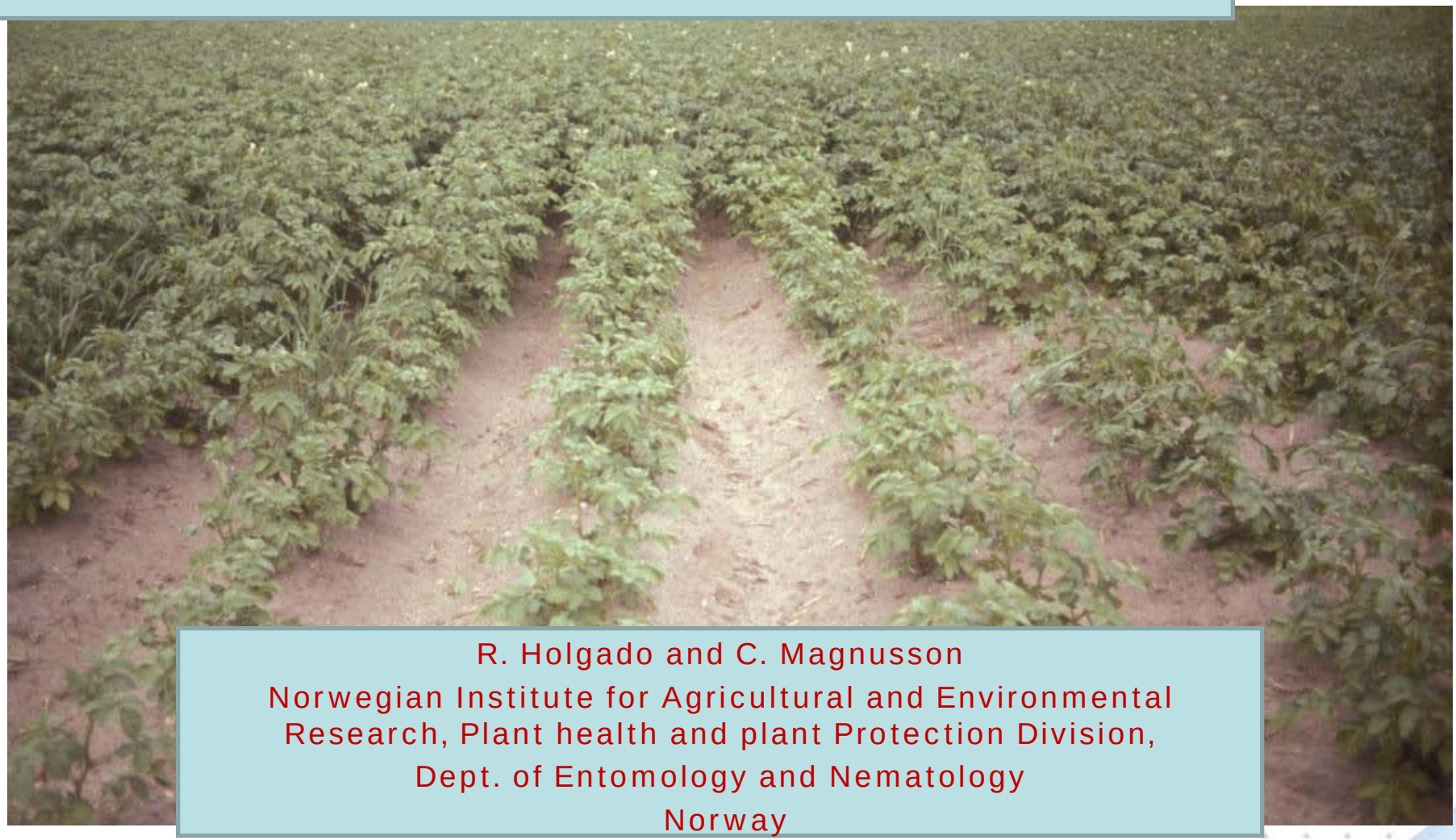
Management of PCN (*Globodera* spp.) populations under Norwegian conditions.



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3rd Symposium on Potato Cyst Nematodes , Harper Adams University College . 14-15 Sept. 2010

Potato cultivation in Norway

- **Farmers in Norway have cultivated potato for more than 250 years.**
- **In 2008 the total potato acreage was 14 400 Ha.**
- **The total potato production 398 000 tonn**
- **The annual production value in potato of approximately 600 millions NOK (75 millions Euro).**
  www.ssb.no

Background of potato cyst nematode (PCN) in Norway

- In 1955 the potato cyst nematode was recorded for the first time in Agder. This detection produced the initial legislation of PCN control, and was implemented based on the statutory regulation of 1916.
- Since 1956 PCN was given quarantine status in infested agricultural land and home gardens.
- The 1956 PCN legislation stipulated measures in event of finding infestation.
- The growing of ware potatoes were restricted to at least 4 year rotation, and prohibited the unauthorised movement of infested soil, by any means, to prevented spread to adjacent areas.
- This detection resulted in extensive surveys.

