorized. *Aphelenchoides* and *Meloidogyne* were the most abundant PPN and *Rhabdites* NPN in both regions and seasons. Application of farm yard manure led to decline of abundance of PPN and an increase in NPN. The results confirm the presence of PPN in the LVB groundnut growing regions and the potential use of farm yard manure in their management. This study recommends further investigation on actual damage potential of these PPN and their management strategies.

**Key words:** *Arachis hypogaea*, Soil nematodes, Meloidogyne, *Aphelenchoides*, *Rhabdites*, *Pratylenchus, Helicotylenchus*

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## INTRODUCTION

Groundnuts (*Arachis hypogaea*) are oilseeds grown throughout the world [1]. It is the 13th most important food crop and 4th in oil seed crop of the world [1], and a basic staple crop, cultivated mainly by small-scale farmers both as subsistence and as a cash crop in Kenya [2, 3]. They are rich source of protein, edible oils and other nutrients for poor rural communities [4]. They can be eaten raw, roasted, boiled, made into peanut butter, used to produce groundnut flour. In farms, they add nitrogen into the soil and can be grown in poor sandy soils [5]. It takes a shorter time span in the farm and the vegetative residues from the crop are excellent forage [4].

Africa accounts for 40 % of the global area cultivated with groundnuts, however, the highest average yields are observed in South Africa and the lowest in East Africa [6]. In Kenya, groundnuts are predominantly grown in Nyanza, Lake Victoria Basin (LVB) and Western region of the country, specifically; Homa Bay, Kakamega, Vihiga, Migori, Kisumu, Bungoma, Siaya and Busia counties. Homa Bay is the highest producer of groundnuts, accounting for up to 27 % of the country production [7]. However, the crop can be found in other parts of the country such as Eastern, Rift Valley and Coastal region albeit in smaller quantities as per AFA 2015/2016 Nuts and Oils report [7]. The crop grows well in warm areas, below 1500 meters above sea level with temperature ranging 28-30$^0$C [8]. The LVB has a tropical climate suitable for groundnut farming, with loose, friable sandy soils and warm temperatures [2, 8].

Groundnuts average yields in Kenya are traditionally low 450 to 700 kg/ha and farmers continue to produce less than 50 % of the yield potential [2, 7, 8]. Production has been on the decline over the last couple of years. Yearly statistical reports by Agriculture and Food Authority (AFA), Nuts and Oil Crops Directorate for the last seven years, from 2015 to 2021 show there has been a consistent decline in groundnut production: the year 2016/2017 country recorded marginal reduction by more than 5.3 Mt which translates to a 25 % drop, the following year, there was decrease by 216 Mt in Homa Bay and 30 Mt in Kisumu and the latest report (2020/2021), indicated decrease with 69 Mt in Kisumu county and an increase with 409 Mt in Homa Bay county [7, 9]. However, the country recorded an overall production increase of 2,826 Mt as a result of an increase in acreage and productivity by opening up new croplands within in Homa Bay, Kakamega, and Migori Counties [9]. It is imperative to note that the country's consumption is much higher than the amount produced and the annual deficit is bridged by imports from neighboring countries within the COMESA region such as Tanzania, Uganda, and

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Malawi [7, 9]. Hence, identifying yield-limiting factors and appropriate agronomic management practices are crucial to increase groundnut yield potential in these regions. The decline in groundnut production in Africa has been attributed to several factors such as pests and diseases occurrence, unavailability of quality seed variety, poor post-harvest handling practices and increased cultivation on marginal land [7-12]. Among the pests are plant parasitic nematode (PPN) that infest groundnut during growth and causes considerable economic losses in agricultural crops. They are primary parasites of groundnut in all production regions of the world [13 -18]. Plant parasitic nematodes known to cause damage to groundnuts worldwide include *Meloidogyne, Aphelenchoides, Pratylenchus, Criconema, Tylenchus, Helicotylenchus, Trichodorus, Scutellonema, Tylenchorhynchus, Hemicycliophora, Belonolaimus, Aphasmatylenchus*, and *Ditylenchus* spp. [15 -18]. In Kenya, the same nematode genera have been recorded as the most economically important agricultural pests in other crops and the studies on plant parasitic nematodes have focused on them as compared to groundnuts [19-24]. This study, therefore, investigates the distribution of nematodes communities in soils under groundnut cultivation in the LVB.

## MATERIALS AND METHODS

### Field Location

The study was conducted in the groundnut production belt of the Lake Victoria Basin. The sites selected were Karachuonyo in Homa Bay County (longitudes 34˚ 27' E and latitudes 0˚ 40' N) and Nyakach in Kisumu County (longitudes 34˚ 46' E and latitudes 0˚53' S). The sites receive an annual average rainfall of 218.04 mm and 1359 mm, and average annual temperature of 21.8ºC and 23.93ºC in Homa Bay and Kisumu counties respectively. Farms in Nyakach were on alluvials soils situated on plains where silt and clay brought by surface run-off are deposited, while Karachuonyo were situated in the lower midland close to Lake Victoria with silt loam soil [25, 26].

