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RESEARCH

Prevalence, Severity, and Distribution of Potato Cyst Nematode in *Nyandarua* and *Nyeri Counties*, Kenya

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ABSTRACT

Purpose: *Potato cyst nematode (PCN) Globodera rostochiensis W. is a major soil borne pest of potato globally. In Kenya, it was reported for the first time in Nyandarua County in 2015. There exists a knowledge gap in understanding the population dynamics of PCN under different farming systems and environmental conditions, which shows that it is essential for developing sustainable management strategies.*

Research Method: *A base line survey was conducted to identify and map out PCN incidence and infestation in Nyeri and Nyandarua Counties. Soil samples were collected from 75 farms from a population of 500 farmers registered in farmers' groups and community-based organizations following purposive, stratified and simple random sampling methods. PCN incidence, infestation, infectivity, yield loss estimation and soil chemical characteristics were determined. Analysis of variance (ANOVA), Chi-Squared test and correlation tests were applied in analysis using R version 4.4.0.*

Findings and Values: *There was a significant difference in mean number of PCN cysts between the two counties; (Wilcoxon rank sum test, P<.001). There was significant difference in PCN infestation across the Sub-counties, (Kruskal-wallis test, p<.001). North Kinangop and Olkalou Sub- County recorded extremely high PCN Infestation, high soil infectivity and high estimated yield loss. Soil chemical properties had, little or no influence on PCN infestation with a weak negative correlation between number of cysts and pH (r=-0.20). The findings provide a comprehensive assessment of PCN prevalence and severity in key potato-growing regions of Kenya. The high infestation levels and associated potential yield losses pose a serious threat to food security and farmer livelihoods. Controlling PCN will help improve potato productivity, secure household incomes, reduce economic losses, and enhance national food security in Kenya's most important potato-producing zones.*

Keywords: *Globodera rostochiensis, PCN incidence, PCN infectivity, PCN Infestation, Potato.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important food crop, consumed by over a billion people worldwide (Nyang'au *et al.* 2023). In 2022, global potato production was estimated at 375 million tonnes (FAOSTAT 2023). Kenya is the largest potato producer in East Africa and is ranked third in Sub-Sahara Africa (Gildemacher *et al.* 2009, Nyang'au *et al.* 2023). The crop contributes towards food security and serves as a source of income for small-scale farmers

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in Kenya (Kiige *et al.* 2025). It earns Kenya around USD 500 million yearly (Nyang'au *et al.* 2023) and supports the livelihoods of about 2.5 million Kenyans, including 800,000 farmers (Kiige *et al.* 2025). However, the average potato yield in Kenya is 7 tonnes per hectare, below the global average of 21 tonnes per hectare, partly due to pests such as potato cyst nematodes (Mburu *et al.* 2020). Nyeri and *Nyandarua counties* in Kenya have prioritized potato as a main crop for food and nutrition security, job creation, and industrial development (NPCK 2023).

Potato cyst nematode (*Globodera rostochiensis* W.) is a globally destructive potato pest, with major cases reported in Europe and Africa (Onditi *et al.* 2025). In Europe, it has been reported as a major constraint to potato production (Mburu *et al.* 2020). Studies by Brown & Sykes (1983) and Minnis *et al.* (2002) documented widespread distribution of PCN in England and Wales, with significant yield losses of up to 80% in severely infested fields. In Africa, PCN has emerged as a devastating pest (Niere & Karuri 2018). In Uganda, Cortada *et al.* (2020) reported the first official detection of *G. rostochiensis*, while similar infestations have been confirmed in Rwanda (Niragire *et al.* 2019). In Kenya, the situation is more advanced, with widespread reports of PCN across multiple counties (Mburu *et al.* 2020). The emergence of PCN in these African countries indicates its expanding distribution and hence the need for region-specific surveillance and control strategies.

G. rostochiensis lifecycle includes five stages: egg, juvenile (J2), root invasion and feeding, development and reproduction, and cyst formation (Swiecicka *et al.* 2009). The juvenile stage is the infective stage whereby second-stage juveniles (J2) invade potato roots, causing stunted growth, yellowing, and reduced tuber size (Ali *et al.* 2017). Male PCN mature and leave the roots, while females swell, break through the root surface, and after fertilization turn into brown, spherical cysts containing hundreds of eggs, which hatch into juveniles (Ngala 2015). These cysts are highly resistant to environmental factors and can remain viable in soil for up to 20 years (Fatemy & Ahmarimoghadam 2019). Hatching of eggs occurs in response to chemical stimuli from host plant roots, ensuring juveniles emerge only when a suitable host is present (Chitambo *et al.* 2019). This aids in the long-term survival adaptation of this pest (Fatemy & Ahmarimoghadam 2019). Heavily infested PCN fields result in up to 80% yield loss (Dandurand *et al.* 2019). A mean yield loss of 2.75 t/ha per 20 eggs/g of soil has been reported in Europe (Brown & Sykes 1983). Infected potato plants produce small-sized tubers that are unmarketable (Nyang'au *et al.* 2023). Farmers incur high costs for nematicides, which can be expensive and need to be applied multiple times during a growing season (Nyang'au *et al.* 2023). PCN is a quarantine pest in many countries (EPPO 2018); hence, its presence can lead to trade restrictions, limiting export opportunities for potato-producing regions.

In Kenya, PCN was discovered in *Nyandarua County* in 2015 (Mwangi *et al.* 2015) and has been reported to cause over 70% potato yield losses (Niere & Karuri 2018, Chitambo *et al.* 2019). This initial report marked a critical point in understanding the spread and impact of this pest on potato production in the country. Mburu *et al.* (2020) reported 71.8% PCN incidence from soil samples collected from 20 potato-growing counties, with *Nyandarua County* showing the highest field-incidence at 47.6%. Nyang'au *et al.* (2023) reported a PCN prevalence of 61.7% in Nyandarua and Nakuru counties. Mbiyu (2023) demonstrated significant yield reductions and recommended urgent need for regular monitoring, improved diagnostic, and management strategies to control PCN spread and infestation levels in *Nyandarua County*.

