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Nematodes as a limiting factor in potato production in Scandinavia

[1]*Norwegian Institute for Agricultural and Environmental Research, Plant Health and Plant Protection Division, Dept of Entomology and Nematology Høgskoleveien 7, 1432 Aas, Norway.*

Ricardo Holgado[1] & Christer Magnusson[1]

*Corresponding author. E-mail: ricardo.holgado@bioforsk.no, Phone + 47 916 827 03

Abstract

Plant parasitic nematodes associated with potato, feed on roots and/or tubers. About 70 species, representing 24 genera have been reported from potato. Since nematodes attack underground plant parts, there are no reliable foliar symptoms to show that nematodes may be the major cause of poor growth and reduced tuber yields. Potato roots damaged by nematodes may show lesions, abnormal proliferation of lateral roots, emerging white females and brown cysts. Nematode attacks may render plants vulnerable to other pathogens, so disease caused by microorganisms may have nematodes as an etiological component. Therefore, nematode damage may often have been attributed to other factors. In Scandinavia, potato cyst nematodes (*Globodera rostochiensis* and *G. pallida*) are by far the most important nematodes on potato. In Norway, the cost of compensations schemes due to imposed statutory regulations of PCN may some years exceed the compensation for any other pests or diseases organism in agriculture. Other important nematodes include root-lesion nematodes (*Pratylenchus* spp.), stubby root nematodes (*Trichodorus* spp. and *Paratrichodorus* spp.), and potato rot and stem nematodes (*Ditylenchus* spp.). Root knot nematode *Meloidogyne hapla* is considered less important. *Meloidogyne chitwoodi* and *M. fallax* are not known to be present in Nordic countries. In control, crop rotations using non-host crops, alternating susceptible and resistant potato cultivars is an important control measure. However, the use of resistant potato cultivars requires knowledge of the species and pathotypes present in the field.

Keywords: plant parasitic nematodes, damages, potato, Nordic countries

Introduction

Nematodes (round worms) are lower invertebrate animals. They are biologically highly diversified and are the most numerous multicellular animals on planet Earth. Nematodes are found in all types of habitats (Eriksson 1997). Plant parasitic nematodes cause economically significant crop losses in tropical, subtropical and temperate production systems. It has been estimated that some 10 % of the world crop production is lost as a result of plant parasitic nematode damage (Whitehead 1998). In potato production, plant-parasitic nematodes are of great economic importance. In some regions of Europe successful potato production normally requires management of potato cyst nematodes. Damage caused by plant parasitic nematodes is generally underestimated by farmers, as symptoms from nematode infection are often less obvious than symptoms caused by many other pests or diseases. Nematode related crop losses are also frequently associated with other biological or physical plant stress factors. Since the effect of nematodes in potato plants is similar to symptoms of drought and/or nutrient stress farmers can easily misidentify the actual cause Nematode management practices must be based on the knowledge of the relationship between initial nematode density and yield, population dynamics, and the measures capable of reducing or keeping the population density below the threshold for economic damage. Crop rotation and the use of cultivars with resistance against nematodes are important measures for controlling nematodes. It is very likely that good management strategies for nematodes would lead to increased yields and better sustainability of potato production.

Agricultural conditions in Scandinavian countries

The agricultural conditions and the agricultural structure, activities and traditions differ between and within countries. Denmark, situated in the south, has a flat topography and a temperate climate. Summers are generally warm with an average temperature of 16.4ºC, and in the winter freezing temperatures for prolonged periods are seldom experienced. The Scandinavian Peninsula (Sweden and Norway), which extends from 55ºN to 70ºN offers a large variation in the conditions for agriculture. Southern Sweden has an average annual temperature of +8.5ºC, compared to –1.2ºC in Karesuando at 68°N. The growing season in the county of Scania in the south is almost 100 days longer than in the region of Norrbotten in the north. The short growing season in the north is partly compensated for by the longer days during the summer months, which allows for the production of high quality potatoes, berries and vegetables. The best arable land is mainly concentrated in the levelled lands of the south, while production in the north to a great extent is grassland and leys. In general, the farther north the agricultural production is located, the smaller the yields will be.

