COST

Domain Committee Food and Agriculture

COST Action 872

Start Date 21/09/2006

Exploiting genomics to understand plant–nematode interactions

MONITORING PROGRESS REPORT

Reporting Period: *from 21/09/2006 – 31/12/2009*

This Report is presented to the relevant Domain Committee.
It contains three parts:

I. Management Report *prepared by the COST Office/Grant Holder*
II. Scientific Report *prepared by the Chair of the Management Committee of the Action*
III. Previous versions of the Scientific Report*; i.e., part II of past reporting periods*

The report is a "cumulative" report, i.e. it is updated annually and covers the entire period of the Action.

Confidentiality: the documents will be made available to the public via the COST Action web page except for chapter *II.D. Self evaluation*.

Based on the monitoring results, the COST Office will decide on the following year's budget allocation.

Executive summary (max.250 words):

The main objective of the Action is to develop a coordinated approach to exploitation of genomics information that is appearing for plant parasitic nematodes and host crops.

I. Management Report prepared by the COST Office/Grant Holder

I.A. COST Action Fact Sheet

Action 872 Fact Sheet

Title

Exploiting genomics to understand plantnematode interactions

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Details

Draft Mou:

Mou: 265/06

Start of Action: 04/12/2006

Entry into force: 21/09/2006

End of Action: 03/12/2010

CSO approval date: 27/06/2006

Objectives

The main objective of the Action is to develop a coordinated approach to exploitation of genomics information that is appearing for plant parasitic nematodes and host crops.

Parties

Country	Date	Country	Date	Country	Date	Country	Date
Austria	04/10/2006	Belgium	03/10/2006	France	02/03/2007	Germany	20/09/2006
Greece	20/06/2007	Ireland	20/09/2006	Israel	06/10/2006	Italy	17/10/2006
Netherlands	20/09/2006	Norway	25/09/2006	Poland	04/10/2006	Portugal	05/12/2006
Slovenia	13/10/2006	Spain	21/09/2006	Sweden	04/06/2007	Switzerland	12/12/2006
Turkey	11/01/2007	United Kingdom	20/09/2006				

Total: 18

Intentions to accept the MoU							
Country	Date	Country	Date	Country	Date	Country	Date
Croatia	N/A						

Total: 1

Participating Institutions from non-COST countries	
Egypt	Agricultural Genetic Engineering Research Institute
Australia	Wollongong University, Centre for Biomedical Science, School of Biological Sciences
Australia	Murdoch University, WA State Agricultural Biotechnology Centre (SABC)
Ukraine	Institute of Plant Protection UAAS

Working Groups
WG1: Functional genomics of plant parasitic nematodes
WG2: Comparative genomics of plant parasitic nematodes
WG3: Functional genomics of plant responses

Website
http://cost872.scri.ac.uk

I.B. Management Committee member list

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I.C. Overview activities and expenditure

Meetings

Meeting Type	Date	Place	Paid part	Cost	Total
Management Committee	04-Dec-2006	Brussels (BE)	14	8368.91	
Joint Management Comm	09-May-2007	La Colle sur Loup (FR	78	52958.65	
Working Group	07-Feb-2008	Vienna (AT)	15	10418.39	
Joint Management Comm	27-May-2008	Postojna (SI)	95	86157.84	
Working Group	19-Nov-2008	Sophia Antipolis (FR)	9	9913.71	
Joint Management Comm	26-May-2009	Toledo (ES)	96	80197.74	
					248015.2

STSM

Beneficiary	Date	From	To	Cost	Total
Mr Paulo Cezanne Reis V	06-Mar-2007	Evora (PT)	Sophia Antipolis (FR)	1200	
Mr Markus Oggenfuss	14-May-2007	CH-8820 Waedenswi	Belfast BT9 5PX, United	1650	
Mr Saša Širca	21-May-2007	1000 (SI)	Rennes (FR)	630	
Dr Barbara Geric Stare	20-May-2007	1000 Ljubljana (SI)	Rennes (FR)	1320	
Ms Sylwia Fudali	12-Aug-2007	Warsaw (PL)	Harpenden (uk)	2500	
Mr Jose Lozano	23-Sep-2007	Wageningen (NL)	Dundee (uk)	1790	
Dr Krzysztof Wieczorek	10-Oct-2007	1190 (AT)	Warsaw (PL)	2500	
Ms MARIA SANCHEZ	06-Jan-2008	TOLEDO (ES)	BARI (IT)	2500	
Ms Mary Portillo	28-Apr-2008	Toledo (ES)	Bet Degan (IL)	2500	
Dr Julia Hofmann	01-Oct-2008	Vienna (AT)	SOPHIA-ANTIPOLIS (FR	1551	
Dr Abd El Naser El Ashry	22-Nov-2008	Vienna (AT)	Sophia-Antipolis Cedex	750	
Mr Shahid Masood Siddic	05-Jan-2009	Vienna (AT)	warsaw (PL)	2500	
Dr Liliya Pylypenko	26-Jan-2009	Kiev (other)	Dundee (GB)	2500	
Ms Dhakshinamoorthy Su	27-Apr-2009	Leuven (BE)	Jena (DE)	2000	
Dr Lee Robertson	30-May-2009	Madrid (ES)	Dundee (UK)	1000	
Mr Fernando Evaristo DIA	01-May-2009	02071 ALBACETE (E	F-06903 SOPHIA ANTIP	2100	
Dr Wim Bert	07-Sep-2009	Ghent (BE)	Wageningen (NL)	1273	
Dr Annelies Haegeman	07-Sep-2009	9000 Ghent (BE)	06903 Sophia-Antipolis C	1650	
Mr Diego Fernando Rose	19-Sep-2009	Madrid (ES)	Bari (IT)	1620	
Dr Tom Tytgat	12-Oct-2009	Wageningen (NL)	Sophia-Antipolis (FR)	800	
Dr MARIA FE ANDRES	17-Nov-2009	28006 MADRID (ES)	BARI (IT)	1100	
					35,434

