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Meloidogyne chitwoodi, *M. fallax* and *M. hapla* – resistance of plants relevant in Swedish cropping systems

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Summary

The genus *Meloidogyne*, i.e. the root-knot nematodes, is widespread and has an extremely broad host range. This report focus on three *Meloidogyne* spp.; *M. chitwoodi* and *M. fallax,* which are both regulated in the EU, and *M. hapla,* which is widely distributed in the EU. Both *M. chitwoodi* and *M. fallax* has recently been found for the first time in Sweden.

These three nematode species are very difficult to control. Preventing introduction and further spread is the most efficient measures. Bare fallow, when the fields are kept clear of all susceptible plants, can efficiently reduce the nematode populations. Due to the very broad host range it is a challenge to manage the nematodes with crop rotation. Nevertheless, this report includes a review of the available information associated with the host status of different plant species relevant for Swedish agriculture. Some crops and cultivars are either immune (i.e. show no nematode feeding or reproduction) or resistant (i.e. severely suppress the reproduction) against certain *Meloidogyne* spp. Further, this report also includes information about the level of damage sustained by the nematodes on different crops and cultivars, i.e. their level of tolerance against the different nematode species.

To briefly summarize; although some crop species were reported as immune or resistant, the response was, to a very high degree, cultivar specific. Relatively few cultivars were immune whereas many were resistant. Immune plants, which does not support any nematode reproduction will be the most efficient in decreasing nematode populations and the effect should theoretically be comparable with bare fallow. In cultivars classified as ”resistant” some reproduction occurs but they do not support a population increase.

Almost all tested weed species were found to be susceptible. Thus it is important to remove all weeds to prevent population growth of the nematodes.

This report provides a first screening of the available information for a very large number crops/cultivars. Therefore, further analysis may change the assessment for some cultivars.

2 Background and assignment

In 2017, *Meloidogyne chitwoodi* was found for the first time in Sweden. The nematode was found in soil samples from three potato fields, owned by the same grower, in the municipality of Sölvesborg (Blekinge province; EPPO, 2018a). In 2018 it was also found outside of Kristianstad (Skåne province; Swedish Board of Agriculture, 2018a). Due to these findings the Swedish Board of Agriculture requested the Unit for Risk Assessment of Plant Pests at SLU to conduct a review of the available information associated with the host status of different plant species relevant for Swedish agriculture. The review also includes information about the susceptibility of plant hosts for *M. fallax* and *M. hapla*. Just before the finalization of this report *M. fallax* was also found for the first time in Sweden (Swedish Board of Agriculture 2018b).

3 A short description of root-knot nematodes focusing on *Meloidogyne chitwoodi*, *M. fallax* and *M. hapla*

The genus *Meloidogyne* represent a large group of plant parasitic nematodes causing the development of root galls following infection. Sasser et al. (1983) vividly describes the ubiquitous nature of the genus *Meloidogyne* as: "The root-knot nematodes (*Meloidogyne* species) are likely to be found wherever plants grow. They have been collected from frozen soil, tropical rain forests, arid plains, and remote islands. The […] *Meloidogyne* species currently described have a host range so extensive as to include almost every known plant."

3.1 Quarantine status

Both *Meloidogyne chitwoodi* and *M. fallax* are currently regulated within the EU according to Council Directive 2000/29/EC. They are quarantine pests in Norway as well as in many other parts of the world. *Meloidogyne hapla*, however, is only categorized as a quarantine pest by Jordan (EPPO, 2018c).

3.2 Geographical distribution

Meloidogyne chitwoodi is present in both Africa and America and it has also been found in several European countries, including Sweden (EPPO 2018c).

Meloidogyne fallax is present in Oceania and currently has a restricted distribution in several European countries (EPPO 2018c). In Sweden it was found for the first time in two fields outside of Kristianstad in 2018 (Swedish Board of Agriculture 2018b).

Meloidogyne hapla is extremely widely distributed and present in Asia, Africa, America, Europe and Oceania (CABI, 2018). In Europe it has been reported from almost all countries (CABI, 2018). Several sources report that *M. hapla* occurs in open land in Sweden (Banck, 1987; Omer et al., 2017) and it has also been reported to have caused damage up to and including the province of Västergötland in southwestern Sweden (Andersson, 2003).

3.3 Host races and pathotypes

In the genus *Meloidogyne*, differential host tests are used to detect mixed nematode populations consisting of more than one species and to describe the intraspecific variation within species (van der Beek et al., 1999). Two concepts have mainly been used to describe the difference in the ability of *Meloidogyne* spp. to infect a host, i.e. host races and pathotypes (van der Beek and Poleij, 2008). Dropkin (1988) denoted a host race a population with distinctive morphological and/or physiological characters, which is partially isolated from other intraspecific nematode groups by geography or genetics. In contrast to host race, a pathotype does not imply partial isolation or uniform genetics (Dropkin, 1988). The concepts has also been defined by responses of nematode isolates in differential host tests where host races are differentiated by responses to single genotypes of different plant species while pathotypes are classified by their response to more than one genotype of a certain host plant species (van der Beek et al., 1999). This pathotype concept is thereby comparable to the physiological race or pathotype concept used for some fungal pathogens, e.g. cereal rusts of the genus *Puccinia* and *Synchytrium endobioticum* causing potato wart disease (Zhao et al., 2016; EPPO 2017).

It has, however, been suggested that the use of the term “race” should be discontinued (e.g. Dropkin, 1988; Moens et al., 2009). Dropkin (1988) recommend that phytonematologists instead should refer to all intraspecific variants as pathotypes to denote a population delimited by its performance in a differential host test. The advantage of this proposal is that the term pathotype makes no implications about genetic determinants in host or parasite. Recently it was also shown, for *M. incognita*, that there was no phylogenetic signal at the whole genome level underlying its four accepted host races which further pushes for the discontinuation of usage of the term “race” (Koutsovoulos et al., 2018). In conclusion, the evidence against using differential host tests to determine “races” is accumulating but the host race concept is still used, for example to discriminate between host characteristics of populations of *M. chitwoodi* (den Nijs et al. 2016).

Meloidogyne chitwoodi

Meloidogyne chitwoodi has been divided into two races to differentiate between populations that differ with regard to their capacity to reproduce in the carrot cultivar Red Cored Chantenay (i.e. Race 1) and the alfalfa cultivar Thor (i.e. Race 2) (Mojtahedi et al., 1988b; Table 1). However, classification of isolates to either host race may be difficult as the differential reactions are not always stable hampering a clear distinction between the races (van der Beek et al. 1999).

Race 2 has been reported from the Pacific northwest of the United States, where 40% out of 32 tested isolates belonged to this race (Pinkerton et al., 1987), and in Mexico, where 11 out of 12 isolates tested were host Race 2 (Van der Beek et al. (1999) citing Cuevas (1995)).

There is currently no information about the host range specifics or race of *M. chitwoodi* present in Sweden (K. Nordin, Swedish Board of Agriculture, pers. comm, 2018). There is also limited knowledge regarding the races present in Europe although so far only race 1 has been reported. In a study performed in the Netherlands, no evidence for the existence of Race 2 was found in the eight isolates tested (van der Beek et al., 1999). Recently, in the Euphresco project MELOPOP, populations of *M. chitwoodi* was characterised in Belgium, France, Germany and the Netherlands using bioassays (den Nijs et al., 2016). It was concluded that the eight tested populations most likely belong to host Race 1, the virulence patterns were not always distinct and technical issues led to a few inconclusive results. Similarly, in Turkey only Race 1 was found when 58 isolates of *M. chitwoodi* were tested (den Nijs et al., (2016) citing Evlice and Bayram (2016)). As a side note, it could be mentioned that a new variant of *M. chitwoodi* first described as “Race 3” was later instead classified as a new pathotype, i.e. Race 2, Pathotype 1 (Brown et al., 2009; Humphreys-Pereira & Elling, 2013).

In the US, sub-populations within the races that have broken the resistance and are able to reproduce in *Solanum bulbocastanum* clone SB_{22} has been found and is classified as pathotype 1 of either race (Table 1) (Mojtahedi et al., 2007). This pathotype was not found in the above mentioned Euphresco project as none of the European isolates tested were able to reproduce on *S. bulbocastanum* SB_{22} (den Nijs et al., 2016).

Four additional pathotypes has also been described based on their capacity to infect different clones of *S. bulbocastanum* (van der Beek and Poleij, 2008). The authors conclude that the largest variation was found in isolates from the US represented by six isolates from three states, where also mixes of the different pathotypes were found within the isolates. The European isolates consisted of 10 isolates from the Netherlands and all of them displayed the virulence pattern of only one of the pathotypes (i.e. *S. bul.* 1/2,3), although two isolates displayed variation in the reproduction. The authors also mention unpublished data of one isolate of another of the described pathotypes in the Netherlands (i.e. *S. bul.* 1,2,3/). No consistent relationship between these described pathotypes and the host race/pathotype classification described earlier by Mojtahedi et al., (1988b) was found (van der Beek and Poleij, 2008).

Table 1. Different host races and pathotype 1 of *Meloidogyne chitwoodi* (Columbia Root-Knot Nematode (CRKN)) based on differential hosts (based on Brown et al. (2009) and Teklu (2018)).

Name	Race	Differential hosts				Pathotype	Differential host
		Susceptible Tomato	Potato: cv. Russet Burbank/ Desiree	Carrot: cv. Red Cored Chantenay	Alfalfa: cv. Thor		*S. bulbocastanum* SB_{22}
CRKN-$_1$	Race 1	Yes	Yes	Yes	No	-	No
CRKN-$_{1(P1)}$	Race 1	Yes	Yes	Yes	No	Pathotype 1	Yes
CRKN-$_2$	Race 2	Yes	Yes	No	Yes	-	No
CRKN-$_{2(P1)}$	Race 2	Yes	Yes	No	Yes	Pathotype 1	Yes

This report only distinguish between Race 1 and 2 since limited information related to different pathotypes associated with plants relevant in Swedish cropping systems was found. Only one study, i.e. Mojtahedi et al. (2007), provided information about Pathotype 1 of both races.