Control of PCN involves cultural, biological, chemical methods, and integrated pest management. Cultural methods include crop rotation, resistant cultivars, trap crops, and quarantine regulations. Crop rotation is highly effective due to PCN's narrow host range (Haydock & Evans 1998) but is constrained by land availability. Resistant cultivars like 'Maris Piper' are commercially available (Minnis *et al.* 2002) but not grown in Kenya. Trap crops can reduce PCN populations by up to 87%, with promising candidates being *Solanum sisymbriifolium*, *Solanum scabrum*, and *Solanum nigrum*, although they have drawbacks like slow establishment and susceptibility to other nematodes (Scholte 2000). Quarantine regulations have faced weak enforcement capabilities due to the nature of informal seed systems among small-scale potato farmers in Kenya. Chemical nematicides are available, though some are banned due to environmental toxicity (Scholte 2000). Biological control agents are effective but remain limited (Nyang'au *et al.* 2023).

There is a lack of longitudinal studies tracking the incidence and infestation of PCN over multiple seasons and years, which is crucial for understanding trends and the effectiveness of control measures. Recent data on infestation levels across different regions are often missing, and more research is needed to understand the impact of varying PCN infestation levels on potato yield. Furthermore, there are limited studies on the relationship between soil characteristics and PCN prevalence. There is a need to determine up-to-date prevalence and infestation levels of potato cyst nematodes to develop policies and strategies for the most effective and sustainable management of this pest.

This study was conducted to determine the prevalence of PCN in potato-growing areas in *Nyandarua* and *Nyeri* counties to identify hotspot areas that require urgent interventions. The findings contribute to sustainable agriculture by informing pest surveillance, directing resource allocation, and promoting evidence-based interventions. By addressing a major threat to one of Kenya's most important food and cash crops, this study contributes to safeguarding potato yields, enhancing farmer livelihoods, and protecting food security in Kenya and across East Africa.

MATERIALS AND METHODS

Description of study site and its characteristics

Nyandarua County is located in central Kenya at coordinates 0°32'60.0"S and 36°36'60.0"E. It has a cool, moist highland climate, with an altitude ranging from 1,970 to 2,800 meters above sea level. The county receives moderate to high rainfall of 1,200–1,800 mm per annum, which allows year-round potato cultivation. The soils are andosols and nitisols (Jaetzold *et al.* 2006).

Nyeri County, on the other hand, is situated at 0.4167°S and 36.9500°E. It receives rainfall of 900–1,200 mm per year and lies at an altitude of 1,600 to 2,600 meters above sea level. The soils are generally fertile volcanic soils (andosols), suitable for a range of horticultural crops such as potato (Jaetzold *et al.* 2006). Both counties have prioritized potato farming for food security, income generation, and agro-industrial development. The main potato variety grown in *Nyandarua* is *'Shangi'*, which is fast-maturing and preferred by markets but also highly susceptible to PCN (Coyne *et al.* 2018), while in *Nyeri*, *'Shangi'* and *'Kanyoni'* varieties are commonly grown.

Farming systems in the two counties are intensive and smallholder-based, with widespread use of farm-saved seeds, limited crop rotation, and variable soil fertility management practices, which contribute to pest build-up (Mburu *et al.* 2020). These agroecological attributes provided a favorable setting to investigate PCN prevalence, severity, soil infectivity, and potential yield losses to inform evidence-based, site-specific control measures.

Research design

A cross-sectional survey design was used to assess the prevalence, severity, distribution, and impact of PCN in selected potato-growing sub-counties of *Nyandarua* and *Nyeri Counties*, Kenya. This design enabled collection of quantitative data from 150 farms at a single point in time, allowing for comparative analysis of infestation levels across the sub-counties. The research was based on the hypothesis that PCN infestation levels vary across sub-counties and are influenced by farm-level practices and soil characteristics. The study used field-level observations and laboratory analyses to link cyst count, cyst viability, and infectivity with soil properties, agronomic, and geographic factors.

Population and sampling

The study population comprised potato-growing smallholder farmers in *Nyandarua* and *Nyeri Counties*, Kenya. These counties were purposively selected due to their significance in potato production. From each county, three major potato-producing sub-counties were purposively selected using a stratified sampling method based on production volumes and agro-ecological variation. *South Kinangop, North Kinangop*, and *Olkalau* sub-counties—well known for potato growing—were sampled in *Nyandarua County*. In *Nyeri County, Kieni East, Mathira*, and *Kieni* West sub-counties were sampled.

A total of 150 soil samples were collected from 75 potato farms randomly selected from 500 potato-growing farmers registered in groups and community-based organizations (Coyne *et al.* 2018). In each farm, two samples were collected: one from the rhizosphere of 10 potato crops exhibiting PCN infection symptoms (EPPO 2017) and another from the rhizosphere of 10 potato crops showing no PCN infection symptoms. Each sample was mixed thoroughly in a bucket, sealed in a 1 kg zip-lock bag, and labelled. Samples were transported in a cool box and stored at 4°C at Jomo Kenyatta University of Agriculture and Technology. For each farm, metadata on GPS coordinates, land size, and agronomic practices (such as farming system, type of tillage, fertilizer or manure use, potato variety, and crop rotation) were recorded.

Extraction of potato cyst nematode

Cyst extraction from a 200 g soil sample was done using the Fenwick can method (EPPO 2013). Each sample was washed through a 1 mm aperture sieve into a Fenwick can using a moderate and constant flow of water. A 250 µm sieve was used to collect the overflow of organic matter that passed through an 840 µm sieve in the can. The final filtrate with the cysts was collected into 200 mL beakers by backwashing the sieve. The filtrate was collected on milk filter papers and air-dried for 24 hours. The cysts were handpicked one by one using entomological forceps and tallied using a Leica MZ12.5 dissection microscope. Cysts were stored in 1 mL Eppendorf tubes before being stored at 4°C. The EPPO (2017) taxonomic guide was used to morphologically identify cysts under a Leica MZ12.5 dissection microscope.

Data collection

Determination of PCN incidence: PCN incidence was evaluated as the number of farms in which cysts were detected divided by the total number of farms sampled in a specific county. After calculation of PCN incidence, the counties were categorized as described by Mburu *et al.* (2020) using the following criteria: low ($50\% \leq X < 70\%$), medium ($71\% \leq X < 90\%$), and high ($X \geq 91\%$).

