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Prioritizing plant parasitic nematodes and mollusca that are likely to be introduced and threaten agriculture, forestry, and biodiversity in Zambia: A horizon scanning approach.

Abstract

Introduction of invasive alien species (quarantine pests) through intentional or unintentional human-mediated activities has caused enormous economic and environmental impacts necessitating forward planning to identify, prioritise, and prevent their introduction. Using CABI's Horizon Scanning Tool, 26 mollusca and 199 plant parasitic nematode (PPN) species not reported as present in Zambia were identified. The list was refined to focus on species affecting Zambia's important value chains resulting in final lists of 130 PPN and 20 mollusca species that were subjected to risk assessment using agreed guidelines. The possible highest and lowest overall risk scores expected were 250 and 2 respectively. The highest overall score was 140 obtained for *Arion hortensis*, *Cornu aspersum*, and *Deroceras reticulatumi* (mollusca) and *Pratylenchus penetrans*, *P. thornei*, and *Rotylenchulus reniformis* (PPN) and the lowest for mollusca was 10, recorded for *Arion ater* and for PPN, three, recorded by for *Peltamigratus luci*. Nine (45%; N=20) and 58 (45%; N=130) of the assessed mollusca and PPN species respectively, attained a suggested minimum overall risk score of 54 necessary for instituting phytosanitary measures that limit pest introduction. All assessed mollusca species were likely be introduced through the contaminant and stowaway pathways. The majority (54%; n=70; N=130) of the PPN species were likely to be introduced via contaminant or stowaway pathways, 7 (5%) and 53 (41%) solely as contaminants and stowaways, respectively. Eleven of the PPN are known vectors of pathogenic organisms. Five of the vectored viruses recorded overall risk scores above 54 and included *Tomato ringspot virus* (105), *Tobacco rattle virus* (90), *Pea early-browning virus* (72), *Tomato black ring virus* (70), and *Arabis mosaic virus*

(60). The assessed PPN were also vectored by insects (order *Coleoptera* and families, *Cerambycidae*, *Curculionidae*, and *Dryophthoridae*), three of which recorded overall risk scores above the suggested minimum, *Monochamus galloprovincialis* (60) *Orthotomicus erosus* (100), and *Rhynchophorus palmarum* (72). Actions to limit introduction were also suggested for pathogenic organism vectored by PPN and vectors of PPN. The information from this assessment will guide a number of interventions aimed at developing strategies that prevent introduction and spread of assessed mollusca and PPN species.

Keywords: invasive alien species, horizon scanning, mollusca, plant parasitic nematodes, pest prioritization, pest risk assessment.

Introduction

The scourge of endemic pests[1] and the diseases they cause continues to be one of the major challenges to agricultural production and productivity especially in sub-Saharan Africa (SSA) (Kansiime et al. 2017). Endemic pests are estimated to causes losses of between 20-40% in pre-harvest yields although in certain circumstances, up to100 % losses have been reported (Oerke 2006, Douglas 2018, Syed Ab Rahman et al. 2018). The losses attributable to endemic pests are further exacerbated by the continuous influx of alien[2] species some of which have become invasive[3] (hereafter referred to as invasive alien species (IAS)). The economic impact of IAS is felt through increased production costs, damage to forest trees, plants and products

[1]The term "**pest**" is used within the context of the International Plant Protection Convention (IPPC) and refers to any species, strain, or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (International Standards for Phytosanitary Measures (ISPM) Number 5). Pathogenic agents include bacteria, fungi, oomycetes, phytoplasma, viroid and virus while animals may include arthropods, molluscs, and nematodes (IPPC Secretariat 2021).
[2]A species introduced outside its natural past or present distribution.
[3]A species whose introduction and/or spread by the human agency directly or indirectly threatens biological diversity.

from both forest trees and plants, along with negative effects on the environment through indiscriminate use of pesticides (Bellard et al. 2016).

The influx of IAS is mainly facilitated by intentional or unintentional human-mediated activities as a result of international trade and travel (Hulme 2009, 2021, Epanchin-Niell et al. 2021b). However, some IAS arrive into new environments unaided such as the fliers or facilitated by natural means such as storms, hurricanes and wind currents (Westphal et al. 2008, Desneux et al. 2011, Nagoshi et al. 2018). In SSA, lack of awareness, facilitated by lack of or limited enforcement of laws, porous borders, and weak border biosecurity have played a significant role in the introduction and spread of IAS over many decades (Mulema et al. 2022) as observed in previous years (Desneux et al. 2011, Day et al. 2017).

Although IAS in the phylum Arthropoda such as the fall armyworm (*Spodoptera frugiperda*), tomato leaf miner (*Phthorimaea absoluta*), and fruit flies (*Bactrocera dorsalis*, *B. invadens*) (Rwomushana et al. 2008, Desneux et al. 2011, De Groote et al. 2020) are the most prominent, IAS have also been reported in other phyla including Nematoda and Mollusca. For instance, invasive nematodes such as *Globodera rostochiensis* and *G. pallida* have already been reported in SSA (Mburu et al. 2018, Cortada et al. 2020). The potato cyst nematode is now regarded as a key threat to potato production in East Africa (Mburu et al. 2020). The economic damage associated with *G. rostochiensis* and *G. pallida*, and other invasive nematodes such as the pine wilt nematode (*Bursaphelenchus xylophilus*), stem and bulb nematode (*Ditylenchus dipsaci*), and the pigeon pea cyst nematode (*Heterodera cajani*) are well documented (Mota et al. 2009). In Kenya, the invasive apple snail (*Pomacea canaliculata*) is already causing massive loses in rice production (Buddie et al. 2021, Munene 2024).

In addition to factors that have been highlighted above as key for introduction of IAS in SSA, lack of adequate and timely information about the likely invasions have also played a significant role (Shackleton and Shackleton 2016, Jubase et al. 2021). Such information can be obtained through strategic foresight, scenario planning, or horizon scanning and enables and guides contingency planning. In this study, horizon scanning was conducted to identify and prioritize plant parasitic nematode species that are not currently recorded as present in Zambia but could be introduced in the future and become invasive. Horizon scanning for IAS is defined as the systematic search for potential biological invasions and an assessment of their potential impacts on the economy, society, and environment considering possible opportunities for mitigating the impacts (Sutherland et al. 2008, 2010, 2020, Roy et al. 2014).

Horizon scanning has been conducted previously to prioritise IAS for example in Cyprus (Peyton et al. 2019, 2020), Great Britain (Roy et al. 2014), Spain (Gassó et al. 2009, Bayón and Vilà 2019), European Union (Roy et al. 2019), and Western Europe (Gallardo et al. 2016). In these studies, candidate IAS for risk assessment were generated through extensive review of published and grey literature and databases in some of the publications. The Horizon Scanning Tool developed by CABI that supports identification of candidate pests for risk assessment was used in this study. The tool was also recently utilised in horizon scanning studies conducted in Ghana (Kenis et al. 2022), Kenya (Mulema et al. 2022), and the United States (Kendig et al. 2022, Lieurance et al. 2023).

Methods

Selection of plant pathogenic nematodes

A preliminary selection of plant pathogenic nematode (PPN) and mollusca species that had not been reported as present in Zambia was conducted using the premium version of the Horizon Scanning Tool (www.cabi.org/HorizonScanningTool). In this tool, information from datasheets available in the CABI Compendia (www.cabidigitallibrary.org/cabicompendium), was used to generate a list of pest species that are not yet reported in the selected 'area at risk' (Zambia) but reported in specified "source areas" (such as trading partner countries). However, due to gaps in pest reporting systems by some countries, absence of a presence record for a given pest in the area at risk is not necessarily a confirmation of a pest's absence. In the Horizon Scanning Tool, the following parameters were used.

The area at risk was identified as Zambia. This was followed by selecting areas from which likely invasive pests could be introduced (source areas). These areas included all geographical areas within all continents (Africa, Asia, Europe, North America, Oceania, and South America) except Antarctica. The search under source areas could be further refined by emphasising countries with matching climatic conditions based on the Köppen-Geiger climate classification (Rubel and Kottek 2010) however, this option was not considered because all geographical areas within all continents were selected. The search could be refined by selecting likely pathways of introduction, affected plant hosts, affected plant parts that may be used in trade, habitats, impact outcomes, and type of organism. However, all these parameters were left open except for the type of pest organism.

The type of pest organisms considered for this study were bacteria, viruses (included viroids) protists, fungi and chromista (oomycetes), and invertebrates (included arthropods, mollusca and plant parasitic nematodes). Other pest categories although not considered for this study were plants, vertebrates, and diseases of unknown aetiology. Plants were not considered due to lack of the appropriate guidelines for their risk assessment. In addition, the resulting pest list could be refined to retain only pests with enhanced (full) datasheets, those that affect plants and those that have been established to be invasive. For this analysis, only pests known to affect plants were retained. The enhanced datasheet and invasive options were left open. The list generated from the tool was downloaded as an excel (.xlsx) file for downstream analysis.