Meloidogyne fallax

For *M. fallax* no information was found about host races. It could however be noted that *M. fallax* was initially described as a new race of *M. chitwoodi* from the Netherlands but later described as a new species (van Meggelen et al., 1994; Karssen, 1996).

Meloidogyne hapla

For *M. hapla* no information was found about host races. However, there are two distinct cytogenetic races, Race A and Race B, where the races differ with regard to the number of chromosomes and the mode of reproduction (Sasser et al., 1983). Race A was found to be much more common than Race B, i.e. 45 vs 5 populations, respectively, based on data from a worldwide investigation (Sasser et al., 1983). The separation into cytogenetic races has some implications for management since, for example, populations of Race A and Race B has been shown to differ in their ability to reproduce on *Tagetes patula* (Buena et al., 2008). *Tagetes patula* is used as a rotation crop in nematode management. However, the cytogenetic races of *M. hapla* have very rarely been determined in studies of host resistance (Ferris et al., 2018). Further it is not known whether Race A or Race B, or both exists in Sweden.

4 Management

It is generally considered that if root-knot nematode populations are left unmanaged they will commonly reach densities that reduce crop yield and vigour (Nyczepir & Thomas, 2009). But these nematode species are difficult to control and manage due to their very broad host range, relatively few resistant crop varieties etc. Further, nowadays applying chemical nematicides is frequently not an option, e.g. due to availability, environmental and human health awareness issues and/or that they are not effective (Nyczepir & Thomas, 2009; Vestergård, 2019), e.g. nematicides does not reduce nematode densities of *M. chitwoodi* sufficiently (Teklu et al. (2014) citing personal communication with L.P.G. Molendijk).

Crop rotation

It is a challenge to manage nematode species with an extremely broad host range with crop rotation. It is not only difficult to find immune or resistant crops but it is also challenging to control all susceptible weeds. For the extremely polyphagous nematodes it is necessary to consider almost everything that is growing in the field as a potential host. There are however some crops and cultivars that are immune or resistant against the *Meloidogyne* species that can be used to decrease the nematode populations (see section 6). Fodder radish (*Raphanus sativus*) is for example a relevant crop in this context and some cultivars are already used in Sweden for managing nematodes (Hushållningssällskapet, 2006; Lyhagen, 2010). It should, however, be kept in mind that repeated use of resistant cultivars always pose a risk of selection for virulence and thus resistance breakdown (Starr & Mercer, 2009).

It is generally considered more challenging and difficult to control *Meloidogyne* spp. in a perennial crop system than in annual crops (Nyczepir & Thomas, 2009). For example rotation schemes that are suitable for annual crops tend to be somewhat impractical when used with perennials.

Fallow

Different types of fallow may be included in a rotation scheme to decrease the populations of *Meloidogyne* spp. (Nyczepir & Thomas, 2009). Clean fallow, or black fallow, for example, may be used where the weeds are removed, preferably every third week, to prevent nematode reproduction. It should be noted that where the crops are normally grown under irrigation the effect of the fallow may not be effective if irrigation is withheld from the fields (Nyczepir & Thomas, 2009). This effect may be due to that a certain level of soil moisture is required for egg development and hatching to feeding adults, which is necessary to starve the nematodes during the fallow period.

The use of green manure crops, which are susceptible, as winter cover has increased the problems since the populations of nematodes are maintained, or they may even increase, during the winter (Teklu, 2018). When the fields instead are kept free from any plants, the population decline dramatically. In a study in the Netherlands they found that 60-95% of the population of *Meloidogyne* spp. died between the harvest of a host crop in the autumn (between mid-September to mid-November) and planting of the next crop in the following spring (between mid-March and early May) (Been et al. 2007). Figure 1 below shows the population decrease when fallow is instead used for one year. Been et al. (2007) concludes that the rate of decline appear to decrease during the end of the period. During an extensive eradication programme of outbreaks in open fields in France the infected fields were kept as bare fallow, free of all weeds, as the main measure (Gamon & Lenne, 2012). After two years neither *M. chitwoodi* nor *M. fallax* was detected in 99% of cases (based on 430 analyses). It could also be noted that, according to a recent article, the French legislation currently require that farmers practise bare fallow for at least 1 year upon detection of *M. chitwoodi* (Garcia et al. 2018).

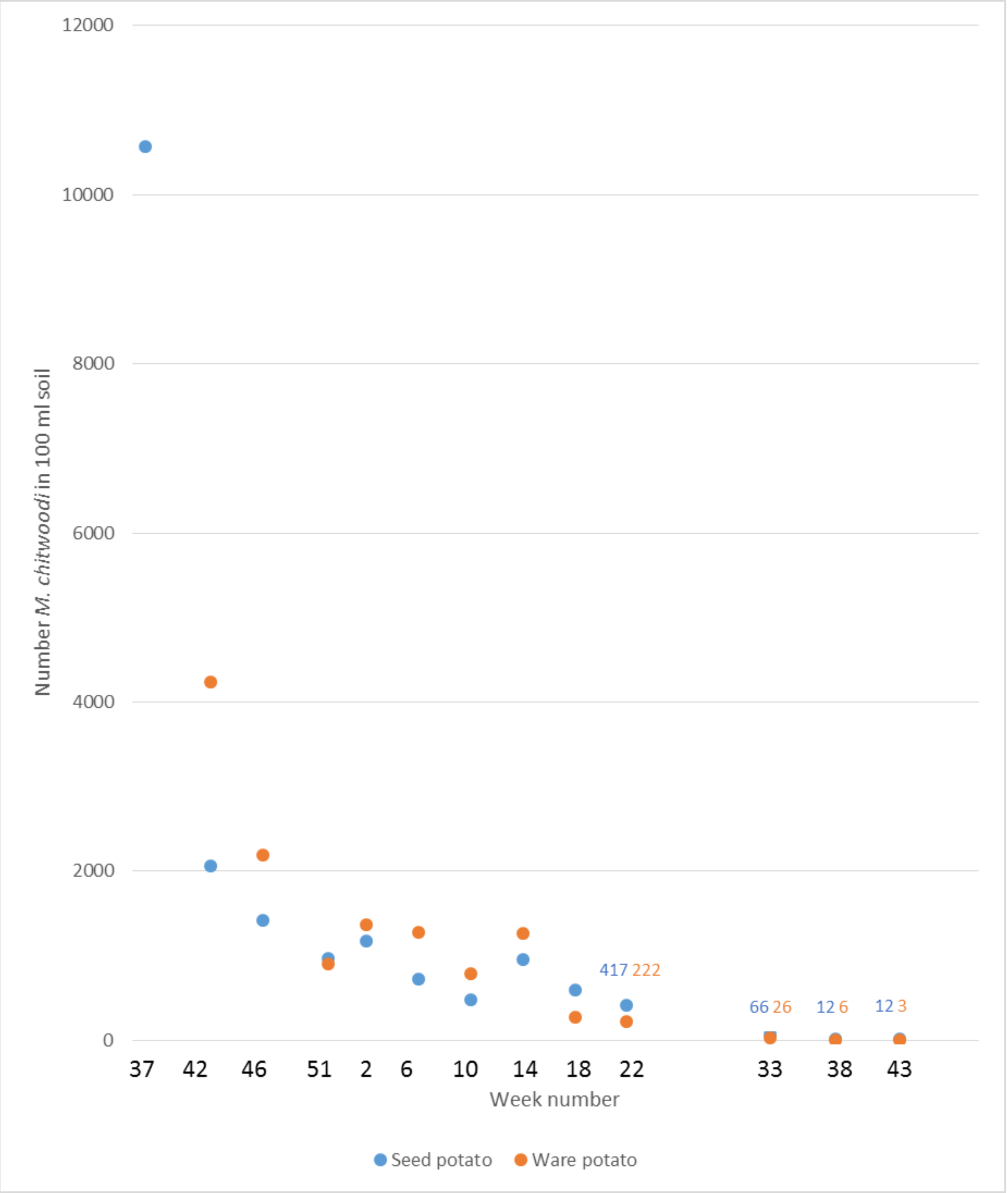

Figure 1. *Average number of* M. chitwoodi *in the soil (0-25 cm depth) during a period when the field were kept fallow. The data was obtained from Been et al. (2007). Note that the time interval between the sampling occasions were irregular.*

Timing of sowing

Meloidogyne chitwoodi hatches early and crops such a potato which is planted early in the year, and has a rapidly growing roots system, benefit the population growth of the nematode. It has also been shown that postponement of the sowing of carrots can offset the damaging effects of *M. fallax* (Molendijk & Brommer 1998). This effect is not solely due to the nematode population decline and it has been suggested that a faster development of the taproot at higher temperatures inhibits the penetration of nematodes (Molendijk & Brommer 1998).

It has also been shown that the severity of injury to carrot by *M. chitwoodi* can be reduced by reducing the interval between planting and harvest (Wesemael & Moens, 2008). For example the sowing density may be reduced, but this will have the disadvantage that the yields will be reduced.

Resources for decision support

University of California (UC Davis) provides the database Nemabase (http://ipm.ucanr.edu/NEMABASE/). Nemabase gathers information from published articles and provides lists of crops, cultivars and other plants and their host status for a wide range of nematodes to support decisions for nematode management (Ferris et al., 2018).

There is a Decision Support System (DSS) available for The Netherlands which aims to predict both population development and calculate possible yield losses, e.g. NemaDecide, which is a tool within the www.aaltjesschema.nl website provided by Wageningen UR (http://www.nemadecide.com/english/home; Been et al., 2006). In the Netherlands an integrated approach has been advised that includes adjusting the sowing date, using poor hosts, resistant green manure crops, black fallow and nematicides (Molendijk & Korthals, 2005; Teklu, 2018). Some parts of that tool, i.e. parts of Aaltjesschema, was translated in 2015 to Swedish in a report by the Swedish Board of Agriculture (Rölin, 2015). A current collaboration project between Hushållningssällskapen, Swedish Board of Agriculture, Nordic Beet Research and SLU is working on a revised version of the Swedish version of Aaltjesschema (Hushållningssällskapen, 2018). Finally, an ongoing European project, Best4SOIL, will make Aaltjesschema available in 22 languages (Molendijk, L. P. G. personal communication, 2018).