Determination of mean number of cysts per county: This was calculated as the number of cysts counted in a county divided by the total number of sampled farms in that county.

Determination of PCN infestation: This was determined as the cysts recorded in a sub-county divided by the farms sampled in the specific sub-county. The infestation level of PCN in each sub-county was classified according to Mburu *et al.* (2020) as follows: “No infestation” (X = 0), “Very low” (1 < X > 25 cysts), “Low” (26 < X > 110 cysts), “Moderate” (111 < X > 230 cysts), “High” (231 < X > 495 cysts), “Very high” (496 < X > 985 cysts), and “Extremely high” (X > 986) per 200 g of soil.

Assessment of cyst viability, PCN infectivity, and yield loss: Nile blue stain was used to determine the viability of eggs in the samples according to Ogiga and Estey (1974). The staining method allows for the visual distinction between non-viable (stained) and viable (non-stained) J2s and eggs. Cysts were hand-picked and placed inside modified 1.5 mL Eppendorf tubes for viability testing. The bottom of the tubes had a nylon mesh bonded across it. The tubes were incubated for 48 hours in the dark at room temperature inside a 24-well flat-bottomed culture plate. The stain was thoroughly washed after incubation and refilled with 1 cc of sterile distilled water.

The contents of the cysts were then carefully sliced open on a glass slide for each cyst (Faggian *et al.* 2012).

Cyst fertility (CF) was determined by counting J2s and both viable and non-viable eggs. The total number of live J2s and viable eggs was divided by the CF and expressed as a percentage to determine cyst viability (CV). For each farm, PCN soil infectivity was evaluated as the mean number of viable eggs per cyst multiplied by the number of cysts obtained in 200 g of soil.

The result was given as viable eggs/g of soil for each sub-county. A rating scale of low (0–3), moderate (4–160), and high (>160) PCN soil infectivity was used to compare the sub-counties (Mburu *et al.* 2020). Potential potato yield loss was evaluated using the Brown and Sykes (1983) formula that estimates a 2.75 tonnes per hectare yield loss for every 20 viable PCN eggs per gram of soil.

Determination of soil chemical characteristics: Soil chemical properties were analyzed to assess their potential influence on PCN infestation levels. The following methods, based on Okalebo *et al.* (2002), were used: Soil pH was measured in a 1:2.5 soil-to-water suspension using a calibrated pH meter. Ten grams of air-dried soil from each sample was mixed with 25 mL of distilled water, stirred thoroughly, and allowed to settle for 30 minutes. The pH was recorded using a glass electrode. Electrical Conductivity (EC) was determined from the same 1:2.5 soil-water extract using a conductivity meter to indicate soil salinity levels. Available phosphorus was extracted using the Mehlich I (double-acid) method and quantified spectrophotometrically using the molybdenum blue method at 880 nm.

Exchangeable potassium (K^+) was extracted with 1N ammonium acetate (pH 7.0) and analyzed using a flame photometer. Total organic carbon (TOC) was determined by the Walkley-Black wet oxidation method, which involves oxidation with potassium dichromate and sulfuric acid, followed by titration with ferrous ammonium sulfate.

Data analysis

All data were analyzed using R version 4.4.0. Mean and standard error of the means were calculated using the "psych" package. Chi-square test, Wilcoxon rank-sum test, and analysis of variance were used to compare incidence and infestation levels of potato cyst nematode at the 95% level of significance. Pairwise comparison of means was done using Dunn's and Tukey's tests. Correlation analysis was done to determine the relationship between potato cyst nematode population and soil chemical characteristics.

RESULTS AND DISCUSSION

PCN incidence, severity and distribution

Potato cyst nematode infestation is widespread in the two counties, with *Nyandarua* having a higher density compared to *Nyeri*. This trend could be due to variations in environmental and agronomic factors like altitude, type of the soil, and farming systems (Fig. 1). Potato nematode cysts were present from farms in all the sub-counties sampled and were detected from a total of 149 out of 150 soil samples.

Nyandarua County had 100% PCN incidence from a total of 97 samples obtained, while *Nyeri County* had a PCN incidence of 98% from 53 samples collected. A chi-square test showed that there was no significant difference in PCN incidence between the two counties ($p = 0.157$). However, the Wilcoxon rank-sum test indicated a significant difference in the mean number of PCN cysts between the two counties ($p < 0.001$) (Table 1).

This study revealed high incidence rates of potato cyst nematodes in both *Nyandarua* and *Nyeri counties*. The findings align with those of Cortada *et al.* (2020), who reported a high incidence of PCN in *Nyandarua County*. This underscores the persistent problem of PCN in the region, highlighting the ongoing threat to potato farming in Kenya. However, while Cortada *et al.* (2020) reported 53% PCN incidence in *Nyeri*, the present study recorded a 98% incidence rate, indicating that the pest has continued to spread.

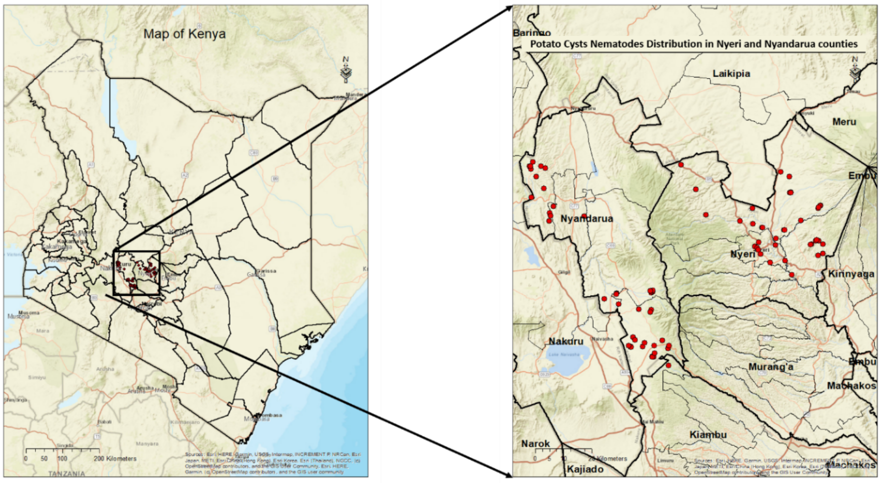

Figure 1. Potato cyst nematode distribution map in *Nyeri* and *Nyandarua County*. Image resolution: 1319x730 pixels. The left panel shows the national context, locating the two counties within Kenya, the right panel shows a detailed view, marking sampling points with red dots where PCN presence was detected.