Workshops

Title	Date	Place		Cost	Total
Joint Management Comm	09-May-2007	La Colle sur Loup (FR)		2,770	
Inter-WG Workshop & MC	27-May-2008	Postojna (SI)		2,940	
WG2 workshop "Tools fo	19-Nov-2008	Sophia-Antipolis (FR)		2,298	
Inter-WG workshop and M	26-May-2009	Toledo (ES)		3,000	
					11,008

General Support Grants

Title	Date			Cost	Total
General	04-Dec-2006			2,000	
General	01-Jan-2007			2,000	
General	01-Jan-2008			2,000	
General	01-Jan-2009			2,000	
					8,000

Schools

Type	Date	Place	title	Cost	Total
					0

Honoraria

Title	Date	Expert		Cost	Total
					0

Grant

Grant Holder	Date			Cost	Total
					0

Dissemination

Title	Date			Cost	Total
					0

Action Total **302457.2**

II. Scientific Report *prepared by the Chair of the Management Committee of the Action*

II.A. Results achieved during the period 1st January 2009 to 31st December 2009

Working group 1: Functional genomics of plant parasitic nematodes

Working group 1 aims to identify and functionally characterise nematode proteins important in the host-parasite interaction, also called effectors. Candidate effectors have been identified from an expanding range of plant parasitic nematodes including *Globodera pallida*, *Radopholus, Ditylenchus* and *Aphelenchus*. Many enzymes that degrade the plant cell wall have been characterised, including one completely novel nematode enzyme (arabinogalactan endo-1,4 beta-galactosidase) from *Heterodera schachtii*. Nematode genes encoding proteins with peptide domains similar to CLAVATA peptides have been cloned and characterised from further cyst nematode species. These peptides may play an important role in induction of the feeding site. Two papers describe a large gene family (SPRYSECs) from *G. pallida* that interact with the host immune system (see WG3 below). Following the sequencing of two *Meloidogyne* genomes in 2008, work has continued on identification and functional analysis of effectors from these species.

The increase in sequence information for a range of plant nematodes has allowed microarrays of nematode genes to be designed and used in studies of the plant-nematode interaction. The expression pattern of the full complement of *H. glycines* effectors has been examined throughout the life cycle of the nematode, providing information about the function of these effectors. Similar studies, using both microarrays and high throughput RNA sequencing (see WG2) are likely for other pathosystems in the near future.

Systems for functional analysis of nematode effectors are now widely in use. Refinements to techniques for *in vitro* RNAi have been published in 2009. A key finding in this area is that short interfering RNAs appear to give more specific knockout of nematode genes than RNAi using long stretches of dsRNA. Papers describing knock out of nematode genes by delivering dsRNA from plants have been published in 2009. One paper describes the use of a virus vector to deliver dsRNA to the feeding nematode while another uses stably transformed plants to deliver the silencing signal. While both these techniques still require optimisation the results presented to date suggest that this technique will be useful for functional studies as well as offering a potential control method for a wide range of plant nematodes using expression of dsRNA targeting nematode genes in genetically modified plants.

High throughput cell biology techniques that allow subcellular localisation of nematode effectors in plants have been published during 2009. Such techniques have shown that different members of a nematode effector gene family can localise to different compartments of the plant cell.

Links with researchers working on other plant pathogens (bacteria, fungi, oomycetes) have allowed techniques that examine the role of nematode effectors in suppressing host defences to be established.

Working group 2: Comparative genomics of plant parasitic nematodes

Genome sequencing projects for several plant parasitic nematodes are still in progress and are expected to finish in 2010. Expressed sequence tags (ESTs) have been generated from further nematode species including *G. pallida, Ditylenchus* and *Aphelenchus*. Comparisons of these sequences and genome sequences has allowed patterns of horizontal gene transfer from bacteria and fungi to be examined and has allowed a hypothesis about how plant parasitism by nematodes has evolved to be suggested. These were key aims in the original proposal. Such studies also require robust phylogenies of nematodes and one remarkable paper this year (which includes a figure 13 pages long!) provides the most comprehensive molecular phylogeny of the Phylum Nematoda to date. Other studies focused specifically on plant nematodes have also been reported. One EST project has led to the unexpected discovery of endosymbiotic bacteria in plant-parasitic nematodes. Endosymbionts have been described from arthropods and from animal-parasitic nematodes and appear to have an important role in the evolution and development of parasitism in these groups. The same may be true for plant-parasitic nematodes.

Caenorhabditis elegans remains a popular model system for some aspects of nematode biology. One study published in 2009 describes the use of *C. elegans* to characterise neurotransmitter receptors of *G. pallida*; such receptors may be important targets of anthelminthics or pesticides.

The increasing accessibility of techniques for ultra high throughput sequencing (454, Solexa Illumina) is likely to impact significantly on plant nematology in the next 12 months, with numerous genome and transcriptome projects in progress.