In the Netherlands and Germany variety lists are provided, including varieties of fodder radish resistant against *M. chitwoodi* (CSAR, 2018; Bundessortenamt, 2018).

5 Population growth, tolerance and effects on crop yield and quality

The population growth and damage of these nematode species depends not only on which plant species are grown but also on e.g. soil characteristics, duration of cultivation and climatic conditions. The impact of temperature on population growth and damage is strong, partly because the nematodes can develop more generations in a warmer climate. A short description of how the average accumulated temperature sums influence the probability for several generations of *M. chitwoodi* in different regions in Sweden is provided in Appendix 2.

5.1 Measures of resistance and tolerance

It is important to separate between the two main categories of measures relating to the results of the interaction between nematodes and their hosts. One category of measures are from the nematode's perspective and the other is from the host's perspective. Measures relating to *resistance* target the nematode population growth while measures related to *tolerance* refer to the capacity of the host to thrive despite hosting a certain density of nematodes. For example, in some hosts the nematode reproduction is high but the damage may be limited due to high tolerance levels in the plant, or the opposite, i.e. in some hosts the nematode reproduction is low but damage may be extensive even at low nematode concentrations. An example of the latter is the carrot cv. Nerac in which *M. chitwoodi* has a relatively low reproduction but causes severe yield and quality losses (Heve et al., 2015). Unfortunately, there seems to be few studies exploring this relationship for root-knot nematodes since Heve et al. (2015) claim that their study provides "…the first reliable quantitative results on the relation between initial population densities and quality loss.".

Thus, in the following compilation of information about host-nematode interactions for different plant species we therefore separate between i) the level of resistance and ii) the tolerance of the host plants.

Three measures used to determine population growth

Several measures have been used to measure population growth and some of the main ones are briefly described below.

*Multiplication rate or reproductive factor (R = Pf/Pi): P*i is the population density of the second stage juveniles (J2) at the time of planting (J2 (g dry soil)$^{-1}$) and *P*f is the population density at the time of harvest (J2 (g dry soil)$^{-1}$). One of the problems with this measure is that different results will be obtained depending on which initial population that is used, i.e. Pf/Pi is density dependent (Teklu 2018). The reason for this is that the nematodes compete with each other and the multiplication rate decrease with increasing initial population densities. Further, also when the same initial population is used in different experiments the multiplication rate may differ due to differences in growing conditions.

The root-galling index: This measure is based on scoring root knots of test plants in comparison with a susceptible reference plant. One of the problems with this measure is that there is large variation between the numbers of nematodes in galls (Teklu, 2018).

Relative susceptibility (RS): This measure is based on i) the maximum population growth rate at very low initial nematode densities when competition is absent and ii) the maximum population density at high nematode density, which is regarded as the carrying capacity of the root system of the investigated crop. In both cases relative values are used, i.e. the RS-values are calculated as the ratio between the nematode density in the tested plant and the nematode density in the susceptible control plant. RS is density independent when the ratio between the maximum population growth rate of a tested plant and a susceptible control plant is equal to the ratio between nematode density at the carrying capacity in the tested plant and the susceptible control plant. Such density independence has for example been shown for *M. chitwoodi* in potato (Teklu, 2018). Further, this measure is independent of environmental factors as long as both the control plant and tested host are grown under the same conditions which for example facilitate comparisons between results from experiments done in different places. This measure has so far rarely been applied but it was recently used to develop a routine test to evaluate the relative susceptibility of potato genotypes with resistance to *M. chitwoodi* (Teklu et al., 2016).

The weaknesses of the measures mentioned above, as well as the difficulties of comparing the results of studies which have used different measures, increase the uncertainty of available information on population growth.

Measures of tolerance

Tolerance refers to the capacity of the host to thrive despite hosting a certain density of nematodes. In most cases tolerance is simply measured as the degree of growth reduction in a host plant that is infested with nematodes compared to a non-infested host plant. However, in most cases the hosts’ tolerance against *Meloidogyne* spp. is not measured (H. Ferris, personal communication).

6 Resistance and tolerance of different hosts relevant to Swedish conditions

6.1 Compilation of host plant lists

In this report the listed plant species are limited to those that are relevant for Swedish cropping systems. When available, information at the cultivar level for these plant species was included regardless if the cultivars are currently available in Sweden.

A list of the plant species considered in this report, for which information was searched, and for which ones information was retrieved, is provided in Appendix 1.

As requested, plant host lists for the three *Meloidogyne* species were compiled into the following categories;

i) Plant species that are not infested by the nematodes hereafter referred to as immune plants (Table 2).
ii) Plant species reported to become infested but where the nematode population does not increase, hereafter referred to as resistant plants (Table 3)
iii) Plants species that can become infested by nematodes but that has been reported to be unaffected by these infestations, hereafter referred to as tolerant plants (Table 4)
iv) Nematode reproduction in different weed species (Table 5).

Data on host status of the different plant species and cultivars was primarily retrieved from Nemabase provided by UC Davis (Ferris et al., 2018). In this database the host status of the plants for different nematode species is classified into qualitative categories indicating the level of resistance as well as the degree of tolerance. The following definitions are given for the different host status categories in Nemabase; Immune - no evidence of nematode feeding or reproduction, Resistant - nematode reproduction severely suppressed, Moderately Resistant - nematode reproduction considerably reduced, Moderately Susceptible - nematode reproduction somewhat reduced and Susceptible - nematode reproduces well (Ferris et al., 2018). The degree of tolerance is classified as the following; Tolerant –suggests no or little damage, Moderately tolerant – some damage but less than intolerant plants (pers. comm. Howard Ferris, 2018).

The information of host status on a plant species level provided in Aaltjeschema was also retrieved (www.aaltjesschema.nl). Further, information about resistant varieties of fodder radish provided by CSAR in the Netherlands (2018) and Bundessortenamt in Germany (2018) was included. Finally, information from some additional articles were also added. All these additional data were included in the provided lists (i.e. Tables 2-6) applying the definitions by Ferris et al. (2018).

Immune plant species and cultivars (Table 2)

Plant species reported as not sustaining nematode feeding or reproduction were classified as immune following Ferris et al. (2018).

Relatively few crops relevant for Swedish conditions were reported as immune against any of the *Meloidogyne* species evaluated in this report (Table 2). Only *Tagetes* was reported as immune against all three *Meloidogyne* spp., but no further details were found regarding specific plant species (www.aaltjesschema.nl). It should be noted that some species of *Tagetes* were not found to be immune in other studies (see Table 6).

A few different cultivars of onion (*Allium cepa*), asparagus (*Asparagus officinalis*), carrot (*Daucus carota*), alfalfa (*Medicago sativa*) and specific cultivars of turnip (*Brassica rapa*), radish (*Raphanus sativus*) and were reported as immune against at least one of the races of *M. chitwoodi* (Table 2). It should however be noted that the different cultivars of carrot was reported as immune only against Race 2 and that the same cultivars were found to sustain high reproduction of *M. chitwoodi* Race 1.

In addition, at the species level, the following plants were reported by Aaltjesschema to be immune: beans (*Phaseolus vulgaris*), chicory (*Cichorium intybus*), radish (*Raphanus sativus*), strawberry (*Fragaria* x *ananassa*), flax (*Linum usitatissimum*), spinach (*Spinacia oleracea*) and tagetes (*Tagetes* spp.) (Table 2).

Apart from *Tagetes*, also beans, chicory, spinach were reported as immune against *M. fallax* but with no further information at cultivar level (Table 2; www.aaltjesschema.nl).

Several cultivars of wheat (*Triticum aestivum*) and single cultivars of maize (*Zea Mays*), oat (*Avena sativa)* and barley (*Hordeum vulgare*) have been reported as immune against *M. hapla* (Table 2). At the plant species level also *Lolium perenne*, *Lolium multiflorum* and *Triticale rimpaui* was reported as immune (Table 2; www.aaltjesschema.nl).

The level of resistance is however cultivar dependent for many of the crops and the resistance of different cultivars of a certain crop species can vary between immune to susceptible (cf. Table 2 and Table 6). This is only found for *M. chitwoodi* and *M. hapla* since the information on immune hosts against *M. fallax* was limited to species level data. Some variability is also observed for specific cultivars where the observed level of resistance varies depending on the study, e.g. cultivars of carrot (Table 2).

Resistant plant species and cultivars (Table 3)

Plants that are resistant hosts are here referring to plants that are infected but where the nematode population does not increase. The measure used in Ferris et al. (2018) is a measure of the suppression of the nematode population in comparison with a susceptible control of the same plant species. The measure 'Resistant' should more or less correspond to no increase in the population (pers. comm. Howard Ferris, 2018). Resistant plants may still display high levels of damage depending on whether the plant has a low tolerance level to nematode infections (see section 5.1).

Specific cultivars of the following crops are reported as resistant against at least one of the races of *M. chitwoodi* in at least one study; beet (*Beta vulgaris*), chicory (*Cichorium intybus*), carrot (*Daucus carota*), rucola (*Eruca sativa*), barley (*Hordeum vulgare*), alfalfa (*Medicago sativa*), fodder radish (*Raphanus sativus*), potato (*Solanum tuberosum*), wheat (*Triticum aestivum*), and maize (*Zea mays*) (Table 3). In addition, at the crop species level also onion, phacelia (*Phacelia tanacetifolia*) and peas (*Pisum sativum*) were reported as resistant. Similar as for the listing of the immune plant species it should be noted that the response of the plants differs depending on which race of *M. chitwoodi* that infects it and is occasionally also study dependent.

