ABSTRACTS OF SYMPOSIA

RESISTANCE AND VIRULENCE GENETIC COMPONENTS OF THE SOLANACEAE/*MELOIDOGYNE* INTERACTIONS. P. Abad, P. Castagnone-Sereno, C. Djian-Caporalino, and A. Dalmasso, Laboratoire de Biologie des Invertébrés, BP 2078, 06606 Antibes Cedex, France.—Plant resistance is the most efficient and environmentally safe way to control root-knot nematodes of the genus *Meloidogyne*. This is particularly true in Solanaceae where resistances have been isolated and characterized in many species. The genetic control of these resistances is different among Solanaceous species. In tomato, resistance to *M. incognita*, *M. arenaria* and *M. javanica* is controlled by the Mi gene. In pepper, the situation is more complex with a number of genes controlling specific resistances against the main *Meloidogyne* species. Among these, 2 independent genes Me1 and Me3 confer the same resistance spectrum as Mi. However, the increasing use of cultivars resistant to *Meloidogyne* has been associated with occurrence of nematode virulence. In addition to observations on naturally occurring resistance breaking biotypes, several lineages of virulent and avirulent strains of *M. incognita* have been selected. The results obtained by the Antibes group on the genetic and molecular aspects of both the cloning of the Me3 gene in pepper and the virulence of *Meloidogyne* against Mi, Me1 and Me3 were shown. These results were discussed in relation to the plant-nematode interaction since the analysis of the virulence phenomenon may provide additional information on how these solanaceous resistance genes work.

INTERACTIONS AMONG PLANT-PARASITIC NEMATODES AND PATHOGENIC FUNGI. G. S. Abawi, Dept. of Plant Pathology, Cornell University, Geneva, New York 14456, U.S.A.—Interactions involving fungal plant pathogens and plant-parasitic nematodes have been studied and documented extensively as suggested by the number of review articles and related publications. Interactions between *Meloidogyne* spp. and Fusarium wilt fungi have received special attention and have been documented on >20 crop species. Synergistic, additive, neutral and (in few cases) antagonistic interactions and/or associations have been reported and well documented. In the majority of the studies, it has been concluded that the presence of plant-parasitic nematodes, especially the root-knot nematodes, tend to increase the incidence and severity of the diseases incited by the interacting fungal pathogen. However, many of the reported interactions appear to be specific to the species and density of the nematode and the other interacting fungal pathogen, cultivar of the host crop, and test conditions. In addition, growth parameters of the host crop also are decreased, often synergistically, as a result of the interaction among the 2 pathogens. Interactions among nematodes and fungal pathogens may occur in the rhizosphere, during root penetration, during pathogenesis of same or adjacent host tissues as well as in the colonization of distant host tissues. The generalized roles of plant-parasitic nematodes in the reported inter-actions included providers of wounds and necrotic infection courts, host/substrate modifiers, host resistance modifiers and others. However, extensive research efforts are needed to elucidate the exact mechanisms involved in the observed interactions. Several examples of specific interactions among plant-parasitic nematodes and fungal pathogens were discussed during the symposium presentation to illustrate our current understanding of these interactions, methodologies used, research needs, and outlook.

AN RDNA BASED PHYLOGENETIC ANALYSIS OF THE GENUS *MELOIDOGYNE*: A RECENT ORIGIN OF MITOTIC PARTHENOGENETIC SPECIES. B. A. Adams, and T. O. Powers, University of Nebraska, Department of Plant Pathology, Lincoln, Nebraska 68583-0722, U.S.A.—The genus *Meloidogyne* includes species which have amphimixis, facultative meiotic parthenogenesis, or obligatory mitotic parthenogenesis as their mode of reproduction. Three mitotically parthenogenic species (*M. arenaria, M. incognita, M. javanica*) exhibit an extremely broad geographic distribution and host range. While it has been suggested that these distributions are evidence of an ancient origin, this hypothesis would make these taxa an exception to the trend among other metazoans in which extant unisexual lineages are invariably recent. To test this, we constructed a phylogeny using rDNA sequences and demonstrated that mitotic parthenogenesis is not an ancestral, but a derived reproductive strategy. While our phylogeny does not include an explicit time of divergence for root-knot nematodes, it is clear that relative to the other members of the genus, *M. incognita, M. javanica*, and *M. arenaria*, are of recent origin.

CROP ROTATIONS FOR MANAGEMENT OF NEMATODES ON TOBACCO. K. R. Barker, Department of Plant Pathology, North Carolina State University, Raleigh, North Carolina 27695-7616, U.S.A.—Crop rotation is one of the oldest and most effective tactics for managing plant-parasitic nematodes. Underlying principles of crop rotation include: selection of nonhosts or poor hosts as rotational crops that effect a sharp reduction in population levels of target nematodes necessary to produce an economically acceptable subsequent crop; preservation of beneficial organisms at population levels to buffer the diverse species of plant pathogens over the long term; and elimination of weed hosts. Although the wide diversity of nematode species attacking tobacco complicates the development of effective rotations for this crop, the choice of crops to be grown in sequence should be dictated by the most damaging nematode species in given fields or regions. Rotation crops may include nonhosts or poor hosts, trap crops, and/or resistant cultivars. Potential nonhosts/poor hosts for some major nematode parasites of tobacco include: *Meloidogyne arenaria* - cotton, peanut (race 2 only) and selected grasses; *M. hapla* - corn, cotton, grasses, and cucurbits; *M. incognita* - fescue, other selected grasses, resistant soybean, and cotton (races 1 and 3 only); *M. javanica* - cotton, peanut (only some populations), sorghum, and velvet bean; and *Pratylenchus* spp. - sudangrass, fescue, oats, and onion. *Crotalaria* spp. are effective trap crops for some nematodes, but they may produce toxins that prohibit their use in many locations. Locally adapted resistant tobacco cultivars may be included with a nonhost crop, and a susceptible tobacco cultivar every third or fourth year. Successful tobacco rotations must encompass excellent management practices such as control of weed hosts of nematodes, destruction of residual tobacco stalks/roots, and general pest/pathogen control.

NEMATODE SURVIVAL AND DISPERSAL IN ARID AND SEMI-ARID REGIONS OF WEST AFRICA. P. Baujard, and B. Martiny, Muséum National d'Histoire Naturelle, Laboratoire de Biologie Parasitaire, Protistologie, Helminthologie, 61, rue Buffon, 75005 Paris, France, and Centre ORSTOM, BP 8006, 97259 Fort de France Cedex, Martinique, F.W.I.—The arid and semi-arid regions of west Africa are characterized by a long dry season (8-11 months), a short rainy season (1-4 months), and high soil temperatures (34-42°C). Throughout the dry season, the upper layers of soil (0-40 cm) are completely dry (soil moisture below 0.2%) and hot dry winds blow from the Sahara desert, carrying away fine sand and dust particles. Seventy species of plant-parasitic nematodes belonging to Tylenchida, Longidoridae and Trichodoridae were identified from field surveys. Data obtained from vertical distribution studies showed that most in Tylenchida were able to enter anhydrobiosis during the dry season; some tylenchids belonging to the genera *Cephalenchus* and *Aphasmatylenchus*. Longidoridae and Trichordoridae were unable to withstand desiccation and were always found in the deeper layers during the dry season. Trapping of wind-blown sand and dust particles showed that they contained mostly mycetophagous and bacteriophagous nematodes, while dorylaimids and plant-parasitic tylenchids were always in low numbers. Laboratory tests showed that wind-borne nematodes maintained their reproductive potential despite mechanical, moisture and thermal stresses. Field population dynamics data and laboratory investigations on hoplolaimid species showed that anhydrobiosis and duration of the anhydrobiotic period might induce physiological changes in nematode behavior, mainly in their ability to go through the Baermann funnel and their multiplication rates.

THE PRODUCTION AND FORMULATION OF ENTOMOPATHOGENIC NEMATODES. R. A. Bedding, Division of Entomology, CSIRO, Box 1700, Canberra, ACT 2601, Australia.—There have been considerable advances in both liquid and solid culture of entomopathogenic nematodes (ENs) with regard to the development of improved media, the technology involved and the scale of production. At the same time, formulation has improved dramatically to provide a shelf life at ambient temperatures of several months for some species. Partly as a result of this, ENs currently account for more of the biopesticide market in industrialized countries than all other organisms put together, apart from Bt. However, further expansion of the market is still limited by cost of production, short shelf life, and the limited number of species and strains available. Cost of production is being addressed by greatly increasing yields and reducing production time in liquid fermenters in industrialized countries, while solid culture is being developed as a cheaper alternative in developing countries. It is likely that the small number of EN species that can be produced in liquid culture will soon be increased while all EN species can already be produced readily in solid culture. Shelf life can be further improved by reducing the rate of usage of storage materials within infective juvenile ENs, and this is achievable by inducing them to produce and maintain optimal levels of trehalose and/or glycerol so that respiratory rates drop by up to 100-fold. Preservatives are important to prevent spoilage and reduce the oxygen demand of formulations stored over long periods, but these can also increase nematode respiratory rates. New packaging technology is being developed to maintain high water activity within formulations over long periods while allowing adequate oxygenation.

MOLECULAR AND GENETIC DISSECTION OF NEMATODE FEEDING SITES. D. McK. Bird,[1] S. Grantner,[2] J. M. Ross,[1] D. M. Saravitz,[3] A. Skantar,[1] W. Song,[3] and M. A. Wilson,[4] Departments of Plant Pathology[1] and Genetics, North Carolina State University, Raleigh, North Carolina 27695, U.S.A.,[3] Department of Anatomy, University of California-San Francisco, San Francisco, California 94143, U.S.A.,[2] and Developmental Signal Transduction, National Cancer Institute, Frederick, Maryland 21702, U.S.A.[4]—We have isolated and extensively characterized ~220 genes expressed in *Meloidogyne incognita*-induced tomato giant cells. Progress towards a functional analysis of these genes was presented.

ORIGINS OF *MELOIDOGYNE* SPP. AND RESISTANCE GENES. V. C. Blok, M. E. M. Ewhaeti, M. Fargette, M. S. Phillips, and D. L. Trudgill, Scottish Crop Research Institute, Dundee DD2 5DA, Scotland.—Increasingly intimate and complex parasite/host interactions tend to expose the pathogen to a greater array of host recognition and defence systems, and hence are typically associated with host specialization and a narrow host range. This is observed with *Heterodera, Globodera* and many amphimictic *Meloidogyne* spp. Exceptions include some ectoparasitic species, e.g. *Longidorus* and *Xiphinema,* where opportunities for the plant to recognize the nematode attack are limited, and a small group of parthenogenetic, mainly tropical *Meloidogyne* spp. which have enormously wide host ranges and world-wide distributions. Whilst it is clear that *Meloidogyne* is an ancient group, molecular studies indicate that these parthenogenetic spp. are relatively homozygous and of comparatively recent origin. If so, their wide distribution must be a consequence of recent spread, presumably aided by man. Equally, if resistance in plants and virulent races of the nematode largely arose during co-evolution between *Meloidogyne* and its hosts, then the wide host ranges of these parthenogenetic spp. could be a consequence of their recent spread to regions where the plants have not yet had the opportunity to develop resistance. This analysis pre-supposes that induction of the susceptible reaction by these *Meloidogyne* spp. involves interacting with genes/alleles common to most plants, and that the nematodes also have the capacity to avoid/suppress a wide range of nonspecific plant defences. Even so, there is specific resistance to these nematodes in plants but it is unclear how this relates to possible centres of origin of the nematodes in relation to their hosts.

NEMATODE COMMUNITIES AS INDICATORS OF NUTRIENT ENRICHMENT. T. Bongers, and G. Korthals. Nematology Department, Wageningen Agricultural University, PB 8123 NL-6700 ES Wageningen, The Netherlands.—Some nematode taxa, like rhabditids and diplogastrids, are typical indicators of nutrient enriched conditions. Recently, these enrichment opportunists were grouped together in c-p 1 of the colonizer-persister scale, the basis of the Maturity Index. A triangle was proposed for graphical presentation of shifts within the nematode community towards enrichment, stress and natural succession. For comparison of habitats, varying in enrichment, the Maturity Index gives variable results, exclusion of c-p 1 yields an index (MI 2-5) which better allows comparison of pollution-induced stress under enriched conditions. Recently several authors proposed to include plant feeding nematodes in the MI. In this contribution, it is shown that the original MI and PPI behave adversely under enriched conditions and that inclusion of plant feeders in the MI leads to a less sensitive index (Sigma-MI). The use of the PPI/MI ratio as a monitoring instrument in agroecosystems was discussed.

GENETIC RESISTANCE AGAINST *MELOIDOGYNE* SPP. IN TOBACCO. M. S. Botha-Greeff, Tobacco and Cotton Research Institute, Private Bag X82075, Rustenburg 0300, Republic of South Africa.—*Meloidogyne* spp., having world-wide distribution, are economically important in most tobacco growing countries. All tobacco types are extremely susceptible to the major root-knot nematode spp., and the costs of control measures are very high. Host plant resistance against *Meloidogyne* spp., is an extremely useful and economic tool in an integrated nematode control strategy. Sources of resistance against *Meloidogyne* spp. have been identified. Incorporation of *Meloidogyne* spp. resistance into commercial tobacco cultivars, by conventional breeding techniques or transgenic resistance, is done in numerous countries. An international nematological project which includes the evaluation of promising resistant tobacco breeding lines was established. In South Africa, the initial screening process for resistance against *M. javanica* and *M. incognita* races 2 and 4 was done in the greenhouse. NOD 8, NOD 20, NOD 31, NOD 90, NG 38 and OD 469 were compared to TL 33 and LK 3/46 in field trials where root-knot and ectoparasitic nematodes occurred. Lower nematode numbers were found in fumigated plots than in unfumigated plots. Although resistant breeding lines had a low visual root gall index, *Meloidogyne* spp. numbers increased in the roots. Interaction occurred with other nematodes, e.g. numbers of *Pratylenchus* spp. and *Paratrichodorus* spp. increased, indicating that long-term use of genetic resistance in the host plant to *Meloidogyne* spp. may result in species shift within a nematode population.

THE NEMATODE PROBLEMS ON BANANAS IN THE AFRICAN HIGHLANDS. J. Bridge, N. S. Price, and P. R. Speijer, International Institute of Parasitology, St. Albans, U.K., and International Institute of Tropical Agriculture (IITA-ESARC), PO Box 7878, Kampala, Uganda.—Ecologically, the highland areas of Africa are generally restricted to those regions 1000-3500 m above sea level. These montane regions where *Musa* spp. have been traditionally grown occur in both East and West Africa. The cultivars grown are mainly the cooking and brewing East African highland bananas (*Musa* AAA-EA) but also with some cultivars of other genotypes including plantains (*Musa* AAB) and 'Pisang Awak' (*Musa* ABB). However, the only member of the Musaceae indigenous to Africa is *Ensete* which also grows in the highlands. The major nematode pests found on *Musa* in the highlands are *Pratylenchus goodeyi*, an indigenous African nematode pest, and *Radopholus similis*, an introduced pest; the former is the only one at the higher, cooler altitudes. *P. goodeyi* is also a major pest of *Ensete* in Ethiopia. Other nematode root parasites commonly found on bananas and plantains in the highlands are *Helicotylenchus multicinctus, Meloidogyne* spp. and *Hoplolaimus pararobustus.* Damage caused by *P. goodeyi* and *R. similis* can be severe and includes root and corm necrosis, stunting and toppling (uprooting). Damage and nematode population levels can be highly variable between farms and regions suggesting that environmental factors, farming practices, cropping systems, and *Musa* types or cultivars play an important part in the damage potential of these nematodes. All the *Musa* and *Ensete* cultivated in the highlands of Africa are food crops grown by subsistence or smallholder farmers. This restricts control options mainly to cultural practices, use of clean planting material, resistant/tolerant cultivars, and possible biological control agents. Nematodes are only one component of a pest and disease complex that occurs on these crops. There are clear indications that interrelationships can occur between nematodes and other pest and disease organisms, particularly weevils and fungi.

NEMATODE-VIRUS INTERACTIONS. D. J. F. Brown, and B. Weischer, Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA, U.K., and Westf. Musuem for Naturkunde, Munster, Germany.—Populations of longidorid and trichodorid nematodes are effectively isolated within the soil environment, each population being distinct and relatively immobile resulting in substantial inbreeding with a consequent increase in homozygosity. In such highly conserved environments, virus-vector nematodes have developed specific associations with their respective viruses. The vectors and viruses have extensive plant host ranges which provides considerable potential for selection and adaption resulting in specificity between the vector and virus at several levels. Examination of factors which predispose these nematodes as virus vectors and the nematodes' role in the etiology of the viruses provides some insight into the evolution of virus and vector interactions. Studies on the genetic determinants of vector transmissibility associated with the viruses is also providing new insight into specific vector nematode-virus interactions.

COFFEE NEMATODES: OCCURRENCE, ECONOMIC IMPORTANCE AND PROSPECTS FOR CONTROL. V. P. Campos, Departamento de Fitossanidade, Universidade Federal de Lavras, MG, 37200-000, Brazil.—Most information on the occurrence and economic importance of coffee nematodes comes from Brazil where for over 100 years the area of coffee cultivation has been infested with many damaging root-knot (*Meloidogyne*) species. In Brazil, it is estimated that nematodes cause a 20% yield loss of coffee, representing US$ 373.8 million per year. In Colombia, *Meloidogyne exigua* and *Meloidogyne javanica* cause an estimated economic loss of US$ 800 million per year. Between South America and Africa, which together account for more than 85% of the world coffee production, the coffee nematode distribution appears to be somewhat different. In South America, *M. exigua, M. coffeicola* and *M. incognita* are the most important coffee nematodes. The control of coffee nematodes should include exclusion and eradication practices. New coffee plantations should not be started with nematode-infected coffee seedlings, nor should nematode-susceptible coffee cultivars be used in already infested areas. Precautions should be taken to avoid dissemination of the nematodes. The application of systemic nematicides will increase only the coffee production in highly productive plantations except where the plants are infected with *M. incognita* which causes severe root necrosis resulting in a drastic reduction of pesticide absorption. Grafting of *Coffea arabica* on cultivar 2258 of *C. anephora* tolerant to *M. incognita* may provide the coffee grower a means to obtain an economic viable yield in areas highly infested with this nematode.

MORPHOLOGY, BIOLOGY, AND MANAGEMENT OF *NACOBBUS ABERRANS* IN PERU. M. Canto-Sáenz, M. J. Arcos, P. Jatala, and R. Haddad, Plant Pathology Department, National Agrarian University, La Molina, Aptado 456 Lima, Peru.—*Nacobbus aberrans* populations from Argentina, Bolivia, Ecuador, Mexico, Peru and the U.S.A. have shown distinct morphological differences. These differences were noted in the tail regions of swollen females and *en face* patterns of second-stage juveniles, males and females. Morphological differences, alpha esterase patterns, and cytogenetics provide justification for separating *N. aberrans* into several species. Life cycle studies on potato has resulted in a race identification scheme proposal. Six races and variants of race 2 and 3 have been identified from these populations. Difference in reaction to potato, quinoa and pepper have been detected. In Peru, potato losses ranged from 10-73%. Interactions with fungi and *Globodera pallida* have been observed. Promising IPM programs are: (i) quality seed potato, (ii) organic amendments (sheep and cow manure, 15 kg/ha), (iii) resistant and/or tolerant potato cultivars, (iv) removal of potato volunteers and weeds in fallow fields, (v) chemical control, and (vi) crop rotation. Manure increased yields by 70-84% and reduced nematode numbers by 85%. Chemical control by methyl bromide, carbofuran or basamid and/or crop rotation with *Oxalis tuberosum* (Oca), barley, wheat, oats, faba beans or *Chenopodium quinoa* are suggested.