The list was manually assessed to remove pests that do not affect crops and forest trees of interest to Zambia and pests represented only by their genera instead of species names. The final list was subjected to a rapid risk assessment by 24 Subject Matter Experts (SMEs) convened from national and international agricultural research institutions, academia and extension institutions in Zambia. The SMEs had experience in the disciplines of bacteriology, entomology, mycology, nematology, and virology acquired from diverse backgrounds including policy, regulation, industrial and academic research. The SMEs were allocated to three thematic groups based on their expertise: Entomology, Nematology and Plant Pathology. Plant pathology included the field of Bacteriology (bacteria and phytoplasmas), Mycology (included Chromista (oomycetes and fungi), and Virology (viruses and viroids).

Description of the scoring system

The risk scoring system (guidelines) used was based on that described by Roy et al. (2019) however, the guidelines have been modified in previous studies (Kenis et al. 2022, Mulema et al. 2022). Roy et al. (2019) assessed the likelihood of arrival, establishment, spread, and magnitude of potential negative impact on biodiversity and ecosystem services whereas in this assessment, the likelihood of entry (arrival), establishment, and potential magnitude of socio-economic impact and potential magnitude of impact on biodiversity were assessed. Parameters to assess the likelihood of spread were considered under establishment. However, once an alien species arrives on the African continent, exponential spread within and between countries in SSA has been observed (Guimapi et al. 2016). This is majorly assisted by human-mediated activities especially if the criteria for entry and establishment are met and the key pathways[4] are available (Mahuku et al. 2015, De Groote et al. 2020).

A 5-score system for the four parameters (entry, establishment; socio-economic and biodiversity impact) was used, where a score of 1 indicated that an organism was unlikely to enter or establish, or minimal impact and a score of 5 indicated that an organism was very likely to enter or establish or have a major economic or environmental impact. The full guidelines and a description of the 5-score system for each of the four parameters are presented in Supplementary file S1 but briefly outlined below. To assess the likelihood of entry, a score of 1 indicated that the organism was absent from Africa and unlikely to be in the imported commodity; 2, absent from Africa but likely to be infrequently imported on a commodity; 3 was ascribed to three scenarios, namely present in Africa (not in countries neighbouring

[4]The term “**pathway**” is used within the context of the IPPC and refers to any means that allows entry and spread of a pest (IPPC Secretariat 2021).

Zambia) and spreads slowly; or absent from Africa but shown to spread very fast on several continents, or often associated to a commodity commonly imported, or frequently intercepted in Zambia; 4, present in Africa (not in neighbouring countries) and spreads rapidly, or in a neighbouring country and spreads slowly; and 5, present in a neighbouring country (Angola, Botswana, The Democratic Republic of the Congo (DR Congo), Malawi, Tanzania, Mozambique, Namibia, and Zimbabwe) and spreads rapidly.

Hulme et al. (2008) indicated three main mechanisms through which an alien species may enter a new geographical or political region. These included importation of a commodity, arrival of a transport vector, and natural spread from a neighbouring region. The three mechanisms comprised six pathways; contaminant, escape, and release under the importation of a commodity mechanism; stowaway under the arrival of a transport vector mechanism; corridor and unaided under the natural spread from a neighbouring region mechanism. To assess the likely pathway of arrival, only three pathways were considered, contaminant, stowaway (hitchhiker), and unaided, abbreviated in the tables as CO[5], ST[6], and UN[7], respectively.

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[5]The contaminant pathway includes planting material and plant products that may carry pathogenic or other organisms (nematodes) either in or on (in the case of seed-borne) or are transmitted with it. Planting materials include bulbs, corms, micro-propagated plants, rhizomes, roots, rootstocks, seed, seedlings, tubers, and other propagative materials; plant products include unprocessed logs, wood products such as timber, chips, pallets, crates, and dunnage), cut flowers, and fruits. Some nematode species are either seed-borne or seed-transmitted. Some planting materials may be contaminated with soil infested with pathogenic or other organisms (with cysts, eggs, juveniles, or adults). A seed-borne organism is any organism (pathogenic) that is carried in or on or with seed. Seed-transmission refers to the transfer and re-establishment of a seed borne pathogen from seed to plant.

[6]The stowaway pathway includes soil or any growing medium carried on machinery, equipment, or land vehicles that is infested with pathogenic and other organisms; vectors carrying pathogenic or other organisms which include fungi (order Chytridiales such as *Synchytrium endobioticum* and order Spizellomycetales such as *Olpidium* spp.), insects (orders Acarida, Coleoptera, Hemiptera, Hymenoptera, Thysanoptera, Diptera, Orthoptera, and Lepidoptera), nematodes (order Dorylaimida such as *Longidorus* spp., *Paratrichodorus* spp., *Trichodorus* spp., and *Xiphinema* spp.), plants (order Solanales such as Cuscuta spp.) and protists (order Plasmodiophorida such as *Polymyxa* spp. and *Spongospora subterranea*); pollen carried across borders by wind currents that may be infested with pathogenic organisms; birds carrying plant products including seed infected with pathogenic or other organisms; and plant debris infested with pests that may be carried across political borders. Some nematode species are known to be soil-borne and could unintentionally be introduced with soil.

[7]The unaided pathway includes fliers such as insects and birds; nematode adults, eggs, cysts, and juveniles that may be carried across borders by wind or in water ways such as creeks, streams, or rivers.

To assess the likelihood of establishment, a score of 1 indicated Zambia is climatically unsuitable or host plants are not present; 2, only few areas in Zambia climatically suitable; or host plants rare; 3, large areas in Zambia climatically suitable and host plant rare; or only few areas in Zambia climatically suitable but host plants at least moderately abundant; 4, large areas in Zambia climatically suitable and host plants moderately abundant; and 5, large areas in Zambia climatically suitable and host plants very abundant.

For the potential magnitude of socio-economic impact, a score of 1 indicated the alien species does not attack plants that are cultivated or utilised; 2, the alien species damages plants that are only occasionally cultivated or utilised; 3, the alien species damages plants that are regularly cultivated or utilised but without threatening the cultivation, utilisation, or trade of this crop; 4, the alien species has the potential to threaten, at least locally, the cultivation of a plant that is regularly cultivated or utilised; or to regularly attack a crop that is key for the Zambian economy without threatening this latter; and 5, the s alien species has the potential to threaten, at least locally, a crop that is key for the Zambian economy.

For potential magnitude of impact on biodiversity, a score of 1 indicated the alien species will not affect any native species; 2, the alien species will affect individuals of a native species without affecting its population level; 3, the alien species has the potential to lower the population levels of a native species; 4, the alien species has the potential to locally eradicate a native species or to affect populations of a protected or keystone species; and 5, the alien species has the potential to eradicate a native species or to locally eradicate a keystone species.

Scoring of alien species

After a group training of SMEs at the initial workshop conducted in July 2022, the scoring of species was done independently by all SMEs. In September 2022, a follow-up consensus workshop was held to review the risk assessments for each attribute one by one, and any discrepancies between the scores were discussed among the assessors. The assessors had the opportunity to modify their scores according to the opinions of the other SMEs. The individual risk scores were validated through consensus, and in cases of disagreement, the individual scores, and the evidence on which they were based were re-discussed.

A confidence rating of low, medium and high was estimated for each score assigned to species for the likelihood of entry; establishment; potential magnitude of socio-economic impact; and potential impact on biodiversity; likely pathway of arrival; and for the overall score as per Blackburn *et al.* (2014). The rating proposed by Blackburn *et al.* (2014) was originally modified from the European and Mediterranean Plant Protection Organization (EPPO) pest risk assessment decision support scheme (OEPP/EPPO 2012). The information to support the scores and confidences and the likely pathways was obtained from CABI Compendia datasheets, reviewed published resources (journal and reviews), EPPO datasheets, grey literature, and expert opinion.

Grey literature included blogs; conference papers and proceedings; disease reports; dissertations and theses; government documents; newspaper articles; pest risk analysis[8] (PRA) reports; and working papers. The SMEs also relied on their existing knowledge for assessing

[8]The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (IPPC Secretariat 2021).

the species. The likely pathway of arrival and associated confidence levels were used to help focus discussions on the possibility of entry and establishment but did not contribute to the overall score. Risk is a product of likelihood of an event occurring and the impact associated with that likelihood. Therefore, the overall risk score was obtained by the following formula:

Likelihood of entry x *likelihood of establishment* x (*magnitude of socio-economic impact* + *magnitude of impact on biodiversity*)

The highest overall expected score was 250 while the lowest was 2. Scores below three were considered low risk because of their low impact on the likelihood of entry, establishment, economic and biodiversity damage; scores of three were considered moderate while scores above 3 (4 and 5) presented a high risk because they had an opposite effect from the low scores. The overall risk score was used to rank species according to their potential threat to Zambia. A minimum score of 54 was considered as the cut-off for further consideration because such a species scored an average of three for all the assessable attributes or more than a three in at least three or more attributes. A score of three or more suggested a situation with higher likelihood towards the possibility of entry, establishment, and higher impact (social-economic or biodiversity). For all assessed species, recommendations on the next course of action were made. Although this horizon scanning investigation covered arthropods, bacteria, chromista (oomycetes), fungi, mollusca, PPN, , protists, viruses and niroids, this publication only focuses on mollusca and PPN.