Nematode derived losses in potato

Plant parasitic nematodes in potato feed on roots, stolons and/or tubers. About 70 species, representing 24 genera, have been reported from potato (Jensen et al. 1979). Besides causing direct yield losses, some nematodes may affect tuber quality. Yield losses depend on the pathogenicity of the species of nematode, the nematode population density at planting, the susceptibility and tolerance of the host and by a range of environmental factors. In the United Kingdom it is estimated that 9 % of the total annual potato crop is lost because of the potato cyst nematodes (PCN), *Globodera rostochiensis* and the dominating *G. pallida* (Evans and Rowe 1998). In the USA, where potato cyst nematodes are rare a survey of 35 States on various crops indicated nematode-derived losses of up to 25% (Koenning et al. 1999). This can be expected to increase as indicated by the new incursion of *G. pallida* in Idaho (Hafez et al. 2007). In Sweden, Sundell (1977) estimated a yearly yield loss caused by PCN of SEK. 10. 000. 000. In Norway, estimates are complicated to do, since the economic loss to PCN includes both the direct yield loss and the indirect cost to society for compensation schemes for affected growers. In the latter case the information is more precise. During the period 2004-2011, annual compensations to affected farmers due to imposed statutory regulations have varied between NOK 108.269 (€ 13.534) to 5.913.780 (€ 739.223). In 2011 the compensation included production of both potato and ready turf. In 2005, 2006 and 2011 PCN related compensations were higher than for any other regulated pests and disease organism (SLF 2011)

Plant parasitic nematodes have been reported to interact with other organisms in potato disease. Well-known examples of this are the interaction between root-lesion nematodes and *Verticilliun dahliae* in the early dying disease of potato (Rowe et al. 1985) and the interaction between *G. rostochiensis* and *Rhizoctonia solani* AG3 (Back et al. 2006). Field observations from Sweden reported that the development of stem cankers of *R. solani* AG3 was favoured at moderate densities (50-99 ind./250 g soil) of root-lesion nematodes. However the interaction was unstable, turning into antagonism at higher nematode densities (Karlsson 2006). For the Nordic region there are so far no estimates of yield losses in potatoes due to nematodes.

Potato cyst nematodes (PCN) *Globodera rostochiensis* and *G. pallida*

With reference to Nordic countries, potato cyst nematodes (*G. rostochiensis* and *G. pallida*) are by far the most important nematodes in potato. PCN originated in South America and the most important introduction into Europe may have occurred in the 19th century along with potato breeding material around 1850 (Turner and Evans 1998, Grenier et al. 2010). PCN have a very narrow host range and infest potato and some other plants in *Solanaceae*, like tomato. PCN were reported in Sweden for the first time in the county of Södermanland in 1922, Denmark in Southern-Jylland 1928, Finland 1946 in the municipality of Hyvinkää in the county of Uusimaa, Faroe Islands 1951, Iceland 1953 in Reykjavik, and Norway 1955 in the region of Sørlandet (Anon. 1971, Videgård 1969, Øydvin 1975).

Damage from PCN can be seen as expanding patches of poor growth. The plants are stunted, chlorotic and wilting, with poorly developed root systems often with an abnormal proliferation of lateral roots making soil adhere to the roots (Andersson 1997). Over time, yields are progressively reduced and tubers become small. Twenty years may elapse from the nematode introduction until field symptoms become obvious. Often PCN is detected too late because the minimal population level for detection may be as high as 60.000.000 cyst per hectare (Southey 1974). Consequently, the nematode infestation is easily overlooked, and the nematodes may unintentionally be spread to new areas in soil adherent to agricultural equipment or through other movements of soil masses. Although the nematodes are difficult to detect, routine monitoring of fields for potato cultivation undoubtedly would be helpful in restricting the spread of the pest