Table 1. Mean number of PCN cysts and PCN incidence between the two counties.

County	Sample size	No. of farms with cysts	Mean no. of cysts	SD	% PCN incidence	p-value (Wilcoxon)
Nyandarua	97	97	270	325	100	<0.001
Nyeri	53	52	32	53	98	

This rise in PCN cases could be due to several factors such as inadequate pest management practices, climate conditions that favour PCN development, or the movement of infested soil through farm tools, equipment, and potato tubers within and across counties in Kenya. A critical factor contributing to the high incidence of PCN in *Nyandarua* is the widespread cultivation of the potato variety *"Shangi*," which is highly susceptible to PCN (Cortada *et al.* 2020). Onditi *et al.* (2025) reported that most farmers in Kenya use uncertified potato seeds from their previous year's crop or obtain seeds from neighbours and local markets, aggravating the spread of PCN. Similarly, Mburu *et al.* (2020) attributed high PCN prevalence to the use of susceptible potato cultivars like "*Shangi"* preferred by about 65% of farmers due to their shorter dormancy, marketability, and short cooking time. The use of farm-saved seeds rather than certified seeds exacerbates the spread of PCN. The susceptibility of the *"Shangi"* variety means that farmers growing it are more likely to suffer infestations, aggravating PCN prevalence in the region (Coyne *et al.* 2018). Mbiyu (2023) also reported that factors such as cropping cycle, seed source, and potato variety contribute to the spread and population build-up of potato cyst nematodes in *Nyandarua County*, indicating that cysts adhering to farm tools, seed potatoes, and footwear lead to further PCN spread from farm to farm. Therefore, continuous monitoring is essential to understand PCN spread dynamics and to develop effective control measures.

Potato cyst nematode infestation

A box plot of the number of cysts across the sub-counties revealed several outliers, indicating high infestation levels in some farms (Fig. 2A). The Kruskal–Wallis test indicated significant differences ($p < 0.001$) in PCN infestation among sub-counties. Tukey's multiple comparison test at $\alpha = 0.05$ showed significant differences in mean cyst counts across sub-counties (Table 2). The highest PCN infestation was observed in Olkalou, followed by *North Kinangop* and *South Kinangop*, with means of 355, 321, and 156 cysts per 200 g of

Table 2. Mean infestation levels across sub-counties with 95% confidence intervals and significance groupings.

Sub-county Grouping	Mean	SE	df	Lower CI	Upper CI
Kieni West	25.6[a]	5.8	144	14.1	37.0
Kieni East	32.4[a]	12.9	144	7.2	57.7
Mathira	35.1[a]	13.5	144	8.6	61.6
South Kinangop	156.0[ab]	29.5	144	98.2	213.8
North Kinangop	321.0[bc]	69.3	144	185.2	456.7
Olkalou	354.8[c]	65.1	144	227.1	482.4

Note: SE = standard error; df = degrees of freedom; CI = confidence interval. Confidence intervals computed at 95% level using the Sidak adjustment for multiple comparisons. Letters indicate results of Tukey's multiple comparison test at $\alpha = 0.05$. Sub-counties sharing the same letter are not significantly different in their means at $p < 0.05$.