ECOLOGY AND USE OF NEMATODE-ANTAGONISTIC PLANTS. E. P. Caswell-Chen, and S. B. Sharma, Department of Nematology, University of California, Davis, California 95616, U.S.A., and International Crops Research Institute for the Semi-Arid Tropics, Asia Center, Patancheru 502 324, Andhra, Pradesh, India.—The degree of antagonism to nematodes among plant species is a continuum, and antagonism may be species specific. Antagonistic properties reside in foliage, roots, or root exudates. A wide range of plants are antagonistic to nematodes including: *Chloris gayana, Digitaria decumbens, Raphanus sativus, Tagetes patula,* and *T. erecta.* Antagonism may be expressed indirectly via induction of suppressive rhizospheres or directly through toxins or chemical suppressants that inhibit the nematode life cycle. The nematode life cycle can be affected at different points, including both preinfectional and postinfectional phenomena: egg hatch, taxis, root penetration, nematode development, nematode fecundity, and mate finding. The influence of antagonistic plants on nematodes is often assessed by measuring nematode reproduction, typically the ratio of final population density to initial population density (Pf/Pi). The influence of antagonistic plants may also be assessed via matrix models of nematode population dynamics. Using a matrix approach, the influence of the antagonist is quantified and reflected in stage transition probabilities and fecundity, defining the stage(s) affected by antagonism and the magnitude of the influence. Such ecological insight can assist in defining management strategies.

NEMATODE COMMUNITY IN HEATED SOILS AT HARVARD FOREST, PETERSHAM, MA. E. P. Caswell-Chen, Department of Nematology, University of California, Davis, California 95616, U.S.A.—The mean annual global temperature is expected to increase ca. 3°C during the next century. In 1990 an in-field experiment was established (Peterjohn, Meilillo, Bowles and Steudler) in a mixed deciduous forest in central Massachusetts (42°30'N, 72°10'W) to determine the long-term response of below-ground processes to elevated soil temperatures. Heating cables were buried to raise soil temperatures 5°C above ambient. Treatments were undisturbed control (C), disturbed control (DC, cables and unheated), and heated plots (H). Plots were monitored for nematode density, bacterial and fungal biomass, and fine root nitrogen uptake at 3 sampling dates over 128 days (June to October). The nematode community at the site included more than 20 nematode genera, and species such as *Acrobeloides buetschlii, Acrobeloides nanus, Aporcelaimellus vanderlaani, Bakernema inaequale, Bunonema reticulatum, Eudorylaimus aquilonarius, Hemicycliophora zuckermani, Plectus sambesii, Prionchulus punctatus,* and *Wilsonema otophorum.* The proportion and density of the nematode community represented by mycophagous nematodes increased in DC plots over time. The influence of resources on the nematode community was discussed.

HOSTS AND NON-HOSTS: THEIR ROLE IN MANAGEMENT OF *ROTYLENCHULUS RENIFORMIS.* E. P. Caswell-Chen, and A. F. Robinson, Department of Nematology, University of California, Davis, California 95616, U.S.A., and USDA-ARS, 2765 F&B Rd., College Station, Texas 77845, U.S.A.—Records of 208 dicot and 39 monocot hosts of *Rotylenchulus reniformis* were retrieved from NEMABASE, a digital database of nematode plant hosts compiled by the University of California. Results were compared with published reviews, research papers, and expert opinion. Altogether, 53 plant families contained hosts. Twenty-six of 50 non-hosts were monocots; only one gymnosperm and no pteridophyte hosts were retrieved. Resistance was reported in 32 host species. Eighty-eight host records were from pot experiments, 53 from crop land, and 102 from other locations. Twenty records reported plant damage, but Koch's postulates often were not tested. In citrus (*Citrus* spp.) and tea (*Camellia sinensis, C. assamica*), dense soil populations have been found with no gravid females on citrus or tea roots, likely due to reproduction on weeds or cover crops. Recent research on management of *R. reniformis* included upland cotton (*Gossypium hirsutum*), pigeonpea (*Cajanus cajan*), chickpea (*Cicer arietinum*), soybean (*Glycine max*), pineapple (*Ananas comosus*), and various vegetables. Management is constrained by the nematode's wide host range, prolific reproduction on numerous weeds, Prolonged survival, and co-occurrence with other pests. Management strategies investigated included rotation of upland cotton with sorghum (*Sorghum bicolor*), maize (*Zea mays*), and resistant cultivars of soybean (*Glycine max*) in the southern United States, rotation of pineapple with sugarcane (*Saccharum* spp.) in Hawaii, rotation with antagonistic crops such as French marigold (*Tagetes patula*), Rhodes grass (*Chloris gayana*) and sunn hemp (*Crotalaria juncea*), and mixed cropping with resistant or immune crops, e.g. cowpea (*Vigna unguiculata*) with maize in Nigeria, and tomato (*Lycopersicon esculentum*) with *Zinnia elegans* in Egypt.

RESISTANCE GENE MANAGEMENT: INTRODUCTORY PERSPECTIVES. R. Cook, Institute for Grassland and Environmental Research, Aberystwyth, Dyfed SY23 3EB, Wales, U.K.—There are many examples within crops and their relatives of genetic variation in resistance to nematode pests. In many cases, resistance has been characterized and germplasm is catalogued. There is a gulf between this available resistance and that which is successfully exploited in purpose-bred crop cultivars. In the few examples where resistance genes have been deliberately deployed in farm practice, there has been increasing concern about the stability of the genes in the face of emergence of virulent nematode populations. There are more examples where resistance is not available to farmers although nematodes are apparently important factors limiting crop production or dictating cropping practices. A prerequisite for the successful management of resistance genes is their introduction into agronomically acceptable crops: the gulf between potential and achievement seems both wide and deep. Its width can only be spanned by linking the multidisciplinary resources essential for resistance breeding; its depth represents potential costs of failure through the challenges posed by nematode variability. In addition to the approaches to these problems explored in this symposium, marker-assisted selection techniques have the potential to incorporate those characteristics contributing to the quantitative and widely effective resistance necessary to provide really useful cultivars.

PHYSIOLOGICAL RACES, PARASITISM, AND MANAGEMENT OF *NACOBBUS ABERRANS* ON VEGETABLE AND FIELD CROPS IN ARGENTINA. M. A. Costilla, Sección Zoología Agrícola, EEAOC, Casilla de Correo 9, 4101 Las Talitas, Tucumán, Argentina.—The false root-knot nematode, *Nacobbus aberrans*, is widely distributed in Argentina where it infects several vegetable and field crops. This pest reproduces also on weed hosts. Potato roots are severely galled by the nematode, whereas potato tubers which are invaded by only the vermiform stages of the parasite, do not show visible infection symptoms. Two physiological races occur in Argentina. The race R1 infects mainly potato, while race R2 infects canning tomato and pepper, but does not attack potato. Alfalfa, bean, corn, table pepper, strawberry and wheat are resistant to nematode infection in Argentina. The most promising management programs to limit the damage by *N. aberrans* include the use of long term rotation with the resistant crops listed above.

NEMATODES IN SOME RICE-BASED SMALLHOLDER CROPPING SYSTEMS, WEST AFRICA. D. L. Coyne, and R. A. Plowright, West African Rice Development Administration, 01 BP 2551, Bouaké, Côte d'Ivoire, and International Institute of Parasitology, St. Albans, Hertfordshire, U.K.—In traditional west African rice farming systems, rice can be monocropped but it is commonly multiple cropped with maize, cassava, yam and a large number of minor intercrops. West African rice hydrological environments are diverse and contiguous and occur as a toposequence from upland, through hydromorphic to lowland. In some areas, single component environments of the toposequence are large and homogeneous, whilst in others (e.g. inland valleys) all toposequence environments occur over a short distance and can be locally very heterogeneous. Nematode species composition and population dynamics are effected by the interaction of hydrological environment, the host status of component crops and rice cultivar and farming practices, but hydrology is a major determinant of the relative density of species along the toposequence. Heterogeneous environments create equally diverse nematode communities of unusual composition. Root-knot nematodes (*Meloidogyne incognita* and *M. javanica*), root lesion nematodes (*Pratylenchus zeae*), cyst nematodes (*Heterodera sacchari*) and rice root nematodes (*Hirschmanniella* spp.) can, for example, all occur in the same rice crop. Rice production pressures have reduced fallow periods and increased rice cropping intensity, and in this context, plant-parasitic nematodes can become more important pests. The complex nature of nematode communities presents challenges both for nematode yield loss assessment and the development of nematode management strategies.

QUIESCENCE, CRYPTOBIOSIS AND CRYOPRESERVATION: THE MAINTENANCE OF NEMATODE GERMPLASM. J. Curran, and N. Galway, CSIRO Division of Entomology and the Cooperative Research Centre for Plant Science, Canberra, ACT 2601, Australia.—Maintenance of genetic integrity of nematode populations and a desire to minimize the costs of continuous culture have led to a range of methods for preserving nematode germplasm. Early approaches used standard cryoprotectants such as ethandiol, glycerol and DMSO with some success. Glycerol-based methods are the mainstay of the large *Caenorhabditis* germplasm stocks around the world. Unfortunately, not all nematode species can be preserved in this way. The assumption has been made that these compounds, including glycerol, are acting as cryoprotectants. More recently work on a wide range of species of *Steinernema, Heterorhabditis* and *Pratylenchus* has shown that prolonged (24-72 hr) exposure to glycerol solutions (water activity ~ 0.97) permits good survival of nematodes that are subsequently cryopreserved. This raises the speculation (with limited experimental data and significant inference) that exposure to partial dehydration conditions induces an internal physiological state that preconditions nematodes to survive freezing in liquid nitrogen. This opens the possibility that the innate ability of nematodes to enter quiescent and cryptobiotic states may be effectively manipulated to provide long-term cryopreservation of a wide range of nematode germplasm.

THE SPORE/NEMATODE INTERACTION: A BIOCHEMICAL EXAMINATION OF HOST SPECIFICITY IN *PASTEURIA*. K. G. Davies, Entomology and Nematology Department, IACR-Rothamsted, Harpenden, Hertfordshire AL5 2JQ, U.K.—The ability of spores of the bacterium to adhere to nematode cuticle is essential for the infection process. Monoclonal antibodies raised to the spore surface have shown that a high degree of heterogeneity exists both within and between different populations of spores. This heterogeneity was found to be reciprocated in the nematode cuticle, as demonstrated by baiting experiments in which different sub-populations of spores were found to bind to the cuticles of different nematode species and sub-species. One particular monoclonal antibody appeared to bind preferentially to the parasporal fibres and biochemical characterization indicated that the epitope was probably a molecular complex of sugars and proteins. Fibronectin was able to compete successfully with the monoclonal antibody for this epitope, and in experiments using potassium thiocyanate, fibronectin bound to the spores through hydrophobic interactions. Immunofluorescence experiments using a polyclonal antibody to fibronectin failed to localize fibronectin in the cuticle. However, several monoclonal antibodies demonstrated in Western blot analysis of cuticle extracts of several nematodes, antigenic similarities between fibronectin and cuticular antigens. Several of these antigens may be involved in spore-binding and account for host specificity.

NEMATODE TAXONOMY - AN ESSENTIAL BUT CONSTRAINING BASIS FOR SOIL ECOLOGY. P. DeLey, Instituut voor Dierkunde, University Gent, Ledeganckstraat 35, B-9000 Gent, Belgium.—Despite the importance and proximity of soils to human activities, our knowledge of the processes of life in this environment is still in its infancy. For example, *Canenorhabditis elegans* is studied most intensively at the genetic and cellular level, but its natural ecology is hardly known. Autecological studies represent a bottom-up approach to soil ecology but face many constraints. The practical difficulties of observing microscopic soil organisms under natural conditions are considerable, the amount of work required is enormous in proportion to nematode diversity, and problems with species concepts, identification and classification easily obscure comparisons between populations. Dominant nematode species often belong to the most difficult taxa, and many are predominantly parthenogenic or hermaphroditic. Fortunately, another approach is more feasible: top-down analyses are less sensitive to the nitty-gritty of taxonomy and allow important synecological insights to be gained about the core processes of entire ecosystems. As such, they are directly relevant to soil conservation, management and exploitation, in line with current trends in science and society. Microcosm studies have proven their value and can be applied under many different conditions, although they may still be constrained by taxonomy. The most promising recent top-down approaches are colonizer-persister analysis methods, which avoid the major pitfalls of taxonomic and trophic characterization without compromising on their analytical potential. On the whole, a synergism between autecology and synecology must be the most productive way forward. Holistic approaches can provide important autecological data and must be based on solid detail to allow corroboration and application. Research on the nutrition, behavior, reproduction and dispersal of individual species not only greatly improves the quality of ecosystem studies but also provides essential feedback to taxonomy. A truly comprehensive understanding of soil ecology thus may be gained and will ultimately be of the greatest value to its future development.

NEMATODE PROBLEMS OF ROOT AND TUBER CROPS IN LATIN AMERICA. R. M. de Moura, Empresa Pernambucana de Pesquisa Agropecuaria-IPA. Av. Gal. San Martin 1371-Bonji 50761-000, Recife Pe. Cx. Postal 1022, Brazil.—Root and tuber crops are staple food for the majority of Latin American populations. *Solanum tuberosum* (potato), *Dioscorea cayenensis* (white or yellow yam), and *Manihot esculenta* (cassava) are major commercial crops in some countries. Some root and tuber crops are primarily used as subsistence food or as raw material for natural medicines. Examples are: *Colocasia esculenta* (taro), *D. alata* (water yam), *Ipomoea batatas* (sweet potato), *Arracacia xanthorrhiza* (arracacha), and *Xanthosoma* spp. (malanga). Nematological information for many of these root and tuber crops is lacking, but on some crops plant-parasitic nematodes may result in high yield losses. These losses include a decreased cash value of the agricultural product for local marketing, disqualification of the product for exportation, and increased fungal rot during storage. *Globodera rostochiensis, G. pallida* and *Ditylenchus destructor* on potato, *Scutellonema bradys* on white yams, *Meloidogyne* spp. and *Pratylenchus* spp. on most of these crops are the main nematological problems. Other nematodes such as *Rotylenchulus reniformis* on sweet potato and *Nacobbus aberrans* on potato also can cause high losses. Genera such as *Helicotylenchus, Trichodorus, Belonolaimus,* among others, have been found associated with root and tuber crops, but data on pathogenicity are lacking. The nematode control measures on root and tuber crops are soil treatment with nematicides, cultural means, use of nematode-free planting material, treatment of seed tubers, and treatment of tubers after harvesting to prevent storage rots.

NEMATODE PEST MANAGEMENT ON FRUIT TREES IN THE MEDITERRANEAN REGION. M. Di Vito, Istituto di Nematologia Agraria, C.N.R., 70126 Bari, Italy.—Citrus, grape (*Vitus vinifera*), peach (*Prunus persica*), almond (*P. amygdalus*), apricot (*P. armeniaca*), plum (*P. domestica*), cherries (*P avium* and *P. cerasus),* apple (*Malus domestica*), pear (*Pyrus communis*), olive (*Olea europeae*), fig (*Ficus carica*), kiwi (*Actinidia deliciosa*), persimmon (*Diospyros kaki*), pistacio (*Pistacia vera*), pomegranate (*Punica granatum*), date palm (*Phoenix dactylifera*), banana (*Musa cavendishii*) and walnut (*Juglans regia* and *J. nigra*) are the most common and extensively cultivated fruit crops in Mediterranean Basin. They are affected by several plant-parasitic nematodes although the most common and severe are species of *Meloidogyne, Pratylenchus, Xiphinema* and *Tylenchulus semipenetrans,* and some cyst-forming nematodes. Control of nematodes on perennials, such as most fruit trees, is a difficult task. However, the use of resistant cultivars, when available as in the case of citrus and peach, and the pre- or post-planting application of nematicides, although expensive, can be effective. Another most important practice is the production of nematode-free planting material.

THE BIOLOGICAL NATURE OF NEMATODE SUPPRESSIVENESS IN FLORIDA SOILS. D. W. Dickson, and S. Y. Chen. Department of Entomology and Nematology, University of Florida, Gainesville, Florida 32611, and Southern Experiment Station, Waseca, Minnesota 56093, U.S.A.—The suppression of natural field populations of *Heterodera glycines, Meloidogyne arenaria, M. javanica,* and *M. incognita* has been observed in a number of soils in Florida. In each case, except *H. glycines,* the nematode suppression developed after the population reached damaging levels. The suppression of the *H. glycines* population is considered to be caused by fungal parasites, whereas the suppression of the *Meloidogyne* spp. is considered to be caused primarily by the endospore forming bacterium, *Pas-*

teuria penetrans. More than 40 fungal species were isolated from *H. glycines* cysts, with at least 9 species considered pathogenic to the nematode. Suppression of *Meloidogyne* spp. occurs when levels of *P. penetrans* endospores reach between 10,000 and 100,000/g soil.

SYSTEMATICS OF NACOBBUS SP. IN ARGENTINA. M. E. Doucet, Laboratorio de Nematología, Centro de Zoología Aplicada, Universidad Nacional de Córdoba, C.C. 122, (5000) Córdoba, Argentina.—Taxonomic studies of the genus *Nacobbus* have been made on several populations from different regions of Argentina. Morphological characters of these populations have shown variability, however, no definitive pattern for the different populations has been determined. Most of the morphometric characters have shown significant differences between populations. Studies of isoenzymes have indicated the existence of different phenotypes of the different populations. Recent enzyme evaluation has expressed intra-population variability. Major characteristics of the Argentina populations fit those of *Nacobbus aberrans* (Thorne, 1935) Thorne & Allen, 1944. The observed variability of the different characters and behavior of some populations suggests that in Argentina, *N. aberrans* is a biological complex that requires further study.

PROBLEMS AND REGULATORY IMPLICATIONS CAUSED BY *ROTYLENCHULUS RENIFORMIS* ON FIELD CROPS AND ORNAMENTALS IN FLORIDA AND MARTINIQUE. R. A. Dunn, R. N. Inserra, and P. Quénéhervé. University of Florida, Department of Entomology and Nematology, Gainesville, Florida 32611-0620, U.S.A., Florida Department of Agriculture, DPI, Gainesville, Florida 32614-7100, U.S.A., and ORSTOM, Lab Nématologie, BP 8006, 97259 Fort de France Cedex, Martinique, FWI.—The reniform nematode, *Rotylenchulus reniformis*, occurs commonly in fine-textured soils of Florida and in volcanic soils of the Lesser Antilles such as in Martinique and Guadeloupe. In Rockdale and marl soils of South Florida, *R. reniformis* is a damaging pest of vegetables and field crops and reproduces on many commercial ornamentals, including banana, daylilies, elephant ear, Everglades and Washingtonia palms, schefflera, snake plant, and taro. About 20 weed species are also hosts to the nematode and perpetuate field infestations in Florida. In Martinique, this nematode species occurs on almost all cultivated crops (vegetables, fruits, ornamentals) and has been recovered from 25 weeds associated with vegetables. Arizona, California, and New Mexico restrict *R. reniformis* to protect their cotton industries from this pest. Chile and Switzerland also impose quarantines against this nematode. In Florida, satisfying those regulations requires nurseries to employ expensive management strategies, including adoption of proper sanitation practices and the use of clean stock, clean soil, and clean pots placed on benches not in direct contact with the ground. Widespread weed hosts such as artillery plant, spurges, Spanish needles, and amaranth complicate management of *R. reniformis* in nurseries and are major sources of nematode contamination for clean ornamentals. From a regulatory point of view, widespread occurrence of reniform nematode on ornamentals remains neglected in Martinique because the export market concerns only cut flowers and foliage at this time. In the future, these regulatory implications will necessitate changes in cultural practices for producing ornamentals for export of potted plants in Martinique as is now the case in Florida.