PCN surveys

- **Extensive surveys started in 1955; and were carried uninterrupted until the end of the 1990ties. These surveys included producing potato agricultural land and home gardens.**
- **In 2009 a new national survey program for the principal potato districts has started, the surveys is aimed to update the PCN occurrence.**
- **The surveys will continue during the subsequently years until all major potato areas will be cover.**
- **Records of all PCN infested land in Norway have been retained since 1955, so decline rates and local spread can be monitored**

Sampling to estimate PCN occurrence and density for statutory and advisory purpose

Type of Sample	Number of cores per sample	Total bulked sample	Area to provide one bulk sample	Patterns of cores grid (Core size 25.0 x 2.5 cm)
Routine	50	250 ml	0.5 ha	Line distance 10 m
Certified potato	50	250 ml	0.25 ha	Line distance 7 m
In stored packing houses of ware potatoes		250 ml	Min. 30 tonnes of potato	Min. 1 sample per consignment

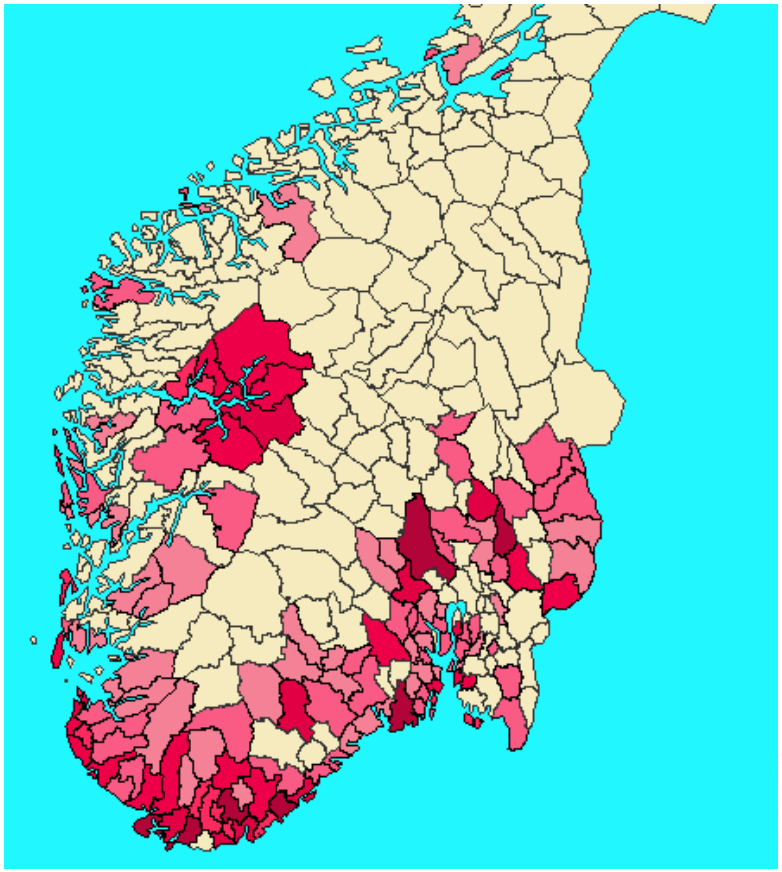
Occurrence of PCN in Norway (farms and home gardens), analysed during the extensive survey period 1955-2000.

	Number of properties with PCN				Analysed samples		
	Home gardens (%)*	Farms	Without information	Total	With PCN (%)**	Without PCN	Total
Total	2979 (47)	1785	1642	6406	4554 (5)	84 608	89 162

* % in relation to the total proprieties with PCN (farms + home gardens)
** % in relation to the total of samples analysed