Actions to determine pest status and manage introduction

An action for management was suggested for all assessed organisms which included mollusca, PPN, vectors, and vectored organisms. Three possible actions were suggested, a no action for all organisms that recorded an overall risk score below the suggested cut-off minimum of 54 while a detection surveillance and a pest-initiated pest risk analysis (PRA) were suggested for those that recorded an overall risk score above 54. However, for some organisms a no action was suggested but the organism monitored to determine change in risk. In exceptional situations, a no action was suggested for organisms with an overall risk score above 54 but whose likelihood of introduction was limited because Zambia does not source plant products and planting materials from those countries. A detection surveillance was suggested for organisms reported as present in neighbouring countries to confirm pest status before phytosanitary measures[9] are instituted. This action was also suggested for organisms reported in countries (such as South Africa) where Zambia has a high traffic of imported commodities (plant products and planting materials) but was mainly for guiding if a pest-initiated PRA was required. A pest-initiated PRA was suggested for organisms outside Africa or in Africa but not in neighbouring countries. In some situations, a pest-initiated PRA was suggested but after a detection surveillance had established pest status.

[9]Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (IPPC Secretariat 2021).

Results

A three-tier analysis approach was adopted to arrive at the final list of nematode and mollusca species with potential to harm crop and forest production and productivity. First, a global horizon scanning was conducted resulting in the identification of 26 Supplementary file 2, Sheet 1) and 199 (Supplementary file 3, Sheet 1) putative mollusca and PPN species respectively, that had not been reported as present in Zambia based on information available in the CABI Compendia. At the second tier, this initial output from the Horizon Scanning Tool was filtered to include only species with complete species names resulting in 185 PPN species (Supplementary file 3, Sheet 2) however, the mollusca list remained unchanged (Supplementary file 2, Sheet 2). Finally, mollusca and PPN species with potential to affect crops and forest trees important to Zambia's economy were selected resulting in a list of 26 mollusca (Supplementary file 4) and 130 PPN species (Supplementary file 5). These final lists were then taken forward for more detailed risk assessment using guidelines detailed in Supplementary file 1.

Assessment of Mollusca

The information to support the assessment was obtained from full datasheets which were available in the CABI Compendia for 45% (n=9; N=20) of the mollusca species (Supplementary file 4). The remaining species (55%, n= 11) only had basic datasheets however, their assessment was supported by expert opinion and information from sources mentioned above (journal publications, reviews, grey literature). A proportion of 45% (n=9; N=20) of the species had been reported as invasive in other countries indicating that, they could affect agriculture, forestry and biodiversity if introduced in Zambia. A similar proportion (45%, n=9) of the assessed species were reported as present in Africa. Two of the nine species reported in Africa, were reported in neighbouring countries, *Achatina fulica* in Tanzania and *Cornu aspersum* in Zimbabwe. In addition, Of the nine species reported in Africa, six were invasive including, *A. fulica*, and *C. aspersum* reported in Tanzania and Zimbabwe respectively and *Deroceras reticulatum*, *Limax maximus*, *P. canaliculata*, and *Zonitoides arboreus*. Seven of all the assessed species recorded overall risk scores above 54 with the highest score of 140 recorded for *Arion hortensis*, *C. aspersum*, and *D. reticulatumi* while the lowest was 10,recorded for *Arion ater*. All the assessed mollusca species were adjudged to likely be introduced through the contaminant and stowaway pathways.

Assessment of PPN

The information to support the assessment was obtained from full datasheets for 61% (n=79; N=130) of the PPN species (Supplementary file 5) while for the remaining species (39%, n=51), only basic data sheets where available and the assessment was based on expert opinion and from information sources indicated earlier. A proportion of 28% (n=36; N=130) of the PPN species had been reported as invasive demonstrating that they could be destructive to agriculture in Zambia if introduced. Fifty-seven (57) percent (n=74; N=130) were reported as present in Africa of which almost one quarter of this category (24%, n=18; N=74) had been reported in neighbouring countries. The highest overall risk score was 140 obtained for *Pratylenchus penetrans*, *P. thornei*, and *Rotylenchulus reniformis* while the lowest was 3 obtained for *Peltamigratus luci* (Supplementary file 5). The PPN species that recorded overall risk scores above the suggested score of 54 accounted for 45% (n=58; N=130) (Table 2). The majority (54%, n=70; N=130) of the PPN species were likely to be introduced into Zambia via the contaminant or stowaway pathways or both while 41% (n=53) and 5% (n=7) where likely to be introduced solely via the contaminant and stowaway pathways respectively (Supplementary file 5). Introduction through soil (stowaway pathway) was more plausible for PPN species reported in neighbouring countries while introduction through seed or plants for planting (contaminant pathway) was more plausible for species within and outside Africa.

Seven of the assessed PPN species are known to infect trees. These included PPN from the genus *Bursaphelenchus* (*B. fungivorus*, *B. pinophilus*, *B. vallesianus*, and *B. xylophilus*) mostly reported on many tree species in the genus *Pinus* all of which recorded an overall risk score of 30 except for *B. xylophilus* whose overall risk score was 90. Other species reported to infect *Pinus* trees included *Seinura wuae* reported on *P. thunbergii* which recorded an overall risk score of 20; *Tylenchorhynchus claytoni* reported on *P. elliottii*, *P. palustris*, *P. taeda*, which recorded an overall risk score of 90 and *Xiphinema rivesi* reported on *P. koraiensis*, which recorded an overall risk score 60. Besides affecting *Pinus* sp., some of the assessed PPN species affected *Camellia sinensis* (*P. loosi*); *Citrus* spp. (*Belonolaimus longicaudatus*, *Elongiphinema insigne*, *Hemicycliophora arenaria*, *Macroposthonia onoensis*, *Paratrichodorus porosus*, *P. vulnus*, and *Tylenchulus semipenetrans*); *Coffea* spp. (*M. coffeicola*, *M. daklakensis*, *M. decalineata*, and *M. exigua*); and *Mangifera indica* (*Hemicriconemoides mangiferae*, *Hoplolaimus seinhorsti*, and *M. onoensis*).

Vectors of pathogenic organisms

Although Table 2 does not present all PPN species that vectored pathogenic organisms because it is based on PPN species that recorded an overall risk score above 54, 11 (8%) of the 130 of assessed PPN species (Supplementary file 5), are known vectors of plant pathogenic organisms. The vectored pathogenic organisms included 11 viruses (Arabis mosaic virus, Carnation ringspot virus, Chilli ringspot virus, Pea early-browning virus, Potato black ringspot virus, Raspberry ringspot virus, Strawberry latent ringspot virus, Tobacco rattle virus, Tobacco ringspot virus, Tomato black ring virus, Tomato ringspot virus) and two bacteria, *Rathayibacter toxicus* and *R. tritici*. Five of the viruses recorded overall risk scores above 54 and included Tomato ringspot virus (105), Tobacco rattle virus (90), Pea early-browning virus (72), Tomato black ring virus (70), Arabis mosaic virus (60) (Table 3; Supplementary file 6). One virus, Tobacco ringspot virus and bacterium, *R. tritici* were not assessed because they are already known to occur in Zambia.

Five of the viruses are vectored by more than one nematode (Supplementary file 6). Pea early-browning virus is vectored by *P. anemones*, *P. pachydermus*, *P. teres*, *Trichodorus primitivus*, and *T. viruliferus*; Raspberry ringspot virus by Longidorus macrosoma and L. elongatus; Tobacco rattle virus by *P. pachydermus*, *T. similis*, and *T. primitivus*; Tomato black ring virus by *L. attenuatus* and *L. elongatus*; and Tomato ringspot virus by *X. americanum* and *X. rivesi*. The bacterium *R. toxicus* is vectored by two assessed nematodes, *Anguina agrostis* and *A. tritici*. Except for the pathogenic organisms known to occur in Zambia, all assessed vectored pathogenic organisms were likely to be introduced as contaminants (through planting materials such as seed) or as stowaways (by the nematodes and through pollen) or both.

Vectors of assess PPN species

Although Table 2 does not present all PPN species that were vectored by some organisms because it is based on PPN species that recorded an overall risk score above 54, four of the assessed PPN, *Bursaphelenchus fungivorus*, *B. mucronatus*, and *B. xylophilus*, and *Rhadinaphelenchus cocophilusi* (Supplementary file 5) were vectored by insects in the order

Coleoptera and families *Cerambycidae*, *Curculionidae*, and *Dryophthoridae* (Supplementary file 7). *B. fungivorus* was vectored by *Orthotomicus erosus* (*Curculionidae*); *B. mucronatus*, by *Monochamus scutellatus* and *M. sutor* (both *Cerambycidae*); *B. xylophilus* by *M. alternatus*, *M. carolinensis*, *M. galloprovincialis*, *M. maculosus*, *M. nitens*, *M. saltuarius*, *Monochamus scutellatus*, and *M. titillator* (all *Cerambycidae*); and *R. cocophilus*, by *Rhynchophorus palmarum* (*Dryophthoridae*).

O. erosus and all species in the genus *Monochamus* are known to infest species in the genus *Pinus* while *R. palmarum* has been reported mainly on *Cocos nucifera*, *Elaeis guineensis*, and *Saccharum officinarum* (Supplementary file 7). All these vectors are known not to occur in Africa except *M. galloprovincialis*, *O. erosus*, and *R. palmarum*. It is also only these three vectors that recorded overall risk scores above the suggested minimum of 54, *M. galloprovincialis* (60), *O. erosus* (100), and *R. palmarum* (72) (Table 4; Supplementary file 7). All the assessed vectors were likely to be introduced as contaminants in unprocessed pine logs and pine wood products (timber, chips, pallets, crates, and dunnage) for those reported to affect *Pinus* species while *R. palmarum* was likely to be introduced through plant products or plants for planting.

