Meloidogyne minor

Photo: Colin Fleming

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INITIATION

STAGE 1: INITIATION		
The aim of the initiation stage is to identify the pest(s) and pathways, which are of phytosanitary concern and should be considered for risk analysis in relation to the identified PRA area.		
Question	**Yes / No / Score**	**Notes**
1. Give the reason for performing the PRA *Go to 2*		*Meloidogyne minor* is a newly described species, causing yellow patches on golf courses in the United Kingdom (UK), Ireland and the Netherlands. In one potato field in the Netherlands, this species caused significant damage. Amongst the experimental hosts are several economically important species. This Pest Risk Assessment investigates whether the organism has the characteristics of a quarantine pest.
2. Specify the pest or pests of concern and follow the scheme for each individual pest in turn. For intentionally introduced plants specify the intended habitats. *Go to 3*		The pest of concern is *Meloidogyne minor Karssen et al. (Meloidogynidae, Nematoda).*
3. Clearly define the PRA area. *Go to 4*		The PRA area is the EU. However, there's currently insufficient data to make a detailed assessment for the entire EU.
Earlier analysis		
4. Does a relevant earlier PRA exist ? *if yes go to 5* *if no go to 7*	**No**	Several risk assessment reports have been written for *Meloidogyne chitwoodi* (*Baker, 1992; Tiilikkala et al, 1995; Braasch et al, 1996)* and *M. fallax* (*Davis and Venette, 2004*). Where applicable, some relevant information from these reports has been used in this PRA.

		Note: M. minor is closely related to M. chitwoodi and M. fallax (sequence pair distance: 88.6 and 88.9% identity respectively (Karssen et al, 2004)). However, the degree to which sequence pair distance information has any relationship with pest attributes is unknown.
Stage 2: Pest Risk Assessment		
Section A: Pest categorization		
Identify the pest (or potential pest)		
6. Is the organism clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank? *if yes indicate the correct scientific name and taxonomic position go to 8* *if no go to7*	**Yes**	The species is a single taxonomic entity and can be identified based on several characteristic features. These features (morphological, host plant and DNA information) are described by Karssen et al (2004). Annex 1 gives an overview of the morphometrics of adult stages and second-stage juveniles (J2) of *M. minor*. <u>Taxonomic Tree</u> Domain:Eukaryota Kingdom:Metazoa Phylum:Nematoda Family:Meloidogynidae Genus:Meloidogyne Species: minor
Confirm pest status (actual or potential)		
8. Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products? *if yes, the organism is considered to be a pest, go*	**Yes**	*M. minor* causes yellow patches on creeping bent grass from golf courses in the UK, Ireland and the Netherlands. The 2000 outbreak of the nematode in a potato field in Zeijerveld (The Netherlands) was an indication that the species can also cause significant damage to potato crops.

to 10

if no, go to 9

Presence or absence in the PRA area and regulatory status

10. Does the pest occur in the PRA area ? **Yes**

if yes go to 11

if no go to 12

11. Is the pest widely distributed in the PRA area? **Probably not (uncertain)**

if not widely distributed, go to 12

if widely distributed, go to 17

Table 1. An overview of the *M. minor* findings in the PRA area (September 2006).

Location	Description	Date finding
UK and Ireland	35 golf courses, 3 football pitches and sand dune habitats[a]	Symptoms observed since 1997
The Netherlands	2 potato fields [b]	2000 and 2005
The Netherlands	6 sports grounds; 1 in and 1 near a coastal dune area [b]	2004 & 2005
The Netherlands	3 golf courses [b]	2005
The Netherlands	5 pasture fields [b]	2005

[a] Info Colin Fleming; [b] survey results Plant Protection Service, the Netherlands

So far, this species has been detected on several golf courses in the UK and Ireland, in the coastal dunes of Ireland and Wales and at some locations in The Netherlands (Table 1). In the UK it has been found on three football pitches. According to our current knowledge of the pest's distribution, *M. minor* may be native in the UK and / or Ireland. The findings in a few pasture fields in The Netherlands are an indication that *M. minor* has been present for quite a long period of time. In the Netherlands, approximately 250 soil samples were taken, mainly from potato fields, pasture land and sports grounds. More surveys within the PRA-area are needed to obtain a more

		accurate picture of the distribution. **Uncertainty:** It is not yet clear how widely distributed *M. minor* is within the PRA area, because this species has only recently been described and surveys have not been carried out in many countries. Comprehensive surveys are needed to obtain more data on distribution.
Potential for establishment and spread in the PRA area		
12. Does at least one host-plant species (for pests directly affecting plants) or one suitable habitat (for non parasitic plants) occur in the PRA area (outdoors, in protected cultivation or both)? *if yes go to 13* *if no go to 17*	**Yes**	Several natural hosts of *M. minor* are widespread in the PRA area, such as creeping bent grass (*Agrostis stolonifera var. stolonifera*) and potato (*Solanum tuberosum*) . Experimental hosts include ryegrass, wheat, barley, oat, carrot and tomato (*Karssen et al, 2004; Fleming 2004, personal communication to G. Karssen*) and are also grown on a large scale in the EU.
13. If a vector is the only means by which the pest can spread, is a vector present in the PRA area? (if a vector is not needed or is not the only means by which the pest can spread go to 14) *if yes go to 14* *if no go to 17*	**Not applicable**	
14. Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive (consider also protected conditions)? *if yes go to 15*	**Yes**	*M. minor* is present in United Kingdom, Ireland and the Netherlands. The exact pest status in these and other EU countries has yet to be determined.

if no go to 17		
Potential for economic consequences in PRA area		
15. With specific reference to the plant(s) or habitats which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area? *if yes or uncertain go to 16* *if no go to 17*	**Yes**	*M. minor* causes yellow patches on creeping bent grass on golf courses in the UK, Ireland and the Netherlands. In the Netherlands, *M. minor* caused significant damage to the potato crop in one field in 2000 and, in 2005, a potato sample from a harvested field resulted in another positive diagnosis. It is possible, however, that the history of these two potato fields contributed to an increase of *M. minor* population levels. Both fields were pasture land for several years prior to the time that potatoes were grown. This might be an indication that *M. minor* does not cause problems in potato crops if these are rotated in a system without pasture land. *M. minor* obviously thrives in grassland habitats, as shown by the problems the nematode causes on golf courses.
Conclusion of pest categorization		
16. ***This pest could present a risk to the PRA area*** *(Summarize the main elements leading to the conclusion that the pest presents a risk to the PRA area)*	**Go to Section B**	*Meloidogyne minor* is a newly described species, causing yellow patches on golf courses in the UK, Ireland and the Netherlands. Furthermore, this species was found in two potato fields in the Netherlands. In one of these fields, the pest caused considerable damage. Its experimental hosts include several economically important host plants. The distribution of *M. minor* in the PRA area (EU) outside the UK, Ireland and the Netherlands is not known. Specific surveys are needed to obtain more data on distribution.

Section B. Assessment of the probability of introduction and spread and of potential economic consequences

1. Probability of introduction

Introduction, as defined by the FAO Glossary of Phytosanitary Terms, is the entry of pest resulting in its establishment.

Probability of entry

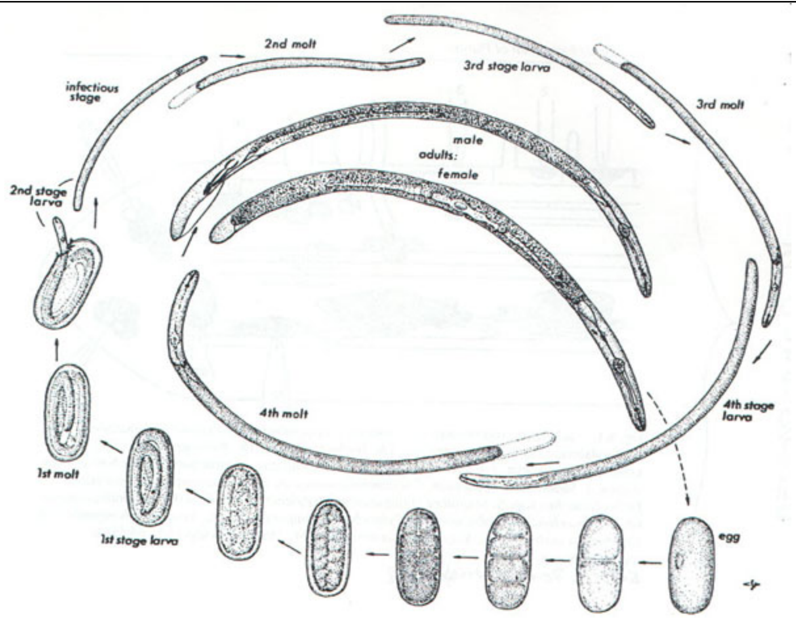
1.1 Consider all relevant pathways and list them. *Relevant pathways are those with which the pest has a possibility of being associated (in a suitable life stage), on which it has the possibility of survival, and from which it has the possibility of transfer to a suitable host* *Go to 1.2*	At this entry section, we have only focussed on those pathways that could cause international movement of *M. minor*. This means movement from the UK, Ireland and / or the Netherlands to other countries in the PRA-area. However, it is uncertain whether *M. minor* is restricted to the above-mentioned countries. The following pathways are assessed in the entry section: Pathways 1) Seed potatoes; 2) Ware and starch potatoes; 3) Traded turf; 4) Golf shoes, golf clubs and sports shoes (athletes, football players) ***Uncertainty:*** *Initial research on host plants has started and several experimental host plants have been identified. However, the natural host plant range might also include other plant species, potentially resulting in a greater number of pathways.* ***Note 1:*** *M. minor has been observed in the dunes of Wales. Virtually all new golf courses in Ireland use coastal sand for construction and weekly maintenance. In addition, many established courses use these sands for weekly maintenance. In the UK, several infested golf courses also used (coastal) sand. There is some international movement of coastal sand but this is*