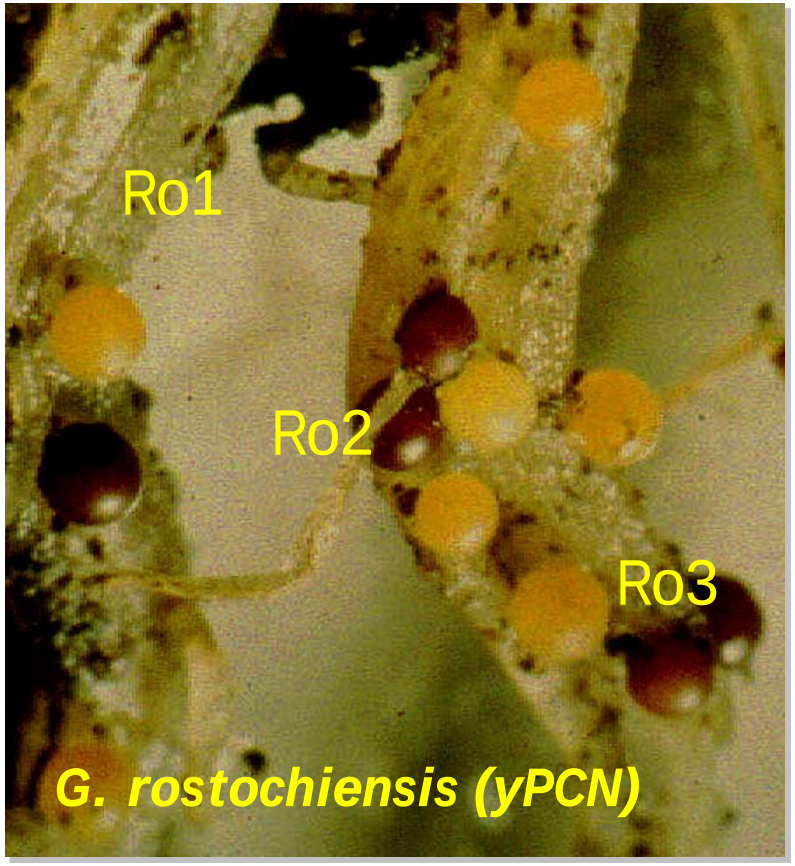
Occurrence of PCN in Norway

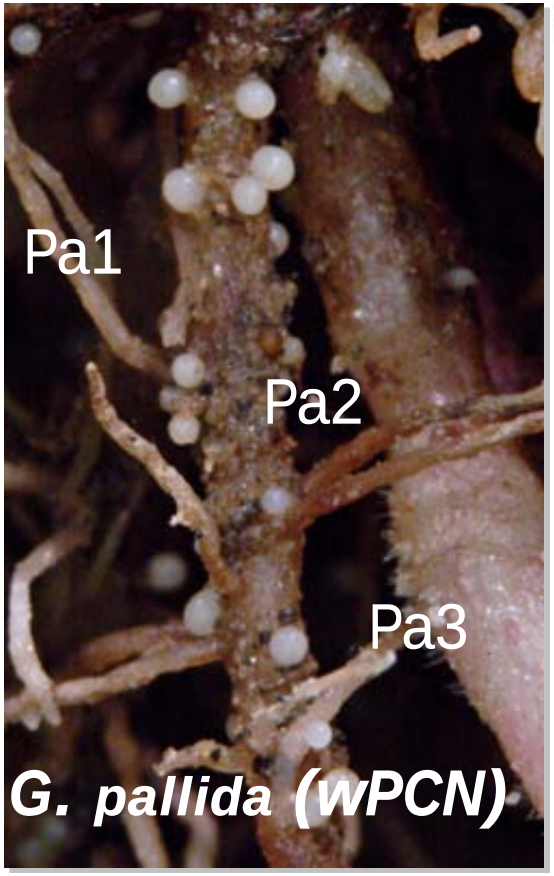
- 1955:Agder-county
- 1976: Southern Counties from Dovre (with exception of Hedmark county)
- 1985: Municipality of Møre and Romsdal, Hedmark, and Sør Trøndelag.
- 1993:Nord Trøndelag municipality of Frosta
- 2004:Municipality of Stjørdal.



http://webgis.no/potetcyste_nematoder/

Pathotypes occuring in Norway





G. rostochiensis **(yPCN) is present and widespread in southern part of the country. Surveys 1956-1978 indicated that Ro1 is present in almost 98 % of the PCN-populations ,**

G. pallida **(wPCN), first recorded in 1974; is present with limited distribution in agricultural land, but with major distribution on home gardens.**

Resistance-breaking pathotypes

- **The selection for resistance-breaking pathotypes has been demonstrated in a long-term field trial.**
- **The continuous cropping of Ro1 resistant potato cultivars for 10 years resulted in Ro3 overcoming Ro1.**
- **Complementary laboratory studies indicated that continuous growing of H_1 resistant cv. Saturna in soil with Ro1/Ro3 mixtures, showed that an initial Ro3 frequency as low as 0.1% in 5 years time resulted in high populations of Ro3.**

PCN Management

- The management of PCN has been based mainly on regulatory restrictions.
- Commercial chemical fumigants, organophosphates or carbamate nematicides have not been used in Norway since the early 1970s.
- Today, policy to manage yPCN Ro1 is still crop rotation using non-host crops, and alternating between susceptible and resistant cultivars every 4 years. This recommendation includes the use of certified seed .
- The 4 years rotations are complicated by restricted acreage.
- Infestations by (wPCN) or virulent (yPCN) results in 40-years ban on growing potato.
- Most Norwegian potato cultivars have the resistance genes, Gro-1 (H_1) from *Solanum tuberosum* ssp. *andigena*.
- In the preceding decades great emphasis has been placed on documenting freedom from PCN in the production of certified seed and on the detection of infested fields and their placement under effective quarantine regulations.
- In the early 1960ties import and movement of all kind of potato seed was prohibited, as a measure to prevent the introduction of new PCN populations, and to prevent contamination of uninfested land.