Suggested actions

For mollusca, a detection surveillance was suggested for two species, *A. fulica* reported in Tanzania and *C. aspersum* reported in Zimbabwe (Table 1). A pest-initiated PRA was suggested for seven species, *A. hortensis*, *B. similaris*, *D. reticulatum*, *L. valentiana*, *L. maximus*, *P. canaliculata*, and *Z. arboreus* (Table 1). For PPN species, a detection surveillance was suggested for 25 species (43%; N=58) (Table 2). However, in 18 species, the action was suggested because the PPN were reported in neighbouring countries. In 7 species, the PPN were reported in a country (like South Africa) with a high traffic of imports likely to introduce pests. The detection surveillance for the 7 species was to guide whether a pest-initiated PRA would be required, or no phytosanitary measures were necessary. A pest-initiated PRA was suggested for 30 (52%, N=58) PPN species (Table 2). Although they recorded an overall score above 54, a no action was suggested for three PPN species *Aphasmatylenchus straturatus* and *Heterodera daverti* reported in Africa and *H. elachista* reported outside Africa (Table 2). For pathogenic organisms vectored by the assessed nematodes, the bacterium *R. tritici* and the virus Tobacco ringspot virus, were not assessed because they were known to occur in Zambia (Table 3). A pest-initiated PRA was suggested for Arabis mosaic virus, Tobacco rattle virus, Tomato ringspot virus, Pea early-browning virus, and Tomato black ring virus however, for Arabis mosaic virus, a detection surveillance was also advised because the virus is seed-borne and there is a high traffic of imports from a country (South Africa) where it has been reported. For vectors of assessed PPN, a pest-initiated PRA was suggested for *M. galloprovincialis*, *O. erosus*, and *R. palmarum* (Table 4). A detection surveillance was also advised for *O. erosus* because of the high traffic of imports into Zambia from South Africa.

Discussion

The SSA region has witnessed a multitude of IAS that have impacted agriculture through their effects on the environment and economy and ultimately the livelihoods of many people that directly or indirectly depend on this sector (Kassie et al. 2020, Eschen et al. 2021). The lack of information on the likely IAS has been one of the main reasons for many unabated introductions. In this work, the risk associated with mollusca and PPN species that have not been reported in Zambia was established through a risk assessment process (Mulema et al.

2024). The information from this study can be used to manage pests that may become invasive if introduced through employing interventions based on the pest invasion curve concept (Fleming et al. 2017, Ahmed et al. 2022). The pest invasion curve describes four stages of IAS management from prevention (pre-arrival), eradication, containment, to asset-based management or protection (long-term control).

Pests that have not yet been introduced into the country or whose absence status has been confirmed through surveillance, it is essential that actions to prevent their introduction are instituted. These actions include analysis of likely pathways for introduction (DeNitto et al. 2015, Douma et al. 2016, McNitt et al. 2019). This can be followed by constriction of those pathways by reducing and limiting the means of entry and spread, intercepting movements at border points, and/or assessing risk of planned imports (Simberloff et al. 2013). The public especially air passengers should be made aware of the high risky prioritised pests and stopped from bringing commodities such fruits that may introduce pests such as fruit flies into Zambia (Urquhart et al. 2017, Jubase et al. 2021). For pests that may be imported through planting materials, the concerned industry should be engaged to ensure that the imports meet phytosanitary requirements. Therefore, putting together PRA documents to guide on import requirements is extremely important (Gordh and McKirdy 2014).

Updating the list of regulated pests will enable smooth implementation of suggested preventive actions and data from horizon scanning can be utilised for this purpose. However, this data may also be added to a pest risk register (PRR) to support periodic review of change in risk of key pests and suggest appropriate and timely actions. Pests that originally were not considered in horizon scanning such as those intercepted may also be added to the PRR and their associated risk determined. Pest risk registers are currently utilised by some countries such as the United

Kingdom[10], Northern Ireland[11], and Finland[12]. A working group (WG) under the National Plant Protection Organisation (NPPO) can be put together to periodically review pests in the PRR and guide on appropriate actions. In some NPPOs, such WGs in the form of PRA Units may be already available. The PRR actions may include regulation (added to the list of regulated pests and highlight those that need PRA reports developed), surveillance (to confirm pest status), highlight pests for public awareness, engage the industry to limit introductions and support pest management, research to guide on precise action, develop contingency plans for high-risk pests, or highlight pests for deregulation.

Public awareness may be in the form of developing publicity materials about species of concern that have been highlighted from horizon scanning or by the PRR Team. For instance, from this data, the following pests could be of concern, *B. xylophilus*, *C. aspersum*, *D. destructor*, *D. dipsaci*, *G. pallida*, *G. rostochiensis*, and *P. canaliculata*. Other nematodes of concern that have been highlighted as new or emerging include *H. glycines*, *M. chitwoodi*, and *M. enterolobii* (Jones et al. 2013, Kantor et al. 2022). Examples of such publicity materials may include photo sheets useful to farmers, frontline extension officers, and other value chain actors to aid in identification, factsheets for farmers and pest management decision guides to support extension staff on management when observed. Leaflets for passengers especially air passengers arriving at international airports such as the Kenneth Kaunda International Airport but also those coming through land borders of Zambia's neighbouring countries (Angola, Botswana, DR Congo, Malawi, Mozambique, Namibia, Tanzania, and Zimbabwe).

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[10]https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register
[11]https://www.daera-ni.gov.uk/publications/ni-plant-health-risk-register
[12]https://finnprio-explorer.rahtiapp.fi

Research supported by academia and national agricultural research systems, may be employed on high risky pests before they are introduced to understand species' life history so as to predict conditions for introduction and establishment (adaptability to environment), impacts (invasiveness), develop or adapt protocols for detection, and develop mechanisms for removal and the necessary required tools. A case in point is the nematode, *B. xylophilus* commonly referred to as the pine wood or pine wilt nematode (PWN). This nematode causes the pine wilt disease in coniferous trees (Li et al. 2022, Back et al. 2024). This disease is one of the most damaging disorders affecting coniferous forests particularly of *Pinus* spp. in Canada, China, Hong Kong, Japan, Mexico, Portugal, South Korea, Spain, Taiwan, Turkey, Ukraine, and the United States (Wingfield et al. 1982, Akbulut et al. 2008, Cheng et al. 2008, Abelleira et al. 2011, Valadas et al. 2013). The main species which PWN has been reported to infect are *P. banksiana*, *P. densiflora*, *P. echinata*, *P. elliottii*, *P. lambertiana*, *P. luchuensis*, *P. nigra*, *P. radiata*, *P. resinosa*, *P. strobus*, *P. sylvestris*, *P. taeda*, and *P. thunbergii*. Although PWN causes minor damage in North America, it catastrophically damaged native *Pine* spp. (*P. densiflora* and *P. thunbergii*) in Japan (Mota et al. 2009). The infestation became the main forest problem causing affected areas to be totally replaced with other tree species (Mota et al. 2009).

The spread of this nematode to warmer climates (Portugal and Spain), demonstrates that it can potentially establish however, the impacts will depend on a favourable climate, availability of susceptible species and vectors (Togashi and Shigesada 2006, Mota et al. 2009). Although it has not been reported on pine species (*P. kesiya* and *P. oocarpa*) grown in Zambia, the fact that it decimated native pine species in Japan, also demonstrates its ability to devastate the species grown in Zambia. Therefore, concerted research efforts need to be undertaken to generate

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information about such highlighted pests to support the country's preparedness[13]. Other PPN species of concern to the pine industry include *S. wuae*, *T. claytoni* and *X. rivesi*. Another *Xiphinema* species, *X. brasiliense* that mainly affects *Nicotiana tabacum* (tobacco), has been reported as a phytonosis[14] (Haouchine et al. 2022).

Periodic surveillance should be maintained for prioritised pests to monitor change in risk. The surveillance could be general such as at Plant clinics or may be specific, targeting particular pests for which their associated risk has been determined such as through horizon scanning or by other alternative mechanisms. The risk could be because the pest has been reported in a neighbouring country, or because they have been identified through analysis of specific imports, or even intercepted at border points. For instance, more than half of the assessed PPN species were reported in Africa with approximately one quarter of this category reported in neighbouring countries. Surveillance plays an important role in early detection (Epanchin-Niell et al. 2021a) however, there should be mechanisms for rapid response. Rapid response requires a contingency plan to define the legal basis for acting against the pest, detail reasons why such action should be undertaken and indicate agencies that are responsible and how they will work together. Therefore, complete removal or eradication of an IAS may be possible if it is detected soon after its introduction.