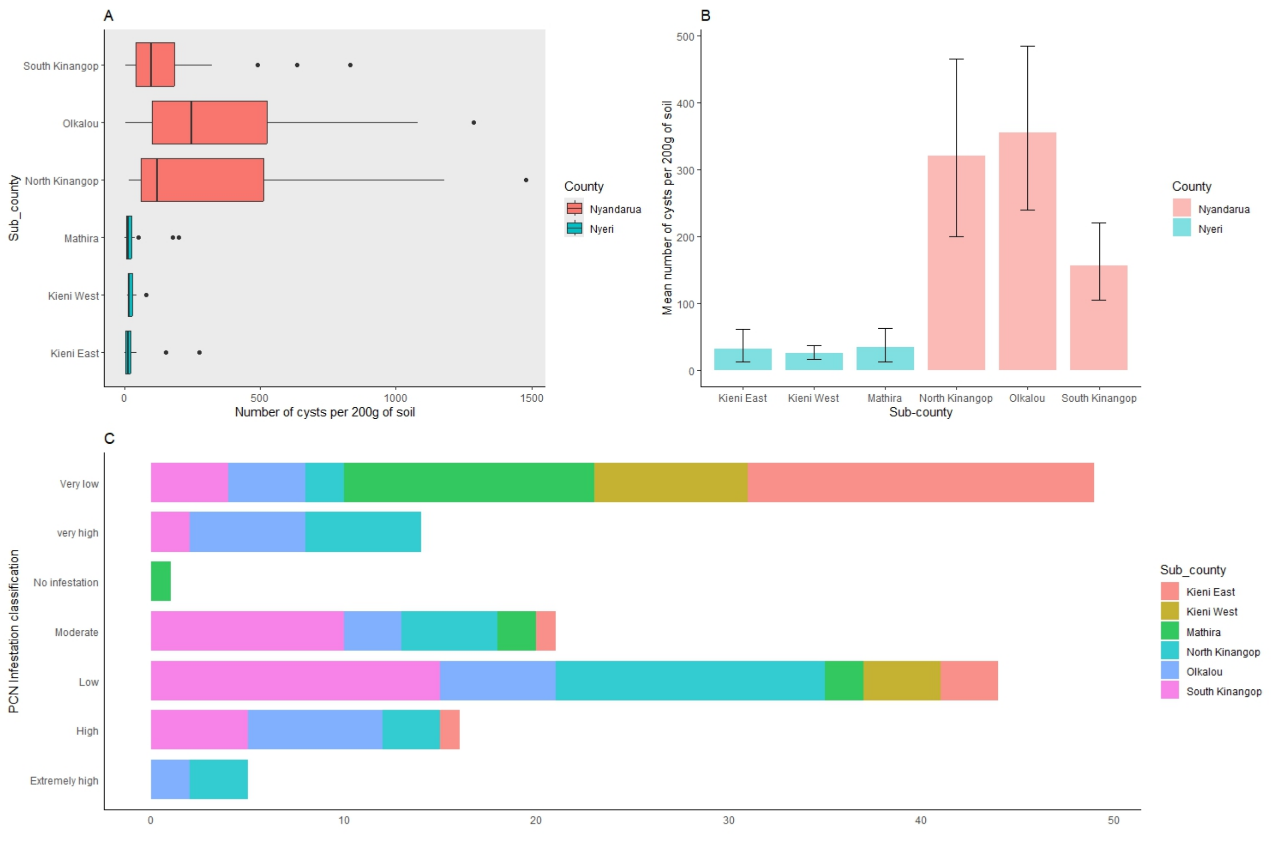

Figure 2. Potato cyst nematode infestation in *Nyandarua* and *Nyeri Counties*. A=Distribution of cysts across sub-counties, B=bar charts indicating mean number of cysts among sub-counties, C=Classification of infestation of PCN across sub-counties.

soil, respectively.

Means of 35, 32, and 26 cysts per 200 g of soil were found in *Mathira, Kieni* East, and Kieni West, respectively (Fig. 2B). Based on infestation level classification, extremely high infestation levels (Fig. 2C) were observed in three farms in *North Kinangop* and two in *Olkalou* (cysts > 986 per 200 g of soil). Very high infestation (495–985 cysts/200 g) was recorded in two farms in *South Kinangop*, and six farms each in *Olkalou* and *North Kinangop*. High infestation (231–495 cysts/200 g) occurred in seven farms in *Olkalou*, five in *South Kinangop*, three in *North Kinangop*, and one in *Kieni East*. Moderate infestation (111–230 cysts/200 g) was observed in 10 farms in *South Kinangop*, five in *North Kinangop*, three in *Olkalou*, two in *Mathira*, and one in *Kieni* East. Low or very low infestation (1–110 cysts/200 g) was observed in 19 farms in *South Kinangop*, 16 in *North Kinangop*, 10 in *Olkalou*, 15 in *Mathira*, 12 in *Kieni West*, and 21 in*Kieni* East. One farm in *Mathira* had no infestation (Fig. 2C). A chi-square test showed no significant relationship between sub-county and PCN infestation level ($p > 0.5$).

This finding shows that PCN is a major threat to potato production in *Nyandarua* and *Nyeri counties*, with extremely high infestation levels present mostly in the major potato-growing county of *Nyandarua*. The infestation levels were particularly high in *Nyandarua County*, with extremely high infestation levels observed in *North Kinangop* and *Olkalou* sub-counties. Mburu *et al.* (2020) also reported higher infestation levels in *Kinangop*. Mbiyu (2023) also reported high average number of cysts per 200 g of soil in *Nyandarua County* caused by more cropping cycles in a calendar year, planting of susceptible *"Shangi"* and *"Desiree"* varieties and use of farmers saved seeds as seed source. The high infestation levels can be explained by continuous cultivation of PCN susceptible varieties and failure to practise crop rotation. The high infestation of PCN across the potato growing sub counties from the study area partly explains the low average potato yield in Kenya (Mburu *et al*. 2020).

With continued cultivation of PCN susceptible varieties and increased PCN infestation as reported in this study, potato yield is likely to remain low. PCN has always been overlooked as a damaging pest by farmers due to their subterranean nature and usually indistinct damage symptoms which leads to neglect and lack of awareness (Coyne *et al.* 2018). In the current study, it was observed that majority of farmers could not identify PCN while others were not aware of its existence. This kind of inherent lack of PCN awareness among farmers could be a main contributing factor to the high infestation.

There were notable variations in PCN infestation levels between farms within the same sub-counties, implying the influence of micro-environmental conditions and varying agronomic practices. For example, in *North Kinangop*, infestation ranged widely from a low of 25 cysts to a high of 1,200 cysts per 200 grams of soil, although the sub-county's average was 321 cysts. Similarly, *Olkalou* showed wide variability; with some farms recording extremely high infestations (over 986 cysts per 200 grams of soil) while others had very low levels (less than 110 cysts per 200 grams of soil). These disparities indicate that factors such as agronomic practices play a key role in influencing infestation levels. On the other hand, sub-counties such as *Mathira* and *Kieni* West had fairly uniform PCN infestations, mostly between 20 and 100 cysts per 200 grams of soil. This uniformity may be due to consistent agro-ecological conditions or similar agronomic practices across these sub-counties. Ultimately, the finding emphasizes the need for targeted, site-specific PCN control.

In comparison to other regions internationally, PCN incidence in this study is elevated. In Europe for example, Camacho *et al.* (2020) reported variable infestation levels with localized hotspots, but national average field-level incidence was 22.5%, partly due to strict certification, surveillance, and use of resistant varieties. In South America, studies from the Andes region have reported PCN prevalence between 35–60%, with infestation mostly confined to specific zones (Dandurand *et al.* 2019). The differences in incidence levels between Kenya and these regions may be attributed to differences in regulatory framework, pest monitoring systems, potato varieties susceptibility, farmers' awareness and agronomic practices (Onditi *et al.* 2025). In Kenya, non-adherence to phytosanitary standards, use of informal seed systems and wide use of susceptible varieties have possibly led to high PCN incidence and severity (Coyne *et al.* 2018).

Determination of cyst fertility, viability, infectivity and yield loss

Olkalou and *North Kinangop* presented the highest soil infectivity levels with 386 and 295 viable eggs/g of soil, respectively, while the moderate soil infectivity levels were observed in *South Kinangop* (101 viable eggs/g of soil), *Kieni* West (78 viable eggs/g of soil), *Kieni* East (69 viable eggs/g of soil) and *Mathira* (54 viable eggs/g soil). *Kinangop North* and *Olkalou* sub-county had cyst viability of 84 and 92%, respectively. The mean soil infectivity was significantly different (P<0.001) across the sub-counties (Table 3). Yield losses determined using a PCN damage threshold of 2.75 t/ha per 20 viable eggs/g of soil (Brown & Sykes, 1983), ranged from 7.4 t/ha in *Mathira* to 53.1 t/ha in *Olkalou* (Table 3) based on soil infectivity data from each sub-county. Estimated yield loss was highest in *Kinangop North* and *Olkalou* sub-county at 40.6 and 53.1 t/ha, respectively.