Statutory regulations from 1956-2010

- PCN initial legislation 1956 :Potato or tomato cultivation every 4 year, prohibited soil or infected plants to be moved.
- In 1962 : the regulation prohibited the movement of equipment and machinery used in the infected area. Unless it was cleaned, inspected and found free of PCN.
- In 1970: the PCN regulation included the use of PCN resistant potato cultivars. For using resistant cultivars a surveillance and official control of the infected areas was recommended, and the use of chemical fumigants in highly infested fields.
- In 1977: the taxonomic separation of yPCN and wPCN, together with emerging information on the existence of pathotypes was taken into consideration, and recommended a controlled use of resistant cultivars, to avoid the increase of resistant breaking pathotypes.
- In 1990: incorporated a prohibition of growing potatoes in areas with wPCN or virulent yPCN, and included further the possibility of imposing a ban on growing potato in areas close to the farms, or on farms sharing equipment or machinery with infested farms.

Statutory regulations from 1956-2010

- In 1998: included measures for potato manufacturing facilities; if PCN was found, sanitary measures are compulsory to the houses committed to packing potatoes. For farmers the movement of their own seed potatoes from packing houses was prohibited.
- Also the possibility of economic compensation for farms affected with a ban for growing potatoes is mentioned.
- In 2000: the PCN regulation stipulated that all potato producers and manufacturing facilities must be officially listed and have an internal control system for PCN management, including preventive measures against its dissemination. The regulation mentioned the possibility of a long quarantine period for resistance breaking PCN populations, in practice more than 40 years due to the long persistence of PCN in the absence of host plants.
- Recently in April 2010: a new regulation was introduced prescribing surveillance and official control of PCN-infected and non-infected areas where potatoes are produced. This new strategy implies the demarking and regulation of the area actually infested.

PCN and certified seed potato

- **Official controls of certified seed potatoes started in 1939.**
- **Surveying areas with production of certified seed potatoes for PCN started already in 1956, soon after the first detections of PCN in Norway.**
- **In 1957, *Heterodera rostochiensis f. solani* was incorporated in the regulations on certified seed potatoes.**
- **In the early 1960ties import and movement of all kind of potato seed was prohibited.**
- **By now, areas with seed potato production have been under constant monitoring for more than 50 years.**
- **Each year about 3000 soil samples are analysed for PCN to clear areas for certified seed potato production.**
- **These areas are so far free of PCN.**
- **The total acreage with seed potatoes in 2009 was 813.7 Ha.**

Identification to species level

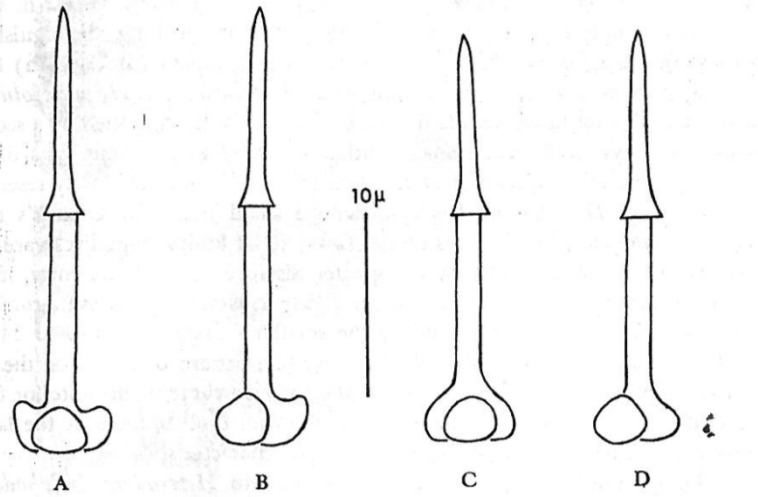
- Studies on the identity of species and pathotypes have been carried out since the middle of the 1970s until present time.
- Specie identification is done in accordance with the EPPO diagnostic protocol PM 7/40(2) (EPPO, 2009) and includes morphology, iso-electric focusing and molecular methods.
- Correct identification to species and pathotype is of crucial importance for management and regulations to be imposed.
- *G. rostochiensis* and *G. pallida* are morphologically and morphometrically closely related
- Therefore the use of a combination of cyst and second-stage juvenile characteristics is recommended for reliable identification.
- In recent times we observed large morphological variability in PCN regarding shape and length of stylet, tail, and characters of the perineal pattern.
- Studies including DNA-based diagnostics of these populations are at present underway.