SPECIES AND RACE RELATIONSHIPS IN *MELOIDOGYNE* BASED ON CONVENTIONAL TAXONOMIC CHARACTERS. J. D. Eisenback, Virginia Tech, Department of Plant Pathology, Physiology, and Weed Science, Blacksburg, Virginia 24061, U.S.A.—The 4 most common species of root-knot nematodes, *Meloidogyne arenaria, M. hapla, M. incognita*, and *M. javanica*, are distributed widely around the world where they parasitize thousands of host plant species. *M. arenaria, M. incognita*, and *M. javanica* are common in tropical, subtropical, and warm temperate climates. *M. incognita* and *M. javanica* often occur together in the same field and sometimes all 3 species may be concomitant. *M. hapla* is more common in cool temperate climates and usually occurs in the absence of other root-knot species. Likewise, *M. arenaria, M. incognita*, and *M. javanica* are similar in some morphological aspects, whereas *M. hapla* is quite different. *M. hapla* is the most cytologically diverse species with populations that have chromosome numbers of n = 13-14, 15, 16, and 17, 2n = 30-32, and polyploid populations of 3n = 43, 45, and 48 chromosomes. These populations reproduce by amphimixis, meiotic parthenogenesis, and even by hermaphroditism. *M. arenaria, M. incognita,* and *M. javanica* all reproduce by mitotic parthenogensis. *M. arenaria* occurs as a diploid (2n = 34-37) and a polyploid (3n = 50-56). *M. incognita* populations may be diploid (2n = 32-32) or polyploid (3n = 40-46). *M. javanica* populations are polyploids (3n = 43-48) and chromosomes behave similar to those of *M. arenaria. M. incognita* contains 4 races based on the North Carolina Host Range test, *M. arenaria* has two host races; but races in *M. javanica* and *M. hapla,* races are not recognized.

RESISTANCE, SELECTION, AND BREEDING OF *PRUNUS* ROOTSTOCKS TO ROOT-KNOT NEMATODES. D. Esmenjaud, Laboratoire de Biologie des Invertébrés, INRA, B.P. 2078, 06600 Antibes Cedex, France.—Resistance appears as the best alternative to nematicides for controlling *Prunus* root-knot nematodes (RKN), *Meloidogyne arenaria* (MA), *M. incognita* (MI), *M. javanica* (MJ) and *M.* sp. Florida (FL). Various sources of resistance have been detected in the subgenus *Amygdalus* (peach and almond) and have been used for years in the U.S.A. and Southern European countries. Different ranges of resistance have been found among the 4 major RKN species. For example, resistance to MA + MJ have been found in almond (Alnem seedlings), MA + MI in Shalil peach (GF.557), MA + MI + MJ in Nemaguard peach and other derived rootstocks (Nemared, G. x N.), and MA + MI + MJ + *M* sp. FL in some *P. davidiana* hybrids (Cadaman . . .). Resistance, particularly in peach, is affected by high temperatures and/or durable inoculum pressure. In the subgenus *Prunophora* (including plums and apricot), some clones belonging to the Myrobalan plum, *P. cerasifera,* are immune to RKN (no virulent isolate up to now) and are not affected by biological or environmental factors. In the clones P. 2175 and P. 1079, single major completely dominant genes (Ma1 and Ma2, respectively) control the resistance to MA and probably other RKN species. Markers linked to the resistance gene Ma1 were detected using RAPD primers in combination with bulked segregant analysis, with the nearest one being located at 5.0 cM. Based on marker-assisted selection, the strong and wide-spectrum resistance of Myroballan plum will be used to breed simple or complex resistant hybrids using Myrobalan, peach and almond which bear most of the adaptative features to Mediterranean environments. Nevertheless, in Myrobalan plum, a comparative study involving RKN and the root-lesion nematode, *Pratylenchus vulnus,* evidenced the absence of a simple relationship between their hosts suitabilities and the need for combining separate sources of resistance to both nematode genera in *Prunus* breeding programs.

THE MANAGEMENT OF POTATO CYST NEMATODES: PROBLEMS AND POSSIBLE SOLUTIONS. K. Evans, P. P. J. Haydock, and D. L. Trudgill, Entomology and Nematology Department, IACR-Rothamsted, Harpenden, Herts., AL5 2JQ, U.K., Crop and Environment Research Centre, Harper Adams University Sector College, Newport, Shropshire, TF10 8NB, U.K., and Nematology Department, Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA, U.K.—The advent of granular nematicides and resistant potato cultivars in the 1960s allowed the use of integrated control schemes which were expected to permit intensive potato production even when land was infested with potato cyst nematodes (PCN). However, the use of cultivars resistant to *Globodera rostochiensis* led to the increase of a second species of PCN (*Globodera pallida*), and it was predicted that this species would eventually predominate. This has now happened and growers have learned that *G. pallida* is more difficult to control with rotation and nematicides and that resistant cultivars are less effective. These problems may be further compounded where nematicide is used frequently and a soil microflora able to break down the nematicide at enhanced rates has been selected, and because changes in potato production practices have led growers to use less efficient methods for nematicide incorporation. Solutions to these problems will depend on better diagnostic systems for PCN, better resistant cultivars, more rational use of nematicides, and perhaps, a variety of more novel techniques such as trap cropping.

INTRASPECIFIC DIVERSITY OF *RADOPHOLUS SIMILIS*. G. Fallas, and J. L. Sarah, CIRAD-FLHOR, B.P. 5035, 34032 Montpellier Cedex 01, France.—Studies on biological and biochemical intraspecific diversity of *Radopholus similis* are presently very active, and this paper presents the most recent outcomes. Reproductive fitness of *R. similis* in banana roots under controlled conditions varies widely depending on the geographical origin of the populations. Root damage and plant growth reduction are a direct consequence of the different multiplication rates. Populations sampled in several countries of Africa and in Costa Rica have the best reproductive fitness in banana roots and are, as a direct consequence, the most pathogenic. In contrast, populations from Martinique, Sri Lanka and Queensland multiply much more slowly and induce less damage. On the other hand, 7 populations of various geographical origin behave similarly in terms of multiplication *in vitro* on carrot discs as a relation of temperature. Maximum multiplication rate occurs at 30°C while the upper thermal limit is around 33°C, and the lower thermal limit is between 16 and 20°C. In parallel RFLP analysis of rDNA revealed very little variation while 2 genomic groups of *R. similis* were clearly separated through PGI electrophoresis and RAPD analysis concordingly. There was no clear relationship between genomical diversity, pathogenicity, and geographical origin. The two genomical groups were apparently widespread independently all over the world through infected suckers or corms, and the pathogenicity may have then evolved under local agro-ecological conditions.

BIOLOGY AND MANAGEMENT OF *NACOBBUS ABERRANS* ON POTATO IN BOLIVIA. J. Franco, N. Ortuño, R. Oros, and G. Main, Programa de Investigaciòn de la Papa (PROINPA), P.O. Box 4285, Cochabamba, Bolivia.—The potato (*Solanun tuberosum*) is the most important crop in the Andean region where it is grown at altitudes between 2,000 to 4,000 m. The false root-knot nematode or potato rosary nematode (*N. aberrans*) is an important limiting factor in potato production and can cause yield losses up to 61.5%. The development of a *N. aberrans* management strategy has required an understanding of its biology, behavior, and relationship with the potato plant. The management program being implemented in potato fields is based on a four-year cropping system consisting of resistant varieties of potato, barley trap crops, lupine or horse-bean soil incorporation after one early harvest, and finally, a tolerant or susceptible potato variety. This strategy also is supported by such cultural practices as chicken or cow manure incorporation, early ploughing, elimination of volunteer potato plants, and burning of infected roots after potato harvest. Monitoring of farmer fields using this management program has shown high potato yields and low nematode population densities in the soil.

DOES NEMATODE DIVERSITY MAKE A DIFFERENCE IN ECOSYSTEM FUNCTIONING OF SOILS AND SEDIMENTS? A DISCUSSION. D. W. Freckman, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado 80523, U.S.A.—Soils and sediments integrate hydrologic, atmospheric and biotic processes. The decompositional processes, essential for the normal functioning of ecosystems, are accomplished by the diverse biological assemblages of soils and sediments. Despite some knowledge of how soil and sediment nematodes contribute to the rates of critical system processes such as carbon storage and nutrient cycling, the role of individual taxa within functional groups remains a black box in our understanding of soil and sediment ecology. The relative contribution of different groups of soil biota to ecosystem processes is unknown. After an introduction, the presentation opened for discussion using the 2 sessions (Marine and Terrestrial) as a basis. Ecological questions for group discussion included: do we know the patterns of biodiversity for soil and sediment dwelling nematodes? is there a succession of nematode diversity, and how is it related to ecosystem function? are key taxa responsible for ecosystem functioning in soils and sediments? how is diversity within soil nematode functional groups involved in maintaining plant productivity? is there evidence to show that the nematode diversity in soils and sediments contributes to the resilience and stability to ecosystems? how could we design experiments that would address these and other questions?

PHORESY BETWEEN DIPLOGASTRID, APHELENCHID, AND TYLENCHID NEMATODES AND INSECTS. R. M. Giblin-Davis, University of Florida, 3205 College Avenue, Fort Lauderdale, Florida 33314-7799, U.S.A.—Phoretically associated nematodes from the orders Diplogastrida, Aphelenchida, and Tylenchida exhibit developmental synchrony with their insect hosts and produce a dispersal stage (i.e., JIII, JIV, or adult female) that is adapted for surviving environmental stress. Similar morphological and physiological adaptations of the dispersal stage and life history strategies between phoretic nematodes from the 3 different orders appear to be independently derived and probably represent convergent evolution. Trophic polymorphism, where differing buccal capsule morphotypes occur within 1 species, appears to be common in insect-associated diplogastrids and may be a survival strategy that is employed along with dispersal juvenile production when food resources associated with an insect host are qualitatively or quantitatively diminished. *Diplogasteritus* sp. (weevil associate), *Aduncospiculum halacti* and *Koerneria* sp. (associates of soil-dwelling bees), and *Parasitodiplogaster* spp. (associates of fig wasps) are presented as models for studying the evolution of phoresy in the family Diplogastridae. The life cycles of stylet-bearing mycophagous or facultative plant and/or fungal parasitic members of the Aphelenchoididae, such as *Schistonchus* spp. (associates of fig wasps), and *Bursaphelenchus* spp. (associates of beetles and bees), and Tylenchidae, such as *Sychnotylenchus* (associates of bark beetles), are presented as models for studying the evolution of phoresy in these 2 orders. In all 3 orders, the basic trend for the evolution of insect parasitism from phoretic ancestors involves specialization from external to internal transport and the concurrent development of a stage or stages that require sustenance from the host.

OPTIMIZING PRODUCTIVITY OF NEMATODE-INFESTED TEA PLANTATIONS IN SRI LANKA. N. C. Gnanaprragasam, Cropoptima (Pvt.) Ltd., 78/3, Pansala Road, Hatton, Sri Lanka.—Tea is the most important industrial crop of Sri Lanka, generating about 62% of the revenues earned through agricultural exports. Tea is cultivated from sea level to an altitude of about 2,000 m. The climatic conditions prevailing in Sri Lanka are ideal for the occurrence of tea pathogens throughout the year. Amongst these pathogens, plant-parasitic nematodes rank as one of the most important pests causing significant economic damage in the mid-elevation and high tea growing areas. The severity of nematode damage and consequent yield loss varies from as low as 4% to as high as 40% or more, depending upon the complex interaction between tea cultivar and age, nematode species and the environment. Surveys in the different tea producing areas of Sri Lanka, as well as detailed investigations on the population dynamics of the nematodes under the prevailing environmental conditions, have enabled the development of an Integrated Nematode Management Program to minimize nematode damage and to optimize tea production. The major components of this program are the use of resistant or tolerant tea cultivars, halting the intercropping of nematode-susceptible green manure crops, encouraging the intercropping of nematode trap crops, use of potash-enriched fertilizers, oil cakes and other plant and animal wastes as rhizosphere dressings and the controlled use of nematicides along with fertilizers following pruning.

FIELD USE OF *PASTEURIA PENETRANS* FOR CONTROL OF *MELOIDOGYNE*. S. R. Gowen, Department of Agriculture, The University of Reading, Earley Gate, PO Box 236, Reading, RG6 6AT, Berkshire, U.K.—Preparations of spores of *Pasteuria penetrans* have been applied under field conditions in Malawi, Tuvalu, Pakistan, Ivory Coast, Crete, and Lebanon during the last 8 years. The success of these treatments has been variable: where single applications have been made and the level of *P. penetrans* infectivity on native root-knot nematodes has been monitored over several cropping cycles, an increase in the proportions of the nematodes infected has been demonstrated. For example, in Ivory Coast between 42-67% of mature females were infected in the 2nd, 3rd & 4th crops following spot treatments of *P. penetrans* and over 90% of the J2 recovered from soil were encumbered with spores. Similar data has been obtained in commercial tunnels in Lebanon.

NEMATODE PROBLEMS AND THEIR MANAGEMENT IN THE MEDITERRANEAN AND MIDDLE EAST COUNTRIES. N. Greco, CNR - Istituto di Nematologia Agraria, 70126 Bari, Italy.—The area is characterized by a large variety of soil types. Winter is mild along the coast and often chilly in the inland areas, while summer is long and hot. Annual rainfall varies from 700-800 to 200-300 mm concentrated between late fall and early spring. Cool season crops, such as cereals and legumes, predominate and often are on marginal lands. Intensive crops, including vegetables and flowers, are of importance in irrigated areas. Despite the large variety of cropping conditions, nematode groups involved in crop diseases are few. *Pratylenchus* spp. do not cause impressive damage at the field level, but they are widespread. Cyst nematodes, *Globodera* spp. and *Heterodera* spp., and stem nematode, *Ditylenchus dipsaci*, are severe pests of several crops. Root-knot nematodes, *Meloidogyne* spp., are the major nematode pests of intensive crops in sandy soil. Problems caused by *H. ciceri*, *H. latipons*, and *M. artiellia* are typical of winter crops in the area. Several ectoparasitic nematodes, including virus vectors, may have local importance. Nematode communities rather than single nematode species are the cause of severe yield losses in many cases. However, the available information is not exhaustive. Cyst and root-knot nematodes of field crops develop only one generation per growing season and the behavior of *H. avenae* is peculiar in the area. Due to the hot summer, nematode decline is rapid. Because of low cash value crops, the use of expensive means of control, such as nematicides and soil solarization although effective, are impractical. Cultivars resistant to major nematodes of field crops are not available, but some cash crop cultivars resistant to cyst and root-knot nematodes are used irrespective of the presence of nematodes. In general, management tactics are not designed to control a specific nematode but aim at controlling major soilborne stresses. Rotation of cereals with legumes and/or fallow, although not always effective, is the only control measure adopted. Properly-designed crop rotations are very effective in controlling cyst, root lesion, and root-knot nematodes on cereals and legumes. Alternating winter and summer crops is satisfactory. Deep plowing in summer accelerates nematode decline, while late sowing in fall may reduce early nematode damage and early harvest build-up of nematode populations.

QUALITY OF ENTOMOPATHOGENIC NEMATODE PRODUCTS. P. S. Grewal, Biosys Inc., Columbia, Maryland 21046, U.S.A.—Quality of entomopathogenic nematode products is determined by their availability, usability, efficacy, and price. The development of cost-effective mass-production technology has led to the availability of nematode products at prices comparable to the standard insecticides in many markets. The usability of nematode products is constantly being improved through formulations research. Invention of water-dispersible granular formulation (WDG) has expanded the market potential of nematode products significantly. Efficacy perhaps is the most important factor determining quality of nematode products. The efficacy depends on many factors, but preservation of high nematode viability and virulence during large-scale production and formulation are essential components of quality control strategies. The most important factors affecting nematode quality are the provision of essential nutrients and appropriate bacteria, delivery of oxygen, production and storage temperature, and contamination control. The quality of nematodes that survive the rigors of the manufacturing process is then analyzed by determining their shelf-life and virulence potential. Nematode shelf-life is predicted from storage energy reserves (e.g., dry wt. or total lipid content) of infective juvenile nematodes, whereas virulence potential is measured using 1:1 bioassays against wax-moth larvae.

IDENTIFICATION OF NEMATODE-RESPONSIVE PROMOTERS AND GENES BY THE GUS REPORTER GENE. F. M. W. Grundler,[1] G. Gheysen,[2] K. Lindsey,[3] W. Robertson,[4] and S. Ohl,[5] Inst. f. Phytopathologie, Univ. Kiel, Germany,[1] Lab. Genetika, Univ. Gent, Belgium,[2] Leicester Biocentre, Univ. of Leicester, U.K.,[3] Scottish Crop Research Institut, Dundee, U.K.,[4] and Mogen, Leiden, The Netherlands.[5]—The gus gene coding for a β-glucuronidase has been proven to be a suitable tool to monitor the activity of known promoters. On the other hand, the gene also can be used to identify regulatory sequences and related genes. Within the EC a concerted action "resistance mechanisms against plant-parasitic nematodes" special interest group was established. In order to identify nematode-responsive promoters, *Arabidopsis thalinana* was transformed with constructs containing a promoterless gus gene. Several thousand independent transformants were screened for nematode-related gus expression. In lines selected for further analysis, the number of insertions was determined by segregation analysis and Southern blots using gus as the probe. Lines with single insertions were then taken for inverse PCR. In this way, sequences bordering the gus gene could be amplified. Wild type Arabidopsis DNA was then tested for the occurrence of the sequences by probing Southern blots and screening gDNA library. From the library, putative regulatory and coding sequences could then be cloned. Regulatory sequences of different lengths were taken for a further gus assay by retransformation of plants, while coding sequences were tried for identification from cDNA libraries.

MOLECULAR ANALYSIS OF NEMATODE SECRETORY PROTEINS. R. S. Hussey, and E. L. Davis, Departments of Plant Pathology, University of Georgia, Athens, Georgia 30602, U.S.A., and North Carolina State University, Raleigh, North Carolina 27695, U.S.A.—Secretory proteins synthesized in the esophageal glands and secreted through the stylet of the sedentary endoparasitic nematodes *Meloidogyne, Heterodera* and *Globodera* induce the formation of complex feeding sites in roots of susceptible plants. Monoclonal antibodies (MAbs) that bind to these secretions have been generated to isolate and identify individual secretory proteins for molecular characterization of their structures and functions. The MAbs have been used to demonstrate developmentally-regulated synthesis of esophageal gland antigens during parasitism of plants; the secretion of dorsal and subventral gland antigens through the nematode's stylet; and for identification and affinity purification of different secretory proteins separated by electro-phoresis. A subventral gland secretory protein common to both *G. rostochiensis* and *H. glycines* has been purified for amino acid sequencing. The MAbs have been used to isolate cDNA clones from *M. incognita* and *H. glycines* expression libraries by immunoscreening. Genomic southern blots indicate these putative secretory protein genes are specific for *Meloidogyne* or *Heterodera* species. As additional secretory protein genes are cloned, biologically important components of nematode stylet secretions can be characterized and their role in plant pathogenesis determined.