North *Kinangop* and *Olkalou* are hot spot areas with the highest PCN soil infectivity and yield loss. Cortada *et al.* (2020) reported high soil infectivity in *Kinangop* and *Kipipiri* sub-counties in *Nyandarua*. This implies that the agro-ecological factors in these areas are conducive for the spread and establishment of high PCN densities. These areas need immediate and intensive PCN management strategies to reduce the impact on crop yields. Although PCN impact is less severe in South *Kinangop, Kieni East, Kieni West*, and *Mathira*, continued monitoring and management are necessary to prevent escalation to high infectivity. There is a clear correlation between high soil infectivity and significant yield loss. A slope of about 0.12 t ha^{-1} per cyst means that every additional cyst is associated with roughly 0.12 t ha^{-1} of extra yield loss. The R^2 of 0.920 indicates that cyst counts alone already explain 92% of the variability in yield loss (Fig. 3). A plot of observed vs. predicted yields (cyst count model) confirmed the fit of the model implying that cyst counts provide an almost perfect explanation of yield loss (Fig. 4). Adding soil infectivity (viable eggs g^{-1}) improves the model even further. Areas with higher viable eggs/g of soil have more potential yield reductions. The estimated yield losses attributable to PCN in studied regions ranged from 7.4 t ha^{-1} to 53.1 t ha^{-1}, highlighting the potential threat to food security and livelihood incomes. For effective management, resources should be allocated based on the severity of PCN infestation. High-risk areas may require more intensive interventions such as crop rotation, resistant crop varieties, and nematicides, while moderate-risk areas can focus on regular monitoring and preventive measures.

This finding shows that PCN is a major threat to potato production in *Nyandarua* and *Nyeri counties*, with extremely high infestation levels present mostly in the major potato-growing county of Nyandarua. The infestation levels were particularly high in *Nyandarua County*, with extremely high infestation levels observed in North Kinangop and Olkalou sub-counties. Mburu *et al.* (2020) also reported higher infestation levels in Kinangop. Mbiyu (2023) also reported a high average number of cysts per 200 g of soil in *Nyandarua County* caused by more cropping cycles in a calendar year, planting of susceptible "Shangi" and "Desiree" varieties and use of farmer-saved seeds as seed source. The high infestation levels can be explained by continuous cultivation of PCN-susceptible varieties and failure to practise crop rotation. The high infestation of PCN across the potato-growing sub-counties from the study area partly explains the low average potato yield in Kenya (Mburu *et al.* 2020).

With continued cultivation of PCN-susceptible varieties and increased PCN infestation as reported in this study, potato yield is likely to remain low. PCN has always been overlooked as a damaging pest by farmers due to its

Table 3. Assessment of cyst fertility, viability, infectivity, and yield loss across the sub-counties.

Sub-county	Mean cyst fertility	Soil infectivity	Mean cyst viability (%)	Soil infectivity classification	Estimated yield loss (t ha^{-1}
North Kinangop	178	295	84	High	40.6
South Kinangop	167	101	76	Moderate	13.9
Olkalou	190	386	92	High	53.1
Kieni East	133	69	73	Moderate	9.6
Kieni West	156	78	70	Moderate	10.7
Mathira	134	54	70	Moderate	7.4
p-value	<0.001	<0.001	<0.001	—	<0.001

subterranean nature and usually indistinct damage symptoms, which leads to neglect and lack of awareness (Coyne *et al.* 2018). In the current study, it was observed that the majority of farmers could not identify PCN while others were not aware of its existence. This kind of inherent lack of PCN awareness among farmers could be a main contributing factor to the high infestation.

There were notable variations in PCN infestation levels between farms within the same sub-counties, implying the influence of micro-environmental conditions and varying agronomic practices. For example, in North Kinangop, infestation ranged widely from a low of 25 cysts to a high of 1,200 cysts per 200 g of soil, although the sub-county's average was 321 cysts. Similarly, Olkalou showed wide variability, with some farms recording extremely high infestations (over 986 cysts per 200 g of soil) while others had very low levels (less than 110 cysts per 200 g of soil). These disparities indicate that factors such as agronomic practices play a key role in influencing infestation levels. On the other hand, sub-counties such as Mathira and Kieni West had fairly uniform PCN infestations, mostly between 20 and 100 cysts per 200 g of soil. This uniformity may be due to consistent agro-ecological conditions or similar agronomic practices across these sub-counties. Ultimately, the finding emphasizes the need for targeted, site-specific PCN control.

In comparison to other regions internationally, PCN incidence in this study is elevated. In Europe, for example, Camacho *et al.* (2020) reported variable infestation levels with localized hotspots, but national average field-level incidence was 22.5%, partly due to strict certification, surveillance, and use of resistant varieties. In South America, studies from the Andes region have reported PCN prevalence between 35–60%, with infestation mostly confined to specific zones (Dandurand *et al.* 2019). The differences in incidence levels between Kenya and these regions may be attributed to differences in regulatory framework, pest monitoring systems, potato varieties' susceptibility, farmers' awareness, and agronomic practices (Onditi *et al.* 2025). In Kenya, non-adherence to phytosanitary standards, use of informal seed systems, and widespread use of susceptible varieties have possibly led to high PCN incidence and severity (Coyne *et al.* 2018).

Determination of cyst fertility, viability, infectivity, and yield loss showed that Olkalou and North Kinangop presented the highest soil infectivity levels with 386 and 295 viable eggs g^{-1} of soil, respectively, while moderate soil infectivity levels were observed in South Kinangop (101 viable eggs g^{-1} of soil), Kieni West (78 viable eggs g^{-1} of soil), Kieni East (69 viable eggs g^{-1} of soil) and Mathira (54 viable eggs g^{-1} of soil). Kinangop North and Olkalou sub-counties had cyst viability of 84% and 92%, respectively. The mean soil infectivity was significantly different ($p < 0.001$) across the sub-counties (Table **??**). Yield losses determined using a PCN damage threshold of 2.75 t ha^{-1} per 20 viable eggs g^{-1} of soil (Brown and Sykes, 1983) ranged from 7.4 t ha^{-1} in Mathira to

Table 4. Assessment of cyst fertility, viability, infectivity, and yield loss across the sub-counties.