In Scandinavia, both species of PCN are quarantine pests subject to specific regulations, which will be enforced on infested land (Andersson 1975, Holgado and Magnusson 2010). The fact that virulence of both species of PCN on *Solanum* ssp and clones varies between populations, has led to distinguishing several "pathotypes" or virulence groups (Kort et al. 1977). The pathotype *G. rostochiensis* Ro1, which is the dominating pathotype in Scandinavia (Ireholm 1987, Magnusson and Hammeraas 1994, Hansen and Jacobsen 2001) and Finland (Magnusson 1979), can be controlled by resistance derived from *S. tuberosum* ssp. *andigena* (H1-gene). In Norway, two pathotypes capable of breaking the "*andigena*-resistance" have been reported in *G. rostochiensis* (Ro2 and Ro3) and three in *G. pallida* (Pa1, Pa2 and Pa3) (Magnusson and Hammeraas 1994). The multiplication of PCN depends on the resistance genes present in the potato and on the virulence genes present in the nematodes. When the same resistant potato variety is grown successively, selection for virulent nematode pathotypes which can overcome the resistance may occur.

This happened in several countries. In the past, *G. rostochiensis* was the prevalent species in the UK, but the repeated use of cultivars with the H1 gene led to an increase and dominance of *G. pallida*, which was previously rarely encountered (Minnis et al. 2000). In New York, USA, repeated use of cultivars with the H1-gene for controlling *G. rostochiensis* pathotype R1A, resulted in the selection of a second pathotype R2A (Brodie 1995). In a long-term field trial in Norway with a population of *G. rostochiensis* Rol containing a low initial frequency (0.1 %) of the *andigena*- resistance-breaking pathotype Ro3, the continuing cropping of Ro1resistant potatoes after seven years resulted in a complete dominance of Ro3 (Øydvin 1978).

Root-lesion nematodes (*Pratylenchus* spp.)

In the literature, more than 10 species of root lesion nematodes (*Pratylenchus* spp) have been reported from potato (Thorne 1961, Koen 1965, Loof 1978, Brodie et al. 1993). The most commonly occurring species of lesion nematode in cultivated fields in Scandinavia include *Pratylenchus crenatus, P. penetrans, P. fallax* and *P. neglectus*. Root lesion nematodes have wide host ranges which makes it difficult to select good crops for rotations. In addition to this, many weeds are good hosts .Field damage can be seen as patches of poor growth with small stunted plants. Damage is often caused by direct feeding on potato tubers, roots and stolons. These can be seen as lesions and necrosis in the epidermis and the cortical tissues. Infected tissue is susceptible to invading secondary pathogens. *P. penetrans* can reduce yields of potato by 30 -70 % (Thorne 1961, Bernard and Laughlin 1976, Otthof 1989, Lazarovits et al. 1991, Philis 1995). The economic threshold is 100-250 nematodes per 250 gram soil (Oostenbrink 1966, Brodie et al. 1993), and this is also applicable under Norwegian conditions (Holgado et al. 2009).

Potato tubers may show symptoms with cross shaped lesions resembling symptoms caused by common scab *Streptomyces scabies*. Examination of such tubers has revealed *P. penetrans* about 0.5 mm under the tuber skin cross-lesions (Thorne 1961, Brodie et al. 1993, Holgado et al. 2009). Yield of affected potato fields can be severely reduced and the tuber symptoms caused by *P. penetrans* affect quality and may reduce the market value of the crop (Holgado et al. 2009). Koen (1965) reported that the “potato peel nematode” (*P. brachyurus*) could spread with infested tubers. Norwegian studies have demonstrated that this is also true for *P. penetrans*, and that this species can survive the normal storage procedures of tubers at 4º C for 20 weeks (Holgado et al. 2009). Survival of *P. penetrans* in stored potato tubers for 19 weeks at +7ºC has been reported from Ontario, Canada (Olthof and Wolynetz 1991), while storage for 20 or more weeks at +5º C caused complete mortality of *P. brachyurus* (Koen and Hogewind 1967). Hence, species seem to differ in this aspect. In Scandinavian countries the relationship between lesion nematodes and potato has only been studied in Norway. The fact that *P. penetrans* may spread with seed potatoes should probably receive more emphasis in seed potato production.