GEOGRAPHICAL DISTRIBUTION AND ECONOMIC IMPORTANCE OF *NACOBBUS* SPP. IN THE UNITED STATES. R. N. Inserra, G. D. Griffin, and E. D. Kerr, Florida Department of Agriculture, DPI, Gainesville, Florida 32614-7100, U.S.A., USDA-ARS, Forage and Range Research Laboratory, Logan, Utah 84322-6300, U.S.A., and Department of Plant Pathology, University of Nebraska, Scottsbluff, Nebraska 69361, U.S.A.—Both *Nacobbus aberrans* and *N. dorsalis* occur in the United States. Females of *N. aberrans* lay one-celled eggs and have 15-24 perineal annuli; *N. dorsalis* females produce embryonated eggs and have 8-14 perineal annuli. The sugarbeet race of *N. aberrans* attacks *Beta vulgaris* in Colorado, Kansas, Nebraska, Montana, South Dakota, Utah, and Wyoming. *N. aberrans* J2 from Nebraska require a minimum threshold temperature (MTT) of 10°C to penetrate sugarbeet roots. The number of degree-days (DD) above MTT for J2 development after root penetration and until the appearance of ovipositing females is 570-750. The range calculated for *N. aberrans* development on tomato is 430-860 in England and 525-720 in Ecuador. The nematode needs more DD for its development than *Heterodera schachtii* (280-350). In Nebraska, sugarbeet crop losses of 10-20% occur in *N. aberrans* infested fields. More than 5 000 ha (40% of the fields) are treated with nematicides to manage *N. aberrans.* In Arkansas, *N. aberrans* was found on tomato (*Lycopersicon esculentum*) and rose (*Rosa* sp.). *N. dorsalis* has been found only in California on weed hosts (*Erodium cicutarium* and *Salvia* sp.) and on sugarbeet in Monterey County. It is of minor economic importance. A *Nacobbus* population was reported in the Rio Grande Valley of Texas on declining spinach (*Spinacia oleracea*). Females produce embryonated eggs and have 8-10 perineal annuli similar to *N. dorsalis.* This population does not attack sugarbeet, but shares spinach, red beet and other hosts with the sugarbeet race of *N. aberrans.*

RESISTANCE GENES TO *MELOIDOGYNE* SPP. AND *GLOBODERA* SPP. IN POTATO. R. Janssen, G. J. W. Janssen, and P. J. C. C. Wolters, CPRO-DLO, PO Box 16, 6700 AA Wageningen, The Netherlands.—In search for resistance to the potato cyst nematodes, *Globodera rostochiensis* and *G. pallida,* several resistant *Solanum* sources have been identified in the past and used for introgression into the potato gene-pool. Although several commonly used sources of resistance are of polygenic nature, monogenic resistance has been identified, like the H_1 gene from *S. tuberosum* ssp. *andigena* and the H_2 gene from *S. multidissectum* conferring resistance to *G. rostochiensis* Ro_1 and *G. pallida* Pa_1, respectively. More recently a gene from *S. tuberosum* ssp. *andigena* CPC 1673, conferring resistance to *G. pallida* population D236 (Pa_2), has been identified and mapped on chromosome 12. With regard to *Meloidogyne* spp., screening trials have identified several wild tuber-bearing *Solanum* sources resistant to *M. hapla, M. chitwoodi* and/or *M. fallax.* Occurrence of resistance to *M. chitwoodi* and *M. fallax* was primarily restricted to North American *Solanum* spp. Moreover, resistance in most North American *Solanum* spp. was effective to both *M. chitwoodi* and *M. fallax.* The genetics of these resistance genes has not yet been studied in detail. More knowledge with regard to the origin of *Meloidogyne* spp. will result in a better understanding of the genetic variation present in *Meloidogyne* spp. and will be useful in detection and evaluation of sources of resistance in potato.

NEMATODE-ANTAGONISTIC FUNGI IN THE RHIZOSPHERE. H-B. Jansson, and L. Persmark, Department of Microbial Ecology, Lund University, Ecology Building, S-223 62 Lund, Sweden.—Nematode-antagonistic fungi have the potential for biological control of plant-parasitic nematodes. Root exudates and sloughed-off root cells make the rhizosphere a favorable environment for nematode antagonistic fungi and other microorganisms. There is a proliferation of both plant-parasitic as well as bacteriovorous and fungivorous nematodes, among other small soil animals. Endoparasitic and nematode-trapping fungi with high parasitic ability have, in several studies, been found to be positively correlated with high nematode numbers. Thus, these species can probably be found in higher numbers in the rhizosphere. Nematophagous fungi which also have an ability to live saprophytically can probably use nutrients released from the roots. Many of these fungi are regarded as poorer competitors in relation to other microorganisms, but their ability to consume nematodes probably compensate for their low competitive ability. In a field study, the rhizosphere of pea plants harbored densities of nematode-trapping fungi up to 10 times higher than root-free soil. In a pot experiment, similar results were observed, and we found both higher densities and more species of nematophagous fungi from the rhizosphere than from equivalent amounts of root-free soil. Furthermore, the species regarded as good parasites had a stronger tendency to form conidial traps in a rhizosphere environment compared to the more saprophytic species. Chemotropic growth of germ tubes of *Arthrobotrys oligospora* occurred towards root-tips of pea, barley and white-mustard. Chemotropism was evident up to 1.0 mm from the root surface and was especially strong around the root-apex. The significance of this and the possible application of nematophagous fungi as rhizosphere organisms was discussed.

DEGRADATION OF NEMATICIDES IN AGRICULTURAL PRODUCTION SOILS. A. W. Johnson, USDA ARS, P.O. Box 748, Tifton, Georgia 31794, U.S.A.—Erratic results often follow the application of nematicides. These results are not always predictable and have been associated with degradation of nematicides. The accelerated degradation of nematicides appears to be biologically mediated and is an agricultural problem that has been observed in crop monocultures and other crop production systems where biodegradable compounds are repeatedly applied to the same soil. The problem can occur in any microbiologically active soil, and it is not unique to any single nematicide or class of nematicides. As indicated by the numbers of *Meloidogyne incognita* second-stage juveniles in the soil and yield in a 5-year sweet corn-sweet potato-vetch rotation, the efficacy of fenamiphos diminished during the third year. Therefore, fenamiphos applied immediately before planting sweet corn, sweet potato, and vetch should not exceed 3 years. Thereafter, the crop rotation and (or) the nematicide should be changed.

FACTORS AFFECTING DEGRADATION OF ETHOPROP AND ALDICARB IN SOIL AND SUBSOILS. R. L. Jones, and F. A. Norris, Rhône-Poulenc Ag Company, P.O. Box 12014, 2 T.W. Alexander Drive, Research Triangle Park, North Carolina 27709-2014, U.S.A.—The chemical and microbial degradation of aldicarb and ethoprop has been extensively studied in both laboratory and field studies. These studies show that temperature is the most important variable affecting the degradation rate of aldicarb and its carbamate metabolites in surface soils. Temperature and organic matter appear to be the most important variables affecting degradation rates of ethoprop under normal agricultural conditions, with increasing organic matter slowing degradation presumably due to increased binding to soil particles. Soil moisture may be important under some conditions for both compounds, with degradation retarded in dry soils. The rate of degradation of aldicarb residues (including carbamate metabolites) does not seem to be significantly affected by depth from the soil surface. An exception is that aldicarb residues degrade more slowly in acidic, coarse sand subsoils. Degradation of ethoprop also continues in subsoils, although field data is more limited due to its lower mobility. Both compounds degrade in ground water. Because of decreasing microbial activity with depth below the soil surface, chemical processes must be important components of the degradation of both aldicarb residues and ethoprop. For aldicarb, transformation to carbamate oxides in surface soils is primarily microbial, while degradation to non-carbamate compounds appears to be primarily the result of soil catalyzed hydrolysis throughout the soil profile. For ethoprop, both chemical and microbial catalyzed hydrolysis are important in surface soils, with chemical hydrolysis becoming more important with increasing depth.

IDENTIFICATION OF RESISTANCE GENES IN TOMATO. I. Kaloshian, and V. M. Williamson, University of California, Department of Nematology, Davis, California 95616, U.S.A.—Plants have geographical centers of origins and have co-evolved with their pathogens and pests to protect themselves from these harmful organisms. The co-evolution of plant and pathogens has made wild relatives of cultivated crops an important source of resistant germplasm. The gene Mi, which confers resistance to *Meloidogyne incognita, M. javanica,* and *M. arenaria,* was introduced into cultivated tomato from its wild relative *Lycopersicon peruvianum.* Mi has been mapped to the short arm of chromosome six and several tightly linked DNA markers have been identified. Meu1, a potato aphid resistance gene, is tightly linked to Mi. It is possible that Mi and Meu1 are the same gene with a pleiotropic effect. Another possibility is that Meu1 is a related gene that differs in pest recognition. Clustering of resistance genes has been identified in different plant-pathogen systems and is thought to have arisen from recombination/duplication and rearrangement events to produce new specificities. We are in the pursuit of resistance genes to *M. hapla* and other variants of *Meloidogyne* spp. that can infect Mi containing tomato. We have identified an isolate of *L. peruvianum* that carries resistance against those nematode strains of *M. incognita* and *M. javanica* that are able to infect tomato carrying the nematode resistance gene Mi. This gene, Mi3, is also resistant at temperatures above 30°C where Mi is no longer effective. We have identified DNA markers (RAPDs) closely linked to this gene, and these markers will expedite incorporation of this trait into cultivated tomato using traditional breeding. Furthermore, with the aid of our markers or by homology to other resistance genes which have recently been cloned, Mi3 will be isolated, making it available for transfer to other plant species where nematode resistance is not available.

BIOLOGICAL AND GENETIC CHARACTERIZATION OF BURROWING NEMATODES, *RADOPHOLUS* SPP. D. T. Kaplan, USDA-ARS, 2120 Camden Road, Orlando, Florida 32803, U.S.A.—The apparent high level of genome conservation apparent among burrowing nematodes should facilitate research to elucidate the genetics of citrus parasitism. Two 2.4 kb DNA fragment (DK#1) amplified and subsequently cloned from a citrus-parasitic and from a non-citrus parasitic strain of *R. citrophilus* from Florida and Hawaii, respectively, shared 99% nucleotide identity. Restriction analyses also indicated that DK#1 sequence is conserved among 8 allopatric burrowing nematode populations. DK#1 is specific to *R. citrophilus.* Using DK#1-specific primers, DK#1 is readily amplified from *R. citrophilus* but not from *R. similis* or from 6 other nematode genera tested. Results of genomic DNA hybridization studies indicate that DK#1 is present in the *R. citrophilus* genome in at least 2 sites, but is absent in the *R. similis* genome. DK#1 can be readily amplified from individual nematodes, and we are using it as a genetic marker in interspecific matings between *R. citrophilus* and *R. similis.* The marker DK#1 is co-segregated with citrus parasitism which appears to be a dominant trait that follows simple Mendelian inheritance. Undoubtedly, characterization of the inheritance of citrus parasitism in burrowing nematodes will identify markers that are more tightly linked with citrus parasitism than is DK#1. Sequence-specific primers created during this process should prove useful for practical identification of citrus-parasitic burrowing nematodes. Furthermore, studies involving genetic markers and traits should resolve the controversy surrounding the sibling species status of these 2 burrowing nematodes. Genetic characterization also may elucidate the basis for enhanced aggressiveness observed in some burrowing nematode populations associated with citrus and banana.

THE NATURE AND EXTENT OF THE SUPPRESSION OF CYST NEMATODE MULTIPLICATION ON SUSCEPTIBLE HOSTS IN SOME SOILS. B. R. Kerry, IACR-Rothamsted, Harpenden, Herts AL5 2JQ, U.K.—Fungal parasites of cyst nematode females and their eggs cause the decline of populations of these nematodes. Natural control has developed under monocultures of several nematode susceptible crops, but it has prevented economic damage caused by cyst nematodes only on cereals. The population dynamics of cereal cyst nematodes, and their fungal parasites has been studied in 4 suppressive soils of different textures in microplots. Half the plots of each soil were treated with formalin (38% formaldehyde) each year for 4 years, and all plots were sown with susceptible cereals. Thereafter, formalin was not applied but untreated and previously treated plots were sown with susceptible or resistant barley or ryegrass which were grown for the next 5 years. The nematode multiplication differed between the soils. Populations of the nematode increased to >300 eggs/g soil on susceptible barley in treated soil. The response to formalin was greatest in the soils in which the fungal parasites were originally most numerous. Populations declined to <5 eggs/g soil on susceptible and resistant barley and on ryegrass within 4 years of the last formalin application. Densities of both *Nematophthora gynophila* and *Verticillium chlamydosporium* were significantly decreased in soils treated with formalin; without further formalin treatment both fungi increased under susceptible barley within 3 years to the densities found in untreated soil. However, the fungi remained scarce in treated soil sown with ryegrass or resistant barley on which few female nematodes developed.

AGRONOMIC CROPPING STRATEGIES FOR NEMATODE MANAGEMENT IN THE SOUTHEASTERN UNITED STATES. R. A. Kinloch, West Florida Research and Education Center, University of Florida, Jay, Florida 32565, U.S.A.—Cotton and soybean are major agronomic cash crops grown in the 9 southeastern states of Alabama (AL), Arkansas (AR), Florida (FL), Georgia (GA), Louisiana (LA), Mississippi (MS), North Carolina (NC), South Carolina (SC), and Tennessee (TN). Other major cash crops, but with more restricted areas of production, are peanut (AL, FL, GA, NC, SC), rice (AR, LA), sugarcane (FL, LA), and tobacco (FL, GA, NC, SC). With the exception of rice, area-wide infestations of *Meloidogyne* spp. occur on all of these crops. Other major nematode pathogens in the region are *Rotylenchulus reniformis, Heterodera glycines,* and *Hoplolaimus columbus.* Various research studies, involving established and introduced non-host crops or resistant and tolerant cultivars, have demonstrated the effectiveness of crop rotations in managing many troublesome nematode problems. However, planned crop rotations for nematode management are not being employed generally. Exceptions are the rotation of cotton and peanut for the management of their respective, and exclusive populations of *M. incognita* and *M. arenaria,* and the alteration of resistant and susceptible cultivars of soybean with sorghum for managing *H. glycines*. Crops are monocultured in many areas, resorting to short-term planting of nonhost crops when populations of nematodes become obviously damaging. Inclusion of graminaceous crops such as maize, sorghum, and pastures into a cropping program are largely confined to farming operations involving livestock production. In general, crop selections are usually short-term options governed predominantly by market pricing and, to a much lesser extent, by weather conditions.

A REVIEW OF ANTAGONISTIC PLANTS AS MODIFIERS OF RHIZOSPHERE BACTERIA. J. W. Kloepper, R. Rodríguez-Kábana, and N. Kokalis-Burelle, Department of Plant Pathology, Auburn University, Auburn, Alabama 36849, U.S.A.—Results of 3 separate studies at Auburn indicate that plants which are antagonistic to nematodes modify both functional groups and community structure of rhizosphere bacteria. In the first study, bacterial rhizospheres of soybean were compared to those of the antagonistic plants Abruzzi rye, velvet bean, castor bean and sword bean. Soybean rhizospheres were predominated by *Bacillus* spp., while those from antagonistic plants included more coryneform and gram-negative bacteria, including *Burkholderia cepacia*. Functional groups of bacteria also were altered with increases on antagonistic plants in comparison to soybean of the percentage of isolates which hydrolyzed starch or gelatin, produced siderophores or hydrogen cyanide, and oxidized phenol. The second study was a 2-yr rotation of cowpea or velvet bean during the first year, followed by soybean the second year. Rotation with velvet bean suppressed populations of root-knot and soybean cyst nematodes in soil and selectively enriched species of *Burkholderia, Arthrobacter*, and *Bacillus* compared to cowpea. In the third study, results of a rotation of peanut and switchgrass indicated that bacterial community structure of the switchgrass rhizosphere was different from the peanut rhizosphere with respect to genera richness, diversity, and evenness. Rhizosphere communities of peanut following switchgrass were dominated by *Bacillus* spp. by 60 days after planting (DAP) and *Burholderia* spp. at 120 DAP, while communities from continuous peanut had 2-4 genera which were dominant throughout the season. These results demonstrate that antagonistic plants support the development of bacterial rhizosphere communities which are functionally and structurally distinct from those of plants susceptible to nematodes. This raises the possibility that some of the antagonistic potential of such plants is due to the distinct rhizosphere bacteria.

CHEMICAL ALTERNATIVES TO METHYL BROMIDE. F. Lamberti, N. Greco, M. Di Vito, and M. Basile, C.N.R.-Istituto di Nematologia Agraria, 70126 Bari, Italy.—Alternatives to methyl bromide for the control of plant-parasitic nematodes are 1,3 dichloropropene (1,3-D) and the methyl isothiocynate producing compounds, such as metham sodium and dazomet among the fumigants, and aldicarb, cadusafos, carbofuran, ethoprophos, fenamiphos and oxamyl among the nonvolatile nematicides. Use of 1,3-D is very effective and advisable when nematodes are the only parasites to be controlled. Metham sodium has very slow action and requires high dosage and continuous delivery to be effective. Dazomet also kills nematodes at high application rates and is not effective at low soil moisture content, which prolongs its degradation with consequent phytotoxic effect. The systemic nematicides, aldicarb and fenamiphos, might be as effective as 1,3-D; however, long persistence of aldicarb may cause accumulation of toxic residues in plants. Carbofuran and oxamyl also are systemic, but because of their shorter persistence are less effective; environmental conditions often affect their efficacy. Cadusafos and ethoprophos have only contact action, and therefore if not applied before endoparasitic nematodes enter the roots, are not very effective. Recently, methyl iodide has been considered as a potential candidate to replace methyl bromide as a soil fumigant. Certainly it has some advantages over methyl bromide including higher nematicidal activity; however, these results need further confirmation.

MEASURING AND DESCRIPTION OF SOIL ECOSYSTEM: RESISTANCE TO NEMATODE DAMAGE. P. W. Th. Maas, C. J. Kok, and F. C. Zoon, DLO Research Institute for Plant Protection, 6700 GW Wageningen, The Netherlands.—Soil suppressiveness is the capacity of the soil ecosystem to prevent nematode damage to a susceptible host crop. It is a quantitative feature and a soil may have different levels of suppressiveness to various soil-borne pathogens or pests. Nematode suppressive soils have been used to isolate biological control agents, but this approach has hardly been practical to date. An additional strategy to exploit soil suppressiveness would be realized by proper management of this natural resource. However, the nature and complexity of suppressive activity is poorly understood. Quantitative techniques to measure soil ecosystems resistance to essential processes of root nematode's life-cycles from initial population in the soil activation, host-finding, root infection and feeding to plant damage, and back via reproduction and survival to a next population in the soil are necessary to describe different types of soil suppressiveness. Mechanisms limiting the first series of root nematode activities from soil population to effective feeding, such as disturbance of plant signals to nematodes or nematode repellent production by microorganisms competing for their niche in the rhizosphere and induced plant resistance to nematodes, are predominantly root activity driven and not nematode specific nor nematode density dependent. Testing soils for nematode suppressiveness with respect to different processes in root nematode's life-cycles may facilitate correlative and causative research to improve rational exploitation, management and enhancement of those mechanisms.

BIOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS OF POPULATIONS OF *NACOBBUS ABERRANS* FROM MEXICO. R. H. Manzanilla-Lopez,[1] K. Evans,[1] and I. Cid del Prado-Vera,[2] Entomology and Nematology Department, IACR-Rothamsted, Harpenden, Herts., AI5 2JQ, U.K.,[1] and Instituto de Fitosanidad, Colegio de Postgraduados en Ciencias Agricolas, Montecillo, Texcoco 56230, Mexico.[2]—Morphological data and information on host ranges for different populations of *Nacobbus aberrans* has led to the suggestion that the species can be considered as a group of physiological races. However, more information on host range is required before a race scheme can be completed, and standard conditions for inoculum, temperature and host cultivars must be defined, bearing in mind the still poorly understood biology of the nematode. We conducted a study of the host range of one Bolivian and 9 Mexican populations of *Nacobbus aberrans* on 13 hosts, including species of Compositae, Cruciferae, Chenopodiaceae, Graminae, Leguminosae and Solanaceae. Plants were inoculated with 740 second-stage juveniles per 500 g soil and kept in a glasshouse for 70 days, when they were examined for galls and females and nematodes in soil and roots were counted. The host status of beans and potatoes for some of the Mexican populations was not consistent with previous reports and morphological and biochemical studies were made in an attempt to elucidate their possible race status. Courgette, chile, bean and potato plants all showed some differences in host status for the populations tested. Non-host plants showed a consistent response to infection. In the root cortex, small chambers with enlarged cells with lignified walls were observed. Juveniles could develop as far as pre-adult stages in these chambers (e.g. in maize). A complication in trying to create a race scheme is that *N. aberrans* seems to be able to adapt to new hosts. Longer term studies of population dynamics on hosts that don't produce galls but do allow reproduction may be necessary before host ranges can be clearly defined.

FIELD DEVELOPMENT OF ENTOMOPATHOGENIC NEMATODES. W. R. Martin, Biosys, Inc. 4131 NW 13th St., Ste. 212, Gainesville, Florida 32609, U.S.A.—The ultimate goal in a field development program with entomopathogenic nematodes is to achieve maximum efficacy by increasing the probability of nematode-insect contact leading to host death. In the field, there are a number of biotic and abiotic elements which can influence both the nematode and its host. Biotic factors include host susceptibility, pest population levels, host behavior, and nematode species and strain. Abiotic factors can include soil type, temperature, and moisture. In addition, application rates and methodology can have a profound influence on efficacy. Crop morphology and phenology must be considered when designing field trials. Finally, nematodes can be integrated with other control strategies, including chemical pesticides as well as other biological control agents, in order to achieve maximum efficacy.

IMPORTANCE OF ABIOTIC AND BIOTIC FACTORS IN *MELOIDOGYNE-PASTEURIA* RELATIONSHIPS. T. Mateille, and R. Duponnois, Laboratoire de Nématologie, ORSTOM, B.P. 1386, Dakar, Sénégal.—To increase the efficiency of endogenous populations of *Pasteuria penetrans*, research is promoted on biocenotic mechanisms which control natural development and parasitism of this microorganism. The success of nematode biocontrol does not strictly depend on biological knowledge of *Meloidogyne*/*P. penetrans* relationships but also depends on the establishment of favorable soil conditions. The survival and the availability of the spores of *P. penetrans* for attachment are conditioned by both soil texture and structure, e.g. for coarse soils, the majority of spores percolate with water, whereas most of them are associated with aggregates of clay soils. The attachment of the spores proceeds from 2 distinct steps: i) the well known biochemical recognition of the cuticle of *Meloidogyne* by the spore, and ii) the less extensively studied hazardous approach of the cuticle. The latter may be due to electrochemical attraction depending on the ionic content of the soil solution and/or on the cationic saturation of clay surfaces. The help of rhizospheric bacteria was demonstrated. Their role could be various: i) biochemical maturation of the external structures of the spores improving the contact with the nematode cuticle, ii) modification of the carbohydrate composition of the cuticle or direct excretion of bacterial saccharides rendering the cuticle more receptive to the spores, iii) transformation of root exudate polysaccharides which modify nematode-*Pasteuria* relations via aggregation.

PERFORMANCE OF VARIOUS CULTURAL CONTROL METHODS USED PRIOR TO REPLANTING TREE OR VINE CROPS. M. McKenry, Department of Nematology, University of California, Riverside, California 92521, U.S.A.—Four years of fallowing or nonhost crops can provide relief from most components of tree and vine replant problems. Forty days of flooding followed by fallowing one year does not reduce population levels of endoparasitic nematodes but does provide first-year growth of replants similar to that achieved from methyl bromide treatments. Foliar treatments of glyphosate herbicide to Nemaguard Peach trees 60 days before their removal followed by 18 months of fallowing also provides replant growth similar to that of methyl bromide treatments but with no reductions in populations of endoparasitic nematodes. Replanting trees in the drive row 3 m away from the old row can double first-year tree growth but that is only one-third of the growth resulting from a methyl bromide treatment. An 18-month crop rotation involving nonhosts for *Pratylenchus vulnus* and *Tylenchulus semipenetrans* gave half the growth achieved by methyl bromide treatments but no protection against nematode buildup. Applications of water extracts from *Tagetes tenuifolia* even when followed in 30 days by 1 m water proved phytotoxic to replanted trees and vines. Urea treatments of 654 kg/ha drenched to 1.7 m depth gave 95% reduction of nematodes in soil but like foliar glyphosate, flooding, crop rotation and Tagetes extracts, provided no reductions of those nematodes present in remnant roots. Effective soil fumigants or their replacement methods must kill remnant roots and nematode stages therein wherever endoparasitic nematodes pose a production problem and resistant rootstocks are unavailable.

MOLECULAR CHARACTERIZATION OF *PRATYLENCHUS* SPECIES BY PCR-BASED METHODS. M. Moens, Centrum voor Landbouwkundig Onderzock, 9820 Merelbeke, Belgium.—To overcome difficulties in *Pratylenchus* species identification, PCR based methods were used to characterize 26 populations belonging to 9 species (*P. vulnus, P. goodeyi, P. penetrans, P. thornei, P. coffeae, P. negletus, P. agilis, P. scribneri* and *P. crenatus*). PCR products of these populations were compared to those of 4 populations of *Radopholus similis.* Out of a total of 32 decamer oligonucleotide primers (OPERON) generating different RAPD fragments, a combination of 3 was found to differentiate the species examined: OPK-7, OPK-10 and OPD-11. Intraspecific variability was present. PCR also was used to amplify a rDNA-fragment. The primers were conserved sequences of the 18S and 26S rRNA genes of

Caenorhabditis elegans. They amplified a fragment ranging in size from 900 to 1200 bp. The rDNA fragments were cut with 9 restriction enzymes (AluI, HinfI, RsaI, HpaII, HaeIII, CfoI, BamHI, HindIII and Sau3AI). The patterns of the restriction fragments showed clear differences between the *Pratylenchus* spp. and *R. similis.* With the exception of *P. agilis* and *P. scribneri,* all nematode species could be differentiated with all the restriction enzymes used. Only AluI could also differentiate *P. agilis* from *P. scribneri.* Intraspecific variability was low.

NEMATODE-FUNGUS INTERACTIONS IN DISEASE COMPLEXES. M. M. Mota, Dept. de Biologia, Universidad de Évora, 7000 Évora, Portugal.—Nematodes and fungi have been known to interact in disease complexes since 1892, when Atkinson observed increased wilting of cotton due to the combined action of *Fusarium* and root-knot nematodes. However, the explanation of the mechanisms by which these interactions take place is still poorly understood. Initially, nematodes were considered wound agents, providing entry for pathogenic fungi. Further studies provided evidence for a physiological role although it is still poorly understood. Physiological changes induced by sedentary endoparasites such as root-knot and cyst nematodes increase the host susceptibility, possibly by interfering with particular genes. Giant cells and syncytia, true metabolic sinks, are preferential sites for many pathogenic fungi such as *Fusarium* and *Verticillium.* Changes in root exudates caused by nematodes seem to affect both plant pathogenic and non-pathogenic fungi. Two main groups of pathogenic fungi interact with plant parasitic nematodes: wilt inducing fungi and root rot fungi. Presently, we know of 70 different f. sp. of *F. oxysporum* interacting with nematodes, and in particular *Meloidogyne incognita.* Other interactions include *Verticillium* with *Pratylenchus* and *Globodera.* There are at least 45 different crops, mainly from tropical countries, where interactions occur between root fungi and plant-parasitic nematodes. Three major types of interrelationships occur: additivity, antagonism, and synergism. Problems hindering studies of interactions include non-uniformity of environmental conditions, unrealistic inoculum levels, artificial soil conditions, and inappropriate data analysis.

PHYSICAL METHODS OF NEMATODE CONTROL. J. W. Noling, University of Florida, IFAS CREC-Lake Alfred, Florida 33850, U.S.A.—Steam and hot water have been effectively used for nematode control to heat soil within greenhouse and small nursery operations but have generally proved impractical for large-scale field use. With limitations, soil solarization has been successfully used to heat noncropped soil to temperatures lethal to many soilborne pests, particularly when integrated with other cultural, chemical, or biological control methods. Soil buffering capacity and lower host tolerance are major limiting factors restricting practical utility of irradiation disinfestation of soil or plant materials for nematode control. Most other physical methods, including sound, electricity, and microwave, have proved either ineffective or impractical for field disinfestation of nematodes. For example, the slow rate of equipment travel and high costs and consumption of fossil fuels have precluded system development for most physical methods in commercial field agriculture. Other considerations such as equipment cost, convenience, applicator certification, worker health and safety, potentials for recontamination of treated areas, depth-limited soil penetration and efficacy, and the inability to simultaneously integrate physical treatments with other agricultural production practices also have posed significant problems which must be resolved to successfully implement these methods in agriculture.

PEACH TREE SHORT LIFE IN THE UNITED STATES: AN UPDATE AND ADVANCES. A. P. Nyczepir, USDA-ARS, S.E. Fruit and Tree Nut Research Laboratory, 111 Dunbar Rd., Byron, Georgia 31008, U.S.A.—Peach tree short life (PTSL) continues to be a major problem in the peach growing regions of the southeastern United States. Trees, usually 3-6 years old when affected by PTSL, die before the orchard reaches full productivity. The ring nematode, *Criconemella xenoplax,* is the major biotic factor responsible for increasing susceptibility to cold injury and/or bacterial canker, *Pseudomonas syringae,* which are responsible for the sudden collapse of peach trees associated with the PTSL syndrome. In South Carolina alone, 1.1 million trees died from PTSL between 1980-92, representing a monetary loss of greater than 6 million $U.S. annually. In recent years, disease management strategies of PTSL have been based on nonchemical approaches, including host resistance, biological control, and cultural practices for suppression of *C. xenoplax.* In 1991, peach seedling rootstock BY520-9 (Guardian™) was identified as providing greater tree survival than Lovell (standard rootstock) on PTSL sites. Preliminary results also indicate that there is some degree of root-knot nematode resistance in the newly released Guardianpeach rootstock. Preplanting wheat and sorghum has proven useful in suppressing the population density of *C. xenoplax* on some PTSL orchard sites. Investigations into the use of preplanting bahiagrass to suppress *C. xenoplax* are continuing. A bacterium (*Pseudomonas aureofaciens*) associated with peach roots is being studied as a potential biocontrol agent for the ring nematode. A water-diffusible substance that kills *C. xenoplax* eggs appears to be an important mechanism of suppression of the nematode.

AN ANALYSIS OF TRANSGENIC ROOT-KNOT NEMATODE RESISTANT TOBACCO. C. H. Opperman, and M. A. Conkling, Departments of Plant Pathology and Genetics, North Carolina State University, Raleigh, North Carolina 27695, U.S.A.—We have identified the tobacco root-specific gene, TobRB7, as being up-regulated during root-knot nematode infection. We have further defined the Nematode Responsive Element (NRE) of the TobRB7 promoter. Full length cDNA antisense constructs of TobRB7 driven by either the NRE or the 35S CaMV promoter were transformed into tobacco. When these plants were infected with root-knot nematode, a substantial reduction in galling and egg production was observed. Greenhouse and field trials with the NRE-TobRB7 antisense plants provided strong evidence that nematode infection was substantially reduced. In all trials, root galling was reduced by approximately 70% compared to control treatments. The field trials indicated that protection lasted for the entire growing season (approximately 4 months). Galls that were observed on the roots of antisense plants were small and tended to appear as discrete entities compared to the large and clustered galls on the controls.

CROPPING SYSTEM AS A MEANS TO CONTROL THE RENIFORM NEMATODE IN COTTON IN ISRAEL. D. Orion, Department of Nematology, A.R.O., The Volcani Center, Bet-Dagen 50250, Israel.—The reniform nematode (*Rotylenchulus reniformis*) is a serious cotton pest in alluvial soils of the north-western valleys in Israel where upland cotton (*Gossypium hirsutum*) has been grown for over 10 consecutive years. The nematode population has reached thousands of free living stages per 100 ml soil which have caused severe stunting of the cotton plants yielding poor crops that could not cover the cultivation expenses. Due to soil properties of over 50% clay, application of nematicides did not prove effective, and farmers have been forced to interrupt growing cotton, the cash crop of the region. Trying to solve the problem, a five-year crop rotation field experiment was conducted aimed at keeping cotton as the major crop. Wheat, corn and Egyptian cotton (*G. barbadense*) were alternated with upland cotton. Both wheat and corn reduced the nematode population level by 90% and cotton yield increased by some 25% the next year. The build-up of the reniform nematode population, following wheat, was very rapid and reached a higher population than that of the continuous cotton control. It was assumed, therefore, that under continuous cotton cultivation, reniform nematode antagonists developed. The nematode population on Egyptian cotton reached about 50% of that of upland cotton. Upland cotton, wheat/corn, and Egyptian cotton has been recommended as a cropping system.

ENHANCED DEGRADATION OF TWO VOLATILE FUMIGANT NEMATICIDES, 1,3-D AND METHYL BROMIDE, IN SOILS. L-T. Ou, Soil and Water Science Department, P.O. Box 110290, University of Florida, Gainesville, Florida 32611-0290, U.S.A.—Enhanced degradation of the fumigant nematicides, 1,3-D and methyl bromide, was observed in soils recently. However, the mechanisms underlying the enhanced degradation of the 2 chemicals are different. Enhanced degradation of 1,3-D was observed in soil from a field site in Florida which had been treated with 1,3-D at least 6 times in the past 12 years. Degradation rates of cis- and trans-1,3-D in surface and subsurface soil samples from the treated site were significantly larger than in the corresponding samples from the untreated site. In addition, differentially enhanced degradation of the two isomers was observed, with the trans isomer being degraded faster than the cis isomer. No or trace amounts of the hydrolysis product of trans-1,3-D, trans-3-chloroallyl alcohol, were detected in field-treated soil amended with trans-1,3-D; whereas much larger amounts of cis-3-chloroallyl alcohol were formed in the same soil amended with cis-1,3-D. Enhanced degradation of methyl bromide in soil can be correlated to the production of mono- or di-oxygenases produced by certain bacteria in response to the oxidation of methane, ammonia, phenol, or 2,4-D. Repeated applications of methane or ammonia to soil greatly increased the degradation rate of methyl bromide in the soil. In conclusion, differentially enhanced degradation of cis- and trans-1,3-D was observed in field treated soil, with trans-1,3-D being degraded faster than the cis isomer. Biological hydrolysis was the main factor responsible for the initial degradation of trans-1,3-D in field treated soil. Methane-monooxygenase and ammonia-monooxygenase produced by methane-oxidation bacteria and ammonia-oxidation bacteria, respectively, were responsible for the enhanced degradation of methyl bromide in soil repeatedly treated with methane and an ammonium salt.

THE IMPACT OF RENIFORM NEMATODE ON COTTON PRODUCTION IN THE U.S.A. C. Overstreet, Louisiana Cooperative Extension Service, LSU Agricultural Center, Baton Rouge, Louisiana 70894, U.S.A.—Cotton is an important fiber crop in the southern areas of the U.S.A. with production occurring on 6.7 million ha during 1995. Reniform nematode (*Rotylenchulus reniformis*) has developed into a major pest of cotton in a number of states that produce cotton in the U.S.A. Ten of the 16 states producing cotton have this nematode. Mississippi and Louisiana have the greatest incidence of reniform nematode with estimates of 283,000 and 206,000 ha, respectively. Losses by this nematode have been reported as high as 40-60% but average 15-30%. Nematicides or rotations are the only methods currently utilized to manage this nematode. Resistant cultivars are in early developmental stages. Development of resistance has been limited due to the difficulty of crosses with other cotton species with upland cotton, *Gossypium hirsutum*. Tolerance by some cultivars has been reported but none either consistently or across geographic regions. Differences in fecundity and aggressiveness by various populations of the reniform nematode are known on several cultivars. The current spread by this nematode and lack of resistant cultivars indicate serious problems in cotton production in the U.S.A.

THE ECOLOGICAL PHYSIOLOGY OF ENTOMOPATHOGENIC NEMATODES. R. N. Perry, and H. Menti, Entomology and Nematology Department, IACR-Rothamsted, Harpenden, Herts, AL5 2JQ, U.K.—The ability of the infective juvenile stage of Steinernematid and Heterorhabditid species to survive desiccation is reviewed. Recent research has used quantitative interference microscopy to determine the water content of individual nematodes in order to relate survival to the rate of water loss at different relative humidities and to examine the role of the sheath in controlling water loss. Populations of *Heterorhabditis megidis* and *Steinernema feltiae* from Greece and the U.K. have also been compared to examine possible physiological adaptation by the populations from Greece to survive severe drying conditions. The physiological studies were extended to examine the survival and ability to control water loss of "ambushers" and "cruisers" under conditions of low humidity and to determine the relationship between nematode water content and humidity associated with nictating behavior.

HOST-INDUCED DORMANCY IN CYST NEMATODES. R. N. Perry, Entomology and Nematology Department, IACR-Rothamsted, Harpenden, Herts, AL5 2JQ, U.K.—The contrasting hatching behavior of cyst nematodes may be related to different strategies for survival. Hatching from cysts of *Globodera rostochiensis* and *G. pallida* is dependent on host root diffusates, ensuring synchrony between emergence of second-stage juveniles (J2) and the presence of roots. Other species of cyst nematodes, especially those from the tropics, complete several generations during the host growing season. Second-stage juveniles (J2) of *Heterodera oryzicola* are always dependent on host root diffusate for substantial hatch, irrespective of generation, and can remain dormant until the subsequent growing season. In contrast, successive generations of *H. cajani, H. sacchari* and *H. sorghi* show a change in hatching behavior; J2 from early generation cysts hatch well in water whereas a large proportion of J2 from the later generations do not hatch but remain dormant during the intercrop period. The changing hatching pattern of cysts produced at different stages of plant growth is an important aspect of host-parasite interactions and will be discussed in relation to future research on the influence of the host plant, and particularly the syncytium, on the biology of the developing nematodes.