Sub-county	Mean Cyst Fertility	Soil Infectivity	Mean Cyst Viability (%)	Soil Infectivity Classification	Estimated Yield Loss (t/ha)
North Kinangop	178	295	84	High	40.6
South Kinangop	167	101	76	Moderate	13.9
Olkalou	190	386	92	High	53.1
Kieni East	133	69	73	Moderate	9.6
Kieni West	156	78	70	Moderate	10.7
Mathira	134	54	70	Moderate	7.4
P-value	< 0.001	< 0.001	< 0.001	—	< 0.001

53.1 t ha^{-1} in Olkalou (Table **??**) based on soil infectivity data from each sub-county. Estimated yield loss was highest in Kinangop North and Olkalou sub-counties at 40.6 and 53.1 t ha^{-1}, respectively.

North Kinangop and *Olkalou* are hot spot areas with the highest PCN soil infectivity and yield loss. Cortada *et al.* (2020) reported high soil infectivity in *Kinangop* and *Kipipiri* sub-counties in *Nyandarua*. This implies that the agro-ecological factors in these areas are conducive for the spread and establishment of high PCN densities. These areas need immediate and intensive PCN management strategies to reduce the impact on crop yields. Although PCN impact is less severe in South *Kinangop, Kieni East, Kieni West*, and *Mathira*, continued monitoring and management are necessary to prevent escalation to high infectivity. There is a clear correlation between high soil infectivity and significant yield loss. A slope of about 0.12 t ha^{-1} per cyst means that every additional cyst is associated with roughly 0.12 t ha^{-1} of extra yield loss. The R^2 of 0.920 indicates that cyst counts alone already explain 92% of the variability in yield loss (Fig. 3). A plot of observed vs. predicted yields (cyst count model) confirmed the fit of the model implying that cyst counts provide an almost perfect explanation of yield loss (Fig. 4).

Adding soil infectivity (viable eggs g^{-1}) improves the model even further. Areas with higher viable eggs/g of soil have more potential yield reductions. The estimated yield losses attributable to PCN in studied regions ranged from 7.4 t ha^{-1} to 53.1 t ha^{-1}, highlighting the potential threat to food security and livelihood incomes. For effective management, resources should be allocated based on the severity of PCN infestation. High-risk areas may require more intensive interventions such as crop rotation, resistant crop varieties, and nematicides, while moderate-risk areas can focus on regular monitoring and preventive measures.

There was a weak negative correlation between number of cysts and pH ($r = -0.20$). Electrical conductivity, total organic carbon, potassium, available phosphorus, and organic matter showed no correlation with number of cysts. Although the correlation between PCN cyst counts and soil pH was weak, sub-county-specific data unravelled important trends. High infestation zones, for instance *North Kinangop* and *Olkalou*, had more acidic soils, with mean pH values of 5.4 and 5.3, respectively, compared to 5.9 in *Mathira* and 6.3 in *Kieni* West, where infestation was lower (Table **??**). Similarly, organic matter levels were higher in low infestation areas in *Mathira* and *Kieni* East as compared to *North Kinangop* and *South Kinangop*. These differences imply that low pH and reduced organic matter may provide favourable conditions for PCN proliferation, although further research is required to ascertain these relationships.

The weak negative correlation between the number of cysts and soil pH suggests that soil pH may play a role in influencing PCN infestation levels. A soil pH closer to neutral might create an environment less conducive

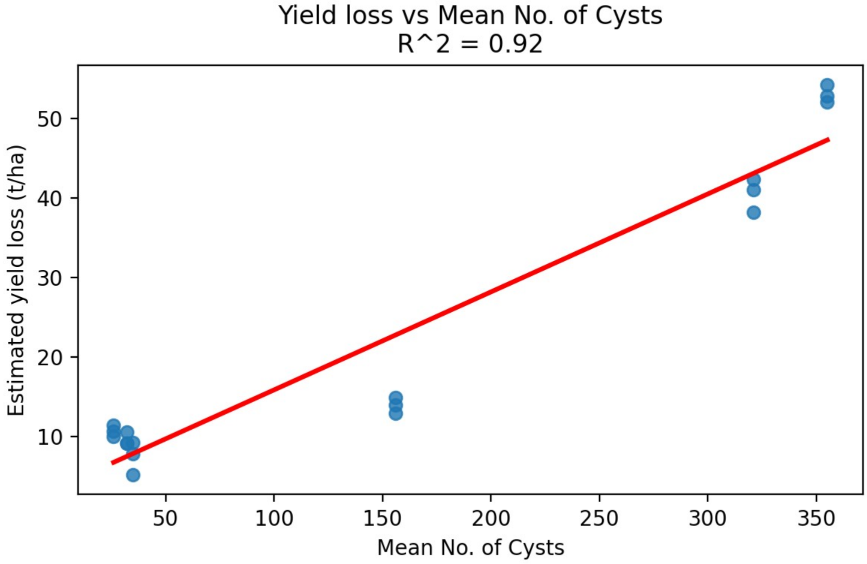

Figure 3. Relationship between cyst infestation and yield loss.