Stubby root nematodes (*Trichodorus* spp. and *Paratrichodorus* spp.)

Stubby root nematodes are migratory ectoparasites and are found in sandy and moist soils. These nematodes are important parasites of potatoes. This relates not only to the direct damage they cause, but also to their transmission of tobacco rattle virus (TRV) giving rise to the symptom known as “spraing” in the tubers. The symptoms, also called “corky ringspot” appear as irregular ring-shaped lesions with a corky texture. The corky rings within the tuber flesh are caused by the autodestruction of virus infected cells. However, not all potato cultivars exhibit these symptoms after TRV infection, and hence tubers without symptoms could spread

TRV to other fields (Winslow and Willis 1972, Brodie et al. 1993). Both genera have wide host ranges of cultivated plants and weeds, making management with crop rotation difficult. The nematodes lose TRV at moulting but can reacquire the virus from feeding on infected plants. TRV affects potato, lucerne, tobacco and ornamental bulbs (Winslow and Willis 1972, Taylor and Brown 1997). Stubby root nematodes are aggregated and seem highly mobile in the soil both horizontally and vertically, which may complicate population estimates (Winslow and Willis 1972).

Potato rot nematode (tuber) and stem nematode (*Ditylenchus* spp.)

Ditylenchus destructor (potato rot nematode) is unable to withstand excessive desiccation, and is usually only important in cool, moist soils. It overwinters in soil as adults, larvae or eggs. The nematodes may also multiply by feeding on alternative weed hosts or on fungal mycelia (Andersson 1967, 1971). *D. destructor* attacks only subterranean plant parts and not the aerial parts. They enter potato tubers through the lenticels, and multiply rapidly, colonizing the whole tuber. They can continue to live and develop within harvested tubers during storage (Anon. 1971, Whitehead 1998). *D. destructor* causes no noticeable symptoms in the aerial parts of the plant, although infested tubers can germinate and produce weak plants which usually die. Early infections can be detected by peeling the tuber which can reveal small, off-white spots in the otherwise healthy flesh. These later enlarge, darken, are woolly in texture and may be slightly hollow at the centre (Anon. 1971). In severely affected tubers there are typically slightly sunken areas with cracked and wrinkled skin partly detached from the underlying tissue. The flesh has a dry and mealy appearance, varying in colour from greyish to dark brown or black. This discoloration is largely due to the invasion of secondary fungi and bacteria. *D. destructor*, which is very common and an important pest of potato in Estonia, Lithuania and in areas of Belarus (Švilponis 2011), is considered uncommon and of little consequence in Scandinavia. The latter fact may relate to the lack of studies in recent years, especially in storage facilities.

The stem nematode *D. dipsaci* may also attack potato. In contrast to infections by *D. destructor*, the skin of tubers infested with *D. dipsaci* is not usually cracked, and the rot darkens towards the inside of the tuber. The symptoms are more obvious in the foliage, which is shortened and malformed. *D. dipsaci* can infest many species of weeds; it also lives in the soil and can survive for several years without a host crop (Whitehead 1998, Plowright et al. 2002, Wharton and Marshall 2002). In Scandinavia the stem and tuber nematodes (*Ditylenchus* spp.), have been reported occasionally as problems both in field and storage. Field damage occurs especially in situations when weeds are not well controlled (Andersson 1967, 1971, Anon. 1971).