SPECIFICITY OF *PASTERIA PENETRANS* ATTACHMENT TO *MELOIDOGYNE* SPP. M. S. Phillips,[1] R. Duponnois,[2] M. Fargette,[3] and L. Gimeno,[3] SCRI, Invergowrie, DD2 5DA Dundee, U.K.,[1] ORSTOM, BP 1386, Dakar, Senegal,[2] and Laboratoire de Nematologie ORSTOM - CIRAD, BP5035, 34032 Montpellier, Cedex 1, France.[3]—*Pasteria penetrans* has potential as a biological control agent against root-knot nematodes but differences in host specificity have been reported. Experiments have been conducted to examine the attachment of the spores of *P. penetrans* to the cuticle of second-stage juveniles (J2) of *Meloidogyne* spp. Two experiments were described. The first tested 6 populations of *P. penetrans* on a large number of *Meloidogyne* clonal lines representing several species and the second tested 18 populations of spores on 4 lines representing *M. incognita, M. mayaguensis, M. chitwoodi* and *M. javanica.* In the first experiment, *P. penetrans* population by nematode line interactions were observed. Within each *Meloidogyne* species, except *M. mayaguensis*, there was a range of response ranging from low to high levels of attachment. Within *M. mayaguensis*, there was some variation for levels of attachment but this varied from none to only low levels of attachment. In the second experiment, there was little or no attachment by any of the *P. penetrans* populations to the *M. mayaguensis* line used and only low levels of attachment to the line of *M. incognita* were observed. Both the *M. chitwoodi* and *M. javanica* lines showed wide variation for attachment. The results are discussed in relation to the use of *P. penetrans* as a biocontrol agent.

PROBLEMS RELATED TO ROOTSTOCK SELECTION AGAINST ROOT LESION NEMATODES IN STONE AND POME FRUIT CROPS IN MEDITERRANEAN ENVIRONMENTS. J. Pinochet, Departamento de Patología Vegetal, Institut de Recerca i Tecnologia Agroalimentaries (IRTA), Crta. de Cabrils s/n, 08348 Cabrils, Barcelona, Spain.—The root-lesion nematode, *Pratylenchus vulnus*, is an important pest attacking stone and pome fruit crops in the United States and southern Europe. This migratory endoparasitic nematode causes the destruction of the root system which results in loss of vigor and yield in young and mature trees. The economic importance of lesion nematodes in the development of orchard replant problems has been recognized over 40 years. Breeding for resistance has been one of the most neglected approaches towards achieving effective control of *P. vulnus* in stone fruit rootstocks adapted to warm Mediterranean environments. A significant effort to incorporating host plant resistance is currently being persued against this pest in the United States, France and Spain. Resistance against *P. vulnus* has been difficult to find, and even more, to transmit the trait from wild *Prunus* into commercial rootstocks. Recent findings also indicate the existence of differences in pathogenicity among populations of *P. vulnus*, a consideration that further complicates the evaluation of plant material in the search for resistance and tolerance in *Prunus* rootstocks against this pathogen. A few sources of resistance have been identified in plums (wild and commercial genotypes) although the nature of the resistance and form of transmission remain unknown.

THE STATUS OF TOBACCO NEMATOLOGY IN CANADA AND EUROPE. J. W. Potter, and D. Mugniery, Agriculture and Agri-Food Canada, Vineland Station, Ontario L0R 2E0, Canada and INRA, Laboratoire de Zoologie, BP 29, Le Rheu, 35650 France.—Although tobacco-producing regions both in Canada and Europe lie between 35° and 45° north latitude, the genera of nematodes which attack tobacco in Canada are more typical of the North Temperate zone, while the European pests are those typically endemic in the SubTropic zone. Thus, *Pratylenchus penetrans* is the major problem in Canada, with sporadic isolated episodes of *Meloidogyne hapla.* By contrast, in the European tobacco production area centered around the Mediterranean Ocean and Aegean Sea, *Globodera tabacum*, several subtropical species of *Meloidogyne* and *Longidorus caespiticola* are the main problems. This difference has important implications in the direction of nematology research in the 2 areas; e.g. European breeding programs concentrating on root-knot and cyst resistance; types of control chemicals; differing management practices; effect of the Canadian climate on economic losses, and others.

NEMATODE PROBLEMS IN DIFFERENT RICE PRODUCTION SYSTEMS IN SOUTHEAST ASIA, FUTURE RESEARCH PRIORITIES. J-C. Prot, International Rice Research Institute, IRRI, P.O. Box 933, 1099 Manila, Philippines.—Rice-root nematodes in irrigated, rainfed lowland, and deep water rice; stem nematode in deep water rice; root-lesion nematodes in upland rice; root-knot nematodes in all rice production systems, all can cause yield losses. However, yield loss intensity depends on interactions between nematode community structure, environment, cultural practices and cultivars. Moreover, environment and cultural practices strongly affect the nematode community structure. Rice production systems are changing. A shift from extensive floating rice to intensive irrigated rice is taking place in the floodplains. Decreasing water availability results in the adoption of intermittent irrigation instead of permanent flooding for irrigated rice. Policies promote permanent agriculture and diversification to alleviate poverty and to reduce environmental effects of shifting cultivation to the uplands. In the lowlands, diversification is taking place where farmers gain access to new markets. These changes will have a strong influence on the nematode community making it seem unrealistic to set future research priorities based on today's yield loss data and existing rice production systems. Changes should be considered to foresee future nematode problems in these systems. Nematode species that can proliferate in various environments and have a wide host range would most certainly become major problems in future rice production systems. Intensification, diversification, land and water use efficiency, sustainability, and profitability are key issues for rice growers. They provide good opportunities for nematologists.

MOLECULAR TAXONOMY AND PHYLOGENY OF STEINERNEMATID NEMATODES. A. P. Reid, W. M. Hominick, and B. R. Briscoe, CAB International, International Institute of Parasitology, 395A Hatfield Road, St Albans, Herts. AL4 0XU, U.K.—The internal transcribed spacer (ITS) region from the rDNA repeat unit of a number of Steinernematid species was amplified by use of the polymerase chain reaction. The resulting products were digested with one of 17 different restriction endonucleases and the fragments separated by electrophoresis. The RFLP profiles were recorded for each enzyme and compared for their suitability for molecular taxonomy. Depending on the enzyme used, all of the species could be differentiated using this method. Phylogenetic relationships between the species also were determined by calculating the number of common bands shared between the species and a tree constructed. Species grouped together by this method often reflected morphological relationships.

ANHYDROBIOSIS IN PLANT-PARASITIC DORYLAIMIDS. G. Reversat, Laboratoire d'Ecologie des Sols Topicaux, ORSTOM, 32 avenue Henri Varagnat, 93143 Bondy Cedex, France.—Plant-parasitic dorylaimids are able to survive in dry soils during the dry season. Anhydrobiosis has not been studied experimentally in this group to the extent that it has been studied in hoplolaimids. In Congo eucalyptus plantations, *Xiphinema* is the main plant-parasitic genus encountered. Two species are found, *X. attorodorum* and less frequently an undescribed new species, *X.* n. sp. In a first step of our study, it was demonstrated that nematodes were present during the dry season within the upper layer of soil. Thên in laboratory experiments, it was demonstrated that X. n. sp. do not survive anhydrobiosis *in vitro* on supports like filter paper, but survive well in cylinders of original soil, for the same value of the hydric stress (pF maximum of 4.5, equivalent to -3.1 MPa water potential). This result supports the hypothesis that one or more components of the soil (organic matter or clay) is necessary for the establishment of anhydrobiosis in this species. This is rather different from other groups, such as hoplolaimids or Heteroderidae, in which anhydrobiosis can be easily observed *in vitro* on a glass support or on filter paper.

FLUE-CURED TOBACCO NEMATODE PROBLEMS IN THE UNITED STATES AND THE FLORIDA EXPERIENCE. J. R. Rich, University of Florida, Route 3, Box 4370, Quincy, Florida 32351, U.S.A.—Major nematode problems in flue-cured tobacco production in the U.S.A. are caused by species of *Meloidogyne* including *M. arenaria, M. hapla, M. incognita,* and *M. javanica.* Additionally, *Globodera tabacum solanacearum* is an important parasite in the state of Virginia and has been recently found in North Carolina. Presence and abundance of *Meloidogyne* species vary with latitude with *M. javanica* most widespread and damaging in Florida, *M. incognita* in North Carolina and *M. hapla* in Virginia. Virulence or aggressiveness of these species is different with *M. hapla* being the least damaging followed by, in increasing order of aggressiveness, *M. incognita, M. arenaria,* and *M. javanica. M. javanica* was first recognized to be the most damaging nematode species in Florida in 1979 after a series of nonfumigant nematicide failures. It is thought that population shifts occurred from *M. incognita* due to widespread use of resistant cultivars. Growers have since returned to using fumigant nematicides and lengthened rotation intervals. The importance of rotation interval and the economics of nematicide treatment were discussed.

DAUER LARVAE OF *CAENORHABDITIS ELEGANS.* D. L. Riddle, University of Missouri, Division of Biological Sciences, Columbia, Missouri 65211, U.S.A.—The dauer larvae of *Caenorhabditis elegans,* a free-living soil nematode, exhibit a diverse repertoire of dispersal behaviors including nictation, which presumably allows them to establish phoretic associations with larger soil inhabitants. Anecdotal accounts have associated *C. elegans* with insects and with Gastropods. Third-stage dauer larvae are facultatively formed in response to a *Caenorhab-ditis*-specific pheromone, which is a measure of population density. The L1 larva responds to a high pheromone:food ratio in the environment by entering a predauer L2 stage called the L2d, which is behaviorally, morphologically, and metabolically distinct from the alternate L2 stage. Extensive molecular genetic analyses have shown that the developmental decision between growth and dauer dispersal is mediated by specific chemosensory neurons in the amphids, and by a protein growth-factor-mediated intercellular signal transduction pathway that is conserved in evolution between mammals, insects, and nematodes. In *C. elegans,* parts of the same pathway regulate cuticle surface antigen switching, adult egg-laying, adult body size, and life span. Thus, a few genes of fundamental importance to development have been recruited for use in different tissues at different times in development to integrate these aspects of *C. elegans* life history. Although the sensory cues for dispersal have diverged with habitat among nematode species, it is speculated that many species may use the same, highly conserved, internal signal transduction machinery to respond to those cues.

NEMATODES AND THE BANANA ROOT PATHOGEN COMPLEX IN THE WEST INDIES: RECENT OUTCOMES AND FUTURE PROSPECTS. J-M. Risede,[1] H. Fagan,[2] D-G. Strullu,[3] and B. Delvaux,[4] CIRAD-FLHOR Station de Neufchateau, Laboratoire de Phytopathologie, 97130 Capesterre Belle Eau-Guadeloupe, F.W.I.,[1] WIBDECO WM Peter Boulevard, P.O. Box 115, Castries, St. Lucia,[2] Universite d'Angers, Faculte des Sciences, Laboratoire des Interactions Plantes-microorganismes, 49045 Angers Cedex, France,[3] and Universite Catholique de Louvain, Faculte des Sciences Agronomiques, Departement des Sciences du Milieu et de l'Amenagement du Territoire, Unite des Sciences du sol, Place Croix du Sud, 2/10; B-1348 Louvain-la-Neuve, Belgium.[4]—Export banana is a major economic crop in the West Indies. Cropping systems vary widely in this region. They involve low-input mixed cropping systems in which bananas are intercropped with other cultivated plants, low input pure stand banana cropping systems as well as intensive banana cropping systems of a monocultural type. During the last decade, damage due to banana nematodes has been studied along with a holistic approach of the soil-root parasites-plant interaction. Root damage is attributed to a root pathogen complex (RPC) involving endoparasitic nematodes among which *Radopholus simi-*

lis and *Helicotylenchus multicinctus* are dominant, as well as soilborne fungi belonging to the genera, *Cylindrocladium* and *Fusarium.* Five main research topics are currently considered: (1) the relationship between soil types and RPC distribution, (2) the characterization of RPC components through morphological and pathological studies including nematode-fungi interactions, (3) the RPC epidemiology, (4) the screening of nematicide molecules, and (5) the characterization of the rhizosphere biocenosis. Results attained give the growers some major tools for integrated control of root parasites: chemical control with 8 active ingredients (carbamates and organophosphates), cultural practices promoting soil cleaning up through "crop rotations" or fallowing, and the use of healthy planting material obtained from tissue culture. These results also give new research perspectives in achieving an integrated control of banana root parasites to improve the sustainability of cropping systems and preserve the environment. These perspectives are: (1) the adaptation of management practices to ecological conditions (soil type, climate), (2) adoption of non-host plants as "rotation crops" with respect to the different components of the RPC, (3) management of beneficial populations of the banana rhizospheric microflora such as endomycorrhizal fungi and rhizobacteria, (4) identification of genetic sources of resistance or tolerance to root parasites, and (5) use of less toxic nematicides.

THE MANAGEMENT OF HOST RESISTANCE-*MELOIDOGYNE* AVIRULENCE GENETIC SYSTEMS FOR CROP PROTECTION. P. A. Roberts, Department of Nematology, University of California, Riverside, California 92521, U.S.A.—The common important *Meloidogyne* spp. have extensive host ranges that limit nonhost rotation options. Numerous host resistance genes in diverse crops have been identified and could be used in annual cropping sequences to manage root-knot. The effective use of resistance is influenced by the level of resistance expressed, the species-specificity of the resistance genes, the frequency of virulence in nematode populations and the rates of selection for virulence, and by the genetic stability of resistance relative to fitness costs. Resistance genes to *Meloidogyne* in tomato, beans, cowpea, cotton, carrot and pepper are being studied to determine their impact on nematode population densities in various rotation sequences. In addition, research on tomato and cowpea has shown that selection and fitness are important components of resistance-avirulence interaction that determine the genetic constitution of nematode populations. Selection and fitness responses may be specific for particular resistance gene and nematode combinations. Knowledge of these responses provides rationale for management decisions.

ORIGINS OF RESISTANCE GENES IN RELATION TO *MELOIDOGYNE* DISTRIBUTION AND VARIATION. P. A. Roberts, and J. C. Veremis, Department of Nematology, University of California, Riverside, California 92521, U.S.A.—The origins of several natural host plant resistance genes to *Meloidogyne* spp. were investigated by analysis of the geographical distributions and centers of diversity of the crop plant species and closely related taxa. Resistance genes in tomato, wheat and different grain legumes were chosen to represent distinct plant families. The putative origins of the resistance genes were compared to the geographicaldistributions of the common *Meloidogyne* species that are either all controlled by a resistance gene, or that in some combinations, are differentially controlled by a resistance gene. Characteristics of the resistance genes such as temperature sensitivity were considered in the comparisons of gene and nematode distributions. Although the extensive global distribution of *Meloidogyne* makes critical assessment difficult, some general implications on the origins of resistance genes and *Meloidogyne* species can be made from these studies.

CROPPING SYSTEMS-MANAGEMENT OF SOIL SUPPRESSIVENESS FOR NEMATODE CONTROL. R. Rodríguez-Kábana, and N. Kokalis-Burelle, Department of Plant Pathology, Auburn University, Alabama 36849, U.S.A.—The practice of monoculture in tropical and subtropical regions generally results in increased inoculum of phytonematodes and other soilborne plant pathogens. Monoculture can increase levels of antagonism against soilborne pathogens; however, this is not consistent and usually results in levels of pathogen suppressiveness inadequate for effective management of diseases. The growing of a crop species in a field exerts a definite and quantifiable effect on the composition of the soil microbiota. Crop mediated changes in the soil microbiota are quantitative and qualitative. Cropping systems can be designed to increase levels of antagonism (degree of suppressiveness) against specific soilborne pathogens. Inclusion of switchgrass (*Panicum virgatum)* or velvetbean (*Mucuna deeringiana*) in cropping systems with peanut, cotton or soybean results in increased parasitism of *Meloidogyne* spp. by soil microorganisms.

INTERACTIONS OF NEMATODES WITH MULTIPLE PESTS. J. S. Russin,[1] E. C. McGawley,[1] C. H. Carter,[1] J. L. Griffin,[1] and D. J. Boethel,[2] Department of Plant Pathology and Crop Physiology,[1] and Department of Entomology,[2] Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803, U.S.A.—Nematodes, fungi, and weeds are common pests on soybean (*Glycine max*), but very few studies focused on interactions among these pest groups or their combined effects on plants. Several years ago, we established a multidisciplinary project to begin study in these areas. Many weed species were hosts for root-knot nematode (*Meloidogyne incognita*), but co-culture of soybean with hemp sesbania (*Sesbania exaltata*) resulted in dramatic increases in root galling, egg production, and juvenile numbers. Nematode numbers and damage were further increased when soybean was stressed by simulated insect defoliation in addition to hemp sesbania. However, this increase in nematode numbers and damage was limited when soybean roots also were parasitized by the charcoal rot fungus (*Macrophomina phaseolina*). Further studies showed that foliage from plants damaged by these pests in concert had dramatically different levels of certain key elements, which resulted in altered feeding and development by soybean looper (*Pseudoplusia includens*) larvae. Short term green-house studies showed fewer cyst nematodes (*Heterodera glycines*) on soybean damaged by the stem canker fungus (*Diaporthe phaseolorum* var. *caulivora*), but greater nematode numbers on plants defoliated by soybean looper. These 3 pest species also had pronounced effects on root nodulation and nitrogen fixation.

FENAMIPHOS PERSISTENCE IN A HAWAII OXISOL: FIELD AND LABORATORY EXPERIMENTS. R. C. Schneider, R. E. Green, and B. S. Sipes, Department of Agronomy and Soil Science and Department of Plant Pathology, College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii 96822, U.S.A.—Fenamiphos is an important nematicide for control of reniform and root-knot nematodes in the Hawaii pineapple industry. Fenamiphos persistence in soil varies widely with soil type on the 2 islands where pineapple is grown. Field experiments were conducted during 2 consecutive years to determine the mobility and persistence of fenamiphos and its metabolites in a representative oxisol. Fenamiphos leached to a maximum depth of 1 m in soil with irrigation over a 90-day period. Fenamiphos degradation was measured in laboratory incubation studies and compared with field degradation rates. In laboratory experiments, total fenamiphos decayed with a half-life of 27-33 days in the surface soil, compared with 20-22 days in subsoils from the experimental site. Field measured degradation rates were comparable to laboratory values, with calculated half-lives of 24-26 days. There was no significant difference in fenamiphos persistence between the 2 field experiments. These data, as well as previous studies, show no evidence of accelerated fenamiphos degradation in Hawaii soils, nor a loss of nematicide efficacy as measured by crop yield.

"PLANTIBODIES": FLEXIBLE GENES FOR ENGINEERING PLANT RESISTANCE. A. Schots,[1] J. Roosien,[1] A. Schouten,[1] A. Wilmink,[2] F. Van Engelen,[2] J. Molthoff,[2] T. Borst-Vrenssen,[1] I. De Jong,[1] R. Pomp,[1] H. Overmars,[1] J. De Boer,[1] D. Bosch,[2] W. J. Stiekema,[2] F. J. Gommers,[1] and J. Bakker,[1] Wageningen Agricultural University, Department of Nematology, P.O. Box 8123, 6700 ES Wageningen, The Netherlands,[1] and DLO-Research Centre for Plant Breeding and Reproduction Research, P.O. Box 16, 6700 AA Wageningen, The Netherlands.[2]—The expression of antibodies in planta offers new perspectives to engineer resistance. The rationale of this approach is the possibility of blocking protein function through antibody binding. We have developed monoclonal antibodies (MAbs) against secretory proteins from the subventral gland (svp) of *Globodera rostochiensis.* MAbs exhibiting different binding properties were expressed in potato roots as full size antibodies and as single chain variable antibody fragments (scFv). In a scFv, the variable domains responsible for antigen binding are fused by a flexible peptide linker. Full size antibodies were designed to be secreted to the extracellular spaces while scFv were used for intracellular expression. For expression of full size antibodies, heavy and light chain cDNAs were amplified by PCR, fused to a signal sequence for secretion and cloned behind the CaMV 35S promoter and the TR2' promoter in a single T-DNA. To obtain expression cassettes for single chain antibodies, the variable domains of the heavy and light chain were amplified by PCR, fused with a flexible linker and when secretion was desired also to a signal sequence. Both functional full size antibodies and scFvs were expressed. Accumulation of functional antibodies was observed up to 1% of total soluble protein for full size antibodies and up to 0.5% for scFvs. Because intracellularly expressed, scFv's are not always stable, different modifications were introduced. Adding of the endoplasmic reticulum (ER) KDEL-retention signal while omitting the ER translocation signal seems to increase stability in the cytosol. The effect of different in planta expressed antibody constructs on the multiplication rate of both potato cyst nematode species, *G. rostochiensis* and *G. pallida*, is being investigated.