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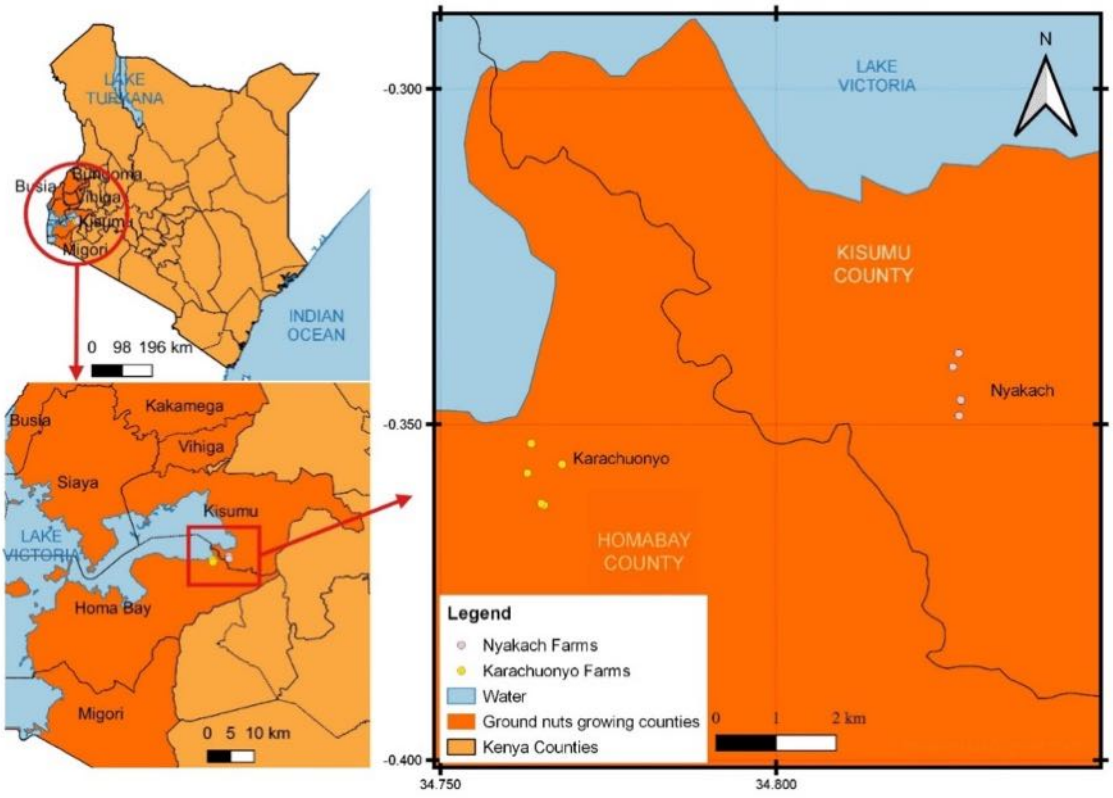


**Figure 1: (Top left) Location of Kenya counties showing the study areas; (Bottom left) Location of Kenya showing the locations of groundnut growing regions in Kenya within Lake Victoria Basin (in brick orange), (Right side) Homa Bay and Kisumu counties showing the enclosed study areas, the sampling points**

## Experiment design

The experiment was conducted in a completely randomized block design comprising six groundnut varieties and ten farms with three replications per farm. Four improved groundnut varieties (CG7, CG9, CG12, and ICGV-SM 90704) were sourced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Malawi while varieties ICGV-12991 and control (Homa Bay Local) were locally sourced in the country. Farmyard manure at the rate of 7 tons per acre was applied to each farm (8 farms) except the control farms (2 farms) where Homa Bay local was planted. A single seed per hole was planted at the depth of 5cm and a spacing of 50 × 10 cm and groundnuts left to mature under rain fed conditions. Three rows of maize were planted at the end of each experimental block to act as border crops. All the recommended agricultural practices of groundnut farming in alignment with locally recommended cultural practices of ploughing, row planting,

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followed by molding, two times of manual weeding were applied to each farm except agronomic interventions of farm yard manure application and spraying for pests and diseases which was applied to the experimental farms only excluding control farms [14]. Two manual weeding regimes and three spraying cycles were carried out during the experimental period. Ridomil 50 g and Duduthrin 65 ml in 20 litres were used to manage fungal diseases and insect pests, respectively.

**Soil sampling for nematodes**

Soil sampling was done according to Jagdale and Arnold-Smith [27]. Soil samples were collected after ploughing and during harvesting. Twenty sampling location points were identified in each farm using the zig zag pattern. At each sampling point, crop residue was removed from the soil surface and a V shaped cut to a depth of 20 cm made into the soil with the aid of a hoe. A uniform thick slice of soil was obtained from the cut and placed into a bucket. The same procedure was replicated until a total of 20 sampling sites were obtained per farm. Using a trowel, the soil in the bucket was thoroughly mixed to form a composite sample and 500 g of the soil subsampled, transferred to a labelled zip lock bag, sealed, transported in a cooler box and stored in the laboratory refrigerator at 10°C awaiting nematode extraction.

**Root and pod sampling for nematodes**

Root sampling was done according to Jagdale and Arnold-Smith [27]. A total of 10 plants (5 healthy plants and 5 symptomatic plants) were randomly selected in each experimental plot. Each plant was carefully dug out to ensure that no damage was done to the entire root system together with the pods and placed in a labelled bag and sealed. The surrounding soil for each plant was also collected and transferred to a labelled zip lock bag, sealed and placed in a cooler box ready for transportation to the laboratory for further analysis. Once in the laboratory, 5 pods were sampled from each healthy and symptomatic plant and transferred to a labelled bag and sealed. All the samples were stored in the refrigerator at 10°C pending nematode extraction.

**Extraction of soil nematode and identification**

Nematodes were extracted within seven days after sampling using the modified Baermann's technique [29]. In the laboratory, 200 g of each soil sample was weighed, the soil clods broken and plant debris removed. The soil was then spread on a double layer of milk filters (serviettes) supported by a sieve (screen). The sieve was placed in a shallow dish and water added to submerge the soil such that the water was just below the rim of the sieve. The set up was incubated for 48 hours in a dark cabinet to allow nematodes to move from the soil to the water.

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Afterwards, the sieve was carefully removed and the nematode suspension in the tray/dish concentrated by passing it 3-4 times through a 25µm sieve to 50 ml. The remaining suspension was transferred into a universal bottle.