Onion, leek (*Allium porrum*), chicory, phacelia, green beans, peas and sudangrass (*Sorghum sudanense*) were reported as resistant against *M. fallax* (Table 3).

For *M. hapla* several different crops and cultivars are listed as resistant.

Tolerant plant hosts (Table 4)

Plant species are considered tolerant when they are reported to be infected by the nematode but sustain no or little damage (Table 4). In order to provide a complete list of crops for which no or limited damage is expected due to nematode presence in the soil also immune plants were included in Table 4. Apart from the plant species categorised as immune, the other plant species listed has reproduction ratings ranging from being resistant to susceptible where the nematode reproduces well (Ferris et al., 2018). Thus, it is important to note that some of the plant species that are listed as tolerant are also rated as susceptible hosts which can lead to a build-up of the nematode populations.

Level of resistance of weeds (Table 5)

Information was found for around half of the weed species relevant for Sweden (mainly based on Fogelfors (2006); the complete list of weed species considered in this report is provided in Appendix 1). There was also very limited information regarding the population growth of *M. chitwoodi* and *M. fallax* in most weed species (Table 5). More weed species have, however, been evaluated for *M. hapla*.

For all weed species listed in Table 5 there are studies that show a high level of nematode production for at least one of the *Meloidogyne* spp.

Overview of the full range of ratings of resistance at the host species level (Table 6)

Table 6 provides an overview at the host species level of the full range of ratings, i.e. including all ratings from susceptible to immune. However, it only contains information about the crops included in Table 2 and 3, i.e. not all relevant crops (Appendix 1).

7 Analysis of the results

The data presented in the tables should be interpreted with care. The aim was to conduct a first screening of the available information with regards to the level of resistance and tolerance of crops, cultivars and weeds relevant for Swedish cropping systems against the three species of *Meloidogyne*. Most of the data was thus extracted directly from available databases using the ratings provided there. The interpretation of the resistance and tolerance ratings may differ depending on the criteria used in different articles and databases. The term 'resistance', for example, is widely used in the literature but the corresponding reproduction rate varies depending on the source. It should also be noted that there is a large variation in the scientific support for the different ratings. In some cases the ratings are based on repeated experiments including field data and in some cases they are based on rather preliminary results from pot tests or the results on which the ratings are based on may not be readily available. Some information on the host status of different crops was for example retrieved from the Dutch online tool Aaltjesschema (www.aaltjesschema.nl). Here information is provided about different crop species and their potential effect on the population of different nematode species. The information about the empirical support for these assessments is however limited and not readily accessible due to language difficulties. In conclusion, the current report is restricted to provide an overview of the available information and further analysis may change the assessment for some cultivars.

A high variability in the level of resistance against the three species of *Meloidogyne* was shown. It is also clear that there is a high variability within different crops, and cultivars sometimes differ in their susceptibility against the nematode species. There are also differences in the susceptibility reported for specific cultivars. For *M. chitwoodi*, differences are for example observed for the different races but different studies also show different results in a few cases (Table 2 and 3).

It is not known whether the *M. chitwoodi* populations found in Sweden shares the host range characteristics of Race 1 or Race 2. The European populations described so far have all resembled Race 1 although the differential host tests performed did not result in a stable reaction hampering a clear distinction of the race (van der Beek et al., 1999). In most studies of the resistance of different hosts against *M. chitwoodi* it is also not known if the tested population of *M. chitwoodi* shares the host range characteristics of Race 1 or Race 2. However, there are some studies, on cultivars of carrot and alfalfa, which shows that the level of resistance against Race 1 and Race 2 may differ (Tables 2 and 3).

Level of resistance and nematode population dynamics

From a nematode control perspective plants reported as immune, i.e. that will not support any nematode reproduction, will be the most efficient in decreasing the nematode populations. If no reproduction occurs the decrease in the nematode population should theoretically be comparable with bare fallow when no plants are available, as long as susceptible weed species are not present. However, as seen in the data presented in Table 2 the number of crops that are immune is limited.

The number of crops and cultivars categorised as resistant is larger, but these will not achieve the same level of control as immune plants. The nematode populations will not increase, but resistant plants will still support some level of reproduction. From an economic point of view, even though the nematode population decrease to a low level, it may still lead to damage in the following crop since the threshold for quality damage in some cases are very low (Teklu et al., 2014).

Fodder radish is an important green manure crop and known to be partially resistant to *M. chitwoodi* (CSAR, 2018, Hushållningssällskapet, 2006; Lyhagen, 2010)). The resistance of fodder radish does however vary with different cultivars (e.g. CSAR, 2018). In the Netherlands, the fodder radish cultivars Anaconda, Contra, Defender, Doublet and Terranova, which are known to have partial resistance against *M. chitwoodi*, was compared to a standard cultivar, Radical (Teklu et al., 2014). None of the cultivars tested were immune, i.e. new nematodes were produced, but they showed a high partial resistance and compared to the standard cultivar reduced the population densities of *M. chitwoodi* with more than 98% (Teklu et al., 2014).

There is an inconsistency in the host susceptibility ratings in the different sources.

In Nemabase, the cultivars assessed in Teklu et al. (2014) were rated as ‘moderately resistant’ and ‘tolerant’ (Table 4; Ferris et al., 2018). However these, as well as some additional cultivars, were assessed as resistant against *M. chitwoodi* according to CSAR (2018) and/or Bundessortenamt (2018) but using different methods. Further, the classification of fodder radish in Aaltjesschema

(2018) indicate that some cultivars are highly resistant or immune (without further specification of which ones).

Mixed nematode population of for example *M. chitwoodi* and *M. hapla* may be common (EPPO, 2018b) and it is very difficult to control both of them at the same time due the obstacles to find suitable host species that are immune to both these nematode species. Although all three *Meloidogyne* sp. are very polyphagous there are differences between them with regard to host range. An important difference between *M. chitwoodi*, *M. fallax* and *M. hapla* is that *M. hapla* does not multiply on cereals whereas the other species do (Table 6). This is important since cereals are used in crop rotation as a management option for *M. hapla* (Bélair & Parent, 1996).

Almost all tested weed species were found to be susceptible (Table 5). It should however be noted that the information for *M. chitwoodi* and *M. fallax* were limited. From a nematode management point of view, it is thus advisable to remove all weeds to prevent population growth of the nematodes.

Impact on crop yield and crop quality

It is clear from the data presented in Table 4 that the level of resistance is variable in the crops/cultivars listed as tolerant. It should be noted that the response of the plants in terms of growth is not always measured and more crops and cultivars than those listed may be tolerant. In terms of impact of the nematodes on particular crops both the level of resistance and tolerance must be taken into account.

A systematic review of the available information on the impact of *M. chitwoodi* and *M. fallax* on crop yield and crop quality has been conducted (MacLeod et al., 2012). Some of the main conclusions were that for *M. chitwoodi* the main crop reported to be of concern is potato. The economic losses are mainly due to reduced tuber quality and less to a reduction in tuber yield. Second to potato with regard to economic impact is carrot where the main issue is reduced quality due to severe galling. Similarly, the main economic impact of *M. fallax* on carrot is due to quality damage. There are also indications that black salsify can be severely damaged by *M. chitwoodi*. For at least one cultivar of onions, i.e. *Allium cepa* L. “Southport White Globe”, stunting and galling of roots has been observed, however no empirical data was presented, (Westerdahl et al., 1993) whereas many other cultivars of onions are immune (Table 2 and 3). Thus, in conclusion, there seems to be an agreement in the literature that the main economic effect generally is due to quality loss of tuber forming crops rather than growth losses.

Table 2. Crops and different cultivars reported as immune against at least one of the *Meloidogyne* spp. For those cultivars the nematode level of resistance for the other *Meloidogyne* species and/or race is also given. The data was mainly retrieved from the database Nemabase (Ferris et al., 2018; references therein). Additional references included is indicated by superscript letters and listed in the table footer.

Latin name	Cultivar	Swedish name	*M. chitwoodi* unspec. race	*M. chitwoodi* race 1	*M. chitwoodi* race 2	*M. fallax*	*M. hapla*
Allium cepa	Carmen	Lök		I	I		
	Cima			I	I		
	Granada			I	I		
	Magnum			I	I		
	Rocket			I	I		
	Snow White			I	R		
	Vega			I	I		
	Walla Walla Sweet			I	R		
	Yula			I	I		
Asparagus officinalis	Mary Washington	Sparris			I		R
	Vroege Argenteuil		I			MS	
Avena sativa	Park	Havre	S[a]				I[a]
	Not specified						I[c]
Brassica rapa	Forage Star	Foderrova			I		
Cichorium intybus	*Not specified*	Cikoria	I[c]				
	Not specified, cultivars for sallad		R[c]			I[c]	MS[c]

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
Daucus carota	Chantenay	Morot	MR	S[1]	**I**[2]		S
	Gold Pak			S	**I**, R		S
	Imperator 58			S	**I**, R		S
	Red Cored Chantenay			S	**I**		
Fragaria × ananassa	*Not specified*	Jordgubbar	**I**[c]			S[c]	S[c]
Hordeum vulgare	Boyer	Korn	S[a]				**I**[a]
	Not specified summer barley		R[c]			R[c]	**I**[c]
	Not specified winter barley		MS[c]			R[c]	**I**[c]
Linum usitatissimum	*Not specified*	Lin	**I**[c]				R[c]
Lolium perenne	*Not specified*	Engelskt rajgräs	R[c]			S[c]	**I**[c]
Lolium multiflorum	*Not specified*	Italienskt rajgräs	S[c]			S[c]	**I**[c]
Medicago sativa	Altra 55	Blålusern		**I**			
	Blazer			**I**	S		
	Pioneer			**I**			
	Thor		R, MS	**I**[1], R	S[2]	MS	S
Raphanus sativus	RsV79/80	Rättika	**I**[b]				
	Not specified		**I**[c]*			MS[c]*	MS[c]
Phaseolus vulgaris	*Not specified*	Bönor	**I**[c]*			**I**[c]	S[c]