MAKING ENTOMOPATHOGENIC NEMATODES BETTER: A GENETIC APPROACH. D. Segal, and I. Glazer, Department of Molecular Microbiology and Biotechnology, Tel-Aviv University, Tel-Aviv 69978, Israel, and Department of Nematology, ARO, Volcani Center, Bet Dagan 52250, Israel.—Genetic breeding has been used successfully for many years for improving farm animals and crops. In recent years, several experimental avenues have been employed to exploit the power of genetics and molecular biology for improving beneficial traits in entomopathogenic nematodes (EPN). Selection of laboratory strains has been used successfully to generate lines with improved host finding, infectivity or heat tolerance. In some cases, however, the improved trait was lost once selection pressure was removed, implying it did not have a genetic basis. This emphasizes the importance of determining first the heritability value of the trait of interest in the population. High heritability implies amenability to selection. In addition, laboratory strains are likely to have lost much of their genetic heterogeneity during the many years of artificial rearing. This would lower the likelihood of success in selection experiments, and underscores the advantage of starting selection with freshly isolated field populations which are often more genetically heterogeneous. In addition, when applying selection it is important to ascertain that other parameters of efficacy are not compromised. Procedures for mutagenesis have been adapted from *C. elegans.* They have been used for generating mutations (affecting e.g.nematode morphology, behavior, resistance to nematicides). These marker mutations greatly facilitate genetic mapping of genes controlling beneficial traits and have been especially helpful in conducting controlled crosses and following the transmission of traits of interest in subsequent generations. Mutations conferring enhanced efficacy can be similarly generated. Molecular biology offers great potential for genetic improvement of EPN. Markers of DNA polymorphism (e.g. RAPD, RFLP, VNTR) can be used to construct a molecular linkage map that in turn can facilitate mapping genes controlling beneficial traits and their subsequent cloning. Genes of interest can be isolated using probes available from *C. elegans.* Recent success in adapting techniques for transformation opens the way for generating transgenic EPN carrying manipulated versions of different genes aimed at enhancing their biocontrol potential.

STATUS OF NEMATODE PROBLEMS OF CEREALS AND GRAIN LEGUMES IN THE SEMIARID TROPICS. S. B. Sharma, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Asia Center, Patancheru, Andhra Pradesh 502 324, India.—Many species of plant-parasitic nematodes are potentially important parasites of major cereals (rice, wheat, maize, sorghum, and millets) and grain legumes (chickpea, cowpea, groundnut, pigeonpea, soybean, blackgram and greengram) in the semi-arid tropics. However, only a few species are economically important: *Aphelenchoides besseyi, Ditylenchus angustus, Meloidogyne graminicola, Hirschmanniella* spp, and *Pratylenchus* spp. on rice, *Heterodera avenae, Anguina tritici, Pratylenchus thornei* on wheat, *H. zeae* and *Pratylenchus* spp. on maize, *Pratylenchus* spp and *Tylenchorhynchus* spp on sorghum and millets, *H. cajani, M. incognita, M. javanica,* *Rotylenchulus reniformis*, and *Pratylenchus* spp. on pigeonpea, chickpea, cowpea, greengram and blackgram, *M. incognita*, *M. javanica*, *R. reniformis*, and *Pratylenchus* spp on pigeonpea, chickpea, cowpea, greengram and blackgram, *M. incognita*, *M. javanica* and *R. reniformis* on soybean, and *M. arenaria*, *M. javanica*, *Scutellonema* spp. and *P. brachyurus* on groundnut. Due to the covert nature of nematode-caused damage and non-availability of adequate number of trained nematologists to show that damage, most farmers and research managers in the region are still unaware of the existence of plant-pathogenic nematodes in their agricultural soils. Consequently, attention given to research on nematode pests by the National Agricultural Research Systems is much less than even a conservative assessment of their importance as agricultural pests would merit. One of the most important initial investments to halt the depredation being caused by nematodes and to provide food security to human beings in the semi-arid tropics, would be to develop trained human resources in nematology in the semi-arid tropics to diagnose, demonstrate, and manage nematode-induced constraints to production of these food crops. The International Agricultural Research Centers and other international organizations have a crucial role in this endeavour.

THE CONTROL OF NEMATODES IN ZIMBABWEAN TOBACCO. J. A. Shepherd, Tobacco Research Board, P.O. Box 1909, Harare, Zimbabwe.—The most important pest of tobacco in Zimbabwe is the root-knot nematode, *Meloidogyne javanica*, and all control measures are directed at reducing the damage caused by this nematode. Control in the seedbed is mainly dependent on the use of chemicals, almost entirely methyl bromide. Control in the field draws on a much wider range of options. Advantage is taken of the climate, cultural methods, rotation crops and chemical control. The breeding of tobacco cultivars with resistance to *M. javanica* has introduced the possibility of less dependence on chemical control measures.

MOLECULAR APPROACHES TO ENGINEER NEMATODE RESISTANCE: PROSPECTS FOR DURABILITY AND APPLICABILITY IN DIFFERENT CROPS. P. C. Sijmons, O. J. M. Goddijn, F. M. v. d. Lee, J. Klap, and S. A. Ohl, MOGEN International n.v., Einsteinweg 97, 2333 CB Leiden, The Netherlands.—The potato cyst nematode (*Globodera* spp.) is one of the most damaging pathogens of potato in The Netherlands. Since the introgression of major resistance traits such as H1 in potato some 35 years ago, new virulent pathotypes have emerged causing a need for new resistance traits and stressing the question about the durability of natural nematode resistance traits. Recently, modern tools of genetic engineering have opened new avenues to generate nematode-resistant cultivars including the cloning and transfer to other species of natural resistance genes and transgenic approaches to interfere with some step in this complex plant-pathogen interaction. This paper discussed several of these new approaches with emphasis on our strategy to prevent the formation of feeding structures induced by sedentary nematodes such as *Globodera* spp. The still rather speculative question was discussed on how these strategies may compare with respect to durability and efficiency in different crops against different nematode species. MOGEN's approach requires the use of nematode-inducible feeding structure-specific promoters for the expression of a phytotoxic gene product. In the model plant *Arabidopsis*, we have identified promoters which are locally induced by nematode species as different as *Heterodera schachtii*, *Meloidogyne incognita* and *Xiphinema diversicaudatum* and which can be utilized to engineer plants with increased nematode resistance.

NEMATODE INTERACTIONS WITH PLANT HEALTH PROMOTING RHIZOBACTERIA. R. A. Sikora, and S. Hoffmann-Hergarten, Universität Bonn, Institut für Pflanzen-krankheiten, Soil Ecosystem Phytopathology, Nussallee 9, 53115 Bonn, Germany.—Plant Health Promoting Rhizobacteria (PHPR) applied to seed or transplants can cause significant reductions in root-knot and cyst nematode infection levels and corresponding increases in plant growth. The advantage of using rhizosphere-competent microorganisms for biological control is the presence of intimate contact between bacteria, plant and parasite at the soil-root interface. Due to the nature of this intimate three-fold interaction, a wide spectrum of direct and indirect mechanisms-of-action have been detected. Direct activity of PHPR and/or their metabolites on the mobility and/or survival of eggs, juveniles and adults has been demonstrated. *In vitro* experiments with PHPR produced high rates of mortality. The presence of these active metabolites in the rhizosphere, however, has not yet been demonstrated. Dependency of many species of nematodes on specific root exudates for development has led to the hypothesis that PHPR may metabolize these components thereby interfering indirectly in the nematode life-cycle. It has been demonstrated, for example, that PHPR reduce the hatch of species of *Globodera* and *Heterodera*. Direct contact of PHPR with root tissue also may lead to stimulation of the plants defense mechanisms. Rhizobacteria applied to half of a split-root system have been shown to induce systemic resistance in potato and tomato resulting in significant reductions in *G. pallida* penetration on the untreated half. The development of more effective application and formulation techniques that enhance root colonization, and the use of combinations of antagonists or genetic improvement of PHPR are avenues of research that will promote progress and technology transfer to practical agriculture in the future.

RENIFORM NEMATODES IN PARADISE. B. S. Sipes, Department of Plant Pathology, University of Hawaii, Honolulu, Hawaii 96822, U.S.A.—*Rotylenchulus reniformis* is a damaging pathogen on several important food, fiber, and ornamental crops in the tropics. It suppresses yield and reduces the quality of crops such as sweet potato, cabbage, melons, and pineapple. Damage threshold levels of *R. reniformis* are unknown for most host plants and probably differ among plants. As few as 2 nematodes/cm^3 soil can damage pineapple in Hawaii, whereas in Florida, thousands of these nematodes/250 cm^3 soil have no effect on taro yield. Control of *R. reniformis* in high value crops such as banana, citrus, coffee, papaya, and pineapple is predominately achieved with nematicides. Some legume and sweet potato cultivars are resistant to *R. reniformis*, but for many host crops, resistant cultivars are unavailable. Populations of *R. reniformis* differ widely in their host ranges. In Hawaii, coffee is a poor host to the endemic *R. reniformis* populations, however, populations of the nematode from Puerto Rico reproduce well on coffee. Much work remains to be conducted in establishing damage thresholds for the varied tropical crops parasitized by *R. reniformis*, in developing resistant cultivars and cropping systems to effectively control the nematode, and in characterizing variation within the species.

FACTORS AFFECTING NEMATODE ACTIVITY AND YIELD LOSS IN SUGARCANE. V. W. Spaull, South African Sugar Association Experiment Station, Mount Edgecombe, KwaZulu Natal, 4300, South Africa.—Data from 47 trials on winter- and early spring-ratooned sugarcane conducted over 3 seasons were used to identify factors that might be used to predict yield loss from nematodes. The trials were on Cartref and Kroonstad form soils with a clay content of about 10%. Treatments comprised an untreated control and aldicarb at 16.8 g/10 m row applied as a split application. The nematode fauna in both soils was dominated by *Helicotylenchus dihystera, Pratylenchus zeae, Xiphinema elongatum* and *Paratrichodorus* spp. The response to treatment, in tons cane/ha, varied from about 11% in a dry season to 32% in a wet season. In the Kroonstad soils the responses were related to the initial population density (Pi) of *P. zeae* ($r^2 = 0.71$, $P \leq 0.001$). In both soil types the response to treatment was correlated with rainfall in one or more months in spring and early summer (maximum $r^2 = 0.73$ in Kroonstad soils and $r^2 = 0.59$ in Cartref soils, $P \leq 0.001$) but not with the rainfall in the first few months after the start of the crop. The R^2 values increased when the rainfall was multiplied by the Pi for *P. zeae* in the Kroonstad soils and by the Pi for *X. elongatum* in the Cartref soils. The influence of rainfall and other factors on the activity and thus the pathogenicity of the nematodes in the two soils was discussed.

BANANA NEMATODE CONTROL IN AUSTRALIA. J. M. Stanton, A. B. Pattison, N. T. Treverrow, and D. Matthews. Queensland Department of Primary Industries, Indooroopilly QLD 4068, Centre for Wet Tropics Agriculture, South Johnstone QLD 4859, NSW Agriculture Tropical Fruit Research Centre, Alstonville NSW 2477, and Queensland University of Technology, Brisbane QLD 4000, Australia.—*Radopholus similis* is the most important nematode on banana in Australia, particularly in tropical north Queensland. It is currently controlled by routine use of nematicides which are applied without knowledge of the nematode status of the crop. Recent research has shown that, by sampling roots of 20 pseudostems per crop in a grid pattern at bract fall and calculating a root disease index, growers can make decisions on nematicide application based on potential yield loss. This study showed that an increase of one in the disease index caused a loss of about one finger while an increase of 10 in the disease index resulted in about 5% yield loss based on pseudostem girth. Therefore, the nematicide application threshold is about 10-15 based on current prices. In subtropical southeast Queensland and northern New South Wales, *R. similis* can be a severe problem but other nematodes, such as *Pratylenchus* spp. and *Helicotylenchus* spp., are more common. Current research is determining the distribution and importance of these nematode species in the subtropics. The Australian banana industry aims to reduce nematode populations before replanting and in existing plantations by the use of cover crops and incorporation of organic matter. A small-plant test for resistance screening showed that the resistance of cv. Goldfinger (FHIA-01) to *R. similis* was not expressed immediately after deflasking tissue-cultured plants. The morphological and histochemical nature of this resistance is being investigated.

THE AUSTRALIAN TOBACCO-NEMATODE STORY. J. M. Stanton, Queensland Department of Primary Industries, Indooroopilly QLD 4068, Australia.—*Meloidogyne javanica* and *M. arenaria* race 2 are the most common nematode problems in tobacco crops of tropical north Queensland, but they are controlled by routine fumigation with ethylene dibromide (EDB). With the eminent deregistration of EDB, growers are now moving toward the use of resistant rotation crops such as forage sorghum and Brachiaria to control nematodes. Little is known about nematode problems in temperate northeast Victoria although *M. javanica, M. incognita* race 1 and *Pratylenchus* are widespread and 15% of growers apply non-volatile nematicides.

IDENTIFICATION OF RESISTANCE GENES INTROGRESSED FROM WILD *ARACHIS* SPP. INTO CULTIVATED PEANUT. J. L. Starr, M. D. Burow, A. H. Paterson, and C. E. Simpson, Texas A&M University, College Station, Texas 77843, U.S.A., and Texas Agricultural Experiment Station, Stephenville, Texas 76401, U.S.A.—*Meloidogyne arenaria* is the predominant species of root-knot nematodes attacking peanut in the U.S.A., whereas *M. javanica* is the major species in Egypt and India. Resistance to these species was introgressed into the tetraploid *A. hypogaea* from 3 diploid wild species by a complex hybrid. DNA from 8 resistant individuals from the BC4F2 generation was pooled and screened for RAPD markers linked to resistance using 540 random decamer primers. RAPD markers initially identified in these assays were confirmed by analysis of DNA from 21 segregating BC4F2 and 63 BC5F2 individuals. Linkage of 3 markers to a single gene, derived from *A. cardenasii*, for resistance to *M. arenaria* was confirmed. Recombination between markers RKN410 and RKN440 and resistance was 5.4% and 5.8%/generation, respectively, whereas recombination between RKN410 and RKN440 was only 1.3%/generation. Recombination between the third marker, RKN229, and resistance was 9.0%/generation. Recombination between RKN410 and RKN229 was 13.8%/generation, indicating that RKN229 and RKN410 flank the resistance gene. Lack of co-segregation of resistance to *M. arenaria* and *M. javanica* in BC4F3 lines indicated that resistance to these species is conditioned by different genes.

IMPORTANT NEMATODE PATHOGENS OF COTTON. J. L. Starr, Texas A&M University, College Station, Texas 77843, U.S.A.—Cotton, *Gossypium hirsutum*, is widely grown with major areas of production in Africa, Asia, and the Americas. World production and consumption is predicted to increase by 10% by 2000. The most important nematode pathogens of cotton are *Meloidogyne incognita* and *Rotylenchulus reniformis*, both of which have been reported from most production regions. *M. incognita* is more aggressive than *R. reniformis* based on apparent damage thresholds, but maximum population densities of *R. reniformis* frequently exceed those of *M. incognita.* Additionally, *R. reniformis* is usually associated with cotton grown on silty soils whereas *M. incognita* is more frequent in sandy soils. The two nematodes are rarely found together in mixed populations. Cultivars with high levels of resistance to *M. incognita* and excellent yield potential are now becoming available. Genes for resistance to *M. incognita* in Auburn 623 are not effective against the African cotton-root nematode *M. acronea.* Resistance to *R. reniformis* has been identified among wild *Gossypium* species but not in *G. hirsutum.* Introgression of resistance from diploid *Gossypium* spp. will be complicated by the tetraploid nature of *G. hirsutum.* Tolerance to *R. reniformis* has been identified in breeding lines of *G. hirsutum.* Increased market demand for cotton will likely increase monoculture production, with an increase in problems due to nematode parasitism. Host resistance and tolerance will play a major role in reducing yield losses due to root-knot and reniform nematodes.

DIVERSITY AND HOST SPECIFICITY IN *PASTEURIA* BACTERIA. D. Sturhan, Biologische Bundesanstalt, Institut für Nematologie und Wirbeltierkunde, Toppheideweg 88, D-48161 Münster, Germany.—Knowledge about the endospore-forming bacteria of the genus *Pasteuria* is largely based on observations on *P. penetrans* (s. str.) parasitic on *Meloidogyne* spp. Studies on *Pasteuria* isolates of other origin revealed that differences exist, e.g., in host range, infection of different nematode developmental stages, heat tolerance, morphology and ultra-structure. Besides divergence in morphometrics, considerable differences in the shape of sporangia and endospores and certain variation in the appearance of the mycelial colonies were observed. These characters are obviously rather constant within an individual *Pasteuria* isolate. While morphometrics appear to be of minor significance to differentiate *Pasteuria* morphological types, characters such as shape of the sporangia, development of the perisporium (including presence or apparent absence of the perisporal fibers), position and shape of the central body of the spore, presence and thickness or obvious absence of coats allow the distinction of various Pasteuria morphological types. Certain basic types, each with a great variety of subtypes, can be found almost exclusively in Tylenchida and Dorylaimida, others are present only in Araeolaimida, Chromadorida, and Enoplida of Triplonchida. It is supposed that the presently recognized *Pasteuria* species and additional morphological types co-evolved with their host nematodes and that the most ancestral *Pasteuria* types are associated with primitive nematode taxa. According to field observations and experimental studies most, if not all, *Pasteuria* species and isolates appear to be highly host specific with the host range being restricted to closely related taxa. However, affinity of spores to the cuticle of other nematodes has been frequently observed.

PHORESY BETWEEN RHABDITID AND DIPLOGASTRID NEMATODES AND INVERTEBRATES. W. Sudhaus, Institut für Zoologie, AG Evolutionsbiologie, Freie Universitaet Berlin, Koenigin-Luise-Str. 1-3, D-14195 Berlin, Germany.—Phoresy is a "key invention" that allows nematodes to inhabit transitory habitats associated with invertebrates. Examples of phoretic associations with diverse insects (beetles, flies, bees, and ants) will be discussed. The phoretic stage, the third-stage larva or dauerlarva, has evolved special behavioral traits and recognition mechanisms. Critical aspects of nematode phoresy include: finding the carrier at the right time, climbing on it, selecting a favorable location, and dismounting into a fresh substratum. Dauerlarvae of generalist nematodes contact their "host" by waving, whereas dauerlarvae of specialists seek out the adult host or move onto the pupa and associate with the adult at eclosion. Some species may change the carrier during copulation of the insect host. Dismounting may be passive and may occur during egg laying or the secretion of accessory glands. Dismounting is usually active and occurs in response to specific stimuli from the substratum that signify a suitable habitat. In a few species, transport is critical because dauerlarvae require substances from the host that act as developmental stimuli or nutrients. Evolutionary transition to larval parasitism might occur from this preadaptation. Entoecy, where nematodes complete their life-cycles as commensals in hollow spaces in the host, evolved in independent evolutionary lines from the transport of dauerlarvae inside the body of the host. From this same starting point, necromeny evolved, where nematodes wait for the cadaver to decompose and feed on bacteria. Spatial and temporal sympatry of potential transporters may allow for the widening of the host range. New host associations may be an avenue for nematode speciation.