Nematodes were extracted from roots and pods using a modified maceration and filtration technique. Roots and pods were chopped into 1 cm pieces and thoroughly mixed. Five sub-samples were composited to give 5 g of the roots and 5 g of groundnut pods and, thereafter, macerated and the resulting homogenate placed on a dish. Nematodes were then extracted over 24 hours' period using tap water. Root samples were also washed and examined for galls. A sample of root was stained for egg masses. The extracted nematodes were identified to genus level.

Nematodes identification, and counts were made from 2 ml aliquots (suspension). Nematode suspension was pipetted into Hawksely counting chamber and examined using a stereo-microscope under x100 –150 magnifications. Based on morphological characteristics of adult and juvenile forms, nematodes were identified according to Mai and Lyon, and Siddiqi [29, 30].

**Statistical analysis**

Statistical analysis were done using R version 4.2.0 with 95 % accuracy [31]. Two-way Analysis of variance (ANOVA) was used to determine any significant differences in abundance and richness while the Shannon index compared diversity of PPN and NPN among the farms in two seasons and regions.

## RESULTS AND DISCUSSION

In this study, different genera of PPN were widespread in groundnut growing fields. Fourteen (14) nematode genera belonging to eight families were found in association with groundnuts in the groundnut production belt of the LVB. Plant parasitic nematode *(Aphelenchoides Meloidogyne, Pratylenchus, Helicotylenchus, Scutellonema, Trichodorus, Hemicycliophora, Tylenchus, Criconema, Aphelenchoides, Rotylenchulus,* and *Radopholus* spp.) and NPN (*Rhabdites*, *Dorylaimus* spp and Predators) were identified from the soil, roots and pod samples collected in two seasons from the experimental and control farms. Similar results were also reported in Egypt, Sudan, Senegal and Brazil, South Africa as well as other groundnut producing regions of the world, showcasing the cosmopolitan distribution of these nematodes [32-35]. Non-parasitic nematode; *Rhabdites*, were the most abundant in both experimental and control plots in the two seasons, on the onset of the trial (35 %) to harvest period (61 %), followed by PPN, *Aphelenchoides*, (27 % and 12 %) and *Meloidogyne* (16 % and 3 %). The

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least isolated were *Radopholus* and *Criconema*. In total, NPN population was greater than that of PPN which were on the other hand, diverse (Table 1).

*Aphelenchoides* spp. and *Meloidogyne* spp were the dominant PPN isolated from soil, root and rotten pods of groundnuts in Lake Victoria Basin, Kenya. The *Aphelenchoides* spp. are the only species known to invade the seed, causing discoloring and rotting of the seeds leading to adverse effect on the appearance and size of the seeds, also predisposes seeds to fungal infection [34, 35]. Root-knot nematode Meloidogyne spp. was the most damaging nematodes in agriculture and several species are highly specialized root endoparasite and pathogenic on groundnut causing considerable yield loss annually [36]. Root-knot nematodes Meloidogyne hapla and Meloidogyne arenaria are among pests that cause severe damage to groundnut in China, which is the world's largest groundnut producer contributing one-third of overall production [34]. They do not exhibit conspicuous symptoms at early stage of development, until near harvest in groundnut [36]. Other groundnut parasitic nematodes *Helicotylenchus, Pratylenchus, Scutellonema, Tylenchus, Trichodorus, Hemicycliophora, Criconema* and *Rotylenchulus* spp. were frequent and present in two regions but at low abundance.

Nematodes mean abundance did not differ across the two sites with seasons or with the stage of cultivation (p-value=0.4749). Karachuonyo had average abundance of 445.96±209.55 and Nyakach 369.93±148.7, in the first season and in the second season 352.93±74.78 and 389.36±99.19 in Karachuonyo and Nyakach respectively. However, the abundance of the 8 families of nematodes isolated was significantly different (p-value = 1.42e-07), Table 1, 2. Further, the abundance was influenced by the crop growth stage (p-value=0.0317). Non-parasitic nematode was more abundant during the harvest compared with land preparation period while the PPN decreased at the end of the second season suggesting effect of the management practice, Fig. 2. Organic fertilizers have the ability to enhance soil biodiversity, making ecosystems more resilient to stress and reducing parasitic nematodes while increasing non parasitic nematodes in the soil [25, 37- 41]. The decrease in population of PPN caused by use of organic manure may be attributed the direct effects of chemicals from biosolids, as an input of organic carbon produced during manure decomposition [41, 42]. Additionally, application of organic amendments such as animal manures have been documented to suppress the plant-parasitic nematodes and, in many cases, increased the population of free-living nematodes like *Rhabdites* and Predators [37-45]. Free-living nematodes suppress the plant-parasitic nematodes either as direct parasites or predators or by their metabolites produced during their activities

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[37-45]. The present results support field observations that 'organic farming favors the management of parasitic nematodes in the soil. The population of *Rhabdites* (bacteriovores) increased greatly with the application of organic manure while a slight increase in population of predators (omnivores) was recorded. These results are in accordance with Akhtar' and Malik' and Liu *et al.* [39, 41], that indicated that an increase in the relative abundance of bacterivores leads to a reduction in the abundance of herbivores (plant parasite) [39, 41]. The use of organic manure offers a better alternative in nematode management as opposed to nematicides which have been shown to be carcinogenic, with build-up residues being detected in plants [38-40].