Nematodes considered less important

Among less important nematodes the main attention has been directed to the root knot nematodes *Meloidogyne* spp. *Meloidogyne. hapla* (the northern root knot nematode) is common in the county of Scania in southern Sweden, and in Denmark. In Norway, this species has in recent years become more frequent especially in field grown vegetables (Magnusson and Hammeraas 2000). In Finland, *M. hapla* may overwinter but the survival and damage is considered very limited (Tiilikkala et al. 1988). *M. hapla* has a wide host range which includes many weeds, but not graminaceous plants (Magnusson and Hammeraas 2000). The recent expansion of *M. hapla* may result in its presence in potato fields in the near future. To the best of our knowledge Scandinavia is so far free from the quarantine pests *M. chitwoodi* and *M. fallax*. Monitoring these species is important as both of them can be expected to survive and cause damage in the whole region (Tiilikkala et al. 1995, Magnusson et al. 2002).

Control of PCN

When PCN is present in the field, complete eradication is not possible. The first line of defense for a farmer is protecting the land from infestation. Scandinavian countries have been restrictive in the use of commercial chemical fumigants like organophosphates or carbamate nematicides (Holgado et al. 2010, Hansen 2010). In Norway, nematicides have not been in use since the early 1970s. Standard strategies for nematode management currently include hygiene, fallow, crop rotation with non- host plants between potato crops, plant resistance and weed control.

The use of seed potato free from PCN and other endoparasitic nematodes like *P. penetrans* and *D. destructor*, and a restricted production of seed material on the farm, are important initial steps in avoiding infestations. In Scandinavian EU-member states, the areas of certified seed potato production, and ware potato fields are monitored according to Council Directive 2007/33/EC (EU 2007). In Norway, fields with potato seed production have been monitored for more than 50 years; these areas are so far free of PCN (Holgado and Magnusson 2010). Every year, almost 3000 soil samples are analysed from the Norwegian seed potato production. Regular surveys of ware potato fields and potato delivery stations have been conducted from 1955-1970 and from 2009. There is a restriction on import of seed potato to Norway.

Management strategies aim to prevent nematode multiplication and hence protect the potato crop from damage. Nematode population densities should be monitored on a regular basis and management strategies should keep plant parasitic nematodes at densities below their economic threshold for damage. The growing of resistant varieties is the most successful means of PCN management. However, while resistant cultivars may prevent nematode multiplication, the plants still may suffer from the nematode attacks. In Scandinavian EU member states both species of PCN are controlled with resistant cultivars and crop rotation. In Norway, non-virulent *G. rostochiensis* (Ro1) is managed by crop rotation, while infestations of virulent *G. rostochiensis* (Ro2, Ro3) and *G. pallida* (Pa 1-3) result in a 40-years ban on growing potato in the infested field (Holgado and Magnusson 2010). The consequences of this may by far exceed the actual costs of yield losses, because PCN infestation may result in enforced and expensive farm practices, reduced sales value of the farm, or in the worst case closing down the business. In Norway, *G. rostochiensis* Ro1 is controlled by crop rotation using non-host crops, and alternating susceptible and resistant potato every four years.

Effective management requires reliable information on virulence, decline rates in field population densities and infectivity in the soil. Reliable information is lacking in Scandinavia for all of these points.
It is likely that appropriate management strategies for nematode control would allow for increased yields and better sustainability of potato production in Scandinavia.

Conclusions

- Nematodes cause significant damage to potato in Scandinavia; damage caused by plant parasitic nematodes is generally underestimated by farmers, as symptoms from nematode infection are often less obvious than symptoms caused by many other pests or diseases.
- Management of nematodes must focus on reducing nematode numbers to levels below the damaging threshold, and on the effective management of nematodes between main crops.
- Increased competence in nematology is the only way of stopping the damage from plant parasitic nematodes; correct identification of species and pathotypes is instrumental for efficient control.
- There is a need to increase the awareness of nematodes in the Nordic extension services and among Nordic farmers.
- Government-regulated PCN quarantine in Norway has been helpful in reducing spread of PCN. The strict control of the production of certified seed potato is of particular importance in this.

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