Working group 3: Functional Genomics of the plant response

A number of high impact papers on the biology of the nematode feeding site have been published in 2009. Changes in auxin levels have been implicated in the development of nematode feeding sites and this year it has been shown that nematodes may manipulate intracellular auxin transport in order to modulate local auxin levels. The mechanisms underlying remodelling of the cytoskeleton in feeding sites have also been investigated and it has been shown that a specific actin depolymerisation factor is essential for changes in actin dynamics.

Microarrays have been applied to several plant-nematode pathosystems. Microdissection techniques that allow isolation of the feeding site from surrounding plant tissues have been described and used in conjunction with arrays to examine changes in gene expression in feeding sites. Another array study has demonstrated a key role for myoinositol oxygenases in development of syncytia.

Studies on individual genes have included analysis of the functional roles of sucrose transporters and of callose deposition in feeding site biology. Another study suggests that nematode carbohydrate binding domains may act in concert with the plant's own cell wall degrading machinery to control the changes in cell wall architecture that accompany development of the feeding site.

Work towards mapping and cloning of resistance genes has continued, particularly in potato and in wheat. The use of molecular markers to assist breeding of resistance to cereal cyst nematodes in wheat has been described.

A key development has been the identification of the first functionally characterised nematode avirulence gene. This gene is a member of a large family (SPRYSECs). Further characterisation of this gene family should lead to identification of more avirulence genes, providing excellent tools for plant breeding. These areas were important goals of the original proposal.

Outputs and overall progress towards goals – the role of COST 872

Excellent progress is being made towards the objectives outlined in the original proposal and COST 872 is playing an important role in allowing these objectives to be achieved. Links within the community have been fostered and, more importantly, links have been made with workers in related disciplines. A specific example is the uptake of techniques for assessing the function of effectors in plants from other plant pathologists. COST 872 has encouraged this by inviting key researchers from other communities to meetings. The main meeting of COST 872 remains an important event in the community calendar. Significant networks have developed from these meetings that will aim to compete for funding in future FW7 calls. The MC of COST 872 has made participation of ESRs at these meetings a key goal and our success in achieving this was commented on by the COST rapporteur who attended the 2009 meeting in Toledo. ESRs have also been the focus for many STSMs. More STSMs were funded through COST 872 in 2009 (10) than in any previous year and the MC is pleased to note that high impact publications have been generated as a result of some of these collaborations. ESRs will also benefit from a training school to be held early in 2010.

Four non-COST participants have contributed towards the aims of COST 872 during 2009; the importance of activities undertaken in this area are outlined in Section IIB.

Tangible outputs of COST 872, other than the scientific and practical developments described above include a large number of publications and grant proposals. These are outlined in Appendices 1 and 2.

COST 872 was a partner in an inter COST meeting with Actions 873 and 604 on “Frontiers of Functional Genomics in Plant Protection”. This meeting provided ESRs associated with all three Actions to receive training, including hands on experience, of functional genomics techniques. Further synergistic activities with COST 873 are being explored for 2010.

Results achieved during the period 1st January 2008 to 31st December 2008

Working group 1: Functional genomics of plant parasitic nematodes

Much progress has been made during 2008 in identifying genes important in the parasitic process from a wide range of plant parasitic nematodes. Novel enzymes that modify plant cell walls have been identified from sedentary and migratory endoparasites including *Globodera rostochiensis* (cellulases), *Radopholus similis* (cellulases) and *Bursaphelenchus xylophilus* (expansins). Chorismate mutase has been described from *Heterodera schachtii* and regulation of expression of this gene by alternative splicing has been reported in *G. rostochiensis*.

The development of genome resources from a wide range of plant parasitic nematodes (see WG2 below) means that, in addition to the studies of single genes described above, much larger scale analysis of pathogenicity genes has taken place. The complete repertoire of proteins secreted by a root-knot nematode has been investigated using a proteomic approach. Large scale analysis of ESTs from another root knot nematode, *Meloidogyne chitwoodi,* has allowed identification of pathogenicity genes. Similarly, EST analysis from migratory endoparasitic nematodes such as *Radopholus* has allowed pathogenicity genes to be identified from these species.

Systems for functional analysis of pathogenicity genes have continued to be developed and applied. The effects of targeting multiple pathogenicity genes by RNAi have been reported. Links have been established between researchers using RNAi in plant and animal parasitic nematodes in order to facilitate research in the development of this important tool for functional genomics. Such links were a key aim highlighted in the original COST 872 proposal. An unanticipated benefit of these links has been the finding that there may be common mechanisms used by plant and animal parasitic nematodes to suppress immunity in their hosts. Links in this area have been established due to interactions funded through COST 872.

Working group 2: Comparative genomics of plant parasitic nematodes

Spectacular progress has been made in this area during 2008. Genome sequences for two root knot nematode species (*M. incognita* and *M. hapla*) have been published. COST 872 has had a notable involvement in the *M. incognita* project with many participants contributing to the annotation of this sequence. A COST 872 workshop provided training in this area for researchers ensuring that the annotation process continues. A draft genome sequence for the soybean cyst nematode *H, glycines* has been released and the *G. pallida* sequencing project is now well underway. It is anticipated that linkages funded via COST 872 will play an important role in the annotation process for the *G. pallida* genome. Other genomic resources have been developed for plant parasitic nematodes including ESTs from *Ditylenchus*, *M. chitwoodi* and *Radopholus*. In addition, the genome sequence of a non-plant parasite *Pristionchus pacificus* has been published. It has been reported that this nematode contains genes similar to the cellulases of plant parasitic nematodes. This finding has important implications for the understanding of processes underlying horizontal gene transfer in nematodes. The evolution of horizontally acquired genes has been further investigated in 2008 and a scheme describing the duplication events that have occurred following acquisition of some genes from bacteria has been suggested. Understanding these processes requires a well founded phylogeny for plant parasitic nematodes and this is also important for comparative genomics studies. Important studies using molecular techniques to resolve phylogeny in these nematode groups have been published in 2008. Developments in new generation sequencing technologies are now starting to have an impact in the plant

nematology field. Application of these techniques to *H. glycines* has led to the discovery of a horizontally acquired pathway for vitamin B6 synthesis that may be important in helping nematodes to evade host defences. It is anticipated that these sequencing technologies will have a major impact on the work areas covered by COST 872 in the next 2 years.