		considered to be more important for spread within countries. Movement of M. minor in (coastal) sand is assessed in the 'Spread' section of this PRA. ***Note 2:*** Seeds are not a pathway, since root-knot nematodes are not seed borne.
1.2 Estimate the number of relevant pathways, of different commodities, from different origins, to different end uses. *Go to 1.3*	**Few**	
1.3. Select from the relevant pathways, using expert judgement, those which appear most important. If these pathways involve different origins and end uses, it is sufficient to consider only the realistic worst-case pathways. The following group of questions on pathways is then considered for each relevant pathway in turn, as appropriate, starting with the most important. *Go to 1.4*		Pathways • Golf shoes, golf clubs and sport shoes (athletes, football players) • Traded turf • Traded seed potatoes • Traded ware and starch potatoes
Probability of the pest being associated with the individual pathway at origin.		
1.4 Is the prevalence of the pest on the pathway at origin likely to be high, taking into account factors like the prevalence of the pest at origin, the life stages of the pest, the period of the year?	**Very unlikely**	**Seed potatoes** The characteristics of the pest and potato cultivation are such that *M. minor* would be associated with the pathway if present in the field. However, *M. minor* has only been observed once in a potato crop and once in a post-harvest potato sample in the Netherlands, despite the fact that since the description of *M. minor* as a new species, many tuber samples

Go to 1.5		in the UK and the NL, that are routinely tested for other *Meloidogyne* species, have also been tested for *M. minor*.
	Very unlikely	**Ware and starch potatoes** As seed potatoes
	Unlikely	**Turf** *M. minor* has been observed three times on sports grounds in the Netherlands. In one case, turf is the most likely source of infestation. However, soil samples, taken by the turf company that delivered the turf, did not result in the detection of *M. minor.* There is currently no indication for a high prevalence of the pest in turf in the UK, Ireland and the Netherlands. Several golf courses in the UK and Ireland are infested with *M. minor.* Although the usage of (coastal) sand for the construction and maintenance of the golf courses is the most plausible infestation source, it is not impossible that incidentally turf also played a role.
	Unlikely	**Golf shoes, golf clubs and sport shoes (athletes, football players)** Several golf courses in the British Isles and sports grounds in the Netherlands and the UK are infested, but the prevalence of the pest on shoes etc. is likely to be low.
1.5 Is the prevalence of the pest on the pathway at origin likely to be high, taking into account factors like cultivation practices, treatment of consignments? *Go to 1.6*	**Very unlikely**	**Seed potatoes** Once a field is infested with *M. minor*, the species will probably remain present in the field if no control measures are taken. The pest is very likely to be associated with seed potatoes. Just like *M. chitwoodi* and *M.* fallax, females, eggs and infectious second-stage juveniles can be present in tubers. However, as mentioned before, up to now only two findings in potato fields have been reported.
	Very	**Ware and starch potatoes**

	unlikely	As seed potatoes
	Unlikely	**Turf** Cultivation practices during the growing of turf are rolling, fertilizing and mowing. None of these practices will eliminate *M. minor*. The most likely source for the infestations of one football field in the Netherlands was turf. However, there is currently no indication for a high prevalence of the pest in turf in the UK, Ireland and the Netherlands.
	Unlikely	**Golf shoes, golf clubs and sport shoes (athletes, football players)** Because of the yellow patch disease, hygiene measures have been required in some golf courses in the UK but this is by no means universal. No hygiene measures for other sports grounds are known. *Note:* *In Ireland, on infested parts of golf courses that did not show symptoms, a concentration of 200 M. minor eggs / 100 ml soil was measured, while visually infested parts contained more than 2000 eggs / 100 ml soil (Fleming, 2004, unpublished results). In the Netherlands, the concentration of eggs in the infested potato field was comparable to the observations in Ireland on golf courses.*
1.6 How large is movement along the pathway? *Go to 1.7*	**Major**	**Seed potatoes** In 2003, the Netherlands traded 332 thousand tonnes seed potatoes to EU countries (UK and Ireland excluded). The UK exported 35 thousand tonnes seed potatoes to EU countries (Irelanc and the Netherlands excluded), while Ireland exported 15 tonnes (Eurostat, 2005).
	Massive	**Ware and starch potatoes** The quantities of traded ware and starch potatoes from The Netherlands, UK and Ireland to

		other EU-countries are greater compared to seed potatoes.
	Minor	**Turf** Turf companies usually sell their product locally or nationally, but several companies in the Netherlands and the UK are known to trade turf to other countries occasionally, for example for the usage on football pitches. Detailed export figures are lacking.
	Major	**Golf shoes, golf clubs and sport shoes (athletes, football players)** There is considerable international movement of golfers, athletes, etc.
1.7 How frequent is the movement along the pathway? *Go to 1.8*	**Often**	**Seed potatoes** Most seed potatoes are traded within the EU from November – April, although there is also some trade earlier and later in the season (Eurostat, 2005).
	Very often	**Ware and starch potatoes** Trade occurs throughout the year.
	Occasionally	**Turf** See 1.6
	Very often	**Golf shoes, golf clubs and sport shoes (athletes, football players)** There is considerable year-round international movement of golfers and football players.
Probability of survival during transport or storage		
1.8 How likely is the pest to survive during transport / storage? *Go to 1.9*	**Very likely**	Other *Meloidogyne* spp such as *M. chitwoodi* are able to survive transit on all suitable pathways (Tiilikkala *et al,* 1995). There is no reason to assume that *M. minor* is not able to survive in transit. For example, in growing media, such as sand, the nematode could survive

		as egg masses.
1.9 How likely is the pest to multiply / increase in prevalence during transport / storage? *Go to 1.10*	**Very unlikely**	 **Figure 1. Life-cycle of *Meloidogyne minor*** Although the results from the Dutch (PPO) research are not yet known, the development from egg to egg takes somewhat longer for *M. minor* than *M. chitwoodi* and *M. fallax*. Depending on the soil temperature and the length of the growing season (the period during which air temperatures exceed a given base temperature) *M. chitwoodi* can complete 3-5 generations per year (Tiilikkala *et al,* 1995). Most likely, *M. minor* will be able to complete 1 - 2 generations at maximum in the PRA area (*G. Karssen, 2004, Plant Protection Service, NL, interpretation of preliminary research results*).
Probability of the pest surviving existing pest management procedures		

1.10 How likely is the pest to survive or remain undetected during existing phytosanitary procedures? *Go to 1.11*		Research by the Dutch PPO has proven that *M. minor* by itself is able to cause typical *Meloidogyne* galls. However, symptoms caused by *M. minor* might be confused with the symptoms caused by other root-knot nematodes. Moreover, the name of the pest fits its size: *M. minor* is a relatively small root-knot nematode. The average body-length of a second-stage juvenile of *M. minor* is 377 µm (310-416) (*Karssen et al, 2004*). The average size of second-stage juveniles of *M. chitwoodi* and *M. fallax* is 390 µm (360-435), *M. naasi* 421 µm (410-450) and *M. hapla* 413 µm (357-467) (*Karssen, 2002*). Therefore, *M. minor* might be overlooked if a soil sample contains both *M. minor* and another (larger) *Meloidogyne spp*, especially if there are relatively few *M. minor* specimens present. In samples that have been tested so far, *M. minor* is often present in combination with *M. naasi.* In such cases, the symptoms are most likely to have been caused by both *M. minor* and *M. naasi*.
	Likely	
		Seed potatoes Symptoms caused by *M. minor* might be confused with the symptoms caused by other *Meloidogyne* species or other nematodes species in general. However, it is quite likely that a moderate to heavy '*Meloidogyne* – infestation' will be recognized during an inspection or test. In light infestations, symptoms are not readily seen. If the infestation is *new*, the females are still immature, opaque and difficult to see in tubers, while galls on roots are less prominent.
	Very likely	
		Ware and starch potatoes There are no specific phytosanitary requirements for ware and starch potatoes within the EU, resulting in the (likely) detection of *M. minor*.
	Very likely	
		Turf No specific phytosanitary procedures are currently undertaken for turf.
	Very likely	

		Golf shoes, golf clubs and sport shoes (athletes, football players) Boot washing is required on some UK golf courses, but this is by no means official nor universal. No hygiene measures are known for football or other sports on outdoor sports grounds.
Probability of transfer to a suitable host or habitat		
1.11 In the case of a commodity pathway, how widely is the commodity to be distributed throughout the PRA area? *Go to 1.12*	**Very widely**	**Seed potatoes** Seed potatoes from the United Kingdom and the Netherlands are distributed throughout the EU (Eurostat, 2005).
	Very widely	**Ware and starch potatoes** Especially ware potatoes are distributed throughout the EU.
	Moderately widely	**Turf** Some large grass turf companies (mainly for sports grounds) export their products to other countries. However, usually these companies have a regional or local market.
	Very widely	**Golf shoes, golf clubs and sport shoes (athletes, football players)** Golf courses and football pitches are almost ubiquitous.
1.12 In the case of a commodity pathway, do consignments arrive at a suitable time of year for pest establishment? *If yes, go to 1.13*	**Yes**	Golf players travel throughout the year. Also potatoes are exported year-round. The optimal period for 'placing' grass turf is August – October, although this is also done in other periods of the year.
1.13 How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?	**Very likely**	All pathways are directly linked with suitable hosts / habitats: **Seed potatoes**