However, if the incursion[15] of a new pest is not spotted early enough resulting in establishment of the population or because the pest can spread rapidly by itself such as in the case of insects that can fly longer distances (Machekano et al. 2018, De Groote et al. 2020), then containment

[13]Preparedness encompasses all the activities and resources necessary to ensure that new incursions ca be successfully managed.
[14]Diseases of plants that are transmissible between plants and human.
[15]An isolated population of a pest recently detected in an area, not known to be established, but expected to survive for the immediate future (IPPC Secretariat 2021).

becomes the immediate option. Containment is concerned with eradicating satellite populations and preventing spread beyond the boundaries of core populations into areas that are suitable for establishment (Fleming et al. 2017). Containment involves a number of interventions such as implementation of regulatory activities such as preventing movement of planting materials and/or produce that could spread the pest from one area to another. The action might also involve sustained pest control activities with the objective to maintain pest free areas[16] or areas of low pest prevalence[17]. Interventions under prevention, eradication, and containment are led by the NPPO supported by various actors in the plant health system (PHS).

Without information on hight risk pests, or if the pests are not detected early enough for action to be taken, the pest establishes and spreads widely. Therefore, there will be little or no practical prospect or economic justification to create pest free areas or areas of low pest prevalence. The focus shifts to controlling the pests to a level that prevents or limits crop loses (asset-based protection). Actions such as deregulation may be considered for pests that have established self-sustaining populations in many locations. The responsibility for management of endemic pests at farm level fall with the owner of the crop but will need agricultural extension guidance which is often the role of the central or local governments. However, advice may be received from many other sources including community-based organisations, civil society organisations, non-governmental organisations, and mass media. Research also plays a major role by developing management options for the pest such as cultural management, testing available agrochemicals, developing resistant varieties, and working out an implementation

[16] An area in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (IPPC Secretariat 2021).
[17] An area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest is present at low levels and which is subject to effective surveillance or control measures (IPPC Secretariat 2021).

plan of all these options in an integrated pest management regime that protects adverse effects to the environment (biodiversity).

Conclusion

Horizon scanning was utilised to select pest species not yet reported as present in Zambia followed by assessing the risk associated with the likelihood of their introduction, establishment and potential impacts to the economy and biodiversity. The information provided by this study and the actions that have been suggested will guide risk managers in Zambia to design initiatives that impede introduction or contain spread of already introduced species. However, this will require leadership from the NPPO, Zambia's Plant Quarantine and Phytosanitary Service (PQPS) supported by major actors in the PHS (public and private research institutions, international research organisations, academia, public and private extension delivery organisations and regional NPPOs). Working with NPPOs from the region is key because close to one quarter of assessed species were reported in neighbouring countries.

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Table 1: Mollusca species that recorded overall risk scores above the suggested cut-off of 54. The likely pathways of arrival were contaminant (CO), stowaway (ST) or unaided (UN).

Mollusca species	Family	Reported as invasive	Host species	Reported in Africa?	Reported in neighbouring countries?	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall score (A*B*C(D+E))	Suggested actions
Achatina fulica Bowdich	Achatinidae	Y	**Main hosts**: *Arachis hypogaea*, *Artocarpus altilis*, *Brassica oleracea* var. *botrytis*, *Brassica oleracea* var. *capitata*, *Carica papaya*, *Cucumis melo*, *Cucumis melo* subsp. *melo*, *Cucumis sativus*, *Cucurbita pepo*, *Dioscorea alata*, *Musa* sp., *Pisum sativum*, *Tagetes patula*	Y	Y	4	CO, ST, UN	5	4	2	120	Detection surveillance
Arion hortensis Ferussac	Arionidae		**Main hosts**: *Beta vulgaris* var. *saccharifera*, *Brassica napus* var. *napus*, *Glycine max*, *Hordeum vulgare*, *Solanum tuberosum*, *Trifolium repens*, *Triticum aestivum*, *Zea mays*	Y	N	4	CO, ST	5	5	2	140	Pest-initiated PRA
Bradybaena similaris (Férussac)	Bradybaenidae		**Main hosts**: *Coffea* sp., *Daucus carota*, *Fragaria ananassa*, *Mikania micrantha*	Y	N	4	CO, ST	3	3	2	60	Pest-initiated PRA
Cornu aspersum Müller	Helicidae	Y	**Main hosts**: *Actinidia chinensis*, *Allium cepa*, *Beta vulgaris*, *Brassica oleracea* var. *capitata*, *Capsicum* sp., *Citrus* sp., *Fragaria ananassa*, *Lactuca sativa*, *Persea americana*, *Phaseolus vulgaris*, *Prunus armeniaca*, *Pyrus communis*, *Ribes nigrum*, *Solanum lycopersicum*, *Zea mays*	Y	Y	4	CO, ST, UN	5	5	2	140	Detection surveillance
Deroceras reticulatum (O.F.Müller)	Agriolimacidae	Y	**Main hosts**: *Beta vulgaris* var. *saccharifera*, *Brassica napus* var. *napus*, *Daucus carota*, *Glycine max*, *Hordeum vulgare*, *Solanum tuberosum*, *Trifolium repens*, *Triticum aestivum*, *Zea mays*	Y	N	4	CO, ST	5	5	2	140	Pest-initiated PRA
Lehmannia valentiana (Ferussac)	Limacidae		**Main hosts**: *Alstroemeria aurea*, *Anthurium anum*, *Aster* spp., *Begonia* spp., *Cyclamen* spp., *Dieffenbachia* spp., *Gerbera* spp., *Hypoestes* spp., *Scindapsus* spp., and *Zinnia elegans*	N		3	CO, ST	4	3	2	60	Pest-initiated PRA
Limax maximus Linnaeus	Limacidae	Y	**Main hosts**: Polyphagous	Y	N	4	CO, ST	4	3	2	80	Pest-initiated PRA
Pomacea canaliculata (Lamarck)	Ampullariidae	Y	**Main host**: *Oryza sativa*	Y	N	4	CO, ST	4	5	2	112	Pest-initiated PRA
Zonitoides arboreus (Say)	Gastrodontidae	Y	**Main hosts**: Orchid plants	Y	N	4	CO, ST	4	3	2	80	Pest-initiated PRA

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Table 2: Nematode species that recorded overall risk scores above the suggested cut-off of 54. The likely pathways of arrival were contaminant (CO), stowaway (ST) or unaided (UN).

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
Achlysiella williamsi (Siddiqi) Hunt, Bridge & Machon	Pratylenchidae		**Main host**: *Saccharum officinarum*			Y	N	3	CO	4	3	2	60	Pest-initaited PRA
Anguina tritici (Steinbuch) Chitwood	Anguinidae	Y	**Main hosts**: *Secale cereale, Triticum aestivum, Triticum dicoccum, Triticum spelta*		*Rathayibacter tritici* (Carlson & Vidaver) Zgurskaya, Evtushenko, Akimov & Kalakoutskii	Y	N	3	CO	4	5	1	72	Pest-initaited PRA
Aphasmatylenchus straturatus Germani	Hoplolaimidae		**Main host**: *Arachis hypogaea*			Y	N	3	CO	4	4	2	72	No action is suggested for now. This position is underscored by the fact that, Zambia is unlikely to source planting materials from the countries where the pest has been reported.
Bursaphelenchus xylophilus (Steiner & Bührer) Nickle	Aphelenchoididae	Y	**Main hosts**: *Pinus banksiana, Pinus densiflora, Pinus echinata, Pinus elliottii, Pinus lambertiana, Pinus luchuensis, Pinus nigra, Pinus radiata, Pinus resinosa, Pinus strobus, Pinus sylvestris, Pinus taeda, Pinus thunbergii*	*Monochamus alternatus* Hope; *Monochamus carolinensis* Olivier; *Monochamus galloprovincialis* (Olivier); *Monochamus maculosus* Haldeman; *Monochamus nitens* Bates; *Monochamus saltuarius* Eschscholtz; *Monochamus scutellatus* (Say); *Monochamus titillator* (Fabricius)		N		2	ST	5	5	4	90	Pest-initaited PRA
Cactodera cacti (Filipjev & Schuurmans-Stekhoven) Krall & Krall	Heteroderidae		**Main hosts**: *Epiphyllum ackermannii, Erysimum allionii, Opuntia microdasys, Opuntia stricta, Saccharum officinarum, Schlumbergera truncata*			Y	N	3	CO	4	3	2	60	Pest-initaited PRA
Ditylenchus africanus Wendt, Swart, Vrain & Webster	Anguinidae	Y	**Main host**: *Arachis hypogaea*			Y	Y	4	CO	4	4	2	96	Detection surveillance
Ditylenchus angustus (Butler) Filipjev	Anguinidae	Y	**Main host**: *Oryza sativa*			N		3	CO, ST	4	4	1	60	Pest-initaited PRA
Ditylenchus destructor Thorne	Anguinidae	Y	**Main host**: *Solanum tuberosum*			Y	N	3	CO, ST	3	3	3	54	Pest-initaited PRA
Ditylenchus dipsaci (Kuehn) Filipjev	Anguinidae	Y	**Main hosts**: *Allium cepa, Allium porrum, Allium sativum, Avena sativa, Beta vulgaris* var. *saccharifera, Cannabis sativa, Fragaria ananassa, Gladiolus hybrids, Hyacinthus orientalis, Medicago sativa, Narcissus pseudonarcissus, Nicotiana tabacum, Phlox drummondii, Phlox paniculata, Pisum sativum, Secale cereale, Solanum tuberosum, Trifolium pratense, Trifolium repens, Tulipa* spp., *Vicia faba, Zea mays*			Y	N	3	CO, ST	3	3	3	54	Pest-initaited PRA

