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Impact of trade on distribution of potato rot nematode (*Ditylenchus destructor*) and other plant nematodes

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Abstract. Scarce status reports give but little substance for convincing conclusions about the gravity of the current problem with the potato rot nematode (*Ditylenchus destructor* Thorne 1945). This paper reviews the international experience and presents the survey of the most recent plant nematode interception reports by member states of the European and Mediterranean Plant Protection Organization. Factors influencing the distribution and invasiveness of the species are discussed. The majority of the nematode infestations were identified in consignments of bonsai or aquarium plants, originating predominantly from Asia via Western European countries. Potatoes were the most frequent nematode pathways as detected by Northern, Eastern and Southern Europe. *D. destructor* has been among the ten best recognised phytonematodes in the international plant trade, even though it was present only in about 3% of the nematode-related interceptions of potato lots. Seed potato has been found contaminated with Potato Cyst Nematodes on several occasions, whereas latent potato rot nematode infestation in ware potato or ornamental plants may easily be overlooked. Special research programs, including the comparative population genetic analyses are necessary to establish the natural and introduced distribution of *D. destructor* and substantiate creating pest free areas.

Key words: plant health, invasion, phytosanitary measures

INTRODUCTION

Potato rot nematode *Ditylenchus destructor* Thorne 1945has resulted in serious economic consequences in Eastern European potato production. The damage occurs at temperatures of 15–20ºC and at a relative humidity above 90% (Sturhan & Brzeski, 1991), whereas according to Ilyashenka & Ivaniuk (2008), potato rot nematode has been favoured by hot dry weather and moisture deficiency in soil. Serious damage by*D. Destructor* may be expected at low densities of 20–50 individuals kg^{-1} of soil (Butorina et al., *2*006). ProMED (electronic reporting system for outbreaks of emerging infectious diseases and toxins) reports of plant diseases published between 1996 and 2002 show that nematodes are only minor pathogens causing about 1% of the plant emerging infectious diseases (Anderson et al., *2*004). It was assumed that this reflects the proportion of targeted research interest rather than the actual proportion established by biodiversity inventories.

Analysing four cargo pathways, Work et al.(2005) estimated that inspections probably detected only 19% to 50% of the non-indigenous pest species being transported, depending on the particular pathway.

After the species differentiation in 1945, *D. destructor* has been recorded in many countries (Fig. 1), mostly from temperate regions (Sturhan & Brzeski, 1991). The wide geographic range of Ditylenchids has been interpreted as evidence of the evolutionally ancient origin of the taxonomic group (Sturhan & Brzeski, 1991). The pan-European invasive alien species inventory established by the European Commission funded project DAISIE (Delivering Alien Invasive Species In Europe)enlists *D. destructor* as alien for the majority of Europe (Fig. 2).

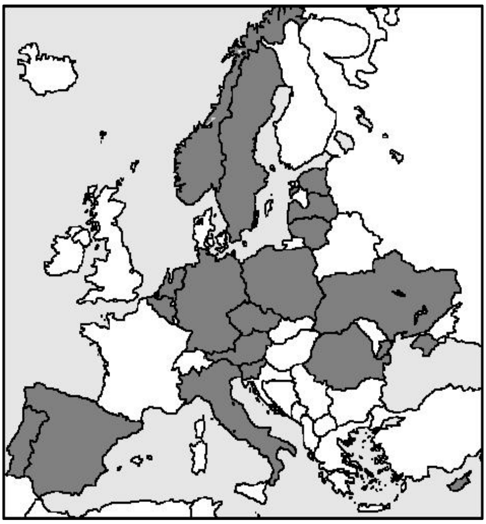

Figure 1. Distribution of potato rot nematode *Ditylenchus destructor* in Europe. Source: Fauna Europaea, 2004. www.faunaeur.org.