Go to 1.14		Infested seed potatoes will (most likely) infest the field in which they are planted, resulting in transfer of the pest to the progeny tubers and other plants (weeds) in the field.
	Unlikely	**Ware and starch potatoes** Waste material (soil) can be distributed on agricultural fields or fed to cattle (tubers). This might result in the transfer from infested ware and starch potato lots to suitable hosts.
	Very likely	**Turf** Infested turf will most likely result in an infested field with symptoms.
	Very likely	**Golf shoes, golf clubs and sport shoes (athletes, football players)** Spiked golf shoes and clubs directly enter the soil surface. Soil adheres to football boots.
1.14 In the case of a commodity pathway, how likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat? *Go to 1.15*	**Very likely**	See answer to question 1.13
1.15 Do other pathways need to be considered? *If no, go to conclusion on the probability of entry*	**No, not at the moment**	If other natural hosts are identified, these might become pathways of importance.
Conclusion on the probability of entry		
Describe the overall probability of entry and identify the risks presented by different pathways		The most important pathway for international movement from one golf course / sports field to another is most likely to be on golf shoes and clubs, football and other sports shoes. The prevalence of *M. minor* on this pathway is likely to be very low, but there is considerable

Go to 1.16	international movement of golf players, athletes, etc. International movement with turf is also possible, although the international trade volume is small and there is currently no evidence that turf producing sites are infested. Up to now, only two potato fields are known to be infested, despite numerous tests in countries where *M. minor* is known to be present. Therefore, the risk of movement of *M. minor* with (seed, ware and starch) potatoes is currently estimated as very low.

Probability of establishment

Availability of suitable hosts or suitable habitats, alternate hosts and vectors in the PRA area

1.16 Specify the host plant species (for pests directly affecting plants) or suitable habitats (for non parasitic plants) present in the PRA area.

Go to 1.17

Table 2. Host plants for *Meloidogyne minor* (situation October 2005)

Common name	Latin name	Experimental or natural host?	Source
Potato	*Solanum tuberosum*	natural	1
Creeping bent grass	*Agrostis stolonifera var. stolonifera*	natural	1
Red clover	*Trifolium pretense*	natural	2
White clover	*T. repens*	natural	2
Timothy	*Phleum pratense*	natural	2
Tall fesque	*Festuca spp.*	natural	2
Tomato	*Lycopersicon esculentum*	experimental	1
Carrot	*Daucus carota*	experimental	1
Phacelia	*Phacelia tanacetifolia*	experimental	1
Alfalfa	*Medicago sativa*	experimental	1
Italian ryegrass	*Lolium multiflorum*	experimental	1
Perennial ryegrass	*Lolium perenne*	experimental	1
Oat	*Avena sativa*	experimental	1
Lettuce	*Lactuca sativa*	experimental	1
Vetch	*Vicia sativa*	experimental	1
Wheat	*Triticum sativum*	experimental	2
Barley	*Hordeum vulgare*	experimental	2

Source: 1. *Karssen et al (2004)* 2. *Fleming (2004, unpublished results)*

Karssen *et al* (2004) found that potato and the grass species *Agrostis stolonifera* var. *stolonifera*, which is used in golf courses, are known to be host plant species for

		Meloidogyne minor. In additional hosts tests at Wageningen University and Research centre (WUR), *Meloidogyne minor* reproduced on carrot, phacelia, alfalfa, Italian ryegrass, perennial ryegrass, oat, lettuce, tomato, vetch, clover and potato, but failed to reproduce on marigold and maize (*unpublished data*). Fleming (*2004, Department of Applied Plant Science (APS), The Queen's University of Belfast, unpublished results*) found that red clover, white clover, timothy and tall fesque are natural hosts, while barley and wheat, are experimental host plants.
1.17 How widespread are the host plants or suitable habitats in the PRA area? (specify) *Go to 1.18*	**Very widely**	Potato, a natural host of *M. minor,* is extensively grown in the EU. Creeping bent grass (*Agrostis stolonifera var. stolonifera*) is one of the other natural hosts. This grass species is widespread in the PRA area. It is grown as a pasture grass and it is the most utilized species for golf courses in temperate regions worldwide (www.aphis.usda.gov/peer_review/peer_review_plan_creeping_bentgrass.html) and on sports grounds. The number of golf courses is increasing in several parts of the PRA area (www.golfeurope.com). The experimental hosts also include extensively grown commercial crops, like tomato and barley.
1.18 If an alternate host is needed to complete the life cycle, how widespread are alternate host plants in the PRA area? (not relevant for plants) *Go to 1.19*	**Not applicable**	
1.19 If the pest requires another species for critical stages in its life cycle such as transmission, (e.g. vectors), growth (e.g. root symbionts), reproduction (e.g. pollinators) or spread (e.g. seed dispersers) how likely is the pest to become associated with such species?	**Not applicable**	

Go to 1.20

Suitability of the environment		
1.20 How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the area of current distribution? *Go to 1.21*	**Moderately similar**	Climatic conditions in the countries where *M. minor* is present (United Kingdom, Ireland and the Netherlands) are similar to other north-western EU countries with temperate climates, i.e relatively damp mild winters and warm summers. Although in only a few locations, the species is widely distributed in the British Isles and there is no apparent climatic limit to its distribution. It is difficult to predict the suitable climatic range of *M. minor* in the rest of the PRA area with the current stage of knowledge. It is possible that cold winters in Northern and Central Europe will restrict its distribution. The hot, dry summers in Mediterranean climates may also limit distribution, but putting greens and sports grounds will generally be well watered, so the lack of summer rainfall may not be important. Rainfall is important for symptom expression: infested golf courses tend to show initial annual symptoms a few days after heavy rain. Following the first heavy rains of the year (April), turf managers all tend to see the symptoms within a few days of one another (Dr K. Entwistle, 2005, The Turf Disease Centre, Bramley, personal communication to Wiebe Lammers; Entwistle, 2003b). *<u>Uncertainty</u>* There is currently too little knowledge of the species distribution. Moreover, species living in the soil have a different microclimate to that recorded at weather stations and establishment may depend on currently unknown soil physical attributes. If the coastal region of the British Isles is the area of origin for this species, this could be an indication that *M. minor* is vulnerable to cold winters. However, the species is observed at inland sites in the Netherlands, locations that in some years face relatively cold winters. Despite all these uncertainties, a rough climatic comparison was made, using the climatic data from Cork, a county where *M. minor* was observed, as a reference. It shows that a large part of Europe has more or less similar climatic conditions (Annex 2). Also a CLIMEX study for

		M. minor was carried out by G. Karssen of the Dutch Plant Protection Service. Species living in the soil have a different microclimate to that recorded at weather stations and establishment may depend on soil physical attributes, making CLIMEX a (much) less useful tool. The results of the CLIMEX study are no more than a rough indication that *M. minor* might be capable of surviving in other parts of Europe (Annex 2). The CLIMEX parameters are partly based on the available temperate template with a slight adaptation of the temperature data as deduced from a greenhouse experiment. The calculation is based on one generation only. Therefore, the presented figure might be the minimal potential distribution for Europe.
1.21 How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the area of current distribution? *Go to 1.22*	**Moderately similar**	As with many other nematode species, root-knot nematodes do not persist readily in fine-textured clay mineral soils (*Potter and Olthof, 1993*). According to Braasch *et al* (1996), *Meloidogyne* spp. can occur on a wide range of soil types, but their association with crop damage is mainly observed in sandy soils. Both observations indicate that areas with coarse-textured (sandy) soils in the EU are the high-risk areas for *M. minor*. These sandy soils are present throughout the EU (Annex 3). Generally, sports grounds and golf course greens are constructed with a high percentage of sandy soil. in order to provide adequate drainage and improve aeration. Recommendations by the United States Golf Association (USGA) for the construction of putting greens on golf courses include a minimum of 60% sandy soil in the rootzone (http://www.usga.org/turf/articles/construction/greens/recommendations.html).
1.22 (Answer this question only if protected cultivation is important in the PRA area.) How often has the pest been recorded on crops in protected cultivation elsewhere?	**Never**	*M. minor* has never been reported from protected cultivation, apart from experimental situations.