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
Globodera pallida (Stone) Behrens	Heteroderidae	Y	**Main host**: *Solanum tuberosum*			Y	N	3	CO, ST	3	3	3	54	Detection surveillance to guide on requirement of a pest-initiated PRA.
Globodera rostochiensis (Wollenweber) Behrens	Heteroderidae	Y	**Main host**:*Solanum tuberosum*			Y	N	3	CO, ST	3	3	3	54	Detection surveillance to guide on requirement of a pest-initiated PRA.
Globodera tabacum solanacearum (Miller & Gray) Behrens	Heteroderidae	Y	**Main hosts**: *Nicotiana rustica, Nicotiana tabacum, Solanum lycopersicum*			Y	N	3	CO, ST	5	5	2	105	Pest-initaited PRA
Hemicriconemoides mangiferae Siddiqi	Criconematidae		**Main hosts**: *Litchi chinensis, Mangifera indica, Musa* x *paradisiaca*			Y	N	3	CO, ST	5	4	1	75	Detection surveillance to guide on requirement of a pest-initiated PRA.
Heterodera avenae Wollenweber	Heteroderidae		**Main hosts**: *Avena sativa, Hordeum vulgare, Secale cereale, Triticum aestivum*			Y	N	3	ST	4	3	2	60	Pest-initaited PRA
Heterodera cajani (Schmidt) Koshy	Heteroderidae	Y	**Main host**: *Cajanus cajan*			Y	N	3	CO, ST	4	4	1	60	Pest-initaited PRA
Heterodera daverti Wouts & Sturhan	Heteroderidae		**Main host**: *Oryza sativa*			Y	N	3	ST	4	4	1	60	No action is suggested for now. This position is underscored by the fact that, Zambia is unlikely to source planting materials from the countries where the pest has been reported.
Heterodera elachista Ohshima	Heteroderidae		**Main host**: *Oryza sativa*			N		2	ST	5	4	2	60	No action is suggested for now. This position is underscored by the fact that, Zambia is unlikely to source planting materials from the countries where the pest has been reported.
Heterodera filipjevi (Madzhidov) Stelter	Heteroderidae		**Main hosts**: *Avena sativa, Hordeum vulgare, Triticum aestivum*			Y	N	3	CO, ST	4	5	1	72	Pest-initaited PRA
Heterodera glycines Ichinohe	Heteroderidae	Y	**Main host**: *Glycine max*			Y	N	3	CO, ST	4	3	2	60	Pest-initaited PRA
Heterodera latipons Franklin	Heteroderidae		**Main hosts**: *Avena sativa, Hordeum vulgare, Secale cereale, Triticum aestivum*			Y	N	3	ST	3	5	1	54	Pest-initaited PRA
Heterodera oryzae Luc & Berdon	Heteroderidae		**Main host**: *Oryza sativa*			Y	N	3	ST	4	3	2	60	Pest-initaited PRA
Heterodera sacchari Luc & Merny	Heteroderidae		**Main hosts**: *Oryza sativa, Saccharum officinarum*			Y	N	3	ST	4	4	2	72	Pest-initaited PRA
Heterodera zeae Koshy, Swarup & Sethi	Heteroderidae		**Main host**: *Zea mays*			Y	N	3	ST	5	4	2	90	Pest-initaited PRA
Hoplolaimus indicus Sher	Hoplolaimidae		**Main host**: *Oryza sativa*			Y	N	3	ST	4	3	2	60	Pest-initaited PRA
Hoplolaimus pararobustus	Hoplolaimidae		**Main host**: *Musa* spp.			Y	Y	4	ST	4	3	2	80	Detection surveillance

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
(Schuurmans-Stekhoven & Teunissen) Sher														
Longidorus elongatus (de Man) Thorne & Swanger	Longidoridae		**Main hosts**: *Beta vulgaris, Daucus carota, Fragaria ananassa, Lolium perenne, Mentha piperita*		Raspberry ringspot virus; Tomato black ring virus	Y	N	3	ST	3	4	2	54	Detection surveillance to guide on requirement of a pest-initiated PRA.
Meloidogyne acronea Coetzee	Meloidogynidae	Y	**Main host**: *Gossypium hirsutum*			Y	Y	4	CO, ST	5	4	2	120	Detection surveillance
Meloidogyne arenaria (Neal) Chitwood	Meloidogynidae	Y	**Main hosts**: *Abelmoschus esculentus, Arachis hypogaea, Avena sativa, Capsicum frutescens, Citrullus lanatus, Coffea arabica, Cucumis sativus, Cucurbita pepo, Daucus carota, Glycine max, Gossypium hirsutum, Hordeum vulgare, Ipomoea batatas, Medicago sativa, Musa* spp. *Nicotiana tabacum, Oryza sativa, Passiflora edulis, Phaseolus vulgaris, Pisum sativum, Prunus persica, Psidium guajava, Saccharum officinarum, Solanum lycopersicum, Solanum tuberosum, Trifolium repens, Vigna unguiculata, Vitis vinifera, Zea mays*			Y	Y	4	CO, ST	5	4	2	120	Detection surveillance
Meloidogyne artiellia Franklin	Meloidogynidae	Y	**Main hosts**: *Brassica napus, Brassica oleracea* var. *botrytis, Brassica oleracea* var. *capitata, Brassica oleracea* var. *gemmifera, Cicer arietinum, Cucumis melo, Hedysarum coronarium, Hordeum vulgare, Lathyrus cicera, Lathyrus sativus, Lens culinaris, Medicago lupulina, Medicago rigidula, Medicago sativa, Nasturtium officinale, Pisum sativum, Raphanus sativus, Sorghum bicolor, Spinacia oleracea, Trifolium incarnatum, Trifolium pratense, Trifolium repens, Triticum aestivum, Triticum turgidum* subsp. *durum, Triticum* x *secale, Vicia articulata, Vicia faba, Vicia narbonensis, Vicia sativa, Vicia villosa*			Y	N	3	ST	5	4	2	90	Pest-initaited PRA
Meloidogyne chitwoodi Golden, O'Bannon, Santo & Finley	Meloidogynidae	Y	**Main hosts**: *Solanum lycopersicum, Solanum tuberosum*			Y	Y	4	CO, ST	5	3	2	100	Detection surveillance
Meloidogyne enterolobii Yang & Eisenback	Meloidogynidae	Y	**Main hosts**: *Coffea* spp., *Cucumis sativus, Enterolobium contortisiliquum, Glycine max, Ipomoea batatas, Maranta arundinacea, Nicotiana tabacum, Phaseolus vulgaris, Psidium guajava, Solanum lycopersicum, Solanum melongena, Solanum tuberosum*			Y	Y	4	CO, ST	5	4	1	100	Detection surveillance
Meloidogyne ethiopica Whitehead	Meloidogynidae	Y	**Main hosts**: *Brassica oleracea* var. *capitata, Actinidia chinensis, Actinidia deliciosa, Capsicum*			Y	Y	4	CO, ST	5	4	2	120	Detection surveillance

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
			annuum, Cucurbita pepo, Lactuca sativa, Phaseolus vulgaris, Polymnia sonchifolia, Solanum lycopersicum, Vigna unguiculata, Vitis labrusca, Vitis vinifera											
Meloidogyne fallax Karssen	Meloidogynidae	Y	**Main hosts**: *Beta vulgaris, Daucus carota* subsp. *sativus, Fragaria ananassa, Hordeum vulgare, Lactuca sativa, Lolium multiflorum, Medicago sativa, Poncirus trifoliata, Solanum lycopersicum, Solanum tuberosum, Stachys arvensis, Trifolium repens*			Y	N	3	CO, ST	4	3	2	60	Detection surveillance to guide on requirement of a pest-initiated PRA.
Meloidogyne graminicola Golden & Birchfield	Meloidogynidae	Y	**Main host**: *Oryza sativa*			Y	N	3	ST	4	4	2	72	Pest-initaited PRA
Meloidogyne hapla Chitwood	Meloidogynidae	Y	**Main hosts**: *Actinidia chinensis, Arachis hypogaea, Beta vulgaris* var. *saccharifera, Cichorium intybus, Daucus carota, Fragaria ananassa, Glycine max, Medicago sativa, Rosa* spp., *Solanum lycopersicum, Solanum tuberosum, Tanacetum cinerariifolium*			Y	Y	4	CO, ST	4	4	2	96	Detection surveillance
Meloidogyne izalcoensis Carneiro, Almeida, Gomes & Hernandez	Meloidogynidae		**Main hosts**: *Brassica oleracea* var. *capitata, Capsicum annuum, Solanum lycopersicum*			Y	Y	4	ST	4	3	2	80	Detection surveillance
Meloidogyne naasi Franklin	Meloidogynidae		**Main hosts**: *Avena sativa, Hordeum vulgare, Secale cereale, Sorghum bicolor, Trifolium repens, Triticum aestivum, Triticum durum*			Y	N	3	ST	4	5	2	84	Pest-initaited PRA
Nacobbus aberrans (Thorne) Thorne & Allen	Pratylenchidae		**Main hosts**: *Atriplex confertifolia, Beta vulgaris, Beta vulgaris* var. *saccharifera, Brassica napus* var. *napobrassica, Brassica nigra, Brassica oleracea* var *capitata*; *Brassica oleracea* var. *gemmifera*; *Brassica oleracea* var. *gongylodes*; *Brassica oleracea* var. *italica*; *Brassica oleracea* var. *viridis*; *Brassica rapa* subsp. *pekinensis*; *Capsicum annuum*; *Chenopodium album*; *Chenopodium quinoa*; *Cucumis sativus*; *Cucurbita maxima*; *Cucurbita pepo*; *Daucus carota*; *Lactuca sativa*; *Pisum sativum*; *Sisymbrium irio*; *Solanum lycopersicum*; *Solanum melongena, Solanum tuberosum, Spergula arvensis, Spinacia oleracea, Tragopogon porrifolius, Tribulus terrestris*			Y	N	3	CO, ST	4	3	2	60	Pest-initaited PRA
Paratrichodorus porosus (Allen) Siddiqi	Longidoridae		**Main host**: *Allium cepa, Brassica oleracea* var. *capitata, Brassica rapa* subsp. *chinensis, Camellia sinensis, Citrus jambhiri, Citrus limon, Citrus reticulata, Citrus sinensis, Citrus* x *paradisi,*			Y	N	3	CO, ST	5	4	2	90	Detection surveillance