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
Secale cereale	*Not specified*	Råg	S[c]			S[c]	**I**[c]
Spinacia oleracea	*Not specified*	Spenat	**I**[c]			**I**[c]	R[c]
Tagetes spp.	*Not specified*	Tagetes	**I**[c]			**I**[c]	**I**[c]
Triticale rimpaui	*Not specified*	Rågvete	MS[c]			R[c]	**I**[c]
Triticum aestivum	Fielders spring	Vete	S[a]				**I**[a]
	Nugaines						**I**
	Stephens						**I**
	Not specified						**I**
	Not specified summer wheat		MS[c]			MS[c]	**I**[c]
	Not specified winter wheat		MS[c]			R[c]	**I**[c]
Zea mays	PX46 (Northrup King)	Majs	S[a]				**I**[a]
	Not specified		MS[c]			R[c]	**I**[c]

[1]Including pathotype 1 of race 1, [2]Including pathotype 1 of race 2. *Depends on the cultivar. **Additional references:** [a]Santo et al. 1980 (I = no or few larvae recovered from roots; S = >100% recovery); [b]Mbiro, 2016 (I = non host - no nematodes produced in roots); [c]Aaltjeschema 2018 (I = natural decrease - the nematodes cannot multiply and mortality is similar to black fallow, R = little propagation - the nematodes can not increase much, MS = moderate propagation, S = high propagation). **Abbreviations:** S = Susceptible (nematode reproduces well), MS = Moderately Susceptible (nematode reproduction somewhat reduced), MR = Moderately Resistant (nematode reproduction considerably reduced), R = Resistant (nematode reproduction severely suppressed) and I = Immune (no evidence of nematode feeding or reproduction), following Ferris et al. (2018). Note that we have removed one report where a host was classified as "Immune" in the database by Ferris et al. (2018), i.e. *Medicago sativa*, cultivar Thor, since it was reported to be a suitable host for *M. chitwoodi* with a R(Pf/Pi) = 6.6 (Mojtahedi et al. 1988a). In addition, R and S ratings on the carrot cultivar Red Cored Chantenay were disregarded since this ratings were based on *M. chitwoodi* populations including both races (Mojtahedi et al. 1988b). It should also be noted that for some of the plants rated as immune no empirical data was provided and only indirect evidence has been used for the rating.

Table 3. Crops and different cultivars reported as resistant against at least one of the three *Meloidogyne* spp. (note that all crops/cultivars rated as immune for one of the *Meloidogyne* spp./race are listed in Table 2). The nematode reproduction rating for the other *Meloidogyne* species and/or race is also given. The data was mainly retrieved from the database Nemabase (Ferris et al, 2018; References therein) limited to plants rated as 'Resistant' (R), i.e. nematode reproduction severely suppressed, for one of the *Meloidogyne* spp. Additional references included is indicated by superscript letter and listed in the table footer.

Latin name	Cultivar	Swedish name	*M. chitwoodi* unspec. race	*M. chitwoodi* race 1	*M. chitwoodi* race 2	*M. fallax*	*M. hapla*
Allium cepa	Pronto	Lök					**R**
	Snow white			I	**R**		
	Walla Walla Sweet			I	**R**		
	Not specified		**R**[a]			**R**[a]	**R**[a]
Allium sativum	Caveat	Vitlök					**R**
Allium porrum	*Not specified*	Purjolök	MS[a]			**R**[a]	**R**[a]
Apium graveolens	*Not specified*	Selleri					**R**
Asparagus officinalis	Mary Washington	Sparris			I		**R**
	Pedigreed Washington						**R**
Avena sativa	Dorval	Havre					**R**
Beta vulgaris	U&I Hybrid No. 9	Sockerbeta	M**R**[c]		**R**		**R**[c]
	Not specified	Sockerbeta/rödbeta		**R**		S	S
	Not specified	Sockerbeta	**R**[a]			S[a]	S[a]
	Not specified	Rödbeta	**R**[a]			S[a]	**R**[a]
Brassica napus	*Not specified, winter and spring variety*						**R**[a]
Brassica oleracea	*Not specified*	Kål (grönkål, brysselkål,	MS[a]				**R**[a]
Cichorium intybus	Edellof Mid-early	Cikoria	**R**			**R**	
	Zoom F1 Hybrid		MR			**R**	

Latin name	Cultivar	Swedish name	*M. chitwoodi* unspec. race	*M. chitwoodi* race 1	*M. chitwoodi* race 2	*M. fallax*	*M. hapla*
	Not specified, cultivars for sallad		**R**[a]			I[a]	MS[a]
Cucumis sativus	Calypso	Gurka					**R**
	Clinton						**R**
	Dasher II						**R**
	Delcrow						**R**
	Dharampur-I						**R**
	Double Yield						**R**
	Early Cluster						**R**
	Gy 14A						**R**
	Gy 4						**R**
	H-19						**R**
	LJ 90430						**R**
	M 21						**R**
	M 41						**R**
	Marketmore 76						**R**
	Mincu						**R**
	PI 137836						**R**
	PI 167043						**R**
	PI 169328						**R**
	PI 178884						**R**
	PI 179260						**R**

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
	PI 182192						**R**
	PI 192940						**R**
	PI 211975						**R**
	PI 249550						**R**
	PI 257487						**R**
	PI 261608						**R**
	PI 264667						**R**
	PI 292012						**R**
	PI 357859						**R**
	PI 368551						**R**
	PI 368560						**R**
	PI 422186						**R**
	PI 432867						**R**
	PI 436610						**R**
	Poinsett						**R**
	Poinsett 76						**R**
	Producer						**R**
	Slice						**R**
	Sprint 440						**R**
	Sumter						**R**, MS
	Tiny Dill						**R**

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
	Wisconsin SMR 12						**R**
	Wisconsin SMR 18						**R**
Cucurbita pepo	Market More	Squash					**R**
	National Pickling						**R**, MS
Daucus carota	A Plus	Morot		S	**R**		S
	Amsterdam Minicor			S	**R**		S
	Chancellor			S	**R**		S
	Charger			R	**R**		S
	Gold pak			S	I, **R**		S
	Golden State			S	**R**		S
	Half-Long Nantes			R	**R**		S
	Imperator 58			S	**R**, I		S
	Orlando Gold			**R**, S	**R**, S		S
	Pak More			S	**R**		S
	Red Cored Chantenay		S	S	**R**	S	S
	Six Pak			S	**R**		S
	Six Pak II			S	**R**		S
	Top Pak			S	**R**		S
	Trophy			S	**R**		S
Eruca sativa	Nemat	Senapskål/Rucola	**R**[b]				
Hordeum vulgare	Briggs	Korn	**R**	**R**			

Latin name	Cultivar	Swedish name	*M. chitwoodi* unspec. race	*M. chitwoodi* race 1	*M. chitwoodi* race 2	*M. fallax*	*M. hapla*
	Laurier						**R**
	Steptoe		**R**	MS	S		
	Not specified summer barley		**R**[a]			**R**[a]	I[a]
	Not specified winter barley		MS[a]			**R**[a]	I[a]
Lactuca sativa	*Not specified*	Sallat					**R**, S
	Not specified						**R**[a]
Linum usitatissimum	*Not specified*	Lin	I[a]				**R**[a]
Lolium perenne	*Not specified*	Engelskt rajgräs	R[a]			S[a]	I[a]
Medicago sativa	Dupuit	Blålusern			S		
	DuPuits		**R**				
	Thor		**R**, MS	I[1], **R**	S[2]	MS	S
	Ladak						**R**
	M-4						**R**
	M-9						**R**
	Lahontan		**R**, S	S	S		S
	Lobo						**R**
	Mn PL9HF		**R**, MS				
	Moapa		**R**, S				S
	Nevada Synthetic XX		**R**, S	R	**R**, MR		**R**, MR, S
	Perry						**R**

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
	Saranac		**R**[(c)]				**R**[c], MS, S
	Shield						S
	Syn XX		**R**				MS
	Syn YY		**R**				
	Vernal 298						R
	W12SR2W1			**R**	**R**, MR		MS, S
	Washoe		**R**		S		
Medicago spp.	*Not specified*		**R**[a]				MS[a]
Phacelia tanacetifolia	*Not specified*	Honungsört	**R**[a]			**R**[a]	MS[a]
Phaseolus vulgaris	Groffy	Böna	S			**R**	
	Nemasnap						S,R
	Strike		S			**R**	
Pisum sativum	*Not specified*	Ärtor	**R**[a]			**R**[a]	S[a]
	Nemasnap						**R**, S
	Strike		S			**R**	
Raphanus sativus	2	Rättika		**R**			
	3			**R**			
	4			**R**			
	5			**R**			
	6			**R**			
	Adagio						**R**

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
	Adventure		**R**[e]				
	Anaconda		**R**[d]				
	Angus		**R**[e]				
	Atlantis		**R**[e]				
	Black Jack		**R**[e]				
	Boss						**R**
	Caruso		**R**[e]				
	Cobra		**R**[e]				
	Contra		**R**[e]				
	Control		**R**[d, e]				
	Cordoba		**R**[d, e]				
	Defender		MR				**R**
	Doublemax		**R**[e]				
	Doublet		**R**[d]				
	Dracula		**R**[d]				
	Farmer		**R**[e]				
	Firework		**R**[e]				
	Geron		**R**[d, e]				
	Jorba		**R**[d, e]				
	Melotop		**R**[d]				
	Merkur		**R**[d]				