INTERACTIONS INVOLVING ROOT-KNOT NEMATODES AND ANNUAL OR PERENNIAL WEEDS. S. Thomas,[1] J. Schroeder,[1] and L. Murray,[2] Department of Entomology, Plant Pathology and Weed Science,[1] and Department of Experimental Statistics, New Mexico State University, Las Cruces, New Mexico 88003, U.S.A.[2]—*Meloidogyne incognita* (RKN) and the perennial weeds *Cyperus esculentus* (yellow nutsedge=YNS) and *C. rotundus* (purple nutsedge=PNS) are common concomitant pests of annual crops worldwide. Using pepper (*Capsicum annuum* cv. NM 6-4) as a model crop, our specific objectives are to determine the influence of RKN on weed growth, development, and competitive interaction with peppers and to determine the influence of YNS, PNS, and selected annual weeds on RKN population development, life cycle, virulence and survival. Field research in which peppers and weeds were interplanted demonstrated that the presence of perennial weeds increased RKN reproduction on peppers and decreased pepper root weight. The annual weeds *Anoda cristata* (spurred anoda), *Amaranthus palmeri* (Palmer amaranth), and *Physalis wrightii* (Wright groundcherry) generally supported greater RKN reproduction than perennials, but had less effect on nematode reproduction on the crop. Persistent PNS roots, rhizomes and tubers maintained RKN eggs at relatively constant levels in the absence of a crop. Greenhouse experiments have demonstrated that PNS root weight, numbers of tubers produced, and tuber weight were largely unaffected by a wide range of RKN inoculum densities. YNS root weight was similarly unaffected, but numbers and combined weights of YNS tubers were directly proportional to the final RKN population. These results indicate that the combined presence of nutsedges and *M. incognita* may enhance survival of both groups of pests.

EVOLUTION OF RESISTANCE/VIRULENCE INTERACTIONS: IMPLICATIONS FOR NEMATODE MANAGEMENT. D. L. Trudgill, and M. S. Phillips, Scottish Crop Research Institute, Dundee DD2 5DA, Scotland.—Some nematodes have sophisticated biotrophic interactions with their hosts, e.g. giant cells induced by root-knot and syncytia by cyst nematodes. Their induction must involve nematode gene products interacting with and/or modifying the expression of plant genes. Resistance is seen as a failure of the susceptible interaction, typically involving a receptor in the plant (the product of the resistant gene which, when activated, initiates a cascade of resistant responses, e.g. phytoalexins) and an 'elicitor' produced by avirulent nematodes. Resistance is regarded as arising in host plants through a process of co-evolution with the pathogen and provides a selection pressure whereby virulence is eventually restored, presumably by a modification of the elicitor so that it is no longer recognized by the resistance receptor. This gene-for-gene interaction leads to pathogen races/pathotypes. Less well defined interactions include those where the plant is partially resistant, poor hosts (for pathogens with wide host ranges) and non-hosts. Do these unsuccessful interactions involve 'non-specific' resistance alleles or a failure of the 'specific' susceptible interaction? The latter, where it occurs, may provide more durable resistance. Lack of a hatching factor for potato cyst nematodes is one possible example, but there is evidence that resistance in *Solanum vernei* also may involve susceptibility alleles. 'Durable' resistance may also arise because several distinct alleles are involved, greatly slowing selection for virulence. However, whatever the basis of its action and inheritance, an understanding of the genetics of resistance/virulence aids both breeding for resistance and its utilization.

CHEMICAL CONTROL OF NEMATODES ON TOBACCO IN SOUTH AFRICA. E. R. van Biljon, Tobacco and Cotton Research Institute, Private Bag X82075, Rustenburg 0300, Republic of South Africa.—The different tobacco growing areas in the RSA are in the Mpumalanga province (flue-cured), Northern province (air- and flue-cured), North-West province (flue-cured), Eastern Cape (air-cured) and Western Cape (oriental tobacco). Much of the flue-cured crop in the RSA is grown in sandy soils where nematode problems may develop rapidly. The dominant nematodes are *Meloidogyne* spp. of which the most important are *M. incognita* races 2 and 4 and *M. javanica*. Chemical control is still playing a major role in the RSA, because growers often do not persist with effective crop rotation owing to lack of available land and intensive farming practises. The number of currently registered nematicides is small but readily available. Fumigants such as EDB, DD and methyl bromide as well as the organophosphate, phenamiphos and the carbamates, aldicarb and oxamyl, are available for use. Most of the producers rely on a multiple treatment approach. It consists mainly of a preplant application of EDB with a follow-up treatment or treatments consisting of aldicarb, oxamyl or phenamiphos either prior to planting, at time of planting or postplant. According to field trials, the best results were obtained with EDB in combination with oxamyl granules or aldicarb where *M. javanica* was the major nematode species present. This resulted in a 17.5 and 35% yield increase respectively, compared to the EDB treatment. A few new nematicides, which are environmentally safer, have become available and evaluation is currently underway.

THE BIODIVERSITY OF NEMATODE COMMUNITIES IN HYDROTHERMAL SEDIMENTS. A. Vanreusel, Marine Biology Section, Zoology Institute, Ledeganckstraat 35, 9000 Gent, Belgium.—Hydrothermal vents, typically associated with deep-sea areas characterized by a high tectonic activity, are extreme habitats providing very specific living conditions. Since the escaping hydrothermal fluids are highly enriched with heavy metals and reduced chemicals, a chemo-autotrophic food chain is supported. Additionally, hydrothermal vents may be considered as biogeographic islands to their endemic fauna. The micro- and macrobenthic communities of these biotopes have been investigated since the discovery of the hydrothermal vents in 1977. The intermediate meiobenthic animals including nematodes are little studied. During the scientific cruise with the German Research vessel SONNE in January 1995 to the North Fiji Basin (South Pacific), sediments were collected from different places in and near the hydrothermal active zones at 2 000 m depth. Some results on the composition and biodiversity of the nematode communities were presented and compared with the reference areas, located at similar depths but outside the hydrothermal influence area. In contrast to the macrobenthos, our observations suggest the presence of a community dominated by the most tolerant deep-sea nematode species rather than a specialized endemic community of species characterized by special morphological adaptations to the extreme environmental conditions. The low species diversity contrasts the high diversity which is normally present in deep-sea sediments. It accords with the high dominance that is found in other reduced habitats such as shallow seeps. The low biodiversity of nematode communities living in reduced environments was evaluated in the frame of the current hypotheses on the processes of faunal diversification.

STRUCTURAL BIODIVERSITY OF FREE-LIVING MARINE NEMATODES AS INDICATORS OF ANTROPOGENIC STRESS. M. Vincx, and M. Steyaert, University of Gent, Department Morphology, Systematics and Ecology, Marine Biology Section, K.L. Ledeganckstraat 35, B 9000 Gent, Belgium.—The nematode communities in the Southern Bight of the North Sea sampled between 1972 and 1995 are characterized by about 600 species, belonging to 180 genera and 40 families. Diversity is determined at different levels of the nematode community, i.e. species diversity of the whole community, species diversity of 8 dominant families (Chromdaridae, Comesomatidae, Cyatholaimidae, Desmodoridae, Microlaimidae, Oncholaimidae, Thoracostomopsidae and Xyalidae), species diversity of the 4 feeding types, and family diversity and trophic diversity within the whole community. The coastal zone, with a high eutrophication pressure, has communities with very low species, family and trophic diversity. Biogeochemical vertical profiles in the sediment, reflecting the antropogenic influences show clear patterns concerning structural biodiversity at the different structural levels of the nematode communities. The relationship between environmental stability (or disturbance) and stability and diversity of the nematode communities can be explained by habitat heterogeneity, food availability, density and population growth rates.

THE GENUS *ROTYLENCHULUS*: SPECIES IDENTIFICATION, PARASITIC HABITS AND HISTOPATHOLOGY. N. Vovlas, and A. Troccoli, CNR, Istituto di Nematologia Agraria, Via G. Amendola 165/A, 70126 Bari, Italy.—The genus *Rotylenchulus* contains 11 species showing slight interspecific diversities. They are distributed throughout tropical and subtropical countries parasitizing a number of cultivated plants and fruit trees. Their host list ranges from quite wide (e.g. *R. borealis, R. parvus* and *R. reniformis*), moderate (*R. macrosomus, R. macrodoratus*) to very narrow (for *R. anamictus, R. brevitubulus, R. calvicaudatus, R. leptus, R. sacchari, R. variabilis*). The economic potential as pathogens for some species requires accurate taxonomic studies for species identification. For this purpose, an illustrative key was presented (mainly by comparison of closely related species) and based on morphometrics, micrographs and drawings of the main morpho-anatomical characteristics of juveniles, males, vermiform immature parasitic females and kidney-shaped mature females. In addition, a compendium key-list with the most important morphometric data (from original descriptions, redescriptions and data from the present study) also is presented. Several aspects of life habits, illustration of embryogenic and postembryogenic stages, and notes on reproductive rates were shown and discussed. The anatomical changes induced by more than half of the members in the roots of their host plants are illustrated from observations made on permanent histological preparations. *R. macrodoratus* induces an uninucleate giant cell on olive, grape, fig, pistachio, etc. originating from an endodermal cell, whereas all the other species studied so far (*R. borealis, R. macrosomus, R. parvus* and *R. reniformis*) induce in the roots of their hosts formation of a stelar syncytium, also from an endodermal cell.

ENGINEERING GENETIC RESISTANCE: BEYOND NEMATODE RESISTANCE. T. Vrain,[1] D. Michaud,[2] M. Korban,[1] and D. Petersen,[1] Agriculture and Agri-Food Canada, Summerland Research Centre, Summerland, British Columbia V0H 1Z0, Canada[1] and Centre de Recherches en Horticulture, Département de Phytologie, Université Laval, Québec G1K 7P4, Canada.[2]—Plant-parasitic nematodes like most herbivorous organisms rely on digestive proteinases for proteolytic processing of their food. Plants protect themselves from herbivorous pests and disease agents by using a battery of chemical defenses, among which are small proteins, called proteinase inhibitors. Genes coding for effective proteinase inhibitors can be overexpressed in transgenic crops and delay the development and multiplication of various pests. Recent work in our laboratory and elsewhere has shown that digestive proteinases of root-knot and cyst nematodes are inhibited by various plant proteinase inhibitors. We are studying the behavior and reproduction of root weevils, two spotted spider mites, root-knot and root-lesion nematodes parasitizing transgenic tomato, potato, strawberry, and raspberry plants, expressing either a cystatin (OCI) from rice or a serpin (CII) from soybean. Disruption of their protein digestion by dietary proteinase inhibitors represents an attractive alternative for control of agricultural pests.

MOLECULAR RELATIONSHIPS IN *XIPHINEMA* AND *LONGIDORUS* SPP. T. Vrain,[1] D. Petersen,[1] D. Brown,[2] R. Robbins,[3] and J. Halbrendt,[4] Agriculture and Agri-Food Canada, Summerland Research Centre, Summerland, British Columbia V0H 1Z0, Canada,[1] Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, U.K.,[2] Department of Plant Pathology, University of Arkansas, Fayetteville, Arkansas 72701, U.S.A,[3] and Pennsylvania State University, Fruit Research Laboratory, P.O. Box 309, 290 University Drive, Biglerville, Pennsylvania 17307, U.S.A.[4]—Many nepoviruses transmitted by certain *Xiphinema* and *Longidorus* species cause devastating diseases in perennial crops such as tree fruits or grapevine. The economic importance of these diseases and the apparent containment of the viruses or the nematode vectors to one continent or another are the basis for quarantine exclusion in those countries free of the diseases. Accurate diagnosis of *Xiphinema* and *Longidorus* species, especially in the *X. americanum* group, is difficult due to the lack of discriminating morphological characters. Nucleotide sequence variability in the ribosomal ITS complements morphometric characterization in these 2 genera. We have studied 80 populations of various species of *Longidorus* and *Xiphinema* collected from countries of Europe, the Americas, Asia, and Australia. RFLP's in the ribosomal ITS region provided an additional basis to separate certain populations and define groupings and relationships between species when morphometrics could not provide a clear diagnosis.

FUNCTIONAL BIODIVERSITY OF NEMATODES. R. M. Warwick, Plymouth Marine Laboratory, Prospect Place, West Hoe, Plymouth Pl1 3DH, U.K.—The term "biodiversity" is usually associated in people's minds with the diversity of animal or plant species which are present in any particular habitat or geographical region. However, biodiversity cannot be equated with species diversity because it comprises several other important elements such as historical and phylogenetic diversity, which are reflected in the "taxonomic distinctness" of an assemblage (how closely are the species present related to each other?), which in turn is related to the functional or ecological diversity (are all the species doing different things?). Unperturbed nematode communities in a late successional stage tend to comprise a range of distinct species belonging to many different sub-orders and orders, with a high functional diversity. In grossly perturbed situations, nematode assemblages are kept in an early successional stage with a low species diversity, and often comprise guilds of closely related cryptic species, or single species with a high genetic diversity, which almost by definition have a low functional diversity. Between these two extremes, taxonomic distinctness may vary according to the age or successional stage of the assemblage. This attribute of biodiversity is more amenable to comparative studies than traditional species diversity measures because: (i) it is not affected by sampling effort, provided that there is no taxonomic bias in this effort, (ii) it is not affected by sample size. (iii) the statistical significance of reduction in taxonomic distinctness can be tested using permutation tests against subsets of species picked randomly from the available species pool, and (iv) it is more ecologically meaningful since it relates more closely to functional diversity. This paper examined these concepts using a series of regional examples of nematode assemblage composition (from the U.K.) ranging from pristine (Isles of Scilly) to grossly polluted (Clyde sewage-sludge dump ground) situations. It then goes on to apply these ideas to more global comparisons, including the sand-beaches of Guadeloupe.

COLD TOLERANCE IN NEMATODES: FROM STRATEGIES TO MECHANISMS. D. A. Wharton, Department of Zoology, University of Otago, P.O. Box 56, Dunedin, New Zealand.—Cold-tolerant animals are either freezing-tolerant or avoid freezing by supercooling. Nematodes use both of these strategies but we are just starting to understand the mechanisms which enable them to survive. Nematodes may avoid freezing or they are not in contact with water if they possess an eggshell or a sheath which prevents inoculative freezing. Differential Scanning Calorimetry (DSC) has detected 3 exotherms during the freezing of the cysts of *Globodera rostochiensis* and has confirmed that the egg shell prevents inoculative freezing and allows the eggs to supercool to -38°C. Most cold tolerant nematodes, however, are freezing-tolerant and survive inoculative freezing from the surrounding water. Some authors have suggested that in soil inoculative freezing may be prevented by freeze-induced dehydration. We have examined the freezing and survival of the Antarctic nematode, *Panagrolaimus davidi*, at a range of osmolalities and cooling rates. Inoculative freezing occurred under all conditions tested, and there was no evidence for freeze-induced dehydration. Inoculative freezing of *P. davidi* occurs mainly via the excretory pore and results in the freezing of all body compartments. Intracellular freezing is usually thought to be fatal for freezing-tolerant animals, but we have demonstrated the survival of intracellular freezing in *P. davidi* using cryomicroscopy and freeze-fracture techniques. DSC studies have shown that 81.7% of the nematode's body water is converted into ice during freezing. Recrystallization inhibition has been demonstrated in the supernatant from homogenized *P. davidi* and may be important in the ability to survive intracellular freezing. The role of cryoprotectants in nematode cold tolerance has yet to be demonstrated, but we have detected glycerol and trehalose in *P. davidi*. Future studies will focus on the role of ice-active compounds and on the location of ice and disposition of cellular components in frozen nematodes.

MOLECULAR TRANSFER OF NATURAL RESISTANCE GENES TO NEW CROPS: MI GENE OF TOMATO. V. M. Williamson, I. Kaloshian, E. Brenner, and B. Ferrie, Department of Nematology and CEPRAP, University of California, Davis, California 95616, U.S.A.—The Mi gene of tomato confers resistance to several species of root-knot nematodes. This gene has been mapped in detail to a region near the centromere of chromosome 6 of tomato. Clones spanning the gene have been identified as a part of a collaborative effort to clone Mi and will be used to identify the gene by complementation of function. A clone of Mi will provide an opportunity to test whether natural resistance genes can be expressed in other species in addition to the original source species. Genes that are induced after pathogen infection are an additional potential source of host resistance. Overexpression of pathogen-induced genes has been shown to produce resistance to certain pathogens. Several genes that are induced in tomato root tips within 12 hrs of nematode infection have been cloned. One of these genes, Lemir, encodes a protein with sequence similarity to a protein that modifies flavor perception and to protease inhibitors. Transgenic tomato with increased or reduced expression of Lemir are being generated in order to determine whether this gene plays a role in nematode resistance.

A GENERAL OVERVIEW OF SURVIVAL IN PSEUDOCOELOMATES: MECHANISMS AND ADAPTATIONS. C. Z. Womersley, Department of Zoology, University of Hawaii at Manoa, Honolula, Hawaii 96822, U.S.A.—Three somewhat disparate phyla (the Tardigrada, Rotifera, and Nematoda) comprise the group referred to as pseudocoelomates. All are essentially aquatic organisms, with species from each phylum being adapted to temporary aquatic or terrestrial environments. A consequence of their adaptive radiation into these environments has been the evolution of survival strategies that permit survival during periods of severe environmental stress (temperature fluctuations, osmotic shock, water and oxygen availability, etc.). The ability of some pseudocoelomates (particularly nematodes) to survive prolonged periods of environmental stress by entering into a true state of 'suspended animation' is seemingly unparalleled amongst multicellular animals. Nematodes, through number of species and diversity of habitats occupied, offer the most comprehensive list of survival strategies which may involve one or more stages of the life cycle. Moreover, because many terrestrial nematode species have complex parasitic life cycles, a number of the survival strategies they employ are not a simple response to physical stress, but an exquisitely orchestrated cascade of behavioral, physiological and biochemical responses to seasonality and host physiology. Nematodes as biological models now provide one of the major avenues through which those adaptive mechanisms that facilitate different modes of survival (quiescence, cryptobiosis, facultative/obligate diapause or dauer larva formation, etc.) can be elucidated.

BIOCHEMICAL ECOLOGY OF ENTOMOPATHOGENIC NEMATODES. D. J. Wright, and M. N. Patel, Department of Biology, Imperial College of Science Technology & Medicine, Silwood Park, Ascot, Berkshire SL5 7PY, U.K.—The current state of knowledge of the biochemical ecology of the (dauer) infective juvenile stage of Steinernematid and Heterorhabditid species was reviewed in comparison with studies on other free-living and parasitic groups of nematodes. Particular emphasis was placed on the relative importance of neutral lipids (primarily triglycerides) and glycogen as utilizable energy stores in relation to survival and infectivity in different species and recent *in vivo* studies using inhibitors of their respective metabolic pathways. The potential role(s) of phospholipids and carbohydrates in the survival of dauer stages under anhydrobiotic conditions also was examined.