Go to 1.23		
1.23 How likely is establishment to be prevented by competition from existing species in the PRA area? *Go to 1.24*	**Very unlikely**	*M. minor* is likely to have competition from *M. naasi* in fields with host plant grass species (golf courses, pasture land), because *M. naasi* is a known parasite of monocotyledonous species (*CAB International, 2004; Cook et al, 1992*) and is widespread in Europe (*Jepson, 1987; Cook and Yeates, 1993; Rivoal and Cook, 1993*). However, the presence of *M. naasi* in the PRA area will not prevent establishment of *M. minor.* In potato fields, *M. minor* will not have competition from *M. naasi*, but could have competition from *M. chitwoodi* , *M. fallax* and *M. hapla*, if these nematodes are present in the same field. *M. chitwoodi* and *M. fallax* are less common in the PRA area than *M. naasi*. *M. minor* might also face some competition from potato cyst nematodes, which infest potato roots, and root lesion (*Pratylenchus* spp.) or stubby root (*Paratrichodorus* and Trichodorus) nematodes common in potato fields. However, again, it is very unlikely that these will prevent the establishment of *M. minor*.
1.24 How likely is establishment to be prevented by natural enemies already present in the PRA area? *Go to 1.25*	**Very unlikely**	The pest has already proven that it is able to establish in parts of the PRA area. ***Uncertainty*** It is unknown whether *M. minor* has any natural enemies. However, some spores of the fungus *Pasteria* were found on second-stage juveniles of *M. minor* in a sample originating from UK coastal dunes (*G. Karssen, 2004, Plant Protection Service, NL, unpublished data*). *Pasteria* is a known parasite for nematodes (*Poinar & Jansson, 1988*).
Cultural practices and control measures		
1.25 To what extent is the managed environment in the PRA area favorable for establishment?	**Highly favorable**	The time of the year that host plant crops are grown, soil preparation, method of planting, irrigation practices, and the time and method of harvest do not seem to stop other *Meloidogyne* species from establishing in parts of the PRA area. It is likely that these factors

Go to 1.26		will also not prevent establishment of *M. minor*. The continuous availability of food is an important factor in the population development of nematodes. If host plants are grown during winter, this may favour the population development (*Braasch et al*, 1996). Therefore, in areas (or lots) where bare fallow is used, *M. minor* might have a harder time to establish over a longer period of time.
1.26 How likely are existing control or husbandry measures to prevent establishment of the pest? *Go to 1.27*		In general, control measures against other nematodes, such as crop rotation, green-manure cover crops and nematicides may reduce population levels but are not likely to prevent establishment.
	Unlikely	**Cultivation of potato** Control measures against other nematodes, such as crop rotation, green-manure cover crops and nematicides may reduce population levels but are not likely to prevent establishment. On the contrary, appropriate action against other nematode infestations could sometimes even result in an increase of *M. minor* population levels. Prior to the *M. minor* observations on two Dutch potato fields, pasture grass was grown on these two fields for many years. This probably resulted in an increase of the *M. minor* populations, which may have already been present in these fields for a long time.
	Unlikely	**Cultivation of turf** Cultivation practices during the growing of turf are rolling, fertilizing and mowing. None of these practices will prevent *M. minor* from establishing.
	Very unlikely	**Golf courses and other sports grounds** The presence of *M. minor* on several golf courses and sports grounds indicates that general husbandry measures do not prevent the establishment of the species.

		Uncertainty At present, it is uncertain whether any control measures are very effective against *M. minor*.
1.27 How likely is it that the pest could be eradicated from the PRA area ? *Go to 1.28*	**Very unlikely**	*M. minor* is already present in several locations in the PRA area, including some coastal dune areas of Ireland and Wales. Eradication programmes in these habitats are, for several reasons, not likely to be successful. Defining outbreaks, monitoring and surveillance will be very difficult. The success of detecting infestations of *M. minor* depends heavily on the amount and intensity of sampling that can be conducted. The current situation in the PRA area is most likely that only few fields are infested and most of the time population levels within infested fields are also low. To discover these infestations reliably, a large number of fields would need to be sampled and the number of sample cores per field would also have to be high, while nematode lab testing of soil samples takes a lot of time. Draconian measures such as soil sterilization by methyl bromide or steam, fallow or the growing of a non-host during many years could eradicate *M. minor* in the known infested cultivation areas, but it is very unlikely that such measures would be used and latent infestations will still be overlooked.
Other characteristics of the pest affecting the probability of establishment		
1.28 How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment? *Go to 1.29*	**Very likely**	Research has shown that *M. minor* usually reproduces by facultative meiotic parthenogenesis (Karssen *et al*, 2004). Therefore, one second-stage juvenile can start a new population. It is likely that *M. minor* is able to complete 1 – 2 generations under field conditions in the PRA area. Preliminary research results are that the life cycle of *M. minor* takes somewhat

		longer than *M. chitwoodi* and *M. fallax*.
1.29 How likely are relatively small populations or populations of low genetic diversity to become established? *Go to 1.30*	**Very likely**	One second-stage juvenile can start a new population. Moreover, *Meloidogyne* spp females are able to lay 100 – 500 eggs (*CAB International, 2004; Enneli and Toros, 1996*). According to Santo (1994), one *M. chitwoodi* female is capable of laying 200 – 1,000 eggs. Combined with the most likely absence of specific natural enemies and the fact that *M. minor* is able to reproduce on monocotyledonous and dicotyledonous species, this makes it likely that small populations of *M. minor* are likely to establish in a new area.
1.30 How adaptable is the pest? *Go to 1.31*	**Adaptability is low - medium**	A characteristic of parthenogenetic *Meloidogyne* species is their genetic stability (*Eisenback & Hirschmann-Triantaphyllou, 1991*). All populations from NL, UK and IR studied have been found to be genetically identical. This could either be an indication of recent introductions (from one source) or, more likely, a high degree of genetic stability. However, a genetically stable organism can be adaptable, as seen by wide host range, distribution in many habitats, resistance to nematicides, etc.
1.31 How often has the pest been introduced into new areas outside its original area of distribution? (specify the instances , if possible) *Go to 1.32*	**Very rarely**	According to our current knowledge of the pest's distribution, *M. minor* may be native in the UK and /or Ireland. The observations in a few pasture fields in the Netherlands suggest that the species has also been present for quite some time in parts of the Netherlands as well. However, more surveys in sand dunes, golf courses, sports grounds, pasture and potato crops in the entire PRA-area are needed to obtain a more accurate picture of the distribution of *M. minor*.
1.32 Even if permanent establishment of the pest is unlikely, how likely are transient populations to occur in the PRA area through natural migration or entry through	**Not applicable**	

man's activities (including intentional release into the environment) ? *Go to 1.33*		
Probability of spread		
1.33 How likely is the pest to spread rapidly in the PRA area by natural means? *Go to 1.34*	**Very unlikely**	**Natural movement in soil** The capacity of *M. minor* for natural movement is very low and comparable to other *Meloidogyne* species; according to *Tiilikkala* (1995), free-living *M chitwoodi* larvae can move 1-2 m at maximum.
	Unlikely	**Natural drainage / run-off / flood water** It is possible that *M. minor,* like other nematodes, can be spread on a limited scale throughout a field and between fields by natural drainage, water run-off and flood water. In the UK, it has sometimes (but not always) been observed that the yellowing symptoms progress along the direction of water movement on greens with slopes or natural run-off patterns. However, on most infested greens, water movement is not an important factor in determining spread and there is no real evidence of spatial distribution of the affected patches (Dr K. Entwistle, 2005, The Turf Disease Centre, Bramley, personal communication to Wiebe Lammers).
	Unlikely	**Wind-dispersal** Because *M. minor* is known to be present in some coastal dunes in Ireland and Wales, it is possible that wind dispersal may play a role in the natural spread of *M. minor* to nearby suitable habitats (i.e. golf courses or other fields with host plants). According to L. van Duijn (2005, The Rijnland District Water Control Board, personal communication to Wiebe Lammers) and B. Arens (2005, bureau voor Strand- en Duinonderzoek, personal communication to Wiebe Lammers), the management and vegetation in the Dutch dunes prevents long-distance spread (more than a few hundred meters) of dune sand by the wind.

		The coastal sand that is being blown away by the wind is mostly beach sand and not dune sand. Small dust particles can be spread over a longer distance (B. Arens, 2005). This situation is probably similar to other countries in the PRA area. De Rooij-van der Goes *et al* (1997) proved that aeolian transport of sand from the root zone of *Ammophila arenaria* – the dominant sand trapping plant species in the European coastal foredunes – may reduce the number of pathogenic soil organisms significantly. They stated that it is likely that the scouring of soil particles probably destroys free-living nematodes between the sand particles. However, cyst nematodes (*Heterodera* spp) and root-knot nematodes (*Meloidogyne maritima*) did not seem to be negatively affected. It is possible that small amounts of wind-dispersed infested (coastal) sand are capable of infesting suitable habitats, such as golf courses, sports grounds, etc., within a few hundred meters distance.
1.34 How likely is the pest to spread rapidly in the PRA area by human assistance? *Go to 1.35*	**Likely**	**(Non) coastal sand for the construction and maintenance of golf courses** *M. minor* is already present in some coastal dune areas in Ireland and Wales, but the prevalence is likely to be low. Coastal sand is often used in construction, and also for the creation and the day-to-day maintenance of golf courses. For example in Ireland, thousands of tonnes of coastal sand are extracted and transported throughout Ireland each year. Therefore, coastal sand is a possible source of infestation for several golf courses in the UK and Ireland. If *M. minor* is present in other coastal dune areas in the EU as well, this particular spread risk would also exist in other countries if coastal sand is being used for the construction and maintenance of golf courses. In The Netherlands, however, the situation is somewhat different from Ireland, since most coastal dune areas are official nature areas and sand from

		these areas cannot be used for other purposes. Only occasionally, coastal sand can be used for the construction of golf courses (L. van Duijn, 2005, The Rijnland District Water Control Board, personal communication to Wiebe Lammers). In the UK, several infested golf courses have used sand from non-coastal sites, thus raising the possibility that *M. minor* is not restricted to coastal sites.
	Moderately likely	**Machinery** If *M. minor* is present in the soil, the unintended movement of attached soil to machinery can result in the spread of the nematode to other suitable habitats. On golf course greens, for example, aeration machinery is used extensively and the machinery normally shifts operation from green to green, potentially leading to the spread of nematodes.
	Very likely	**Pathways mentioned at Entry section** The pathways that were discussed in the entry section can also spread *M. minor*: ✓ Golf shoes, golf clubs and sports shoes (athletes, football players) ✓ Traded turf ✓ Traded seed potatoes At the moment, the possibility of spreading *M. minor* by golf players seems to be the most important means of spread. Some golf courses in the UK and Ireland require compulsory shoe cleaning as a means of limiting spread. ***Uncertainty*** It is uncertain whether many of the infestations in the UK, Ireland and the Netherlands are the result of any of the above-mentioned (non-)natural means of spread. *M. minor* might already have existed in many of these infested sites for a long period of time. Changes in

		management (of golf courses) may have resulted in damaging and thus noticable population levels of *M. minor*.
1.35 How likely is it that the spread of the pest could be contained within the PRA area? *Go to Conclusion on the probability of introduction and spread*	**Unlikely**	In order to prevent spread between golf courses, cleaning of golf shoes, golf clubs and football boots would have to be made compulsory. This would be very difficult to enforce. In agricultural areas, spread can be contained in fields by taking appropriate hygienic measures (cleaning machinery, etc) and prohibit the transportation of soil and infested propagation material. However, total prevention of spread of latent infestation, especially by turf or seed potatoes will be almost impossible with the techniques available. The intensity of soil sampling in suspected areas will determine the success ratio, but a 100% watertight system is not feasible. The trade in infested seed potatoes would need to be prohibited.