Latin name	Cultivar	Swedish name	*M. chitwoodi* unspec. race	*M. chitwoodi* race 1	*M. chitwoodi* race 2	*M. fallax*	*M. hapla*
	Miracle		**R**[e]				
	Nerus				**R**		
	Pegletta			**R**			
	Radetzky		**R**[d, e]				
	Siletena			**R**			
	Siletta Nova			**R**			
	Tajuna		**R**[d, e]				
	Terranova		**R**[d, e]				
	Triangel		**R**[e]				
	Trident		**R**[e]				
	Valencia		**R**[d, e]				
Raphanus sativus var. oleiferus	Nemex			**R**		S	
Festuca arundinacea	Jesup (Max-Q)	Rörflen					**R**
Sinapis alba	Absolut	Vitsenap					**R**
	Accent						**R**
	Condor						**R**
	Not specified					MS[a]	**R**[a]
Solanum tuberosum	AR 04-4096	Potatis	**R**, MR				
	AR 04-4098		**R**, MR				
	AR 04-4107		**R**, MR				
	CBP-233			**R**			

	CS8617						**R**
	PA99N82-4			**R**			
	Voran						**R**
Sorghum sudanense	*Not specified*	Sudangräs				**R**[a]	
Spinacia oleracea	America	Spenat					**R**
	Not specified		I[a]			I[a]	**R**[a]
Trifolium repens	224	Vitklöver					**R**
	234						**R**
Triticale rimpaui	*Not specified*	Rågvete	MS[a]			**R**[a]	I[a]
Triticum aestivum	Laurier	Vete					**R**
	Synthetic hexaploid G4299		**R**				
	Not specified winter wheat		MS[a]			**R**[a]	I[a]
Zea mays	Idahybrid 303	majs		**R**	S		
	Sweet Tooth			S	**R**		
	Not specified		MS[a]			**R**[a]	I[a]

[1]Including pathotype 1 of race 1, [2]Including pathotype 1 of race 2. **Additional references:** [a]Aaltjeschema 2018 (I = natural decrease - the nematodes cannot multiply and mortality is similar to black fallow, R = little propagation - the nematodes can not increase much, MS = moderate propagation, S = high propagation); [b]Mbiro 2016 (R = reproductive factor *Rf* was 0.65); [c]Santo et al., 1980 (R = <21% recovery; MR = 80% recovery ; S = >100% recovery); [d]CSAR 2018 (R = a relative susceptibility compared to the average of non-resistant varieties Radical and Siletina < 6%); [e]Bundessortenamt 2018 (R = egg mass from roots is >95% lower compared to a susceptible fodder radish variety). **Abbreviations:** S = Susceptible (nematode reproduces well), MS = Moderately Susceptible (nematode reproduction somewhat reduced), MR = Moderately Resistant (nematode reproduction considerably reduced), and R = Resistant (nematode reproduction severely suppressed) and I = Immune (no evidence of nematode feeding or reproduction), following Ferris et al. (2018). Note that all crops/cultivars reported to be Immune against at least one of the three *Meloidogyne* spp. are not listed here but in Table 2.

Table 4. Crops and different cultivars reported to sustain no or limited damage due to the presence of the different *Meloidogyne* spp. in the soil . The data was mainly retrieved from the database Nemabase (Ferris et al, 2018; References therein) limited to plants rated as 'Immune' or 'Tolerant' (T) , with the corresponding nematode reproduction rating is given in parenthesis. Additional references included is indicated by superscript letter and listed in the table footer.

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
Allium cepa	Carmen	Lök		I	I		
	Cima			I	I		
	Downing Yellow Globe						T(S)
	Granada			I	I		
	Magnum			I	I		
	Rocket			I	I		
	Snow White			I			
	Spartan Banner						T(S)
	Spartan Sleeper						T(S)
	Vega			I	I		
	Walla Walla Sweet			I			
	Yula			I	I		
Allium sativum	Caveat	Vitlök					T(R)
	Mercury						T(MR)
	Rio Tinto						T(MR)
Allium porrum	*Not specified*	Purjolök	T(MS[a])			T(R[a])	T(R[a])
Avena sativa	*Not specified*	Havre					I[a]
Brassica napus	Humus	Kålrot			T(MR)		

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
	Not specified, winter and spring variety	Raps					T(R[a])
Brassica rapa	Forage Star	Foderrova			I		
Brassica oleracea	*Not specified*	Kål (grönkål, brysselkål)	T(MS[a])				T(R[a])
Cichorium intybus	Edellof Mid-early	Cikoria	T(R)			T(R)	
	Not specified		I[a]				
Daucus carota	Berlanda	Morot	T(MR)				
	Bolero		T(MR)				
	Chantenay		T(MR)		I[2]		
	Gold Pak				I		
	Imperator 58				I		
	Nantucket		T(MR)				
	Orlando Gold			T(S)	T(R, S)		
	Parmex		T(MR)				
	Red Cored Chantenay			T(S)	I, T(R)		
Fragaria x ananassa	Catskill	Jordgubbar					T(S)
	Prelude						T(S)
	Not specified		T(I[a])			T(S[a])	

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
Hordeum vulgare	*Not specified*	Vår och höst korn					T(I[a])
Linum usitatissimum	*Not specified*	Lin	T(I[a])				
Lolium perenne	*Not specified*	Engelskt rajgräs	T(R[a])			T(S[a])	I[a]
Lolium multiflorum	*Not specified*	Italienskt rajgräs	T(S[a])			T(S[a])	I[a]
Lotus corniculatus	*Not specified*	Kärringtand	T(MS)				T(MS)
Medicago falcata	*Not specified*	Gullusern	T(S)				
Medicago sativa	Altra 55	Blålusern		I			
	Blazer			I			
	Ladak						T(R)
	Lahontan		T(R, S)				T(S)
	Moapa		T(R)				
	Nevada Synthetic XX		T(R, S)				T(R, S)
	Perry						T(R)
	Pioneer			I			
Medicago spp.	*Not specified*	Lusern	T(R[a])				
	Ranger						T(S)
	Syn XX		T(R)				
	Syn YY		T(R)				

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
	Thor			I[1], T(R)	I		
	Vernal 298						T(R)
Raphanus sativus	Adagio	Rädisa/Rättika					T(R)
	Anaconda		T(MR)				
	Boss						T(R)
	Contra		T(MR)				
	Defender		T(MR)				T(R)
	Doublet		T(MR)				
	Radical		T(S)				
	Terranova		T(MR)				
	Not specified					T(MS[a])	T(MS[a])
Phacelia tanacetifolia	*Not specified*	Honungsört	T(R[a])			T(R[a])	T(MS[a])
Phaseolus vulgaris	*Not specified*	Bönor	I[a]			I[a]	
Secale cereale	*Not specified*	Råg					I[a]
Sinapis alba	*Not specified*	Senap				T(MS[a])	T(R[a])
Solanum tuberosum	AR 04-4096	Potatis	T(R)				
	AR 04-4098		T(R)				
	AR 04-4107		T(R)				
	CS8617						T(R)
	Russet Burbank		T(S)				T(S)

Latin name	**Cultivar**	**Swedish name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
Sorghum sudanense	*Not specified*	Sudangräs				T(R[a])	
Tagetes spp.	*Not specified*	Tagetes	I[a]			I[a]	I[a]
Trifolium repens	c17504	Vitklöver					T(MR)
	c17507						T(MR)
	c17522						T(MR)
	c17534						T(MR)
Triticale rimpaui	*Not specified*	Rågvete					I[a]
Triticum aestivum	Nugaines	Vete	T(S)				I
	Prodax		T(S)				
	Stephens						I
	Not specified						I
	Not specified	Höst och vårvete					I[a]
Zea mays	Hybrid AP622	Majs			T(MR)		
	Jubilee		T(S)				
	Not specified					T(R[a])	I[a]

[1]Including pathotype 1 of race 1, [2]Including pathotype 1 of race 2 [3]Race dependent. **Additional references:** [a]Aaltjeschema 2018 (I = natural decrease - the nematodes cannot multiply and mortality is similar to black fallow, R = little propagation - the nematodes can not increase much, MS = moderate propagation, S = high propagation, T = no damage has been measured). **Abbreviations:** S = Susceptible (nematode reproduces well), MS = Moderately Susceptible (nematode reproduction somewhat reduced), MR = Moderately Resistant (nematode reproduction considerably reduced), R = Resistant (nematode reproduction severely suppressed) and I = Immune (no evidence of nematode feeding or reproduction), following Ferris et al. (2018).

Table 5. Weed species in Swedish plant production systems and their resistance rating to the different *Meloidogyne* spp. The information in the table was mainly retrieved from the database Nemabase (Ferris et al., 2018; References therein). Additional references included is indicated by superscript letter and listed in the table footer.

Swedish name	Latin name	*M. chitwoodi*	*M. fallax*	*M. hapla*
Backförgätmigej	*Myosotis collina*			S
Bergssyra	*Rumex acetosella*			S
Besksöta	*Solanum dulcamara*			S
Blåklint	*Centaurea cyanus*			S
Brännässla	*Urtica dioica*			S
Brunskära, släktet	*Bidens* spp.			S
Daggkåpa, släktet	*Alchemilla* spp.			S
Duvvicker	*Vicia hirsuta*			S
Fältveronika	*Veronica arvensis*			S
Gängel	*Galinsoga parviflora*	MR		S
Gråbo	*Artemisia vulgaris*	S[a]		S[1]
Groblad	*Plantago major*			S
Grönknavel	*Scleranthus annuus*			S
Gullkrage	*Chrysanthemum segetum*			S
Harkål	*Lapsana communis*			S
Hönsnarv	*Cerastium vulgatum*			S
Hundäxing	*Dactylis glomerata*	S		MS
Kålmolke	*Sonchus oleraceus*			S
Kamomill	*Matricaria chamomilla*			S
Klibbnattskatta	*Solanum sarrachoides*	S		S
Knölklocka	*Campanula rapunculoides*			S
Kornvallmo	*Papaver rhoeas*			S
Korsört	*Senecio vulgaris*	S		S
Krusskräppa	*Rumex crispus*			S
Lomme	*Capsella bursa-pastoris*	S		S
Luddvicker	*Vicia villosa*			S
Majveronika	*Veronica serpyllifolia*			S
Maskros	*Taraxacum officinale*			R - S
Maskros	*Taraxacum vulgare*			S[b]
Mjuknäva	*Geranium molle*			S[c]
Mjukplister	*Lamium amplexicaule*			MS - S
Nattskatta	*Solanum nigrum*	S	S	S
Näva, släktet	*Geranium* spp.			S
Pilört	*Polygonum persicaria*			S
Pipdån	*Galeopsis tetrahit*			S
Revormstörel	*Euphorbia helioscopia*			S
Revsmörblomma	*Ranunculus repens*			S
Rödklint	*Centaurea jacea*	S[a]		S[c]