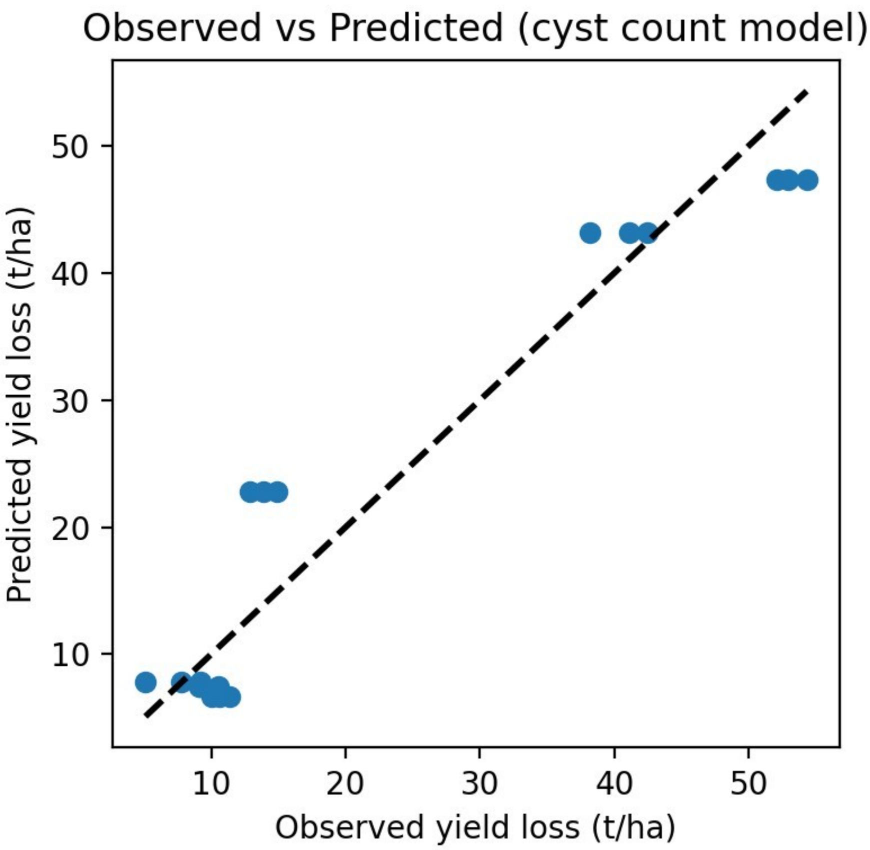

Figure 4. A plot of observed versus predicted yield loss.

Table 5. Mean soil chemical characteristics across sub-counties and cyst counts.

Sub-county Cysts Count	pH	EC	%TOC	%OM	%N	P_2O_5 (mg/kg)	%K
Kieni East 32	6.3	0.22	6.2	10.8	0.6	17.61	2.89
Mathira 18	5.9	0.17	6.7	11.6	0.7	11.39	2.73
North Kinangop 190	5.5	0.32	3.7	6.4	0.4	10.18	2.62
Olkalou 296	5.3	0.22	5.8	10.1	0.6	4.97	3.01
South Kinangop 369	5.7	0.29	5.0	8.7	0.5	6.69	2.53
Kieni West 13	6.5	0.17	4.4	7.6	0.4	3.25	3.92

to PCN survival and reproduction. Conversely, more acidic soils could potentially support higher PCN populations, though the exact mechanisms behind this relationship require further investigation. It would therefore be important for farmers to use farming practices that maintain soil pH within the optimal range of 5.5–7.0. Leiva *et al.* (2020) reported that soil properties affect nematode populations, particularly for the *Pratylenchus* sp. They concluded that *Pratylenchus* was associated with sandy, acidic, low-fertility soils. The lack of correlation between PCN numbers and soil chemical characteristics like electrical conductivity, total organic carbon, potassium ions, phosphate ions, and organic matter indicates that these factors may not directly affect PCN infestation. Abdelkader *et al.* (2022), however, reported significant correlations of electrical conductivity, moisture content, and total nitrogen with cereal cyst nematodes and the potato nematode. Similarly, Onditi *et al.* (2025) reported that adjusting soil physico-chemical properties such as electrical conductivity, pH, salinity, temperature, solarization, and use of synthetic nematicides reduces cyst viability and severity. These contradictory findings therefore require more research to ascertain the association of PCN with soil physico-chemical characteristics.

In general, farming practices appeared to influence PCN prevalence, severity, and infestation. High infestation zones such as *North Kinangop* and *Olkalou* were dominated by continuous potato cropping without practising crop rotation, widespread adoption of the susceptible *"Shangi"* variety, and planting of farm-saved seeds. In contrast, farms in *Kieni* East and *Mathira*, which reported low cyst densities, practised rotation of potatoes with maize or legumes and planted the less PCN-susceptible variety *"Kanyoni"*. This suggests that poor agronomic practices harbour an ideal environment for PCN establishment and spread in *Nyandarua* compared to *Nyeri*.

The disparity in potato cyst nematode (PCN) infestation levels between *Nyandarua* and *Nyeri* counties can also be attributed to variations in environmental and climatic conditions. *Nyandarua*, with cooler temperatures and more consistent rainfall, offers a moist and temperate climate (Jaetzold *et al.* 2006) which favours PCN survival and cyst development. These conditions enhance PCN persistence in soil and promote their proliferation (Coyne *et al.* 2018). In contrast, the lower-altitude zones of *Nyeri*, such as *Kieni* East and *Kieni* West, experience warmer, drier conditions with seasonal rainfall, which are less ideal for sustained PCN establishment and survival. Differences in soil types further contribute to the observed infestation trends. *Nyandarua*'s deep, poorly drained andosols retain moisture and facilitate continuous potato cropping, creating a conducive environment for PCN build-up over time (Jaetzold *et al.* 2006). *Nyeri*'s well-drained, loamy soils have lower water retention, potentially limiting the nematodes' long-term viability. These findings emphasize the need to customize PCN management methods according to local agro-ecological conditions, especially concerning environmental variability and distinct agronomic practices.

CONCLUSION

This study provides a comprehensive assessment of potato cyst nematode (PCN) infestation in *Nyandarua* and *Nyeri counties*, offering valuable insights into incidence, severity, soil infectivity, and potential yield loss. It highlights key intra-regional variability by using stratified sampling across various sub-counties, thus identifying infestation hotspots and key environmental and management factors influencing PCN dynamics. *Nyandarua County* exhibited significantly higher mean numbers of cysts compared to *Nyeri County*, indicating a greater prevalence and severity of PCN infestation in *Nyandarua*. The extremely high infestation levels observed in specific sub-counties, such as *North Kinangop* and *Olkalou*, underscore the urgent need for targeted management strategies in these high-risk areas. *North Kinangop* and *Olkalou* were identified as high-risk zones with the highest PCN soil infectivity and greatest estimated potential yield losses due to PCN infestation. These findings provide a foundation for tailoring integrated pest management strategies, informing seed certification policies, and enhancing farmer-targeted extension programs in Kenya. While the study focused on two counties, expanding PCN surveillance to other potato-growing regions is recommended to generate national-level prevalence and severity data. Longitudinal studies are also recommended to monitor PCN dynamics over time and to assess the effectiveness of various control strategies. Furthermore, there is a need for farmer training and policy interventions to mitigate the spread and impact of PCN in Kenya.

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