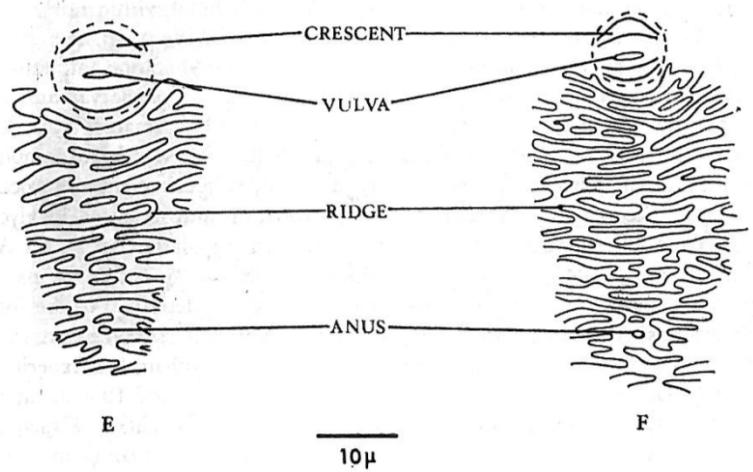
Identification of pathotypes

- Studies on the identity of species and pathotypes have been carried out since the middle of the 1970s until present time.
- The initial studies on pathotypes were made according to Kort *et al*., 1977.
- Under Norwegian conditions all pathotypes of wPCN and most pathotypes of yPCN except Ro1 are considered virulent on *andigena*-resistant potatoes.
- In the 1980s a simpler method was introduced using resistant potato cv. Saturna (resistant to Ro1, Ro4) with the susceptible variety Kerrs Pink as control. Populations developing on cv. Saturna are classified as resistance breakers.

Globodera spp. in Found in Norway

SPECIES	COMMON NAME	HOST RANGE
G. rostochiensis	Golden cyst nematode	*Solanaceae e.g.* potatoes, tomatoes
G. pallida	Pale cyst nematode	
G. achilleae	Yarrow cyst nematode	Compositae *e.g* Yarrow (*Achillea milefolium*)
G. artemisiae	Mugwort cyst nematode	Mugwort (*Artemisia vulgaris*)





G. pallida
A, B, E

G. rostochiensis
C,D,F

Fig. 4. Larval stylets and cuticle surface in anal-vulval region of ♀♀. A, B, E — *H. pallida* n. sp. C, D, F — *H. rostochiensis*.