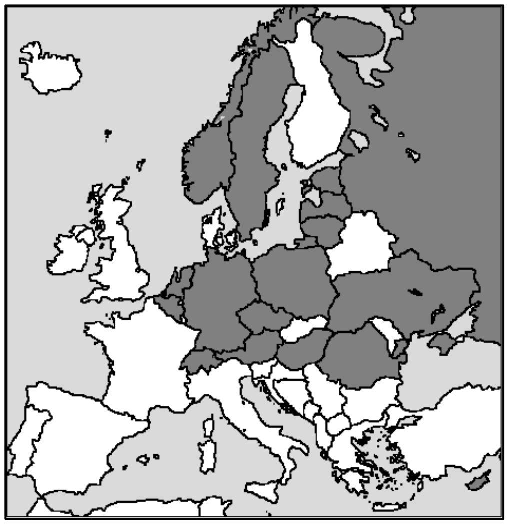

Figure 2. Distribution of potato rot nematode *Ditylenchus destructor* in Europe. Source: Pan-European Invasive Alien Species inventory, 2003.www.europe-aliens.org.

According to the European and Mediterranean Plant Protection Organization (EPPO), potato rot nematode is reported to be present in over 70% of the member countries of the organization in the European territories (Fig. 3). Most countries have stated the pest status being of limited distribution or only a few published records.

The peak of potato rot nematode damage in Eastern Europe was limited to the 1960–70s (Gul'skova, 2006). Nowadays, there are serious outbreaks on ware- and seed potatoes reported in Lithuania (EPPO, 2000, 2005), Belarus (Ilyashenka & Ivaniuk, 2008; Ivaniuket al., *2*008) and Estonia (Švilponis et al., 2008). In Japan, *D. destructor* has caused damage on 18 host plants including *Brassica chinensis*, *B. oleracea*, *Capsicum annuum*, *Dendranthema morifolium*, *Cucumis sativus*, *Cucurbita moschata* and *Lycopersicon esculentum* (Nakanishi, 1979). However, serious problems occur essentially on iris and garlic crops, spreading despite the control measures (Nishizawa, 1999). In China, it was first found parasitizing on sweet potato, potato and *Mentha* (Ding & Lin, 1982). From 2004 to 2006, a root rot caused by *D. destructor* was observed on American ginseng (*Panax quinquefolium*) cultivated in the Beijing area and in Hebei Province in China (Zhang &Zhang, 2007). Infested ginseng was also found in Korea (Young & Seung, 1995).

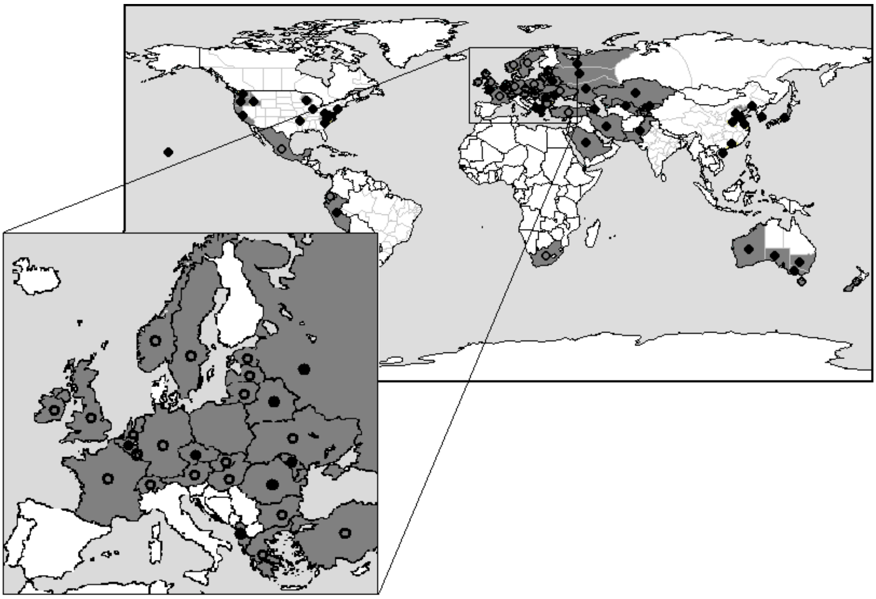

Figure3. The distribution of potato rot nematode *Ditylenchus destructor*. Full circles demarcate presence in national or sub-national level, open circles demarcate presence only in some areas. Source: European and Mediterranean Plant Protection Organization, Distribution maps of quarantine pests for Europe, 2006. www.eppo.org.