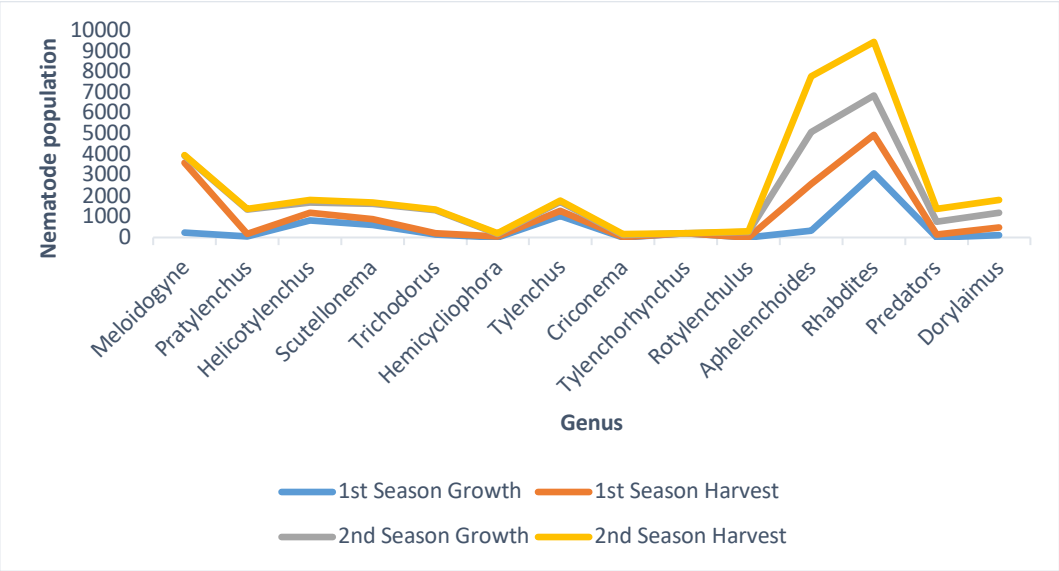


**Figure 2: Population trend of parasitic and non-parasitic nematodes in the two seasons with farm yard manure application**

The diversity and abundance of nematodes varied between the experimental farms though not significantly Table 3, 4. Karachuonyo and control farms were richer than Nyakach farms. There was a sharp increase in diversity and abundance of nematodes in all the farms during the second season of the experiment, at land preparation Fig. 4. However, a decline was recorded in all the managed farms at the end of the second season, at harvest Table 3, Fig. 4. This decline was relatively minimal in the control farms and Table 4 and Fig. 4 confirms that the high numbers of nematodes in the control farms at the second harvest were the PPN. Figures 3 and 4 further confirm that PPN were abundant and diversified in control farms by the end of the second season. Climatic conditions may have also contributed to the decline in abundance of nematodes obtained in the second season [46-48]. Rainfall performance was near average in the LVB in the 2021 long rains season [49]. In the year 2022 season, the rainfall performance was

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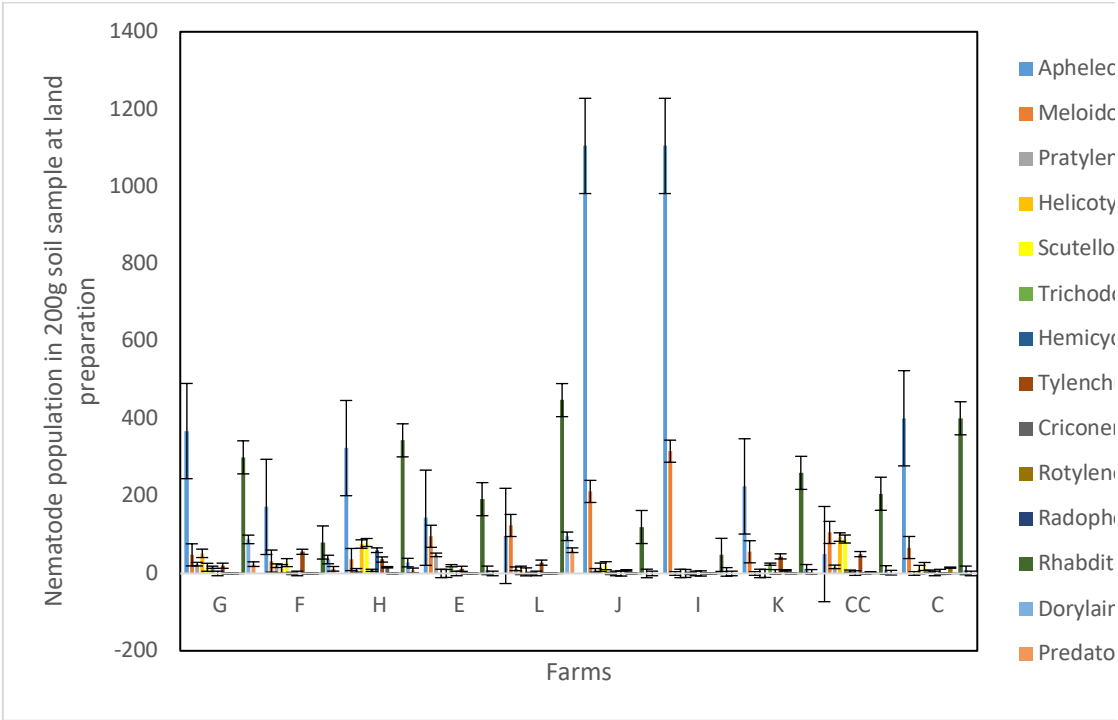
below average over most parts of the country [50]. The decline in the amount of rainfall would have resulted in reduced soil moisture levels in the soil, affecting nematode survival. Nematodes are mostly found in the upper soil layers and they are sensitive to climate and environmental changes thus their use as climate change indicator organisms [46]. Altitude, temperature, and precipitation are listed as the main ecological factors controlling terrestrial nematode diversity [46-48]. Nematodes prefer warm weather in moist well aerated sandy soils in the presence of a host plant. Bakonyi *et al.* [47] has reported that slight changes in soil moisture and temperature affected the structure and diversity of nematode communities [47]. Temperature changes results in a short generation time for nematodes while moisture on the other hand, is crucial for movement and infectivity of soil nematodes [46]. Bakonyi *et al.* [47] and Song *et al.* [48], noted a significant increase in the abundance and generic richness of nematode in the soil due to high moisture content [47, 48]. During this study, the drier conditions experienced in Kenya in the second season in the year 2022 could have caused the decline in nematode abundance, due to low moisture content in the soil [50].