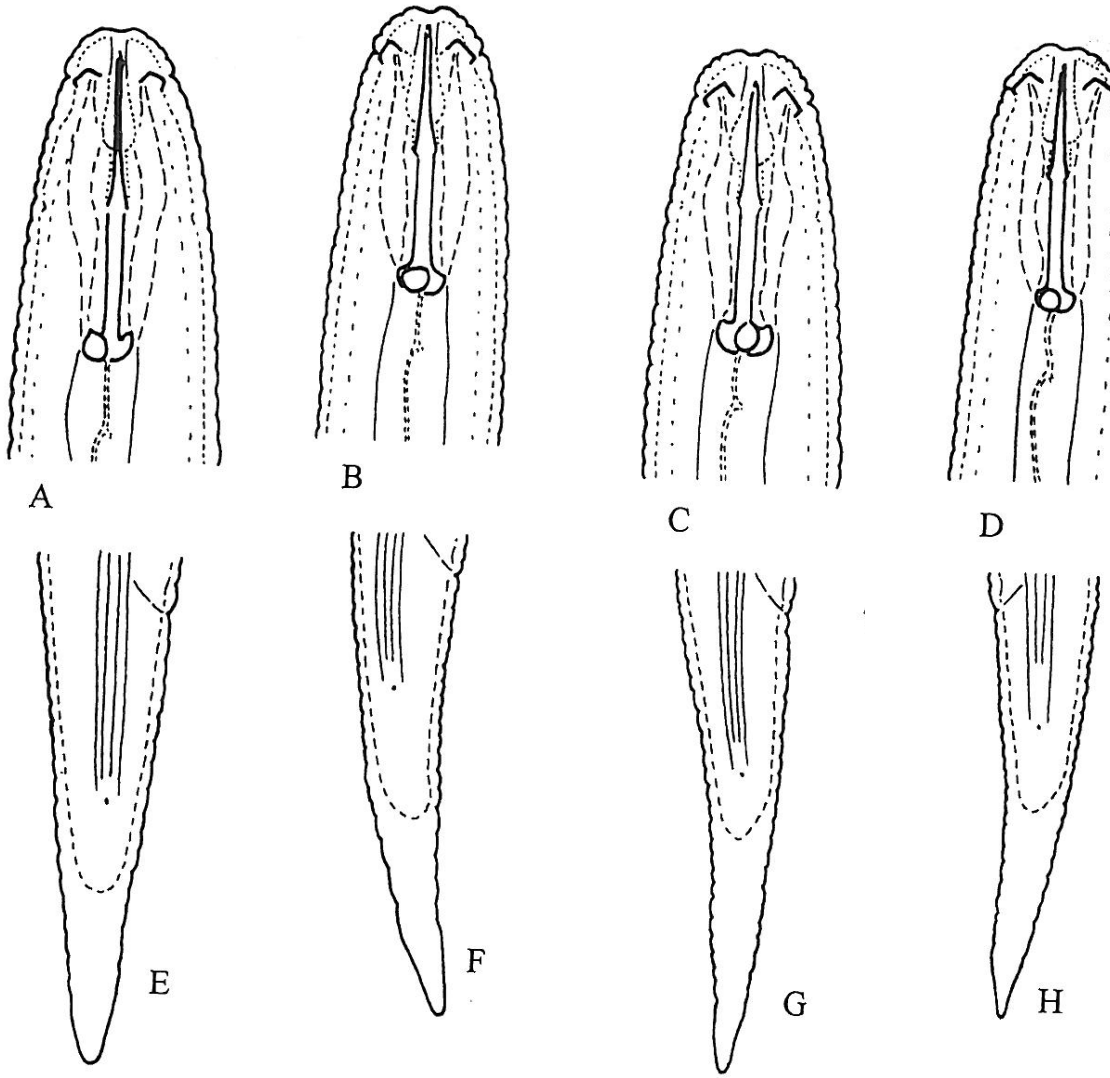
Stone , A.R. 1973

G. achillae
A-E

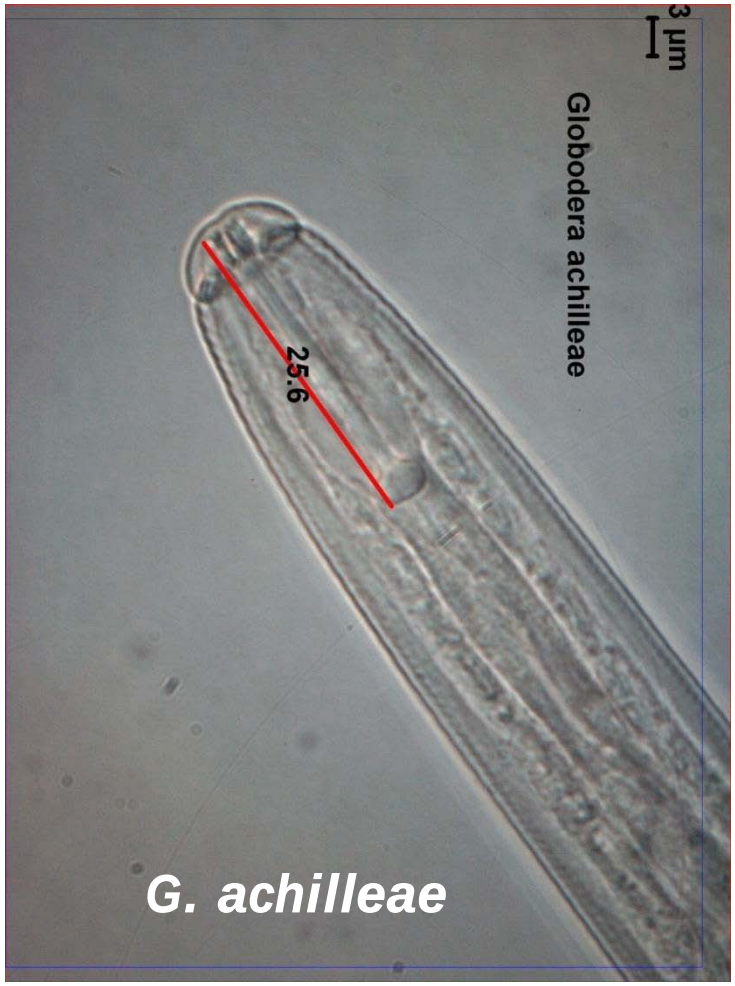
G. artemisiae
B-F

G. pallida
C-G

G. rostochiensis
D-H

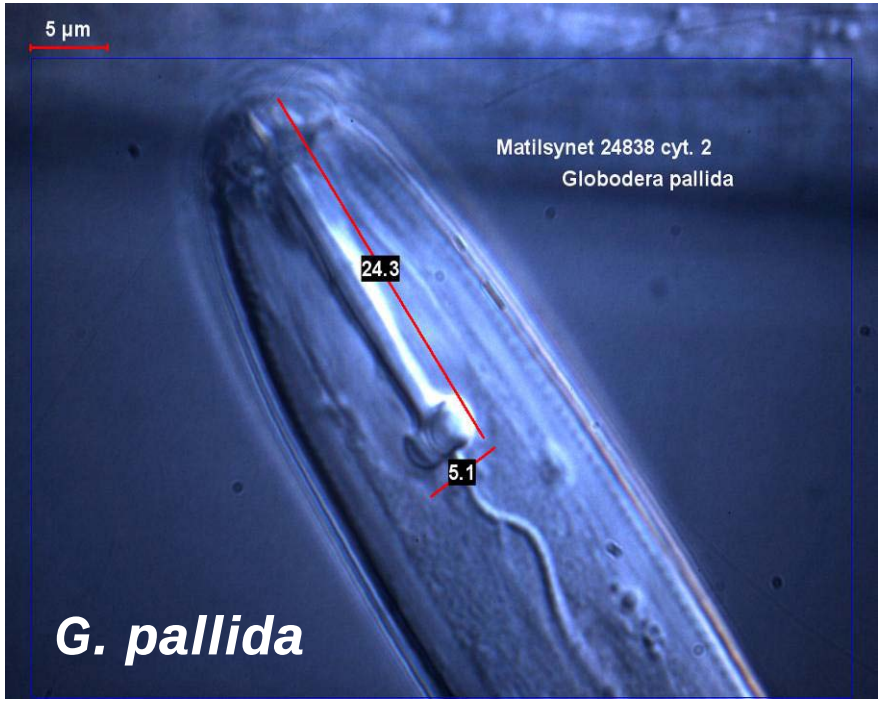


Brzseki, M.W. 1998

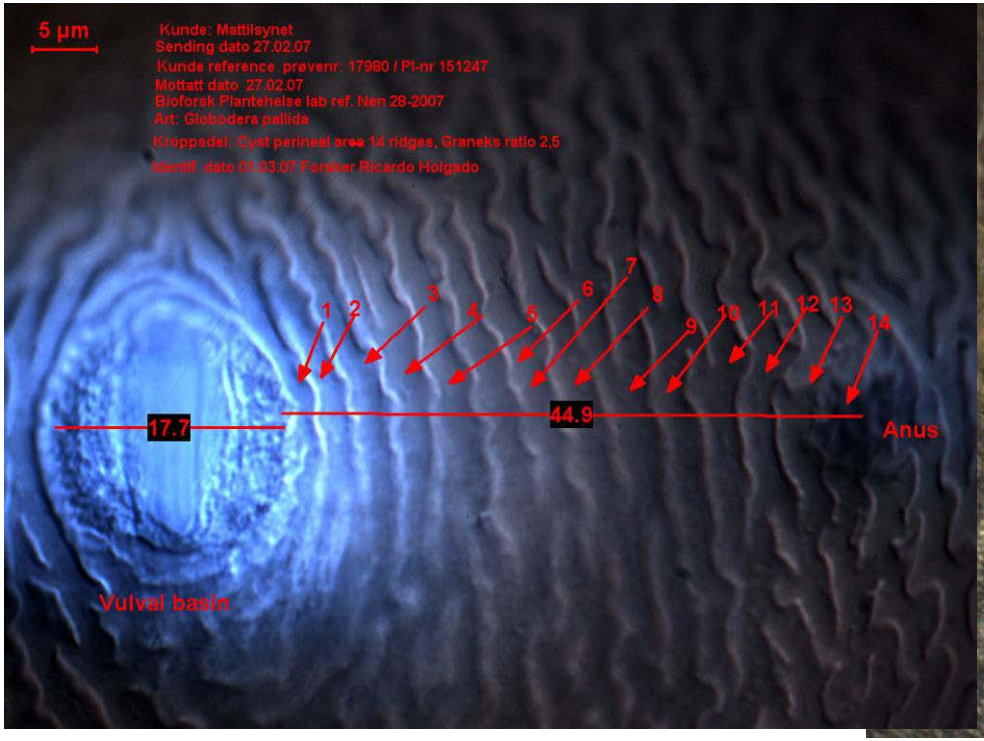


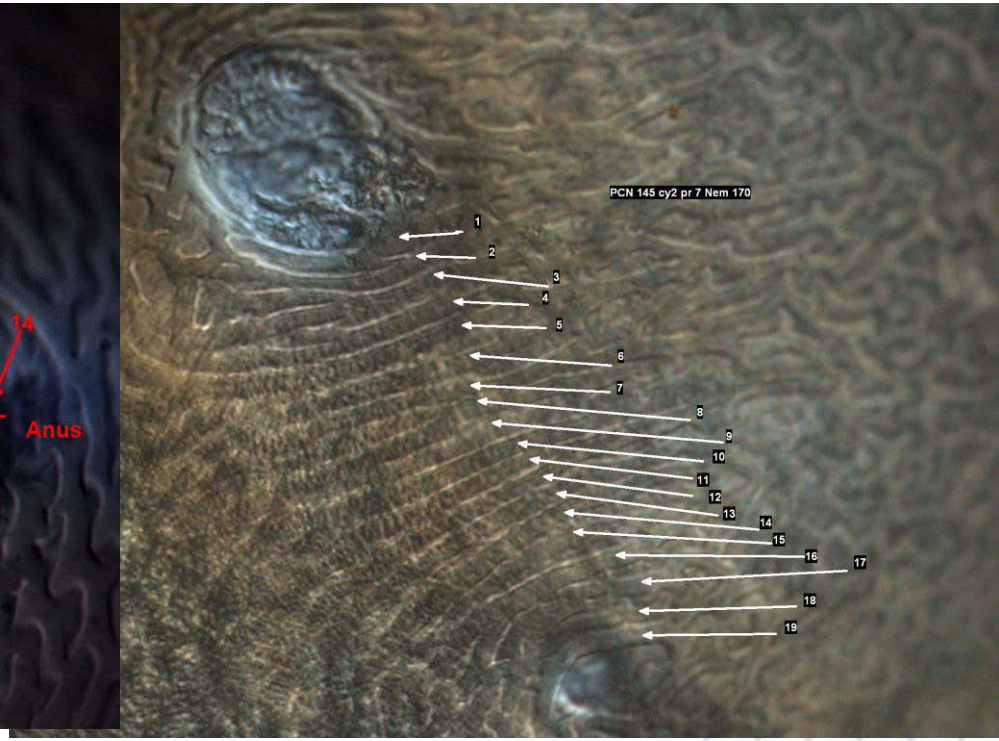
G. achilleae

G. artemisiae


5 µm
Matilsynet 24838 cyt. 2
Globodera pallida
24.3
5.1
G. pallida


2 µm
Globodera rostochiensis
Stylet 21, 10
G. rostochiensis





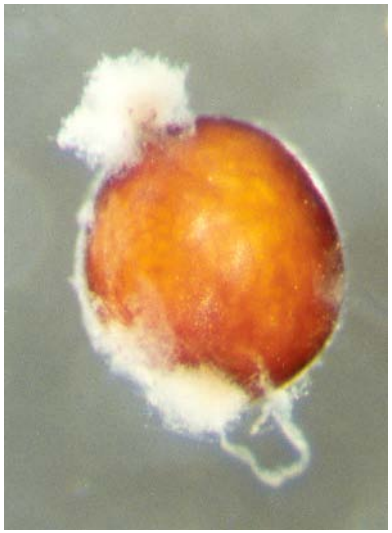
G. rostochiensis

Potential for using trap crops

- **The use of early potatoes as a trap crop is recommended for reducing PCN populations.**
- **The establishment of *Solanum sisymbriifolium* in field trials using the commercial varieties Pion and White Star are in progress.**
- **So far studies in 2009 , in the counties of Nord Trøndelag and Rogaland, using White Star with two sowing times have been completed.**
- **The preliminary studies indicated that *S. sisymbriifolium* could established successfully if due attention was paid to proper weed management and sowing time.**

Occurrence and pathogenicity of microbial antagonists parasitic to PCN

- **Soil from fields with PCN was collected and bait**