Potato rot nematode may spread not only by planting material but also via irrigation water. It has been shown that despite the general tendency to cause damage in colder and more humid areas (EPPO/CABI, 1997), the presence of *D. destructor* has been detected in the Iranian arid or semi-arid provinces of Semnan and Tehran, where potato production relies heavily on irrigation. The percentage of infestation with the nematodes causing various root lesions was 87% and 54% in Semnan and Tehran respectively (Maafiet al., *2*004). The percentage of field infestation with *D. destructor* was 11% in Semnan and 2% in Tehran samples (Moafi et al., *2*005). Similarily, *Ditylenchu ssp.* has been found infesting 28% of the samples from six major potato-producing regions in Saudi Arabia in the survey conducted from 1989–91 (Al Hazmiet al., 1993).

In general, plant and soil community assembly during secondary succession depends on the initial species composition, colonization from the local species pools, and on the response of the resident and colonizing species to the changing biotic and abiotic environmental conditions as shown by Kardol (2007). His data indicated that changes in the soil nematode community composition were mainly due to gradual shifts in dominance patterns in response to altered environmental conditions, even though, clear successional trends in densities of endoparasitic plant-feeding nematodes could not be determined. Polish researchers have found *D. destructor* present on dicotyledonous weeds *Anthemis arvensis*, *Bertoroa incana* and *Lycopsis arvensis* when 205 fields of common crops (20% of which were fallow) were surveyed in Wielkopolska region during 1993–94 (Kornobis & Wolny, 1997).

Conversely, the general quarantine regulations against the potato rot nematode in European territories have been abolished, as it was removed from the EPPO A2 quarantine pest list in 1984, because of its very wide distribution in the region (EPPO, 1987, 1988). Nowadays, *D. destructor* is regulated under the EU Plant Health Directive 2000/29/EC Annex II/A2, e.g. it is included among harmful organisms whose introduction into, and whose spread within, all member states shall be banned if they are present on flower bulbs and corms of *Crocus*, *Hyacinthus*, *Iris*, *Trigridia*, *Tulipa*, miniature cultivars and their hybrids of the genus *Gladiolus*, intended for planting, and potato tubers, intended for planting. Due to these rules, the findings of *D. destructor* on other ornamental host species are not subjected to notification nor are they actionable. Apart from general plant health regulations, there are no intergovernmental programs targeted against the potato rot nematode nor is there evidence of allocations for specific measures.

The current paper aims to review the international experience with potato rot nematode in order to understand the gravity of the pest problem in contemporary agriculture. We assume that the distribution and spread of *Ditylenchus destructor* in potato growing areas is favoured by several anthropogenic factors: trade volume and market demand, absence of legislative measures and targeted research programs, cultivation practices and availability of control options. The data survey was conducted to summarize the existing plant nematode records within the context of current trends in trade. The objective of the research was to identify major nematode problems, estimate the relative importance of potato rot nematode in imported potato consignments and compare the pest risk originating from European and non-European territories. An attempt was made to investigate the reasons for variation in the presence of potato rot nematode in Europe.

MATERIALS AND METHODS

Data was retrieved from the '*EPPO Reporting Services'*, which are regularly published by the EPPO, where notifications of noncompliance (detection of regulated pests) are reported by the member countries. The analysis considered all the pest interceptions having occurred in the eleven years from 2000–20 10. According to the availability of data, the reports of a total of 28 countries were considered. According to the United Nations geoscheme (United Nations Statistics Division, 2011), the countries were separated into following regions:

- Western Europe: Austria, Belgium, France, Germany, the Netherlands, Switzerland;
- Northern Europe: Denmark, Estonia, Finland, Ireland, Latvia, Lithuania, Norway, Sweden and the United Kingdom;
- Southern Europe: Greece, Slovenia and Spain;
- Eastern Europe: Bulgaria, Czech Republic, Hungary, Poland and Russia;
- Northern Africa: Algeria and Tunisia;
- Western Asia: Cyprus, Israel and Turkey.