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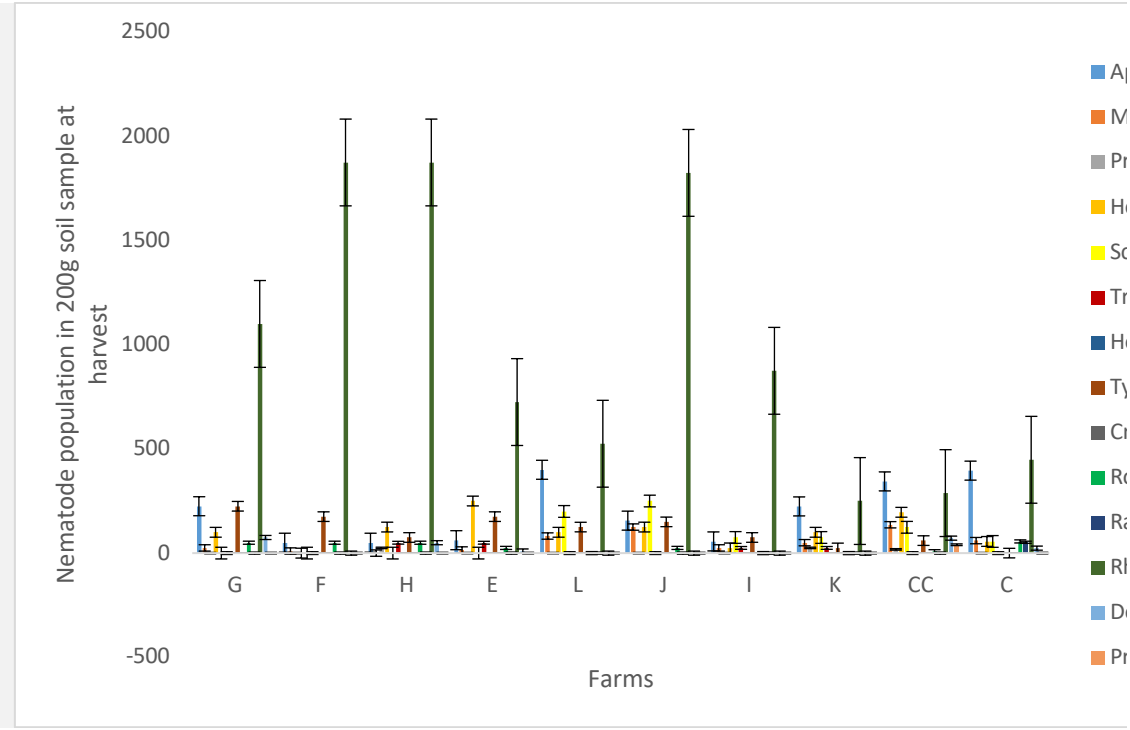


**Figure 3: Diversity and abundance of parasitic and non-parasitic nematodes in different farms in season one**

*Farms notations: G, F, H, E, L, J, I, K are managed farms and CC, C are control farms



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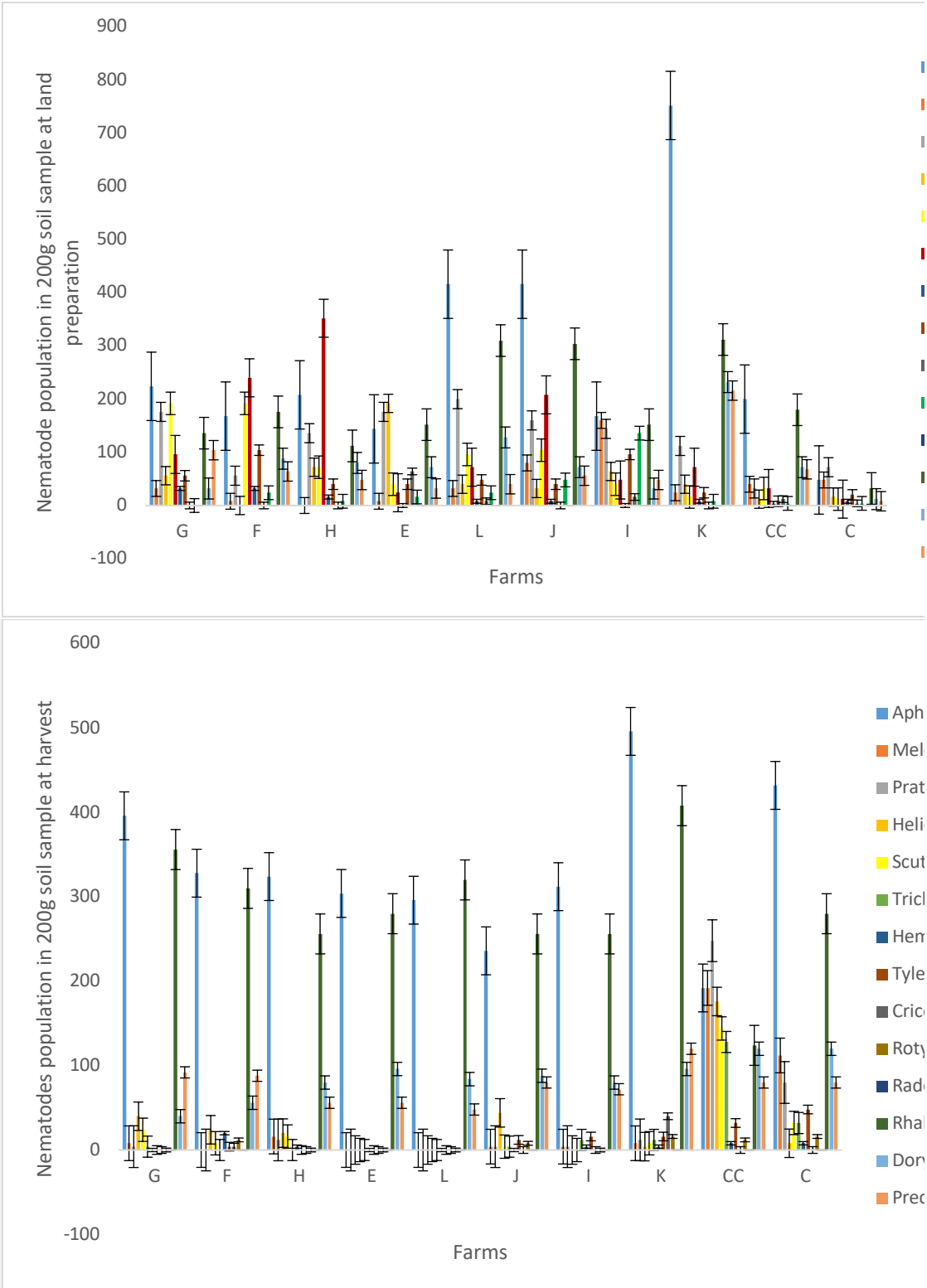