Comparative studies using *C. elegans* as a model system have been published in 2008. Mechanisms underlying formation of the dauer larvae (a survival stage) have been compared in plant nematodes and *C. elegans* and, surprisingly, many differences in gene expression in this conserved biological stage have been reported. By contrast, it has been suggested that parallels exist between the pathways used by *C. elegans* and plant nematodes in fighting infection by bacteria and other pathogens.

Working group 3: Functional Genomics of the plant response

Studies describing the roles of individual genes in nematode feeding sites as well as large scale microarray analysis of infected plant material have been published in 2008. The importance of an auxin responsive transcription factor (WRKY23) for development of nematode feeding sites was demonstrated and it was also shown that blocking of the cell cycle by silencing of CDK1A reduced nematode infection. Studies on plant expansins and cell wall degrading enzymes have shown that modifications in the plant cell wall induced by the nematode are essential for normal development of the feeding site. Collaborative projects in this area have benefited from funding provided through COST 872. Similarly, the role of a microtubule associated protein (MAP65-3) in development of the giant cells induced by root knot nematodes has been demonstrated.

Larger scale studies using microarrays have continued in 2008 and the signalling pathways affected by nematode infection have been analysed. It has been shown that nematodes suppress basal defences in plants and several groups have work in progress that aims to identify the mechanisms used by nematodes to achieve this. Proteins that suppress defences are often recognised by resistance genes. Identifying these avirulence factors is a key aim of COST 872 and good progress has been made in this area. A candidate avirulence gene for the *Mi* resistance gene has been identified and work in progress by several COST participants has described several candidate avirulence genes recognised by other resistance genes. For one SPRYSEC protein an interaction with a resistance gene has been demonstrated. Identification of nematode populations that are virulent on various resistance genes is important for this area and work published in 2008 has identified *M. javanica* and *G. pallida* populations that overcome *Mi* and *Gpa5* respectively.

Outputs and overall progress towards goals – the role of COST 872

For all areas, a comparison of progress to date with the plans submitted in the original proposal show that the activities are proceeding as anticipated. No major scientific problems have been encountered that will impede development of the scientific field as a whole. COST 872 has contributed substantially to the development of the discipline. As in previous years, participants in COST 872 have published extensively during 2008 (Appendix 1) and have also submitted numerous grant proposals (Appendix 2). Interactions funded or stimulated by COST 872 have been instrumental in many of these outputs. The main annual meeting of COST 872 is viewed as one of the most important forums for exchanging information in this area and has attracted delegates from several non-COST countries. Interest in the 2009 meeting has already been expressed by several groups from these countries. The MC of COST 872 has tried to ensure that early

stage researchers (ESRs) are recipients of funding from COST to attend its meetings and these researchers (like all meeting participants) are strongly encouraged to present their work at the meetings. COST 872 therefore provides a route for ESRs to present their work in a supportive environment, providing training in this area. The COST 872 workshops held in 2008 have had a positive impact on their fields. The role of the WG2 genome annotation workshop is described above and a WG3 workshop on microarrays allowed common protocols and data analysis to be discussed in detail by researchers working in this area.

The MC of COST 872 has continued to maintain an open call for applications for STSM funding and regards STSMs as one of the most important ways of achieving the links and collaborations that were among the main aims of the original proposal. The vast majority of these STSMs have been made by early stage researchers. Ongoing collaborative links, including funded grants and high impact papers, have been established as a result of STSMs funded through COST 872.

There are currently 4 Institutions from non-COST Countries linked to COST 872. Researchers at two groups in Australia (Murdoch University and Wollongong) have now developed links with several participants in COST 872 and exchange visits of personnel have taken place. Participants from Australia have attended each of the COST 872 main meetings. The Australian groups are among the world leaders in their respective fields and their involvement has been particularly beneficial for WG3 and WG2. Three separate groups from COST 872 applied for the additional funding for exchange visits with Australian institutions recently released by COST Office. A participant (Institute of Plant Protection) from a near neighbour country (Ukraine) has sent a delegate to the main meeting of COST 872 in 2008 and been awarded funding for a prolonged exchange visit in 2009. The Ukrainian institution views links developed through COST 872 as an important route for scientific development and, in particular, for training in genomics techniques that would otherwise be particularly difficult to obtain. Activities involving the other non-COST participant are expected to become more prominent in 2009.

At the time of writing discussions are ongoing with the Chairs of two other Actions (873 and 604) about a bid for funds for a joint additional activity involving early stage researchers in 2009. In addition, participants in COST 872 are also linked to various EU funded projects, ensuring that potential synergies between COST 872 and other funded projects are explored regularly. Participants in COST 872 also have links to various technology platforms that aim to prompt further funding opportunities of relevance to COST 872.