Swedish name	**Latin name**	***M. chitwoodi***	***M. fallax***	***M. hapla***
Rödplister	*Lamium purpureum*			S
Rölleka	*Achillea millefolium*			S
Skär kattost	*Malva neglecta*			S
Skatnäva	*Erodium cicutarium*			R - S
Sminkrot	*Lithospermum arvense*			S
Sommargyllen	*Barbarea vulgaris*			S
Sommarvicker	*Vicia angustifolia*			S
Sommarvicker	*Vicia sativa*			S
Stånds	*Jacobaea vulgaris*	S[a]		
Stillfrö	*Descurainia sophia*			S
Stor kardborre	*Arctium lappa*			S[d]
Strandfräne	*Rorippa sylvestris*	S[a]		
Styrmorsviol	*Viola tricolor*			S
Svinmålla	*Chenopodium album*			S
Svinmolke	*Sonchus asper*	S		S
Syska, släktet	*Stachys* spp.			S
Tistel, släktet	*Cirsium* spp.			S
Trampört	*Polygonum aviculare*			S
Tussilago	*Tussilago farfara*			S
Vägtistel	*Cirsium vulgare*	S		S
Vårförgätmigej	*Myosotis stricta*			S
Våtarv	*Stellaria media*	I		R - S
Viol, släktet	*Viola* spp.		S[e]	
Vitplister	*Lamium album*			S
Åkerkulla	*Anthemis arvensis*			S
Åkermynta	*Mentha arvensis*			S
Åkersenap	*Brassica kaber*			S
Åkerspergel	*Spergula arvensis*			S
Åkersyska	*Stachys arvensis*			S
Åkertistel	*Cirsium arvense*	S	S[e]	S
Åkerveronika	*Veronica agrestis*			S
Åkerviol	*Viola arvensis*			S
Ängssyra	*Rumex acetosa*			S

[1]Listed as cultivar 'Indica' in Ferris et al. (2018)

Additional references: [a]Viketoft and van der Putten, 2015; [b]de la Pena & Bonte 2014; [c]Wilschut et al., 2016; [d]Zhuran et al., 2014; [e]Hodgetts et al., 2016.

Abbreviations: S = Susceptible (nematode reproduces well), MS = Moderately Susceptible (nematode reproduction somewhat reduced), MR = Moderately Resistant (nematode reproduction considerably reduced), R = Resistant (nematode reproduction severely suppressed) and I = Immune (no evidence of nematode feeding or reproduction), following Ferris et al. (2018).

Table 6. Summary of the range of resistance rating reported for different crops for the different *Meloidogyne* spp. Note that this table summarizes the ratings at the plant species level (see Table 2 and 3 for information at the cultivar level for plants that are rated as immune and resistant, respectively.). The data was mainly retrieved from the database Nemabase (Ferris et al., 2018; References therein). Additional references included is indicated by superscript letter and listed in the table footer.

Swedish name	**Latin name**	***M. chitwoodi*** **unspec. race**	***M. chitwoodi*** **race 1**	***M. chitwoodi*** **race 2**	***M. fallax***	***M. hapla***
Blålusern	*Medicago sativa*	R, MS, S	I, R, S	I, R, MR, MS, S	MS	R, MR, MS, S
Böna	*Phaseolus vulgaris*	I[a]*, MS, S		S	I[a], R, MS,S	R, MR, MS, S[(a)]
Cikoria	*Cichorium intybus*	I[a], R[(a)], MR, MS, S			I[a], R,MR, MS	MS[a], S
Dill	*Anethum graveolens*					R, S
Engelskt rajgräs	*Lolium perenne*	R[a]			S[a]	I[a]
Foderraps, raps	*Brassica napus*	MR	S	MR, S		R[a], MR, MS,S
Gurka	*Cucumis sativus*					R, MS, S
Havre	*Avena sativa*	S	S	S		I[a,b], R,S
Honungsört	*Phacelia tanacetifolia*	R[a]			R[a], S	MS[a]
Italienskt rajgräs	*Lolium multiflorum*	S[a]			S[(a)]	I[a] ,S
Jordgubbar	*Fragaria* x *ananassa*	I[a], MR			S[(a)]	MS, S[(a)]
Kål, Broccoli, fodermärgkål	*Brassica oleracea*	MR, MS[a]				R[a], MR, S
Kärringtand	*Lotus corniculatus*	MS				MS, S
Korn	*Hordeum vulgare*	R[(a)], MR, MS[(a)], S[(b)]	R, MS	S	R[a], S	I[a,b], R
Lin	*Linum usitatissimum*	I[a]				R[a], S
Lök	*Allium cepa*	R[a], S	I	I, R	R[a]	R[(a)], S
Majs	*Zea mays*	S[(b)], MS[a]	R, S	R, MR, MS, S	MR, R[a]	I[a,b], S
Morot	*Daucus carota*	MR, S	R, S	I, R, S		S
Piplök	*Allium fistulosum*					MR
Potatis	*Solanum tuberosum*	R, MR, S	R, S			R, MS, S

Swedish name	**Latin name**	***M. chitwoodi* unspec. race**	***M. chitwoodi* race 1**	***M. chitwoodi* race 2**	***M. fallax***	***M. hapla***
Purjolök	*Allium porrum*	MS[a]			R[a], S[d]	R[a], S
Råg	*Secale cereale*	S[a]	MS		MS, S[(a)]	I[(a)]
Rågvete	*Triticale rimpaui*	MS[a]			R[a]	I[a]
Rättika	*Raphanus sativus*	I[c], I[a]*, MR, S	R, MS	R, MS	S, MS[a]*	R, MR, MS[(a)], S
Rörflen	*Festuca arundinacea*					R
Sallat	*Lactuca sativa*					R, S
Selleri	*Apium graveolens*	S			S	R, S
Senapskål/Rucola	*Eruca sativa*	R[c]				
Sockerbeta/Rödbeta	*Beta vulgaris*	R[a], MR[b], S	R	R	S[(a)]	R[b], S[(a)]
Sojaböna	*Glycine max*					MR, MS, S
Solros	*Helianthus annuus*		S			MR, MS, S
Sparris	*Asparagus officinalis*	I		I	MS	R
Spenat	*Spinacia oleracea*	I[a]			I[a]	R[(a)], MS, S
Squash	*Cucurbita pepo*					R, MS,S
Tagetes	*Tagetes spp.*	I[a], MR, S			I, MS	I, MR, MS, S
Vete	*Triticum aestivum*	R, MS[a], S[(b)]	MS, S	S	R[a], S[(a)]	I[(a,b)], R, S
Vitklöver	*Trifolium repens*	S				R, MR, S
Vitlök	*Allium sativum*					R, MR, MS, S
Senap	*Sinapis alba*			S	MS[a]	R[(a)], MR, MS
Åkerkål/Rybs/Rova/ Salladskål	*Brassica rapa*		S	I, S		MR, MS,S
Ärter	*Pisum sativum*	R[a], S		S	R[a]	S[(a)]

Additional references: [a]Aaltjeschema 2018 (I = natural decrease - the nematodes cannot multiply and mortality is similar to black fallow, R = little propagation - the nematodes can not increase much, MS = moderate propagation, S = high propagation); [b]Santo et al. 1980 (I = no or few larvae recovered from roots, R = <21% recovery; MR = 80% recovery ; S = >100% recovery); [c]Mbiro, 2016 (I = non host - no nematodes produced in roots, R = reproductive factor *Rf* was 0.65); [d]Topalovic et al. 2017

Abbreviations: S = Susceptible (nematode reproduces well), MS = Moderately Susceptible (nematode reproduction somewhat reduced), MR = Moderately Resistant (nematode reproduction considerably reduced), R = Resistant (nematode reproduction severely suppressed) and I = Immune (no evidence of nematode feeding or reproduction), following Ferris et al. (2018).

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Appendix 1. List of plant species considered in this report to be relevant for Swedish cropping systems and for which information was searched and whether it was found.