**Figure 4: Diversity and abundance of parasitic and non-parasitic nematodes in different farms in season two**

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The ordination plots in Fig. 5 shows the influence of farm management on the distribution of nematodes. The PPN were more inclined to the control plots while NPN were abundant in managed farms. Predators were inversely proportional to the PPN, suggesting predation. Meloidogyne was more common in Nyakach, while the other species were found in all farms.

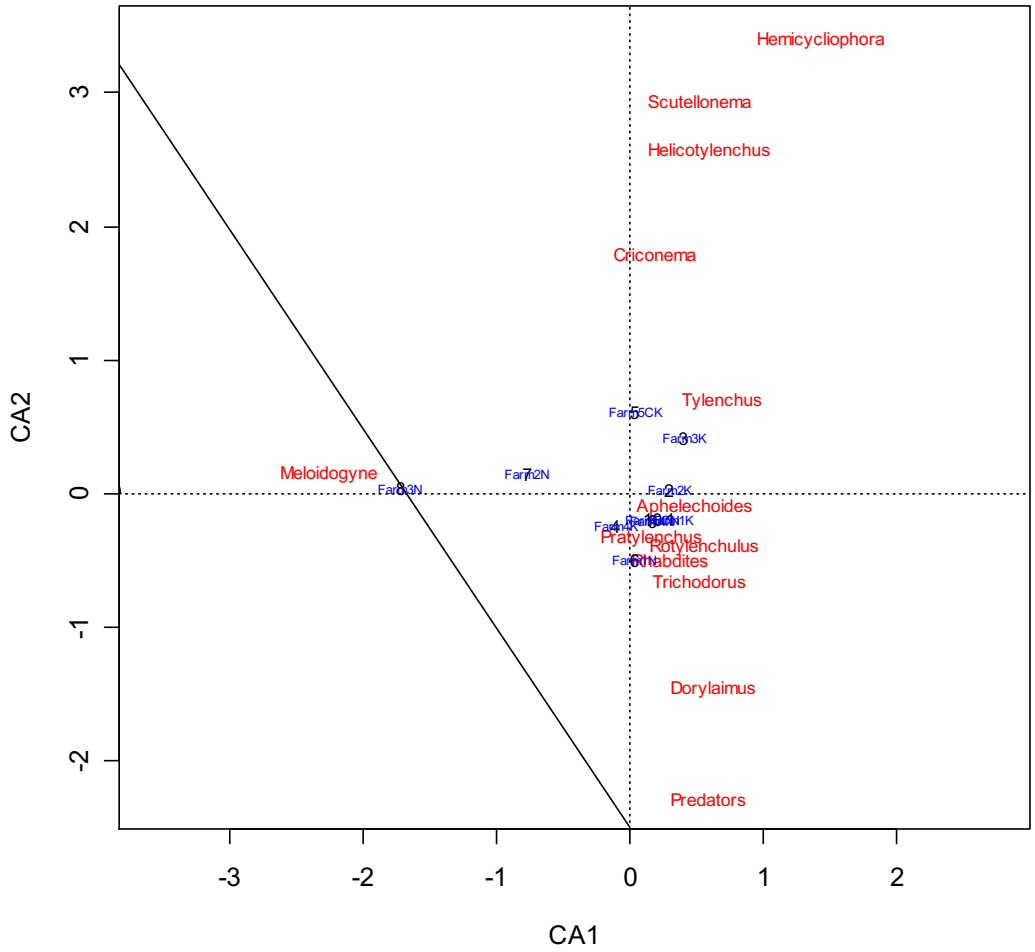


**Figure 5: Distribution of plant parasitic nematodes and non-plant parasitic nematodes in farms in Lake Victoria Basin**

*Farms notations: N farms in Nyakach, CN control farm in Nyakach, K farms in Karachuonyo and CK control farms in Karachuonyo

Nematode diversity and abundance were high in the soil, compared with pods and roots. This observation supports research findings that show that organic fertilizer application that boast soil fertility and crop production have the ability to enhance soil biodiversity, making ecosystems more resilient to stress and reducing parasitic