Relative importance of different nematode families and major species intercepted, relative importance of associated commodities, and originas classified into the regions according to the categories of the United Nations geoscheme were identified as variables to be surveyed.

The survey data on most important plant parasitic nematodes was collated in order to calculate the relative indices on pest risk. Comparison of the indices was performed by the *Chi-square* test.

RESULTS AND DISCUSSION

Altogether, 879 reports were reviewed with the details of 1088 nematodes, 318 of which concerned nematode infested bonsais, 312 plants for planting, 114 aquarium plants, 113 wooden packaging materials, 97 ware potatoes, 28 bulbs (tubers) of ornamentals or vegetables excluding potatoes, 26 raw wood, 16 soil or growing medium, 7 seed potato, 6 seeds and 6 other materials.

Analysis of the relative importance of nematodes in the international plant trade shows that potato rot nematodes were present in about 3% of 221 potato lots intercepted with nematode contamination whereas 90% of interceptions were caused by potato cyst nematodes. Nevertheless, *D. destructor* was among the ten most recognised phytonematodes in the international plant trade, although it has been identified to species level only in 8cases while *Globodera rostochiensis* has been reported in 69 and *Bursaphelenchus xylophilus* in 60 cases for the same period. Nematode families (sub-families) intercepted in international consignments during phytosanitary checks are presented in Figure 4.

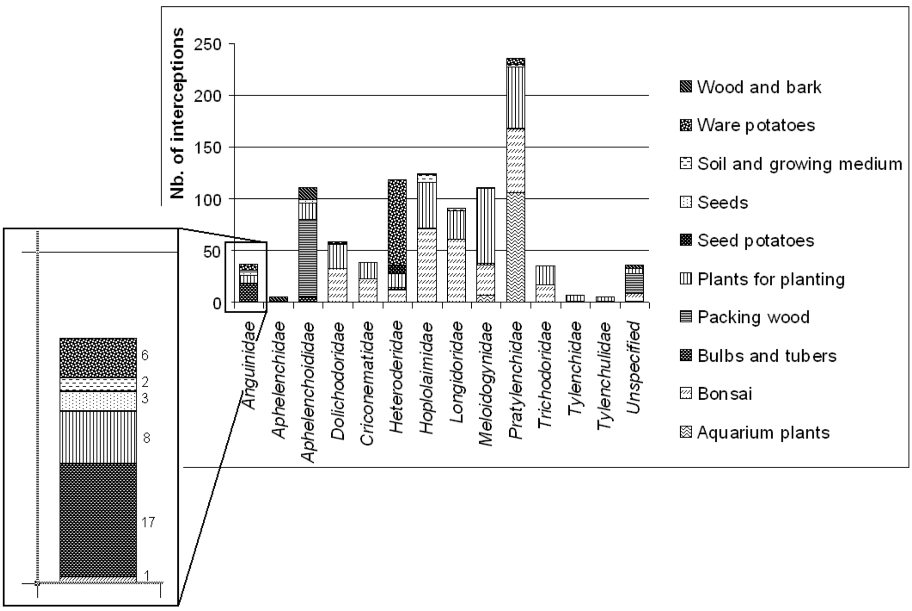

Figure 4. Nematode groups associated with major commodities intercepted by EPPO member countries from 2000–2010. Genus *Ditylenchus* belongs in the family Anguinidae.

Of the 1088 nematode interceptions that occurred from 2000–2010, the vast majority concerned nematodes related to bonsais or aquatic plants. The origin of alien nematodes differed significantly depending on the associated commodity (comparing potatoes with timber χ^2=96.35; p =0.000 or with bonsais χ^2=334.37;p =0.000).The nematode species arriving with bonsais and wood packaging material originated predominantly from Asia (96.7 and 76.9%, respectively) whereas those arriving with timber and logs came from Russia (47.9%) but also through intra-European exchanges. In addition, the diversity of nematodes carried by bonsais was significantly higher than that of the nematofauna carried by potato or timber products (χ^2=7.26; p =0.007 and χ^2= 7.61; p =0.005 respectively). The majority of the ware potato consignments in our survey originated from Europe (66 interceptions). To a lesser extent, other continents contributed: Western Asia with 25 consignments and Northern Africa with 3 consignments. Potato rot nematode was found by Bulgaria in 2 consignments from Turkey and by Lithuania in 4 consignments imported from the Eastern European countries (Belarus, Moldova, Poland and Hungary).