Conclusion on the probability of introduction (= entry + establishment) and spread

Describe the overall probability of introduction and spread. The probability of introduction and spread may be expressed by comparison with PRAs on other pests. *Go to 1.36*		**Introduction** International movement of *M. minor* from one golf course / sport field to another golf course / sports ground is possible on golf shoes and golf clubs (or other sports shoes), since there is considerable international movement of golf players and several golf courses and sports grounds are known to be infested. The prevalence of *M. minor* on this pathway is very likely to be low. However, since even one second-stage juvenile can start a new population and *Meloidogyne* spp females are able to lay many eggs, even very small population levels are likely to result in establishment. Especially since most golf courses and sports grounds are constructed with sandy soil, an environment preferred by root-knot nematodes. Movement of *M. minor* with turf is also possible. If *M. minor* is associated with this pathway, establishment of *M. minor* on golf courses and other sports grounds is very likely. However, the prevelance of the pest on turf is probably very low at the moment and international trade

	volumes are low. The same goes for seed potatoes. **Spread** *M. minor* may spread nationally or regionally level in several ways. The most important means of spread is probably the use of infested coastal sand or sand from inland pits for the construction of golf courses. The levels and pattern of infection on many UK golf courses suggest that these became infested in such a way (observation Colin Fleming). Also, the use of infested turf may spread the nematode. On a local scale, *M. minor* can spread by wind, soil attached to machinery, drainage water, water run-off, etc. If one or several production fields of, e.g. (seed) potatoes, became infested, the movement of machinery and the trade of seed potatoes may lead to establishment of *M. minor* in larger parts of these production areas.
Conclusion regarding endangered areas	
1.36 Based on the answers to questions 1.16 to 1.35 identify the part of the PRA where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area. *Go to 2 Assessment of potential economic consequences*	At the moment, golf courses and sports grounds constructed with sandy soil are the high risk habitats. Other endangered areas in the EU are most likely the fields where host plants are grown on coarse sandy soils (Annex 3). The history of the two Dutch fields where *M. minor* was found in potatoes suggest that potatoes are mainly at risk when grown following pasture land.

2. Assessment of potential economic consequences

Pest effects

2.1 How important is the effect of the pest on crop yield and/or quality to cultivated plants or on control costs caused by the pest within its area of current distribution? *Go to 2.2*	**Minor**	There are only a few outbreaks of *M. minor* reported in NL, UK and IR. Consequently, there are no quantitative data available on damage levels and economic impact. **Golf courses (and sports grounds)** Since 1997, over 35 golf courses in the UK and Ireland showed unusual patches of yellowing turf grass across the surface of putting greens. The symptoms are patches of yellowed turf grass approximately 30 cm in diameter, developing from April, a couple of days after torrential rain, and persisting until November each year. At first, it was believed that a fungus caused these symptoms. However, experiments proved that the causal agent was the previously unknown *Meloidogyne*-species *Meloidogyne minor*. High-density populations have now been shown to cause loss of turf density and increased wear and tear. This results in a quite dramatic visual effect (due to the extent of patch development across affected greens) and significant damage to the turf from normal play. 'Normal play' is favored by a beautiful turfgrass and a *smooth, fast* and *consistent* playing surface. This is especially true on putting greens *(Crow, 2005)*. In general, nematode development and damage is often favoured by sandy soils (Braasch *et al* 1996; Crow, 2005; Report on Plant Disease, 1993). Since many putting greens are constructed of over 90% sand content, this is a very good habitat for plant-parasitic nematodes (Crow, 2005), such as *M. minor*. This is confirmed by the observation that damage occurs almost exclusively on new courses or newly constructed / reconstructed existing courses with USGA or high sand rootzones. This might be an indication that *M.*

minor was already present on these courses and becomes dominant after the construction / reconstruction with USGA or high sand rootzones and seeded with a non-native grass. The patches return to the affected greens every year, but have been seen to reduce in severity following several years of maintenance post-construction, suggesting that the increasing rootzone diversity is reducing the 'dominance' of the *Meloidogyne minor* (Entwistle, 2003a; 2003b; 2003c; Entwistle, personal communication to Wiebe Lammers, 2005).

Currently, a relatively low number of golf courses is known to be infested; in total, about 2,600 golf courses are present in the British Isles (www.golfeurope.com/clubs/europe.htm). In The Netherlands, at least 545 golf courses are present (www.golfscores.nl). It is likely that the number of infested golf courses increases in the future if no (hygienic) measures are taken to prevent further introductions and spread.

Golf course greenkeepers may apply additional foliar nutrients (see 2.9) to reduce symptom expression and some courses may provide shoe/equipment washing facilities but the costs of this are very small in relation to total budgets. Additional costs of control and symptom suppression can be paid for by increased fees to golfers.

Minimal

Potatoes

Up to now, *M. minor* has only been observed twice in potatoes in the Netherlands. In one of these cases, quite severe underground and above ground *Meloidogyne* symptoms were present. There are no data from this specific field on yield losses. In both cases, pasture grass was grown on the fields for several years prior to the potato cultivation. This probably resulted in an increase of the *M. minor* populations, which could be an indication that *M. minor* only causes problems on crops like potato if high population levels are reached in the previous years on pasture land (*Agrostis stolonifera* is often grown as a pasture grass). However, the cultivation of potato after pasture land is no uncommon practice (in The

		Netherlands and the UK). **Other host crops** *M. minor* has not yet been observed in other cultivated crops.
2.2 How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area? *Go to 2.3*	**Minor** **Minor / moderate**	**Golf courses (and sports grounds)** Looking at the possibilities for entry, establishment and spread of *M. minor*, it is very likely that infestations will occur on golf courses in the PRA-area besides those in the UK, Ireland and the Netherlands. **Potato** *M. minor* can cause damage in potatoes, but it remains questionable how high damage levels could be if the species establishes widely in potato areas. It is believed that mainly potatoes grown after pasture land on sandy soils in warm summers can suffer damage. In general, the economic importance of most root-knot nematodes is related to yield reduction, growth reduction and deformation or similar kinds of damage to host crops, which reduces the marketability of produce (*Davis and Venette, 2004; Potter and Olthof,* 1993). In potato, symptoms of *M. chitwoodi* are more apparent in some cultivars than in others. Tubers may be infected without visible symptoms. When present, galls appear as small swellings on the tuber surface and the internal tissue underneath the gall is necrotic and brownish (*CAB International, 2004*). Just like with other root-knot nematode species*, M. minor* could cause mainly quality damage to certain potato varieties, as shown by one infested potato field in the Netherlands and a small greenhouse experiment that was carried out in The Netherlands to verify if *M. minor* enters and damages potato tubers. The trial tubers were heavily infested with *M. minor* and showed typical *Meloidogyne* gall symptoms (*R.J. Bolk, 2004, PPO, personal communication to G. Karssen*). Because of symptoms, potatoes

		would need to be peeled thicker and more soil would adhere to the tubers. In one region in the Netherlands, ware potato lots are sometimes rejected for industrial processing (peeled fresh potatoes, vacuum packed potatoes, etc), if *M. chitwoodi* damage levels reach a certain threshold. The processing industrial companies in this region currently require that fields are tested for *M. chitwoodi* prior to the cultivation of the ware potatoes (and carrots and Scorzonera as well). Since this requirement, the number of rejected lots has decreased. ***Uncertainties*** On new or newly (re)constructed golf courses, patches return to the affected greens every year, but have been seen to reduce in severity following several years of maintenance post-construction. This suggests that the increasing rootzone diversity is reducing the 'dominance' of *M. minor* or that *M. minor* is quite sensitive to competition of other (nematode) species. Other nematode species present in potato fields might generally outcompete *M. minor*, but this is uncertain. It is uncertain if potatoes suffer damage if grown in a ‘normal’ rotation scheme without pasture.
2.3 How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area? *Go to 2.4*	**Minor** **Minor / Moderate**	**Golf courses** Golf course greenkeepers may apply additional foliar nutrients (see 2.9) to reduce symptom expression and some courses may provide shoe/equipment washing facilities but the costs of this are very small in relation to total budgets. **Potato** *M. minor* can cause damage in potatoes, but it remains questionable how high damage levels could be if the species establishes widely in potato areas. In general, the economic impact from nematodes is probably underestimated (*Davis and Venette, 2004*). In Washington (USA),