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nematodes and increasing beneficial nematodes in the soil [ 37, 39-42]. PPN isolated from the root and rotten pods of groundnuts, were *Aphelenchoides* with the highest proportion of 26 %, followed by *Meloidogyne* 7 % *Scutellonema* 6 %, *Helicotylenchus* 3 % and the least was *Pratylenchus* 1 %. NPN were *Rhabditis* 27 %, Predators 17 % and *Dorylaimus* 13 %. Figure 6. Different species of nematodes isolated cause damage to different parts of groundnut plant, they include; Root Ectoparasite (*Aphelenchoides, Tylenchorhynchus, Trichodorus, Helicotylenchus, Hemicycliophora* spp.); Migratory endoparasites (*Pratylenchus, Scutellonema* spp), Sedentary endoparasites (*Meloidogyne* and *Helicotylenchus* spp.), and Semi endoparasites (*Tylenchorhynchus, Rotylenchulus, Tylenchus* and *Criconema* spp.). The damage caused by nematodes will be determined by different species and high diversity will result into serious damage of groundnut crop.

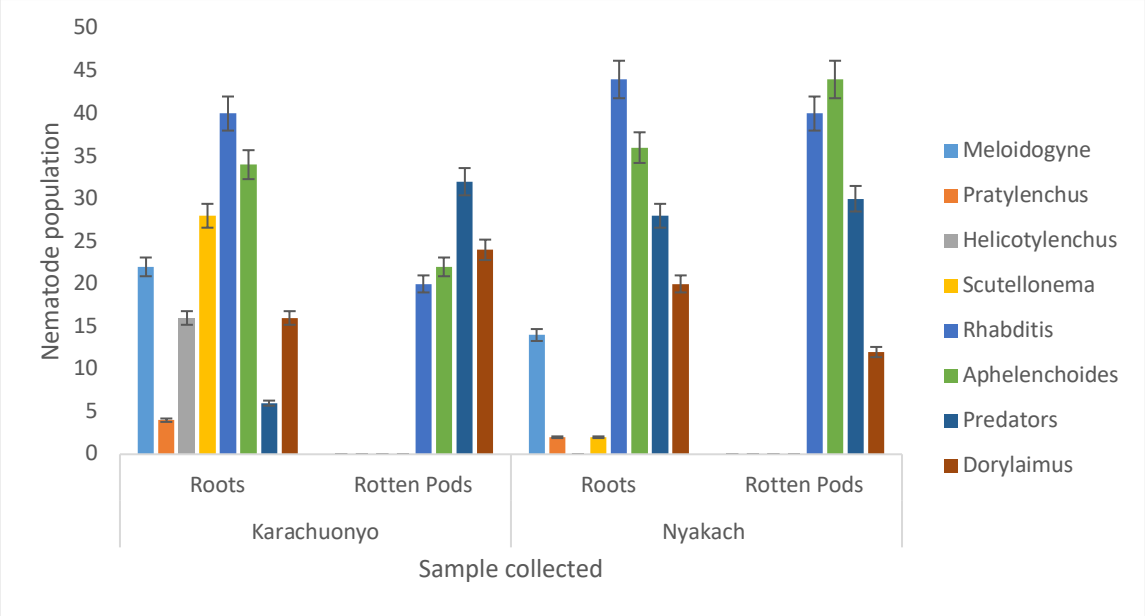


**Figure 6: Nematodes diversity and abundance present in groundnut roots and rotten pods**

## CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

This study has confirmed the presence of PPN of economic significance in the LVB groundnut production regions in Kenya. *Aphelenchoides* spp. and *Meloidogyne* spp. were the dominant parasitic nematodes isolated from the soil, roots and rotten pods on groundnut farms. These findings call for awareness on the incidence of PPN among groundnut farmers and crop protection extension officers. This is because many studies on plant parasitic nematodes have focused on other crops and little has been done on nematodes associated with groundnuts. Additional investigations in protection of crop yields from nematodes pests is also

recommended to guide in policy- making. The use of animal farm yard manure offers a better alternative in nematode management. The findings, indicated that an increase in the bacterivores (free-living parasites) suppress the herbivores (plant-parasitic nematodes) either as direct parasites or predators leading to their reduction. Further work on actual damage potential of these nematode species on groundnut and their management strategies is suggested.

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**Table 1: Diversity and abundance of nematodes isolated from 200 g of soils in groundnut producing farms in Lake Victoria Basin, Kenya**

| Nematode Taxa | | Groundnut sampling method | | |
|---|---|---|---|---|
| **Family** | **Genus** | **Parasitic (P) or Non parasitic (NP)** | **Abundance during land preparation** | **Abundance during groundnut harvesting** |
| *Rhabditidae* | *Rhabdites* | NP | 2399 (35)* | 9786(61) |
| *Dorylaimidae* | *Predators* | NP | 110 (2) | 40(0.2) |
| *Dorylaimidae* | *Dorylaimus* | NP | 289 (4.2) | 231(1.4) |
| *Aphelenchoidae* | *Aphelenchoides* | P | 1824(27) | 1963(12) |
| *Heteroderidae* | *Meloidogyne* | P | 1093(16) | 528(3.3) |
| *Pratylenchidae* | *Pratylenchus* | P | 137(2) | 68(0.4) |
| *Hoplolaimidae* | *Helicotylenchus* | P | 268(4) | 1077(7) |
| *Hoplolaimidae* | *Scutellonema* | P | 255(4) | 780(5) |
| *Tylenchulidae* | *Tylenchus* | P | 250(4) | 1085(7) |
| *Trichodoridae* | *Trichodorus* | P | 80(1) | 150(1) |
| *Criconematidae* | *Hemicycliophora* | P | 65(1) | 0(0) |
| *Criconematidae* | *Criconema* | P | 32(1) | 0(0) |
| *Hoplolaimidae* | *Rotylenchulus* | P | 18(0.3) | 265(2) |
| *Pratylenchidae* | *Radopholus* | P | 0 | 50(0.3) |