Results achieved during the period 1st January 2007 to 31st December 2007

Working group 1: Functional Genomics of Plant Parasitic Nematodes

In the year 2007 most progress in the areas covered by WG1 has been achieved in the application of RNA interference to knock-down gene transcription in plant-parasitic nematodes. Several groups have tested and further refined the methodology of RNA interference by soaking the nematodes in highly concentrated solutions of double stranded RNA. Most of the genes targeted in these studies were chosen based on an expectation that they have a role in the initial stages of parasitism, such as host invasion. One group has successfully targeted a neuronal peptide with RNAi in plant-parasites; a remarkable finding as the neuronal tissue seems to be refractory to RNAi in *Caenorhabditis elegans*. Another noteworthy finding was the delivery of RNAi from the host to a plant-parasitic nematode (by an Australian group) who targeted a transcription factor in the root-knot nematode *Meloidogyne javanica*. In this project a strong reduction of transcript levels was found in nematodes feeding on transgenic plants overexpressing dsRNA, although no lethal phenotype was observed. The group was able to show the presence of small interfering RNAs

originating from the dsRNA construct suggesting that at least part of the dsRNA is digested in the plant prior to delivery into the parasite. So far all reports on host delivered RNAi in plant-parasitic nematodes involved root knot nematodes, while the method has not proven of value for cyst nematodes as yet. RNAi continues to be used with animal parasitic nematodes. In order to develop links with people working in this area a researcher (Peter Geldhof) who has recently co-authored a review on RNAi in animal parasitic nematodes has been invited to attend the 2008 inter-WG workshop.

Work in other areas highlighted in WG1 is in progress but not yet completed. Several groups are using cell biological techniques and assays for suppression of plant defences in order to examine function of selected nematode proteins. This work is drawing heavily on the experience of researchers using other pathosystems (bacteria, fungi and oomycetes). Microarrays carrying nematode genes are being developed by several groups and it is likely that data will emerge from these studies in the coming year.

Working group 2: Comparative genomics of plant parasitic nematodes

Sequencing of two root-knot nematode genomes (*Meloidogyne hapla* and *M. incognita*), and the first detailed annotation of these sequences, has been completed in 2007. Tools for automated annotation, including gene finding software optimised for *Meloidogyne*, have been developed. Manual annotation of one of these genomes (*M. incognita*) has been performed by a consortium of researchers, including participants in COST 872. A project to sequence the genome of the potato cyst nematode *Globodera pallida* has been approved and is now underway. This project is run by a consortium of UK based partners but exploitation of the sequence will involve groups across the EU and will be facilitated by activities within COST 872. In addition, Expressed Sequence Tags have been generated from plant nematode groups that have not previously been analysed including *Bursaphelenchus, Aphelenchus* and *Radopholus*.

A significant advance within the area of WG2 is the continued development, and associated reduction in costs, of new DNA sequencing technologies. As a result of these changes obtaining genome scale sequence data is likely to become easier. Far more sequence data is likely to become available than could have imagined just a few years ago. Major opportunities for comparative genomics are therefore likely to emerge and there will be a greatly increased requirement for bioinformatics expertise. The MC of COST 872 will examine how COST funding can assist plant nematologists in this area.

Researchers working with plant parasitic nematodes continue to use comparative studies with animal parasites and *C. elegans* as a way of driving their work forward. For example, studies on mechanisms of innate immunity in plant parasitic nematodes as compared to *C. elegans* have been published during 2007. In addition, sequence information that is developed for plant parasitic nematodes is being exploited in comparative studies that aim to develop diagnostic tools for specific nematode groups or pathotypes.

Working group 3: Functional Genomics of the plant response

In WG3 most efforts are currently directed towards transcriptome analyses of host plants in order to dissect specific metabolic pathways that are altered upon nematode infection. Several groups in France, Spain, UK Germany and Austria are working in this area with different species of cyst nematodes and root-knot nematodes. The first results have been published but many more are in the pipeline. A recent WG3 workshop held in Vienna revealed an urgent need for a common platform for dissemination of microarray data. Means of supporting this area through COST 872 are currently being investigated.

Detailed gene expression, biochemical, microscopicaland functional analyses have been performed on sugar transport and metabolism in syncytia, indicating a complex interplay of apoplasmic and symplasmic sugar transport pathways and starch synthesis and storage. The essential role of specific expansin and endo-1,4-beta-glucanases in the development of syncytia has been confirmed in *Arabidopsis* and tomato.

A research area that is currently very promising is the study of the effect of nematode proteins on plant defense and hormone signaling pathways. The plant response in the compatible interaction appears to be strongly modulated by secreted proteins from the nematodes. Clearly this work overlaps extensively with areas covered under WG1.

Outputs and overall progress towards goals – the role of COST 872

For all areas, a comparison of progress to date with the plans submitted in the original proposal show that the activities are proceeding as anticipated. Participants in COST 872 have published extensively during 2007 (Appendix 1) and have also submitted numerous grant proposals (Appendix 2). Interactions funded or stimulated by COST 872 have been instrumental in many of these outputs. For example, several STSMs have led to preliminary data that has been used to prime joint grant applications. Other groups have used STSMs as a means of developing collaborative links in new and emerging areas. Early career stage scientists have often been the direct beneficiaries of these projects. Meetings funded through COST 872 have also led to several new collaborations or have helped scientists interpret their results. Early career stage scientists have been funded to attend COST 872 meetings and encouraged to present their work in order to help with their training. The MC of COST 872 considers this an important role for COST 872.

Results achieved during the period 4th December 2006 to 31st December 2006

The main objective of the Action is to develop a co-ordinated approach to exploitation of genomics information that is appearing for plant parasitic nematodes and host crops. Since this action was only running for three weeks at the end of 2006 there will clearly be little to report for this period. However, several significant steps forward have been reported in the areas covered by this Action since the original proposal was formulated, and these are noted below.