		70 - 80% of the potato acreage receives nematicide treatments to control *M. chitwoodi* and *M. hapla* at an annual cost of $20 million.
2.4 How great a reduction is the pest likely to cause on consumer demand in the PRA area? *Go to 2.5*	**Minimal**	There are no indications that *M. minor* would reduce consumer demands significantly. For other *Meloidogyne* species, the main impacts are related to producer profits (reduced yields and market values) and environment (use of nematicides). *M. minor* infested golf courses are less *appealing* (lower 'quality') and might result in lower visitor numbers or a shift of golf players from one course to another. However, this is speculative.
2.5 How important is environmental damage caused by the pest within its area of current distribution? *Go to 2.6*	**Minimal**	Currently, the species is not widely distributed and it is does not have to be controlled on commercial sites. Consequently, there are no or minimal negative effects to the environment of applied chemicals. Moreover, the use of nematicides on amenity turf to control *M. minor* is not allowed in the UK and Ireland (*Entwistle, 2003b)*.
2.6 How important is the environmental damage likely to be in the PRA area? *Go to 2.7*	**Minimal**	It is likely that the use of (available) nematicides would increase if *M. minor* establishes in larger parts of the PRA area and if the use of nematicides on for example amenity turf is allowed. However, chemicals are already being applied on golf courses against other pests and weeds, since for example eight fungicidal, seventeen herbicidal and one insecticidal active ingredients are approved for use on golf courses in the UK (www.stri.org.uk/pdf/Pesticide%20review.pdf). The additional environmental pressure, therefore, would probably be limited. In general, newly established species may reduce biodiversity, disrupt ecosystems, stimulate the use of chemical control etc. In Washington (USA), 70 - 80% of the potato acreage receives nematicide treatments to control *M. chitwoodi* and *M. hapla* at an annual cost of $20 million

		(*Santo, 1994*).
2.7 How important is social damage caused by the pest within its area of current distribution? *Go to 2.8*	**Minimal**	At the moment, there are no indications that *M. minor* causes social damage.
2.8 How important is the social damage likely to be in the PRA area? *Go to 2.9*	**Minimal**	Increased application of nematicides will increase side effects on environment and humans. This process is undesirable. However, increased applications will only be permitted if side effects are acceptable.
2.9 How easily can the pest be controlled in the PRA area? *Go to 2.10*	**With some difficulty**	**Golf courses** In the UK and Ireland, where currently the most infested golf courses are present, the use of nematicides on amenity turf is not allowed to control *M. minor*. Short-term masking of symptoms can be done by foliar applicants of nutrients. This is not a control option, but can reduce symptom expression for a couple of weeks. The foliar application bypasses the damaged roots in order to sustain sufficient growth to prevent loss of turf cover during the summer months (*Dr K. Entwistle, 2005, The Turf Disease Centre, Bramley, personal communication to Wiebe Lammers; Entwistle, 2003b*). Damage is almost exclusively observed on new courses or newly constructed / reconstructed existing courses with USGA or high sand rootzones. Damage could be prevented by using soils with a lower percentage of sandy soil. However, this would result in other unwanted side-effects.
	With much difficulty	**Potato (or other possible host plants)** Control strategies based on the growing of non-hosts or resistant (trap) crops (or cultivars) in

		a crop rotation system are most effective. However, at present only few crops are known on which *M. minor* is not able to multiply: Tagetes and maize (Karssen *et al*, 2004). The application of nematicides primarily reduces the impact of *M. minor*, but limits multiplication insufficiently in combination with a host crop. The application of nematicides is only a supportive measure in combination with appropriate crop rotation. ***Uncertainty*** On new or newly (re)constructed golf courses, patches return to the affected greens every year, but have been seen to reduce in severity following several years of maintenance post-construction. This suggests that the increasing rootzone diversity is reducing the 'dominance' of *M. minor* or that *M. minor* is quite sensitive to competition of other (nematode) species. Other nematode species present in potato fields might generally outcompete *M. minor*, but this is uncertain.
2.10 How probable is it that natural enemies, already present in the PRA area, will suppress populations of the pest if introduced? *Go to 2.11*	**Unlikely**	It is unknown if *M. minor* has any natural enemies. However, some spores of the fungus *Pasteria* were found on second-stage juveniles of *M. minor* in a sample originating from UK coastal dunes (*Karssen, unpublished data*). *Pasteria* is a known parasite for nematodes (*Poinar & Jansson, 1988*). Nevertheless, nematodes are not likely to be controlled by natural enemies.
2.11 How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment? *Go to 2.12*	**Unlikely**	Control measures against nematodes are primarily based on suitable crop rotation. Due to their specific host ranges, every nematode pest has to be controlled by a specific set of crop rotation measures. The introduction of *M. minor* will complicate crop rotation because crop rotation requirements may or may not be mutually compatible with the grower's demands. The application of soil disinfection is restricted in the Netherlands to once every 5 years.

2.12 How likely is the presence of the pest in the PRA area to affect export markets? *Go to 2.13*	**Unlikely**	Some other *Meloidogyne* species, like *M. chitwoodi,* have a quarantine status in several non-EU countries (Russia, Argentina, Brazil, Canada, Chile). However, the presence of *M. chitwoodi* in parts of the EU does not seem to have negatively affected the volume of exported potatoes from these areas to countries that have *M. chitwoodi* listed as a quarantine pest.
2.13 How important would other costs resulting from introduction be? *Go to 2.14*	**Minor - moderate**	It cannot be excluded that trading partners of the EU require phytosanitary measures for *M. minor*. Inspection and certification systems might need to be implemented. In potatoes, these could be integrated with *M. chitwoodi* and *M. fallax* systems, if these are in force. If phytosanitary requirements would include turf, this would mean extra costs, since there is currently no phytosanitary inspection system implemented within the EU. Research on host plant range, crop rotation systems, resistant cultivars and other crop protection measures would be needed. The crop protection industry could benefit from the introduction of this pest, although in The Netherlands application of soil nematicides is limited to one treatment per 5 years.
2.14 How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests? *Go to 2.15*	**Very unlikely**	There is no evidence that *M. minor* can hybridise successfully with other nematode species.
2.15 How likely is the pest to act as a vector or host for other pests? *Go to 2.16*	**Moderately likely**	Members of the genus *Meloidogyne* are not known to transmit viruses, but are able to act as a vector for several fungi.

Conclusion of Assessment of potential economic consequences

2.16 Referring back to the conclusion on endangered area (1.36), identify the parts of the PRA area where the pest can establish and which are economically most at risk. *Go to Degree of Uncertainty*	Since 1997, several golf courses in the UK and Ireland showed unusual patches of yellowing turf grass across the surface of putting greens. High density populations have now been shown to cause loss of turf density and increased wear and tear. This results in significant damage to the turf from normal play. Moreover, the visual effect can be quite dramatic due to the extent of the patch development across each green. The patches return to the affected greens every year, but have been seen to reduce in severity following several years of maintenance post-construction, suggesting that the increasing rootzone diversity is reducing the 'dominance' of and damage caused by *Meloidogyne minor*. Looking at the possibilities for entry, establishment and spread of *M. minor*, the number of infested golf courses with symptoms is very likely to increase in the PRA-area, including UK, Ireland and the Netherlands. It is possible that yellow patches are already present in other areas in the EU, but not being recognized as a problem that's caused by *M. minor*, principally because the borders of the pests current area of distribution are unknown. *M. minor* may, for example, be present in coastal areas of the PRA area outside the British Isles and the Netherlands. If this is the case, outbreaks on golf courses in these areas may occur, not only by the movement of golf players, but also by their location (near / in an infested coastal area) or by the use of infested coastal sand. The presence and recognition of *M. minor* on golf courses is likely to result in an increasing use of nematicides, if these are registered. Although there are currently no indications that *M. minor* is causing problems in commercially grown crops, this may become a reality in the future. In the Netherlands, *M. minor* has been found twice in potatoes. In one of these cases, the pest caused serious damage. It should be noted that prior to the year that *M. minor* was observed in potato, pasture grass was grown on these fields for many years. This probably resulted in an increase of the *M. minor* populations, which could be an indication that *M. minor* only causes

problems on crops like potato if high population levels are reached in the previous years on pasture land (*Agrostis stolonifera* is often grown as a pasture grass).

Degree of uncertainty

Document the areas of uncertainty and the degree of uncertainty in the assessment, and indicate where expert judgment has been used. This is necessary for transparency and may also be useful for identifying and prioritizing research needs.

Go to Conclusion of the Risk Assessment

PRA topic	**Uncertainties**	**Further work that could be undertaken to improve the PRA**
Taxonomy	-	-
Distribution	No clear picture of pest distribution in the EU, especially outside the Netherlands, UK and Ireland.	Surveys are needed
Hosts	No extensive host range research has been carried out yet. Therefore, no clear picture of pathways, endangered species and efficacy of crop rotation as a management option.	Host range research
Establishment	Climatic responses, e.g. effect of long cold winters and hot dry summers. Sensitiveness of *M. minor* to competition from other species is also uncertain.	
Pathway/Spread	See 'hosts'.	See 'hosts'.
Economic impact	See 'hosts'. Potential impact on potato (and other commercially grown crops) is uncertain. It is also unknown why this is a new pest; new introduction, behavior change or different golf course construction techniques, etc?	Host range research. Field studies for impact on potato + other crops.

3. Conclusion of the Risk Assessment

Current situation in the PRA area

M. minor may be a native species in the UK, Ireland and other countries in Europe, e.g. the Netherlands, since it has been observed in coastal dune areas in Wales and on approximately 40 golf courses and sports grounds. It is possible that *M. minor* was already present at many sites that currently show symptoms of yellow patch disease or that these became infested due to spread from an infested site. A general survey is ongoing in the Netherlands and resulted in some findings on sports grounds, but also in two findings of *M. minor* in potatoes and four on pasture land. The findings in pasture fields and the two potato fields, which were former pasture lands, suggest that this nematode has been present in the Netherlands for a long period of time. In general, survey data are too limited to provide a clear picture of the presence of *M. minor* in the EU.