* Relative proportion (%) of nematodes isolated

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**Table 2: ANOVA Table showing Variation of nematode abundance with season, site and groundnut growth stage in experimental farms in the Lake Victoria Basin**

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|---|---|---|---|---|---|
| Stage | 1 | 499691 | 499691 | 1.127 | 0.29 |
| Type | 1 | 14308513 | 14308513 | 32.284 | 1.42e-07 *** |
| Season:site | 3 | 137445 | 45815 | 0.103 | 0.967 |
| Stage:Type | 1 | 2107505 | 2107505 | 4.755 | 0.03* |
| Season:Site:Stage | 3 | 1117715 | 372572 | 0.841 | 0.47 |
| Season:Site:Type | 3 | 584865 | 194955 | 0.440 | 0.72 |
| Season:Site:Stage:Type | 3 | 415347 | 138449 | 0.312 | 0.82 |
| Residuals | 96 | 42548312 | 443212 | | |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

**Table 3: Richness and abundance of parasitic and non-parasitic nematodes in the Lake Victoria Basin**

| Season One | | | | | | | | Season Two | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| During land preparation | | | | At Harvest | | | | During land preparation | | | | At Harvest | | | |
| Farm | RH | AB | SH | Farm | RH | AB | SH | Farm | RH | AB | SH | Farm | RH | AB | SH |
| 1K | 10 | 956 | 1.66 | 1K | 7 | 1800 | 1.27 | 1K | 11 | 1136 | 2.19 | 1K | 9 | 964 | 1.93 |
| 1N | 9 | 896 | 1.54 | 1N | 6 | 1432 | 1.56 | 1N | 13 | 1422 | 2.05 | 1N | 4 | 748 | 1.40 |
| 2K | 9 | 448 | 1.83 | 2K | 5 | 2160 | 0.53 | 2K | 11 | 1152 | 2.13 | 2K | 10 | 854 | 1.15 |
| 2N | 7 | 484 | 1.41 | 2N | 7 | 2656 | 1.14 | 2N | 12 | 1528 | 2.10 | 2N | 11 | 740 | 1.49 |
| 3K | 12 | 1024 | 1.80 | 3K | 8 | 2300 | 0.82 | 3K | 11 | 1144 | 2.03 | 3K | 9 | 784 | 1.62 |
| 3N | 4 | 398 | 0.68 | 3N | 7 | 1156 | 0.96 | 3N | 12 | 1104 | 2.30 | 3N | 9 | 760 | 1.50 |
| 4K | 7 | 520 | 1.53 | 4K | 8 | 1312 | 1.35 | 4K | 12 | 960 | 2.16 | 4K | 4 | 736 | 1.42 |
| 4N | 9 | 602 | 1.47 | 4N | 8 | 774 | 1.72 | 4N | 12 | 1816 | 1.77 | 4N | 13 | 1240 | 1.20 |
| 5CK | 12 | 680 | 1.90 | 5CK | 10 | 1287 | 1.94 | 5CK | 13 | 696 | 2.01 | 5CK | 12 | 1456 | 1.57 |
| 5CN | 9 | 812 | 1.24 | 5CN | 8 | 1148 | 1.52 | 5CN | 13 | 296 | 2.22 | 5CN | 12 | 1248 | 1.93 |

*RH-Richness, AB-Abundance, SH- Shannon Index

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**Table 4: Richness and abundance of parasitic nematodes in the Lake Victoria Basin**

| Season One | | | | | | | | Season Two | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| At Planting | | | | At Harvest | | | | At Planting | | | | At Harvest | | | |
| Farm | RH | AB | SH | Farm | RH | AB | SH | Farm | RH | AB | SH | Farm | RH | AB | SH |
| **1K** | 6 | 176 | 1.67 | **1K** | 4 | 400 | 1.10 | **1K** | 7 | 640 | 1.73 | **1K** | 5 | 80 | 1.24 |
| **1N** | 5 | 176 | 0.95 | **1N** | 4 | 507 | 1.33 | **1N** | 9 | 528 | 1.80 | **1N** | 0 | 0 | 0.00 |
| **2K** | 5 | 148 | 1.49 | **2K** | 3 | 235 | 0.69 | **2K** | 7 | 656 | 1.52 | **2K** | 6 | 72 | 1.59 |
| **2N** | 5 | 264 | 0.75 | **2N** | 5 | 675 | 1.45 | **2N** | 8 | 680 | 1.79 | **2N** | 7 | 80 | 1.44 |
| **3K** | 8 | 320 | 1.83 | **3K** | 5 | 325 | 1.48 | **3K** | 7 | 696 | 1.44 | **3K** | 5 | 68 | 1.51 |
| **3N** | 1 | 316 | 0.00 | **3N** | 5 | 225 | 1.47 | **3N** | 8 | 704 | 1.90 | **3N** | 5 | 40 | 1.42 |
| **4K** | 4 | 176 | 1.11 | **4K** | 5 | 515 | 1.19 | **4K** | 8 | 560 | 1.65 | **4K** | 0 | 0 | 0.00 |
| **4N** | 5 | 136 | 1.31 | **4N** | 6 | 300 | 1.63 | **4N** | 8 | 304 | 1.72 | **4N** | 9 | 120 | 1.95 |
| **5CK** | 8 | 366 | 1.59 | **5CK** | 6 | 543 | 1.48 | **5CK** | 9 | 176 | 1.95 | **5CK** | 8 | 940 | 1.76 |
| **5CN** | 6 | 120 | 1.34 | **5CN** | 5 | 280 | 1.61 | **5CN** | 9 | 196 | 1.78 | **5CN** | 8 | 336 | 1.76 |

*RH-Richness, AB-Abundance, SH- Shannon Index

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