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
			Dioscorea spp., *Juglans regia*, *Lycopersicon peruvianum*, *Musa* spp., *Musa* x *paradisiaca*, *Prunus armeniaca*, *Prunus persica*, *Pyrus communis*, *Rubus loganobaccus*, *Saccharum officinarum*, *Sorghum bicolor*, *Tagetes erecta*, *Tagetes patula*, *Vitis vinifera*, *Zea mays* *Viburnum odoratissimum*											
Pratylenchus goodeyi Sher & Allen	Paratylenchidae	Y	**Main hosts**: *Musa* spp., *Musa* x *paradisiaca*			Y	Y	4	CO, ST	3	4	2	72	Detection surveillance
Pratylenchus loosi Loof	Paratylenchidae		**Main host**: *Camellia sinensis*			Y	N	3	CO, ST	4	5	2	84	Pest-initaited PRA
Pratylenchus neglectus (Rensch) Filipjev & Schuurmans-Stekhoven	Paratylenchidae		**Main host**: *Triticum aestivum*			Y	N	3	ST	4	5	1	72	Pest-initaited PRA
Pratylenchus penetrans (Cobb) Filipjev & Schuurmans-Stekhoven	Paratylenchidae		For hosts see sheet named ***Pratylenchus penetrans*** in **Supplementary file S5**			Y	Y	4	CO, ST	5	5	2	140	Detection surveillance
Pratylenchus rwandae Singh, Nyiragatare, Janssen, Couvreur, Decraemer & Bert	Paratylenchidae		**Main host**: *Zea mays*			Y	N	3	ST	5	5	1	90	Pest-initaited PRA
Pratylenchus thornei Sher & Allen	Paratylenchidae		**Main host**: *Cicer arietinum*, *Triticum aestivum*, *Triticum turgidum*			Y	Y	4	CO, ST	5	5	2	140	Detection surveillance
Pratylenchus vulnus Allen & Jensen	Paratylenchidae		**Main hosts**: *Actinidia arguta*, *Actinidia deliciosa*, *Araucaria araucana*, *Berberis thunbergii*, *Brassica oleracea* var. *capitata*, *Buxus sempervirens*, *Carya illinoinensis*, *Citrus aurantium*, *Citrus sinensis*, *Citrus* x *paradisi*, *Corylus avellana*, *Crotalaria juncea*, *Crotalaria spectabilis*, *Cydonia oblonga*, *Cytisus scoparius*, *Daucus carota*, *Eriobotrya japonica*, *Ficus carica*, *Forsythia intermedia*, *Fragaria ananassa*, *Gossypium hirsutum*, *Impatiens balsamina*, *Juglans hindsii*, *Juglans major*, *Juglans microcarpa*, *Juglans nigra*, *Juglans regia*, *Juniperus chinensis*, *Lathyrus odoratus*, *Ligustrum ovalifolium*, *Lilium longiflorum*, *Lilium speciosum*, *Lotus corniculatus*, *Malus domestica*, *Malus sylvestris*, *Medicago sativa*, *Melilotus albus*, *Nicotiana tabacum*, *Olea europaea* subsp. *europaea*, *Papaver somniferum*, *Persea americana*, *Phaseolus lunatus*, *Phaseolus vulgaris*, *Pistacia vera*, *Pisum sativum*, *Prunus amygdalus*, *Prunus armeniaca*, *Prunus avium*, *Prunus besseyi*, *Prunus cerasifera*, *Prunus domestica*, *Prunus dulcis*, *Prunus mahaleb*, *Prunus persica*,			Y	N	3	CO, ST	5	5	2	105	Detection surveillance

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
			Pterocarya stenoptera, *Pyrus communis*, *Rosa* spp., *Rosa canina*, *Rosa chinensis*, *Rosa multiflora*, *Rubus* spp., *Taxus baccata*, *Vicia benghalensis*, *Vicia faba*, *Vigna catjang*, *Vitis rupestris*, *Vitis vinifera*, *Zea mays*											
Robustodorus arachidis (Bos) Kanzaki, Shokoohi, Fourie, Swart, Muller & Giblin Davis	Aphelenchoididae	Y	**Main host**: *Arachis hypogaea*			Y	N	3	CO, ST	4	4	2	72	Pest-initaited PRA
Rotylenchulus reniformis Linford & Oliveira	Hoplolaimidae		For hosts see sheet named ***Rotylenchulus reniformis*** in **Supplementary file S5**			Y	Y	4	CO, ST	5	5	2	140	Detection surveillance
Scutellonema bradys (Steiner & Le Hew) Andrássy	Hoplolaimidae	Y	**Main host**: *Dioscorea alata*, *Dioscorea bulbifera*, *Dioscorea esculenta*, *Vigna unguiculata*			Y	Y	4	CO, ST	4	3	1	64	Detection surveillance
Tylenchorhynchus annulatus (Cassidy) Golden	Dolichodoridae		**Main hosts**: *Oryza sativa*, *Saccharum officinarum*			Y	Y	4	CO, ST	5	3	1	80	Detection surveillance
Tylenchorhynchus brevilineatus Williams	Dolichodoridae		**Main host**: *Oryza sativa*			Y	N	3	ST	4	4	1	60	Pest-initaited PRA
Tylenchorhynchus claytoni Steiner	Dolichodoridae		**Main hosts**: *Arachniodes adiantiformis*, *Avena sativa*, *Glycine max*, *Gossypium* spp., *Lolium perenne*, *Medicago sativa*, *Nandina* spp., *Nicotiana tabacum*, *Olea europaea* subsp. *europaea*, *Oryza sativa*, *Paeonia* spp., *Photinia glabra*, *Pinus resinosa*, *Pisum sativum*, *Prunus persica*, *Rhododendron indicum*, *Rhododendron japonicum*, *Rhododendron obtusum*, *Saccharum officinarum*, *Secale cereale*, *Solanum tuberosum*, *Trifolium* spp., *Zea mays*; **Other hosts**: *Arachis hypogaea*, *Aucuba japonica*, *Cajanus cajan*, *Citrus aurantium*, *Citrus limon*, *Citrus* x *paradisi*, *Eleusine coracana*, *Ipomoea batatas*, *Litchi chinensis*, *Picea abies*, *Pinus echinata*, *Pinus elliottii*, *Pinus palustris*, *Pinus taeda*, *Rubus fruticosus*, *Solanum lycopersicum*, *Solanum melongena*, *Vaccinium myrtillus*; **Wild hosts**: *Agrostis stolonifera* var. *palustris*, *Arctium lappa*, *Bouteloua curtipendula*, *Bouteloua gracilis*, *Camellia japonica*, *Chamaecyparis pisifera*, *Cynodon dactylon*, *Echinochloa colona*, *Enkianthus perulatus*, *Erica* spp., *Festuca* spp., *Festuca arundinacea*, *Osmanthus fragrans*, *Pieris japonica*, *Poa pratensis*			Y	N	3	CO, ST	5	4	2	90	Detection surveillance to guide on requirement of a pest-initiated PRA.

Nematode species	Family	Reported as invasive	Host species	Vectored by?	Vector for?	Reported in Africa?	Neighbouring countries	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
Tylenchorhynchus mashhoodi Siddiqi & Basir	Dolichodoridae		**Main hosts**: *Triticum aestivum, Zea mays*			N		2	ST	5	4	2	60	Pest-initaited PRA
Xiphinema brasiliense Lordello	Longidoridae		**Main host**: *Nicotiana tabacum*			Y	N	3	CO, ST	5	4	1	75	Pest-initaited PRA
Xiphinema brevicolle Lordello & Da Costa	Longidoridae		**Main host**: *Polyphagous*			Y	Y	4	CO, ST	5	3	2	100	Detection surveillance
Xiphinema ifacolum Luc	Longidoridae		**Main hosts**: *Oryza sativa*			Y	N	3	CO, ST	4	4	2	72	Pest-initaited PRA
Xiphinema rivesi Dalmasso	Longidoridae		**Main hosts**: *Avena sativa, Betula pubescens, Chenopodium quinoa, Fragaria ananassa, Malus domestica, Malus sylvestris, Medicago sativa, Nicotiana tabacum, Picea glauca, Picea pungens, Pinus koraiensis, Prunus avium, Prunus domestica, Prunus persica, Rosa* spp., *Rubus idaeus, Sorghum bicolor, Trifolium pratense, Trifolium repens, Vaccinium* spp., *Vitis vinifera*		Cherry rasp leaf virus; Tobacco ringspot virus; Tomato ringspot virus	Y	N	3	CO, ST	5	3	1	60	Pest-initaited PRA
Zygotylenchus guevarai (Tobar-Jimenez) Braun & Loof	Pratylenchidae		**Main hosts**: *Apium graveolens* var. *rapaceum, Avena sativa, Cicer arietinum, Cupressus sempervirens, Lathyrus cicera, Phaseolus vulgaris, Pisum sativum, Vicia faba, Viola odorata, Viola wittrockiana, Vitis vinifera, Zea mays*		Tomato ringspot virus	Y	N	3	CO, ST	5	4	2	90	Detection surveillance to guide on requirement of a pest-initiated PRA.