Because golf courses and sports grounds are very different habitats compared to potato fields, these are separately evaluated for their risks.

Entry

Golf courses and sports grounds

The most important pathway for international movement from one golf course / sports field to another is most likely to be on golf shoes and clubs, football and other sports shoes. There is considerable international movement of golf players, athletes, etc, although the prevalence of *M. minor* on this pathway is likely to be very low. International movement with turf is also possible, although the international trade volume is small. Moreover, until now, *M. minor* has not been detected at turf producing sites.

ENTRY RISK: LOW

Potato fields

Up to now, only two potato fields are known to be infested. Therefore, the risk of international movement of *M. minor* with potatoes is currently estimated as very low. No other commercially grown crops are known to be a natural host of *M. minor*.

ENTRY RISK: VERY LOW

Establishment

Golf courses and sports grounds

Even one second-stage juvenile can start a new population and *Meloidogyne* spp females are able to lay many eggs. Establishment of (very) small population levels is therefore likely. Climatic conditions in the countries where *M. minor* is known to be present (United Kingdom, Ireland and the Netherlands) are similar to some other north-western EU countries with temperate climates. Golf courses in other countries of north-western Europe are therefore also at risk, but it is likely that climatic conditions in central, eastern and southern Europe will limit establishment.

It is also possible that climatic conditions in other countries in the EU are suitable for *M. minor* establishment. It is important, however, to realise that there is currently little knowledge of the species distribution and that establishment of species living in the soil may depend on currently unknown soil physical attributes. It is assumed that *M. minor*, like other *Meloidogyne* species, thrives best in sandy soils, which are present on many locations throughout the EU. Moreover, sand is generally used for the construction of golf courses and sports grounds.

ESTABLISHMENT RISK: HIGH IN NW EUROPE BUT LOW IN SOUTHERN, EASTERN & NORTHERN EUROPE: THEREFORE OVERALL RISK: MODERATE

Potato fields

As above.

ESTABLISHMENT RISK: HIGH IN NW EUROPE BUT LOW IN SOUTHERN, EASTERN & NORTHERN EUROPE: THEREFORE OVERALL RISK: MODERATE

Spread

Golf courses and sports grounds

Golf courses and sports grounds may become infested with *M. minor* by using infested coastal sand or sand from inland pits for construction and maintenance purposes. The risk of this pathway logically depends on the source of the sand, but little information is available on the presence of *M. minor* in the PRA area. It is known that the nematode is present in some coastal dune areas in Ireland and Wales, but the prevalence is likely to be low. In the UK, several infested golf courses have used sand from non-coastal sites, thus raising the possibility that *M. minor* is not restricted to coastal sites. It is possible that *M. minor* was already present at many of sites that currently show symptoms of yellow patch disease. Spread between golf courses / sports grounds may also occur on golf shoes and clubs, football and other sports shoes. On a local scale, *M. minor* can spread by drainage water, water run-off, wind, soil attached to machinery, etc. The only, more or less, proven spread mechanism is with water run-off: On greens with slopes or natural run-off patterns it has sometimes (not always) been observed that the yellowing symptoms progress along the direction of water movement.

SPREAD RISK TO AND BETWEEN GOLF COURSES AND SPORTS GROUNDS: MODERATE

Potato fields

M. minor could be spread between fields by attached soil on machinery and with seed potatoes, but the current number of infested potato fields seems to be very low with only two known infestations in the Netherlands. However, the observations of *M. minor* on a few pasture fields in the Netherlands might be an indication for a future increase in the number of infested potato fields. Pasture land is quite regularly being rented by potato growers in order to cultivate potatoes in these fields. Furthermore, it is inevitable that not all infestations in pasture land will show up during a survey, since only several dozens of samples were taken from pasture land.

SPREAD RISK BETWEEN POTATO FIELDS: MODERATE

Economic impact

Golf courses and sports grounds

Since 1997, several golf courses in the UK and Ireland showed unusual patches of yellowing turf grass across the surface of putting greens. High density populations have now been shown to cause loss of turf density and increased wear and tear. This results in significant damage to the turf from normal play. Moreover, the visual effect can be quite dramatic due to the extent of the patch development across each green. Looking at the possibilities for entry, establishment and spread of *M. minor*, the number of infested golf courses with symptoms is very likely to increase in the PRA-area, including UK, Ireland and the Netherlands. Damage is almost exclusively observed on new courses or newly constructed / reconstructed existing courses with USGA or high sand rootzones. This might be an indication that *M. minor* was already present on these courses and becomes dominant after the construction / reconstruction with USGA or high sand rootzones and seeded with a non-native grass. The patches return to the affected greens every year, but have been seen to reduce in severity following several years of maintenance post-construction, suggesting that the increasing rootzone diversity is reducing the 'dominance' of the *Meloidogyne minor*. The presence and recognition of *M. minor* on golf courses is likely to result in an increasing use of nematicides, if these are registered.

ECONOMIC IMPACT: MINOR [TAKING ALL EU INTO CONSIDERATION]

Potato fields

Although there are currently no indications that *M. minor* is causing problems in commercially grown crops, this may become a reality in the future. In the Netherlands, *M. minor* has been found twice in potatoes. In one of these cases, the pest caused serious damage. It should be noted that prior to the year that *M. minor* was observed in potato, pasture grass was grown on these fields for many years. This probably resulted in an increase of the M. minor populations, which could be an indication that M. minor only causes problems on crops like potato if high population levels are reached in the previous years on pasture land (*Agrostis stolonifera* is often grown as a pasture grass). Furthermore, mainly potatoes grown on sandy soils are most likely to suffer damage. The extent to which *M. minor* is sensitive to competition of other (nematode) species in the soil may be a significant factor in damage levels. Inspection and certification systems might need to be implemented. In potatoes, these could be integrated in *M. chitwoodi* and *M. fallax* systems, if these are already in force. If phytosanitary requirements would include turf, this would mean extra costs, since there is currently no phytosanitary inspection system implemented within the EU.

ECONOMIC IMPACT: MINOR [TAKING ALL EU INTO CONSIDERATION]

Conclusion on Pest Risk Assessment

M. minor is an unwanted organism for the golf course (and sports field) industry, although symptoms on infested greens seem to fade after some years. The current problem for infested golf courses is that there are no registered nematicides available. The key question for non-infested golf courses is to determine whether introduction and damage can be prevented. At least, in the UK and Ireland, it seems that *M. minor* is native and might be present at several sites. Constructing a golf course on such an infested site is likely to result in damage. Non-infested golf courses might become infested in several ways.

Currently, there are only two (Dutch) records of *M. minor* in potato. Both potato crops were grown on fields that were long-term pasture land in the years prior to the findings. Furthermore, in The Netherlands, four pasture fields were found infested in 2005. Growing potatoes after pasture is not an uncommon practice (in The Netherlands and the United Kingdom). Potentially, this situation might result in more future outbreaks in potato crops. However, there is currently insufficient knowledge on the species distribution in the PRA area and its potential economic impact to determine if official measures are worthwhile discussing.

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ANNEX 1. Morphometrics of Meloidogyne minor n. sp. (mean + SD [range]; n= 25; all measurements in µm). Source: Karssen *et al, 2004*

Character	Females	Males	J2
L	526 ± 71 (416-608)	1045 ± 54 (790-1488)	377 ± 7.8 (310-416)
Greatest body diam.	339 ± 55 (240-464)	26.9 ± 4.5 (21.5-31.6)	13.3 ± 1.3 (12.0-15.8)
Body diam. at stylet knobs		15.9 ± 2.2 (13.3-18.3)	
Body diam. at excr. pore		23.6 ± 3.6 (20.2-26.5)	13.3 ± 0.9 (12.6-15.2)
Body diam. at anus			9.6 ± 1.2 (7.6-10.7)
Head region height		3.9 ± 0.7 (3.2-4.4)	2.0 ± 0.2 (1.9-2.5)
Head region diam.		9.6 ± 0.9 (8.9-10.7)	5.2 ± 0.4 (5.1-5.7)
Neck length	138.2 ± 41.5 (96.0-240)		
Neck diam.	72.3 ± 13.2 (48.0-96.0)		
Stylet	14.2 ± 1.1 (12.6-15.2)	17.8 ± 1.0 (17.1-19.0)	9.2 ± 0.9 (7.6-10.1)
Stylet base-ant. end			13.2 ± 0.9 (12.0-15.2)
Stylet cone		10.1 ± 0.6 (9.5-10.7)	
Stylet shaft and knobs		7.7 ± 0.9 (6.9-8.8)	4.7 ± 0.6 (3.8-5.1)
Stylet knob height	1.7 ± 0.5 (1.3-1.9)	2.0 ± 0.3 (1.9-2.5)	1.3 ± 0.2 (1.2-1.4)
Stylet knob width	3.5 ± 0.5 (3.2-3.8)	4.2 ± 0.5 (3.8-5.1)	1.9 ± 0.3 (1.8-2.0)