Scientific developments

The identification of parasitism genes is no longer a bottleneck for our understanding of plant-nematode interactions. Consequently, the focus of many researchers is beginning to shift towards the design of novel functional assays to study genes involved plant-nematode interactions. Several groups have reported the use of RNAi to study gene function in plant parasitic nematodes, confirming that this technique will be an important tool for functional studies on plant parasitic nematodes. In addition, three independent publications have reported the generation of transgenic plants expressing dsRNA targeting (different) nematode genes followed by an assessment of the effects on parasitism.

Studies on genes important in parasitism have previously been focused on the economically important root knot and cyst forming nematodes. However, in 2006 further publications on genes important in the parasitic process of another nematode – the pine wood nematode *Bursaphelenchus xylophilus* were reported. These studies demonstrated that multiple independent horizontal gene transfer events from bacteria and fungi have played an important role in the evolution of nematode parasitism of plants in several nematode taxa.

Genome projects for two major nematode species continued in 2006. Work is in progress in the USA on a sequence for *Meloidogyne hapla* and one invited speaker for the 2007 COST 872 meeting will provide further details of the *M. hapla* project. Within the EU, work has begun on the sequence of the *M. incognita* genome; at the time of writing 5X coverage has been achieved and gene-finding software is being used to analyse the sequence. An application for funds to sequence the genome of a cyst nematode *Globodera pallida* is under review at the time of writing.

Progress was made in several aspects of the plant response to nematode infection. The role of a range of enzymes in metabolism of free radicals produced response to nematode infection has been studied and it has been shown that reactive oxygen species are produced in the early stages of an incompatible interaction between cyst nematodes and plants. The roles of various phenylpropanoids in basal resistance of banana against nematode infection have also been analysed. Meanwhile, in other plant-pathogen interactions, a range of avirulence proteins have been identified including Avr3a from late blight and dspE from *Pectobacterium*. These studies have shown that avirulence proteins frequently have an important role in manipulation of plant defence signalling pathways. The prospect that nematodes may produce proteins with similar functional roles will be investigated by several groups within COST 872.

For the compatible interaction, the role of host expansins in development of the feeding site has been studied using microarrays. Several studies have also examined the molecular mechanisms underlying sugar translocation into nematode feeding sites. Studies published in 2006 have shown that expression of genes encoding sucrose transporters is activated in syncytia and that functional plasmodesmata are formed between the phloem and syncytia during the later stages of syncytium formation.

COST 872 Activities in 2006

The first MC meeting for COST 872 was held in Brussels on December 4th 2006 at which the working structures of the Action were agreed and the Chair, vice-chair and WG coordinators were elected. As outlined in the original MOU, three WGs were established in the areas of “Functional genomics of plant parasitic nematodes”, “Comparative genomics of nematodes” and “Functional genomics of plant responses”. It was agreed that the aims of the Action would be best served by holding a relatively large inter-WG workshop in 2007 in order to encourage communication between scientists working on various aspects of molecular host-parasite interactions. A gathering of this type has not taken place in the community for some years.

In order to encourage participation of younger scientists in COST 872 plans were made to set aside a substantial sum of money for STSMs from the 2007 budget. An STSM committee composed of the Action chair, Action vice-chair and the WG Coordinators has been set up to evaluate applications for funds under this scheme.

II.B. Dissemination of results

Action related Publications and Reports (list)

A report of the COST 872 main meeting held in Toledo was produced for COST Office and is provided as Appendix 3. A comprehensive book of abstracts was produced for this meeting and is provided as Appendix 4. A presentation summarising the activities of COST 872 and their contribution towards scientific progress in this area was produced for the Annual Monitoring meeting in Prague (June 2009) and a pdf of this presentation is provided as Appendix 5. A book summarising progress in the areas covered by COST 872 is currently being written and Springer have agreed to publish this book with COST support. This will be a "Final Publication" for COST 872 and will provide an important resource for workers in the field. The current list of chapters and authors for the book is provided as Appendix 6.

Conferences, Workshops and Training Schools (list and programme)

Owing to the mismatch between the COST financial year and the calendar year this appears to have been a quiet year for COST 872 with only one major meeting. However, a WG1 training school in RNAi is to be held shortly (Belfast, UK) and at least three further events are planned for 2010. In 2009 COST 872 held a large inter-WG workshop combined with an MC meeting in Toledo (ES) from 26th – 28th May. Over 125 delegates attended this meeting. A joint additional event was held with Actions 873 and 604 (see Section IIA).

Web site (description)

The Action website (http://cost872.scri.ac.uk) has been updated regularly throughout the year. Interested parties can access all meeting reports and abstract booklets through this site. Information on how to participate in the activities of the Action is also provided. The website management software has registered over 17,000 hits since the website was created, illustrating that the site remains an important resource to the community. The site is maintained and updated by the Action Chair.

Scientific and Technical Cooperation

Four institutions from non-COST countries are linked to COST 872. Researchers at the two groups in Australia continue to have excellent links with participants in COST 872. Funding (from a non-COST source) was obtained for a PhD student from Wollongong University to spend several months at the laboratory of one COST 872 participant and the group leader also visited during this time. Representatives from the other Australian group (a world leader in the field) have attended each COST 872 annual meeting and have developed links with a number of COST 872 participants. The participation of this group has been of particular benefit to participants in COST 872 and joint funding applications with this group are being planned. The Institute of Plant Protection (Ukraine) has sent a delegate to each of the COST 872 main meetings and has also

undertaken a 3 month visit to a participating laboratory during 2009. The Ukrainian partner has received valuable training and access to facilities unavailable at their home institution as a result of this visit. The value of the contribution to the research programme of the host institution is illustrated by the fact that one joint publication has already arisen from this visit, with others planned. The near neighbour scheme has been of great value to both COST countries and to the Ukrainian partner. The other non-COST institution associated with COST 872 has sent one delegate to the 2009 meeting in Toledo.