Of the 1181 consignments, 678 were intercepted by Western European countries, including 245 with bonsais, 186 of plants for planting and 167 of aquarium plants. In Northern Europe, 362 consignments were found infested, with the major risk commodities being ware potatoes, wooden packaging material and plants for planting (138, 115 and 44 interceptions respectively). In this region, bonsais were reported as carriers of plant nematodes only by the United Kingdom, whereas aquarium plants, by Denmark. The major nematode concerns for Eastern and Southern European countries were associated with ware potatoes (66 interceptions of total 111 by the former) and raw timber (5 reports of total 9 by the latter). Western Asia contributed with 16 interception reports and Northern Africa, 5 reports. Intercepted seed potato was exclusively of Western European origin. Only potato cyst nematodes (*Globodera rostochiensis* and *G. pallida*) were found in seed potatoes.

The interception data analysis shows clearly that the origin of the consignments plays a critical role in nematode incidence rate. Our survey results support the theory by Blumler (2006), indicating that the number of introduced species present correlates with the number of different early trade routes, frequency of intentional introductions, trade volume (particularly of unprocessed agricultural products) and the size of the region receiving introductions. According tothe statistical office of the European Union, EUROSTAT database, yearly ware potato trade in Europe from 2000–10 totals over 900 to 1600 billion of Euros in value. Considerably smaller volume is imported from Western Asia or Northern Africa, with the same indicator ranging roughly between 50 and 100 billions of Euros annually. According to the current European Union general plant health rules, importation of seed potatoes is prohibited from third countries other than Switzerland, whereas ware potatoes may be imported only from Algeria, Egypt, Israel, Libya, Morocco, Syria, Switzerland, Tunisia and Turkey, and from European third countries. Ware potato infestation rate with all nematodes detected by our survey was shown to be larger in consignments originating from Europe (70%) in comparison to third countries (30%). These data are roughly comparable to *D. destructor* findings with no significant differences (χ^2 = 0.85; p = 0.35). Recognizing the fact that the international potato trade with third countries averages only 10% of the intra-European trade values, we may conclude that the import material is of significantly higher pest incidence ergo higher phytosanitary risk (χ^2 = 6.02; p = 0.014).

The correlation between trade volume and the number of invasive species incursions has been reported by many authors (Levine & D'Antonio, 2003; Blumler, 2006; Švilponis et al., 2010). In the case of weeds, Forcella & Wood (1984) envisaged a geographical rule that invasion success correlates with the size of a species' natural distribution. It has been suggested, that the biological traits enabling some species to spread across their native territory also facilitate their invasion to new areas (Roy et al., 1991). Due to the unknown history in the case of potato rot nematode, the foreign nature of the species in Europe can not be confirmed and it should be categorized as cryptogenic. Hence, the invasion success cannot be estimated without respective population genetic evaluations.

Comparison of the distribution maps (Figs2, 3 and 4) shows the limitations of information for establishing the present range of the species. Apart from trade-policy, reasons may be the absence of recent findings on a regional level (e.g. in Western Europe) or lack of nematology expertise (e.g. in Eastern Europe). In an attempt to explain the variation in the presence of *D. destrucor* in Europe, one may appeal to the ecological principle of Competitive Exclusion (Speightet al., *2*008). Evidently, homogeneous habitats with relatively few niches available support fewer species than heterogeneous ones, since the species-rich habitat allows for more coexistence by enabling them to partition resources within the habitat and avoid interspecific competition. Mosaics of mixed seminatural habitats were characteristic of Eastern European agricultural landscapes, whereas human impact has been more disruptive in Central and Western European rural areas. Such habitat mosaics are also considered to reduce the probability of extinction of rare species.