- **Nord Trøndelag and Rogaland.**
- **The following nematophagous fungi were found: *Pochonia chlamydiosporia*, *Paecilomyces lilacinus* and *Catenaria* spp.**
- **Further studies are in progress.**



Conclusions

- **The regulations have without doubt contributed in preventing PCN infestations in the seed potato areas, and probably also prevented further spreading of wPCN and virulent yPCN as each the find has been placed under quarantine. Permanent grass as a statutory regulation in home garden plots may have contributed to reduce the spread of wPCN to commercial fields.**
- **The regulations have most probably made possible the early reduction in use of chemical fumigants, organophosphates or carbamate nematicides. These chemicals have not been used since the early 1970s.**
- **The domestic production of seed potato has been kept free of PCN by frequent inspections and analyses for more than 50 years.The fact that farmers are not allowed to import seed potatoes adds to the level of security.**

Conclusions

- **The occurrence of aberrant PCN populations also reported in other countries needs to be investigated further.**
- **The reaction of these nematodes on resistant cultivars including cultural practices would provide valuable information for management routines.**
- **There are few laboratories working on morphological identification of plant parasitic nematodes, this create a challenge to the science of nematology. Not only concerning identification also in the management programs**
- **To alleviate the present situation for Norwegian farmers it is necessary to provide new information for a better prognosis of rates of decline in PCN numbers and infectivity in field soil. Any possible reduction in the quarantine period would have immediate positive economic effects for farmers and for the local enterprises, and will contribute to the sustainable development of potato production.**

Acknowledgements

- To the Norwegian Research Council for financial support (Projects 190370/I99 & 199604).
- To B-J.van Dinter from Vandijke Semo seed and services, The Netherlands, and B. Niere from Julius Julius Kühn-Institute Germany for providing seeds of *Solanum sisymbriifolium*.
- To Bonsak Hammeraas, Kari-Anne Strandenæs, Irene Rasmussen, from Bioforsk for technical assistance.
- To thank Håkon Brække and Randi Knudsen from the Norwegian Food Safety Authority for the information provided.

Thank you for your attention !