Links with other sectors are described in the "*Transfer of results*" section below.

Transfer of results

Participants in COST 872 continue to publish in high quality and specialist journals and have presented their work at a wide range of national and international meetings. As for all science professionals these are the main routes for dissemination for the participants in COST 872. Links with industry have been fostered during COST 872; many industry representatives attend COST 872 meetings and build links with relevant academic partners as a result of attending these meetings. COST 872 has two MC members that work in industry, as opposed to academia. In addition, COST 872 participants include workers from sectors other than the research community, including plant protection workers, workers in quarantine organisations and advisory bodies. Meetings of COST 872 allow workers from these sectors to access the latest scientific developments of relevance to their field. A specific example of the utility of these links is in the development of molecular diagnostic tools for plant nematodes of use for quarantine organisms. Further links between sectors will be fostered in a technology transfer event held under the auspices of COST 872. This event is still being planned but may be embedded within a meeting of the European Society of Nematologists to be held in Vienna in 2010, which attracts a wide range of Plant Nematode professionals.

Participants in COST 872 are required make presentations to non-specialist end users (*e.g.* growers, farmers) in the course of their work. In order to facilitate this process and encourage wider dissemination of the work undertaken in COST 872 the MC plan to run a workshop on "Science Communication for non-specialists" as part of the 2010 meeting. ESRs will be especially encouraged to attend this workshop.

The production of a final publication for COST 872 will further encourage transfer of results from the research community to a wider audience (see "*Action related Publications and Reports*" above).

Contacts in the ERA

Although few calls directly relevant to many of the partners in COST 872 have not yet appeared as part of the FW7 work programme some evidence of that COST 872 is starting to have an impact at the EU funding level is emerging. Projects that include work on plant nematodes are now up and running including an ERASMUS MUNDUS MSc programme (EUMAINE) and the QBOL programme. In addition, a call for proposals on an introduced nematode pathogen, *Bursaphelenchus xylophilus,* was made in a recent call list. Applications that include participants in COST 872 are currently being prepared.

In order to ensure that the problems posed by plant parasitic nematodes are adequately addressed by the EU, several members of the COST872 MC are preparing a "position paper" outlining the main issues faced by farmers within the EU due to nematodes and the withdrawal of most effective nematicides. This paper will also highlight the networks that have formed as a result of the activities of COST 872 with the aim of demonstrating that sufficient critical mass exists to deliver practical benefits from research projects. It is hoped that this will encourage further FW7 calls of relevance to COST 872 in the future.

From the 2008 report

Action related Publications and Reports (list)

Reports of the three meetings held under the auspices of COST 872 in 2008 have been produced and are provided as appendices 3, 4 and 5. A series of position papers were produced as part of the WG3 workshop on Microarray analysis of plant-nematode interactions and these are provided as Appendix 6. A book of abstracts was produced to accompany the main meeting held in Postojna Slovenia and this is provided as Appendix 7. A training manual was produced for participants in the WG2 workshop on annotation tools and this is provided as Appendix 8. A poster on the activities of COST 872 was produced for the monitoring meeting held in Ljubljana on 4th/5th November 2008 and a pdf of this poster is provided as Appendix 9.

Conferences, Workshops and Training Schools (list and programme)

Three meetings have been held with the support of COST 872 in 2008. A workshop on "Microarray analysis of plant-nematode interactions" was organised by the Chair of WG3 and held in Vienna from 7th-8th February. A combined inter-WG workshop and MC meeting, the main meeting of COST 872 for 2008, was held in Postojna Slovenia from 26th-29th May. A WG2 workshop that provided training in the tools used for annotation of the root knot nematode genome was organised by the chair of WG2 and held in Sophia Antipolis from 19th-21st November.

Web site (description)

The Action website (http://cost872.scri.ac.uk) has been updated regularly throughout the year. Interested parties can access all meeting reports and abstract booklets through this site. Information on how to participate in the activities of the Action is also provided. Over 8000 "hits" to the COST 872 website have been recorded by the content management software, demonstrating that the site is of interest to considerably more than the approximately 150 researchers that have participated directly in the activities of COST 872 in 2008.

Scientific and Technical Cooperation

Four outside institutions are linked to COST 872 and the impact of their participation is discussed above. Many participants have individual links with a variety of end users including very large biotech companies (*e.g* Syngenta) as well as smaller companies. Company representatives are members of the COST 872 MC and we have approached other companies and invited them to send representatives to our main meeting. Many participants in COST 872 are also partners in FW7 projects (*e.g.* BIOEXPLOIT) allowing effective communication of recent advances in these areas to other COST participants.

Transfer of results

Scientists working in the areas covered by COST 872 have published extensively in 2008 and have presented their work at national and international meetings. These avenues are the main route for dissemination to scientific users. Partners in COST 872 have links with a wide range of industrial partners and these links serve as an informal route for dissemination. In the original proposal a technology transfer meeting was envisaged and in 2009 we will begin planning of this event, which will be a major route for dissemination to a range of end users.