Swedish name	**Latin name**	**Information retrieved**
Crops, vegetables and forage crops		
Blålupin	*Lupinus angustifolius*	x
Blålusern	*Medicago sativa*	x
Bönor	*Phaseolus vulgaris*	x
Cikoria	*Cichorium intybus*	x
Dill	*Anethum graveolens*	x
Engelskt rajgräs	*Lolium perenne*	x
Fodervicker	*Vida sativa*	-
Gullusern	*Medicago falcata*	x
Havre	*Avena sativa*	x
Honungsört	*Phacelia tanacetifolia*	x
Humlelusern	*Medicago lupulina*	x
Hundäxing	*Dactylis glomerata*	x
Italienskt rajgräs	*Lolium multiflorum*	x
Jordärtsskocka	*Helianthus tuberosus*	x
Jordgubbar	*Fragaria × ananassa*	x
Kål/Broccoli/fodermärgkål	*Brassica oleracea*	x
Käringtand	*Lotus corniculatus*	x
Korn	*Hordeum vulgare*	x
Kummin	*Carum carvi*	x
Lin	*Linum usitatissimum*	x
Lök	*Allium cepa*	x
Luddvicker	*Vida villosa*	-
Majs	*Zea mays*	x
Morot	*Daucus carota*	x
Palsternacka	*Pastinaca sativa*	x
Pepparrot	*Armoracia rusticana*	x
Persilja	*Petroselinum crispum*	x
Potatis	*Solanum tuberosum*	x
Pumpa	*Curcurbita maxima*	*x*
Purjolök	*Allium porrum / Allium ampeloprasum*	x
Råg	*Secale cereale*	x
Rågvete	*× Triticosecale / Triticale rimpaui*	x
Rajsvingel	*× Festulolium*	-
Raps/Foderraps/kålrot	*Brassica napus*	x
Rättika	*Raphanus sativus*	x
Rödklöver	*Trifolium pratense*	x

Swedish name	**Latin name**	**Information retrieved**
Rödsvingel	*Festuca rubra*	x
Rörflen	*Phalaris arundinacea*	x
Rybs/salladskål	*Brassica rapa*	x
Sallat	*Lactuca sativa*	x
Selleri	*Apium graveolens*	x
Sockerbetor/rödbetor	*Beta vulgaris*	x
Sojaböna	*Glycine max*	x
Solros	*Helianthus annuus*	x
Sparris	*Asparagus officinalis*	x
Spenat	*Spinacia oleracea*	x
Squash	*Curcurbita pepo*	x
Svartkämpe	*Plantago lanceolata*	x
Timotej	*Phleum pratense*	x
Vete	*Triticum aestivum*	x
Vitklöver	*Trifolium repens*	x
Vitsenap	*Sinapsis alba*	x
Åkerbönor	*Vicia Faba*	x
Alsikeklöver	*Trifolium hybridum*	x
Ängsgröe	*Poa pratensis*	-
Ängssvingel	*Festuca pratensis*	-
Ärter	*Pisum sativum*	x
Weeds		
Backtrav	*Arabidopsis thaliana*	-
Baldersbrå	*Matricaria inodora*	-
Bergsyra	*Rumex acetosella*	x
Besksöta	*Solanum dulcamara*	x
Bladvass	*Phragmites australis*	-
Blåklint	*Centaurea cyanus*	x
Blåmadra	*Sherardia arvensis*	-
Brännässla	*Urtica dioica*	x
Brunört	*Prunella vulgaris*	-
Brunskära	*Bidens tripartita*	x
Buskmåra	*Galium album*	-
Daggkåpa	*Alchemilla vulgaris*	x
Duvvicker	*Vicia hirsuta*	x
Fältveronika	*Veronica arvensis*	x
Fliknäva	*Geranium dissectum*	x
Flyghavre	*Avena fatua*	-
Förgätmigej	*Myosotis arvensis*	x
Gängel	*Galinsoga parviflora*	x
Gårdsskräppa	*Rumex longifolius*	-
Gåsört	*Argentina anserina*	-
Glim	*Silene* spp.	-

Swedish name	**Latin name**	**Information retrieved**
Gråbo	*Artemisia vulgaris*	x
Groblad	*Plantago major*	x
Grönknavel	*Scleranthus annuus*	x
Gullkrage	*Chrysanthemum segetum*	x
Hårgängel	*Galinsoga quadriradiata*	-
Harkål	*Lapsana communis*	x
Hönsarv	*Cerastium fontanum/Cerastium vulgatum*	x
Höstfibbla	*Scorzoneroides autumnalis*	-
Hundkäx	*Anthriscus sylvestris*	-
Jordrök	*Fumaria officinalis*	-
Jungfrukam	*Aphanes arvensis*	-
Kålmolke	*Sonchus oleraceus*	x
Kamomill	*Matricaria chamomilla*	x
Kardborre	*Arctium* spp.	-
Klofibbla	*Crepis tectorum*	-
Knölklocka	*Campanula rapunculoides*	x
Knölsyska	*Stachys palustris*	x
Kornvallmo	*Papaver rhoeas*	x
Korsört	*Senecio vulgaris*	x
Krusskräppa	*Rumex crispus*	x
Krypnarv	*Sagina procumbens*	-
Krypven	*Agrostis stolonifera*	-
Kvickrot	*Elytrigia repens*	-
Lentåtel	*Holcus mollis*	-
Lomme	*Capsella bursa-pastoris*	x
Luddvicker	*Vicia villosa*	x
Majveronika	*Veronica serpyllifolia*	x
Maskros	*Taraxacum officinale*	x
Mjuknäva	*Geranium molle*	x
Nagelört	*Erophila verna*	-
Nattglim	*Silene noctiflora*	x
Nattskatta	*Solanum nigrum*	x
Nysört	*Achillea ptarmica*	x
Paddfot	*Asperugo procumbens*	-
Penningört	*Thlapsi arvense*	-
Pilört	*Polygonum lapathifolium/ Polygonum persicaria*	x
Pipdån	*Galeopsis tetrahit*	x
Plister	*Lamium* spp.	x
Rast/Fårtunga	*Anchusa arvensis*	-
Råttsvans	*Myosurus minimus*	-
Rävtörel	*Euphorbia peplus*	-
Renkavle	*Alopecurus myosuroides*	-

Swedish name	**Latin name**	**Information retrieved**
Revormstörel	*Euphorbia helioscopia*	x
Revsmörblomma	*Ranunculus repens*	x
Riddarsporre	*Consolida regalis*	-
Rödmire	*Anagallis arvensis*	-
Rödtoppa	*Odontites vulgaris*	-
Rölleka	*Achillea millefolium*	x
Ryssgubbe	*Bunias orientalis*	-
Sanddådra	*Camelina microcarpa*	-
Sandnarv	*Arenaria serpyllifolia*	-
Sandtrav	*Cardaminopsis arenosa*	-
Skär kattost	*Malva neglecta*	x
Skatnäva	*Erodium cicutarium*	x
Småsporre	*Chaenorrhinum minus*	-
Sminkrot	*Lithospermum arvense*	x
Smörblomma	*Ranunculus acris*	-
Snärjmåra	*Galium aparine/Galium spurium*	-
Sommargyllen	*Barbarea vulgaris*	x
Sommarvicker	*Vicia angustifolia*	x
Stillfrö	*Descurainia sophia*	x
Storven	*Agrostis gigantea*	-
Styvmorsviol	*Viola tricolor*	x
Svinmålla	*Chenopodium album*	x
Svinmolke	*Sonchus asper*	x
Trädgårdsveronika	*Veronica persica*	-
Trampört	*Polygonum aviculare*	x
Tussilago	*Tussilago farfara*	x
Tuvtåtel	*Deschampsia caespitosa*	-
Våtarv	*Stellaria media*	x
Vattenpilört	*Persicaria amphibia*	-
Vildmorot	*Daucus carota* ssp. *Silvestris*	-
Vildpersilja	*Aethusa cynapium*	-
Vitgröe	*Poa annua*	-
Åkerbinda	*Fallopia convolvulus*	-
Åkerfräken	*Equisetum arvense*	-
Åkergyllen	*Smalkinis tvertikas*	-
Åkerkål	*Brassica campestris*	x
Åkerkulla	*Anthemis arvensis*	x
Åkermynta	*Mentha arvensis*	x
Åkersenap	*Sinapis arvensis*	-
Åkerspergel	*Spergula arvensis*	x
Åkersyska	*Stachys arvensis*	x
Åkertistel	*Cirsium arvensis*	x
Åkerven	*Apera spica-venti*	-

Swedish name	**Latin name**	**Information retrieved**
Åkerveronika	*Veronica agrestis*	x
Åkerviol	*Viola arvensis*	x
Ängssyra	*Rumex acetosa*	x

Appendix 2. Influence of temperature on population growth

Temperature has a major impact on population growth of nematodes partly because they may have many generations per year. *Meloidogyne chitwoodi* requires 600-800 day degrees above 5°C for development of the first generation (Pinkerton et al., 1991). The requirements for development of a second, third and fourth generation was 950-1100, 1500-1600 and 2150 day degrees, respectively (Pinkerton et al., 1991). Usually at least three generations is required before there is a high probability of damage on potato (Braasch et al. 1996). Thus the risk for a third generation is much higher in regions with a temperature accumulation above 1500 day degrees but there is a potential during warm years for a third generation in regions where the average temperature is below 1500 day degrees. Fig. 1 below, which show the number of day degrees in different regions in Sweden, can be used to give a rough estimate of the impact of temperature on the expected population growth, e.g. the darkest green region show the region where the risk for a damaging third generation is highest.

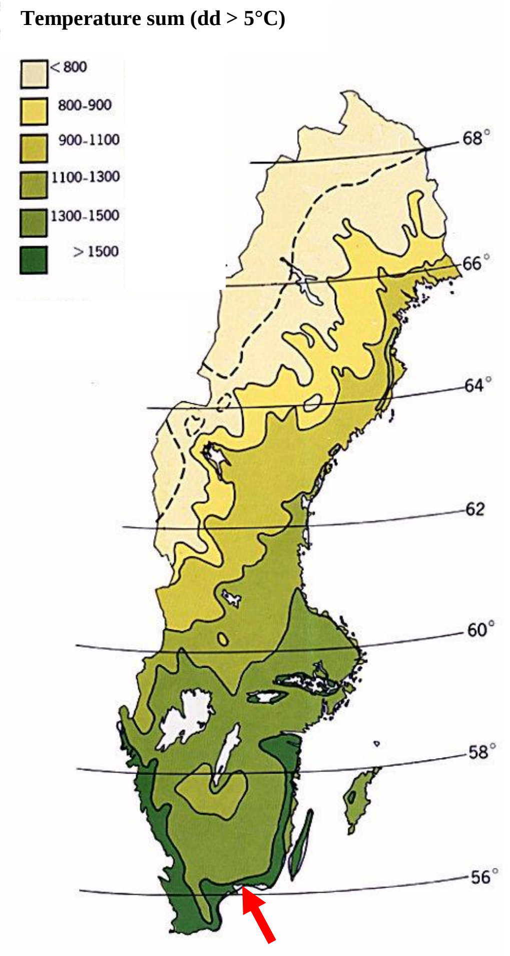

Fig. 1. Accumulated day degrees above 5°C. The red arrow indicate where *M. chitwoodi* was found (EPPO 2018a). Modified from SLU (2006).