Character	Females	Males	J2
DGO	4.1 ± 1.2 (3.2-6.3)	3.8 ± 0.4 (3.2-4.4)	3.0 ± 0.5 (2.5-3.2)
Ant. end to metacorpus	53.3 ± 10.7 (40.5-67.6)	61.1 ± 12.3 (37.9-71.4)	43.3 ± 3.1 (39.2-46.8)
Metacorpus length	34.5 ± 6.8 (27.2-45.5)		
Metacorpus diam.	31.2 ± 7.3 (22.1-41.7)	9.0 ± 1.7 (7.6-12.0)	
Metacorpus valve length	11.5 ± 1.6 (9.5-13.3)	5.0 ± 0.7 (4.4-5.7)	3.3 ± 0.3 (3.2-3.8)
Metacorpus valve width	8.9 ± 1.2 (7.0-10.1)	3.6 ± 0.5 (3.2-3.8)	2.9 ± 0.5 (2.5-3.2)
Ant. end to end of gland lobe			35.3 ± 3.0 (32.9-41.1)
Excretory pore-ant. end	18.3 ± 7.8 (13.9-25.9)	114 ± 24.9 (87.9-137)	70.5 ± 6.6 (58.1-77.1)
Tail		10.5 ± 2.3 (8.2 ± 12.6)	54.1 ± 6.2 (48.7-63.2)
Hyaline tail terminus			16.1 ± 3.9 (12.0-22.1)
Phasmids-post. end		2.6 ± 0.8 (1.9-3.2)	
Spicule		25.6 ± 3.4 (22.8-28.4)	
Gubernaculum		6.1 ± 0.6 (5.7-6.3)	
Testis		529 ± 302 (316-876)	
Vulva slit length	25.8 ± 2.5 (22.8-29.1)		
Vulva-anus distance	15.3 ± 2.5 (12.6-17.1)		

Character	Females	Males	J2
a	1.6 ± 0.3 (1.1-2.3)	39.0 ± 4.2 (29.8-48.3)	28.4 ± 2.0 (23.9-32.4)
c		101± 21.3 (72.4-140)	7.0 ± 0.3 (6.2-7.6)
c’			5.7 ± 0.4 (4.5-6.3)
T		48.4 ± 12.3 (29.9-73.2)	
Body length/neck length	4.1 ± 0.7 (2.7-5.3)		
Body length/ant. end to metacorpus			8.7 ± 0.5 (7.9-9.4)
Stylet knob weigth/height	2.2 ± 0.5 (1.7-3.0)	2.2 ± 0.2 (11.1-1.4)	
Metacorpus length/width	1.2 ± 0.2 (0.9-1.7)		
(Excretory pore/L) x 100		11.1 ± 1.4 (8.2-15.2)	18.7 ± 0.8 (17.0-20.1)

ANNEX 2. Climatic comparison and CLIMEX study results of *Meloidogyne minor*

Figure. Climatic comparison, using the climatic data from Cork (UK)

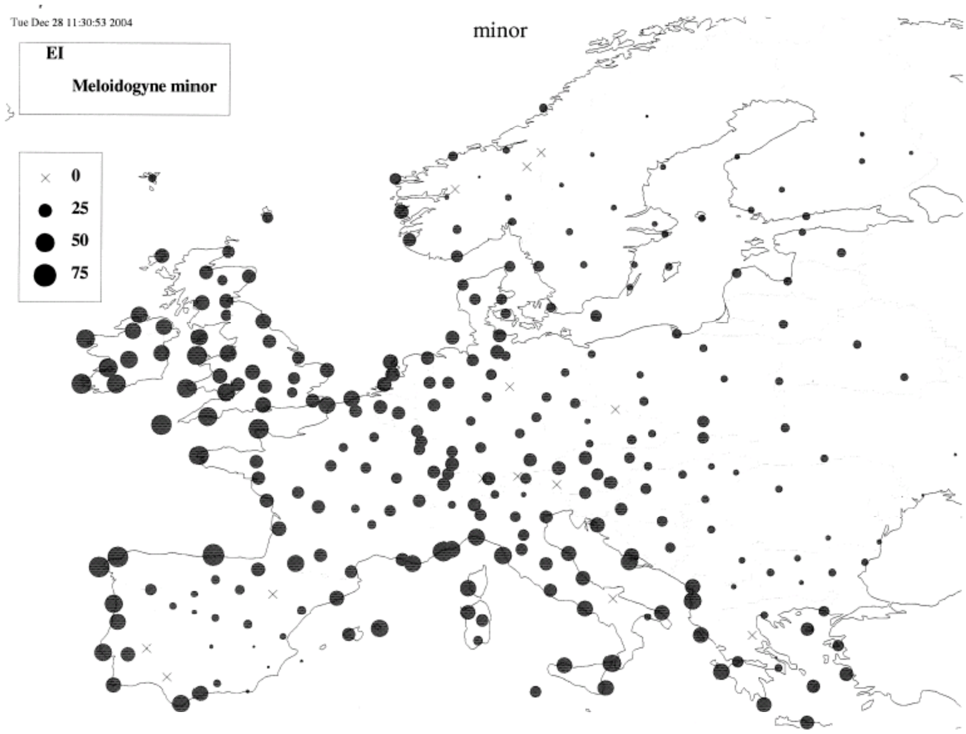


Figure 3. CLIMEX study results for *Meloidogyne minor.* The smaller the dots the lower the change the organism can establish after introduction.

The used parameters for the CLIMEX study with values other than 0:

Temperature

DV0:	5.000000
DV1:	15.000000
DV2:	20.000000
DV3:	25.000000
PDD:	600.000000

Moisture

SM0:	0.250000
SM1:	0.800000
SM2:	1.500000
SM3:	2.500000

Cold stress

DTCS:	15.000000
DHCS:	0.000100

Heat stress

TTHS:	30.000000
THHS:	0.005000

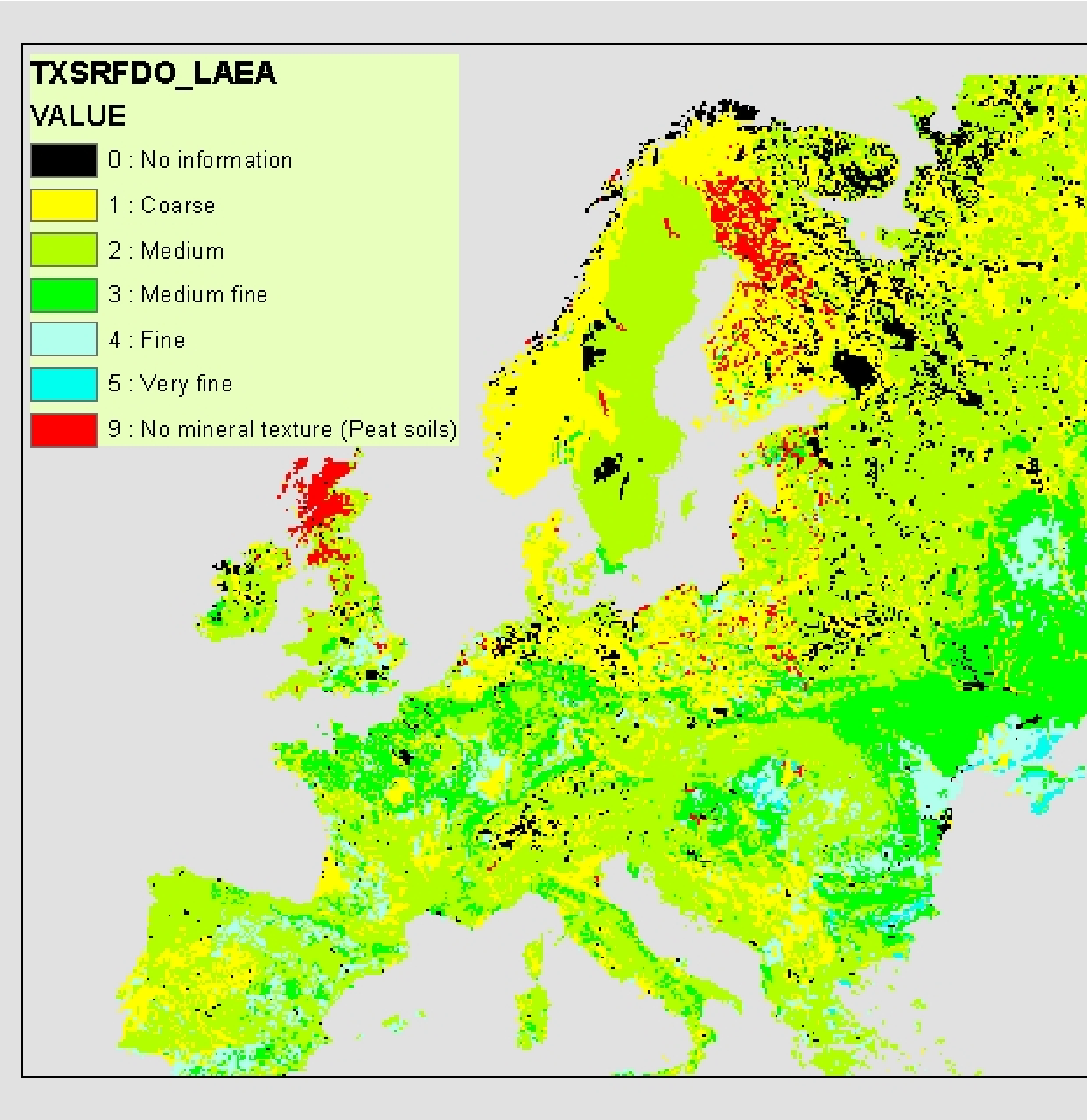
Dry stress

SMDS:	0.200000
HDS:	0.005000

Wet stress

SMWS:	2.500000
HWS:	0.002000

Annex 3. Soil types of Europe



Source: http://eusoils.jrc.it/ESDB_Archive/ESDBv2_ETRS_LAEA_raster_archive.html