Potato rot nematode infests various plant commodities. The two interceptions of *D. destructor* with ornamentals (*Polygonum cuspidatum* plants from Czech Republic intercepted by France and unspecified flower bulbs or tubers from the Netherlands intercepted by Lithuania) in our database survey confirm the species' ability to make use of alternative pathways in addition to the seed- or ware potato trade. The WTO sanitary and phytosanitary agreement of the General Agreement on Tariffs and Trade (GATT) stipulates that control measures must be proportional to the phytosanitary risk, developed in accordance with international standards, and must not form a disguised barrier to international trade. Since many nematodes are not readily detected by visual inspection, sampling for laboratory diagnosis is used more frequently than for other groups of organisms (Ward & Hockland, 1996). In intra-community trade between countries where *D. destructor* has been considered of minor importance (Ward & Hockland, 1996), this procedure may be perceived as unjustified delay, especially in visually undetectable contamination levels.

The current legal regulation stipulates absence of the potato rot nematode in the seed potato, but a control mechanism for this has not been introduced, apart from the random visual tuber check. However, light infestation can easily be overlooked by visual check since the exterior appears healthy (Kikas, 1969). Situations in which the data on nematode status of soils are not systematically recorded may lead to silent build-up of pest populations in consecutive potato cultivation. In order to escape incidental contamination of seed potato production fields by uncooperative private farmers, formation of a seed potato production region has been recommended. We suggest that current regional development initiatives could still benefit from the idea (Švilponis et al., 2008).

Conditions necessary for eradication of the potato rot nematode from infested fields still need to be verified. The importance of healthy planting material, general sanitation measures as well as crop rotation has been stressed as main instruments to control and prevent the spread of *D. destructor*. The nematode has been reported unable to survive in soil under cereals in 3–4 years (Sturhan & Brzeski, 1991) or in 5 years (Kikas, 1969). However, according to Estonian experience, there have been instances with contaminations of pedigree seed potato nuclear stock occurring over 5 years after the last potato crop grown in the soil (Švilponis et al., 2008). The polyphagous habits of the nematode and wide host range led us to conclude that since the species is able to maintain the population in formerly contaminated fields for an undetermined period, a pest-free area is the only reliable control measure to guarantee safe plant material in international plant trade.

The hypothesis of alien origin of the potato rot nematode will have to be challenged by genetic comparisons of populations in the future. These data would also facilitate identification of local and imported inocula, which is the basis for clarification of the infestation history in the production site as well as in the trading partner's domain.

CONCLUSIONS

By reviewing pest reports and notifications of interceptions, it was revealed that trade volume and origin have a significant impact on the incidence of nematodes in imported plant consignments. Major risk commodities vary depending on the country of interception and traditional trade routes. Pratylenchids in aquatic plants or bonsais represent the most abundant invasions among plant nematodes, with the diversity of the nematofauna in bonsais significantly higher than in potatoes or timber products. Although seed potato imports are banned and the consignments originated from Western Europe, several instances of potato cyst nematode interceptions (*Globodera rostochiensis* and *G. pallida*) were recorded, which indicates the need for extreme caution. Even though the potato rot nematode appeared as a minor problem according to the survey data, its presence in ware potato lots as well as in ornamental plants may easily be overlooked; this explains why the risk may be underestimated. However, this might not result in invasion and establishment, under the assumption that ware potato and pot plants (including bonsais) are final consumption products and under normal circumstances will not become the sources of re-infestation. Nevertheless, ornamental plants for planting can be the primary carriers of the potato rot nematode, since it is a polyphagous pest, the identification of which is possible only after specific sample analysis that may be considered an unnecessary delay in border control. Legislative restrictions against consignments originating from countries outside Europe are still justified as we proved the third country ware potato imports of higher risk in comparison to intra-community trade.

Clarification of the current distribution of the species in international, national and subnational levels has so far relied primarily on random findings by the programs targeted at other potato pathogens.The foreign nature of the potato rot nematode in Europe can not be confirmed and it should be categorized as cryptogenic. Special research programs are necessary to establish the natural and introduced distribution of *Ditylenchus destructor* and substantiate creating pest free areas with a goal to eliminate the unintentional spread of contamination in a free plant market.

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