Many participants in the Action have also provided information on the work in this area to growers and other end users. Presentations on the practical benefits likely to emerge from this area have been made to plant protection workers and farmer advisors. COST 872 meeting delegates are drawn from a range of sectors including advisory bodies and scientists working in quarantine areas in addition to those performing scientific research. The meetings of COST 872 therefore act as a conduit to ensure that the information from scientific participants is passed directly to end users. Informal contacts at these meetings are as important as the presentations in this context.

A book reviewing progress in the main research areas covered by COST 872 is currently being planned. A small committee (The Action Chair and Vice Chair along with Prof Carmen Fenoll, MC representative for Spain) has been formed and is in the process of determining a list of chapters and authors. Several publishers have expressed interest in publishing the book.

Contacts in the ERA

Calls for EU proposals in the area covered by COST 872 have not yet been made. However, researchers working within COST 872 have formed groups that are prepared to respond to such calls when they arise and are lobbying through a range of organisations in order to highlight the need for research in this area. For example, the requirement for nematology research in relation to plant health has been discussed via EUPHRESCO with the aim of influencing FP7 calls in future.

A number of partners have obtained funding through ESF and a new MSc in plant nematology (EUMAINE)

funded through the ERASMUS-MUNDUS scheme has now started its first full year of operation; several participants in COST 872 are part of this multi-site scheme. In addition, exchange visits have been made between participants in COST 872 funded through the ERASMUS programme.

From the 2007 report

Action related publications and reports

A report of the first combined MC meeting and inter-WG workshop was produced and is appended to this report (Appendix 3). In addition, a full booklet of abstracts was distributed to delegates attending the meeting and is available on the Action website. This abstract booklet is appended to this report (Appendix 4). STSM reports (7 in total) have been produced to date and are available on the Action website.

During the 2007 meeting, the MC of COST 872 decided to investigate the possibility of producing a book on "Molecular and cellular aspects of plant-nematode interactions". A book of this nature was published in 1997 following a CAP programme but is now considered outdated. Various publishers are being contacted to assess the appetite for a publication in this area.

A leaflet publicising the aims and activities of the Action has been produced with input from a professional design company. A pdf of this leaflet is appended to this report (Appendix 5). Copies of this leaflet have been sent to COST Office for use in their activities and are available to all Action participants.

Web site

A website has been created with input from a professional designer. The site (http://cost872.scri.ac.uk/) is hosted at the institute of the Action Chair and features a simple-to-use content management system that allows the Action Chair or Vice-Chair to update the site without the need for IT support. Information on upcoming and past activities is available on the site, with registration documents and programmes available for download. STSM reports are also available on the site. The site also provides instructions on how to access STSM funding through COST 872.

Scientific and Technical Cooperation

Three additional countries (France, Greece and Sweden) have become signatories to COST 872 during 2007 and three outside institutions, (Wollongong University (Australia), Murdoch University (Australia) and The Institute of Plant Protection (Ukraine) have become external participants in the action. The Action Chair has been in contact with the proposer of a new COST Action (Multiscale Analysis of the Response of Key Food Web Organisms to Environmental Change - MARKER), which will include work on ecological aspects of plant nematodes, in order to explore potential synergy between the two programmes.

Participants in COST 872 have generated grant proposals to a variety of sources (Appendix 2) and COST 872 has been an important factor for several of these. For example, collaborative grant proposals have been generated by institutes in Slovenia (KIS) and France (INRA Rennes) to various awarding bodies (including ERA) and these have arisen from STSMs between the two institutions. Participation in COST 872 has also been a factor in the success of other National grant applications including one on "Comparative genomic studies on root -knot nematodes (Meloidogyne spp.) in Switzerland and Europe" to the State Secretariat for

Education and Research (SER), Switzerland by Dr. S. Kiewnick and Dr. J. Frey and a genome sequencing project for *G. pallida* by a consortium of UK researchers. COST 872 is therefore acting as a stimulus that is enabling participants to attract additional funds to the field.

Transfer of results

This Action has been running for a relatively short time and links with industry and other end-users are likely to be established later in the course of the Action. However, a number of the delegates at the 2007 combined MC meeting and inter WG workshop were from various industrial companies, and two of the MC members for COST 872 are from industry. Individual participants in the Action have links with a range of industry representatives.

Dissemination plan with regard to end users

All participants in the Action publish scientific papers in refereed journals and a full list of these is appended to this report (Appendix 1). Such publications, and presentations at scientific meetings, are the primary means of disseminating information to scientific end users. During compilation of the list of papers for this report the participants were asked to assess whether COST related activities had any impact on each publication; over half of the publications were assessed by the authors as having benefited from the activities of this Action, demonstrating the impact of COST funding to this field.

Contacts in the ERA

This Action has been running for a relatively short time and these links are likely to be established later in the course of the Action. Calls under FW7 to which research on plant nematodes is applicable have been scarce. It is planned to address this through COST 872. However, a proposal has been submitted to SEE ERA-NET by participants in the Action and several partners have projects funded through ESF. A new MSc in plant nematology (EUMAINE) has been funded through the ERASMUS-MUNDUS scheme and several participants in COST 872 will be part of this multi-site scheme.

From the 2006 report:

Given the short time frame that the Action has been running in 2006 little progress has been made in this area. However, the Chair is building a website for COST Action 872 that will incorporate a SharePoint site to facilitate reporting.

We have aimed to include representatives from industry at all stages of the planning of this Action in order to encourage uptake of knowledge that is generated by the Action. In this regard it is encouraging to note that MC representatives for two countries are from the commercial rather than the academic sector.