Table 8: Pathogenic organisms vectored by the assessed plant pathogenic nematode species. Only vectored organisms that recorded an overall risk score equal or above the suggested minimum of 54 and those known to occur in the country and therefore not assessed are presented. The likely pathways of arrival were contaminant (CO), stowaway (ST) or unaided (UN).

Vectored species	Kingdom	Family	Host species	Vectored by?	Reported in Africa?	Neighbouring countries	Reported in Zambia	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
Arabis mosaic virus	Viruses and Viroids	Secoviridae	**Main hosts**: *Apium graveolens*, *Apium graveolens* var. *dulce*, *Armoracia rusticana*, *Asparagus officinalis*, *Beta vulgaris* var. *saccharifera*, *Buxus sempervirens*, *Chamaecyparis lawsoniana*, *Cucumis sativus*, *Cucurbita pepo*, *Cyphomandra betacea*, *Daphne mezereum*, *Daucus carota*, *Dianthus caryophyllus*, *Forsythia intermedia*, *Fragaria vesca*, *Humulus lupulus*, *Lactuca sativa*, *Prunus avium*, *Prunus domestica*, *Prunus persica*, *Rheum hybridum*, *Rosa* spp., *Rubus idaeus*, *Syringa vulgaris*, *Trifolium repens*, *Vitis vinifera*	*Xiphinema diversicaudatum* (Mikoletzky) Thorne; *Cuscuta* spp.	Y	N	N	3	CO, ST	4	3	2	60	Pest-initiated PRA but a detection surveillance is also advised.
Pea early-browning virus	Viruses and Viroids	Virgaviridae	**Main host**: *Cicer arietinum*	*Paratrichodorus anemones* (Loof) Siddiqi; *Paratrichodorus pachydermus* (Seinhorst) Siddiqi; *Paratrichodorus teres* (Hooper) Siddiqi; *Trichodorus primitivus* (de Man) Micoletzky; *Trichodorus viruliferus* Hooper	Y	N	N	3	ST	4	4	2	72	Pest-initiated PRA
Rathayibacter tritici (Carlson & Vidaver) Zgurskaya, Evtushenko,	Bacteria	Microbacteriaceae	**Main hosts**: *Triticum aestivum*, *Triticum dicoccum*		Y	Y	Y		ST					Not assessed because the virus is present in Zambia.

Vectored species	Kingdom	Family	Host species	Vectored by?	Reported in Africa?	Neighbouring countries	Reported in Zambia	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
Akimov & Kalakoutskii														
Tobacco rattle virus	Viruses and Viroids	Virgaviridae	**Main hosts**: *Beta vulgaris* var. *saccharifera*, Capsicum annuum, *Daucus carota*, *Freesia* sp, *Iris germanica*, *Lilium candidum*, *Nicotiana tabacum*, *Secale cereale*, *Solanum tuberosum*, *Tulipa*	*Paratrichodorus pachydermus* (Seinhorst) Siddiqi; *Trichodorus primitivus* (de Man) Micoletzky; *Trichodorus similis* Seinhorst	Y	N	N	3	ST	5	4	2	90	Detection surveillance
Tobacco ringspot virus	Viruses and Viroids	Secoviridae	**Main hosts**: *Capsicum annuum*, *Citrullus lanatus*, *Cucumis melo*, *Cucumis sativus*, *Cucurbita pepo*, *Gladiolus* hybrids, *Glycine max*, *Nicotiana tabacum*, *Solanum lycopersicum*, *Vaccinium corymbosum*, *Eupatorium purpureum*	*Xiphinema rivesi* Dalmasso	Y	Y	Y							Not assessed because the virus is present in Zambia.
Tomato black ring virus	Viruses and Viroids	Secoviridae	**Main hosts**: *Allium ascalonicum*, *Allium cepa*, *Allium porrum*, *Allium sativum*, *Allium schoenoprasum*, *Apium graveolens*, *Arctium lappa*, *Armoracia rusticana*, *Asparagus officinalis*, *Beta vulgaris* var. *saccharifera*, *Brassica napus*, *Brassica oleracea* var. *botrytis*, *Brassica oleracea* var. *capitata*, *Brassica rapa* subsp. *rapa*, *capsicum* sp., *Cucumis sativus*, *Cucurbita pepo* cv. *giromontiina*, *Cynara cardunculus* var. *scolymus*, *Daucus carota*, *Fragaria ananassa*, *Gerbera jamesonii*, *Gladiolus* sp., *Lactuca sativa*, *Lolium perenne*, *Malus domestica*, *Medicago sativa*, *Narcissus* sp., *Nicotiana tabacum*, *Pastinaca sativa*, *Petroselinum crispum*, *Prunus avium*, *Prunus persica*, *Ribes*	*Longidorus attenuatus* Hooper; *Longidorus elongatus* (de Man) Thorne & Swanger	N			2	CO, ST	5	5	2	70	Pest-initiated PRA

Vectored species	Kingdom	Family	Host species	Vectored by?	Reported in Africa?	Neighbouring countries	Reported in Zambia	Likelihood of entry [A]	Pathway of arrival	Likelihood of establishment [B]	Magnitude of socio-economic impact [D]	Magnitude of environmental impact [E]	Overall risk score (A*B*C(D+E))	Suggested actions
			nigrum, *Ribes rubrum*, *Rubus fruticosus*, *Rubus idaeus*, *Solanum lycopersicum*, *Solanum melongena*, *Solanum tuberosum*, *Spinacia oleracea*, *Vigna unguiculata*, *Vitis vinifera*											
Tomato ringspot virus	Viruses and Viroids	Secoviridae	**Main hosts**: *Cydonia oblonga*, *Fragaria chiloensis*, *Malus domestica*, *Nicotiana tabacum*, *Pelargonium* sp., *Prunus armeniaca*, *Prunus avium*, *Prunus cerasus*, *Prunus domestica*, *Prunus persica*, *Prunus salicina*, *Ribes* sp., *Rubus idaeus*, *Vitis vinifera*	*Xiphinema americanum* Cobb; *Xiphinema rivesi* Dalmasso	Y	N	N	3	CO, ST	5	5	2	105	Pest-initiated PRA

Table 4: Vectors of assessed plant pathogen nematode species. Only vector organisms that recorded an overall risk score equal or above the suggested minimum of 54 are presented. The likely pathways of arrival were contaminant (CO), stowaway (ST) or unaided (UN).

Vector species	**Kingdom**	**Family**	**Host species**	**Vectored by?**	**Reported in Africa?**	**Neighbouring countries**	**Reported in Zambia**	**Likelihood of entry [A]**	**Pathway of arrival**	**Likelihood of establishment [B]**	**Magnitude of socio-economic impact [D]**	**Magnitude of environmental impact [E]**	**Overall risk score (A*B*C(D+E))**	**Suggested actions**
Monochamus galloprovincialis (Olivier)	Animalia	Cerambycidae	**Main hosts**: *Pinus halepensis*, *Pinus nigra*, *Pinus pinaster*, *Pinus pinea*, *Pinus radiata*, *Pinus sylvestris*	*Bursaphelenchus xylophilus* (Steiner & Bührer) Nickle	Y	N	N	3	ST	4	4	1	60	A pest-initiated PRA
Orthotomicus erosus (Wollaston)	Animalia	Curculionidae	**Main host:** *Pinus armandii*, *Pinus brutia*, *Pinus brutia* var. *eldarica*, *Pinus canariensis*, *Pinus halepensis*, *Pinus kesiya*, *Pinus massoniana*, *Pinus nigra*, *Pinus pinaster*, *Pinus pinea*, *Pinus sylvestris*, *Pinus taiwanensis*, *Pinus uncinata*, *Pinus yunnanensis*	*Bursaphelenchus fungivorus* Franklin & Hooper	Y	N	N	5	CO	4	4	1	100	A pest-initiated PRA however, a detection surveillance is also suggested because of the traffic of imports into Zambia from South Africa.
Rhynchophorus palmarum (Linnaeus)	Animalia	Dryophthoridae	**Main hosts:** *Cocos nucifera*, *Elaeis guineensis*, *Metroxylon sagu*, *Phoenix canariensis*, *Phoenix dactylifera*, *Saccharum officinarum*	*Bursaphelenchus cocophilus* Cobb	Y	N	N	3	CO, ST	4	4	2	72	A pest-initiated PRA