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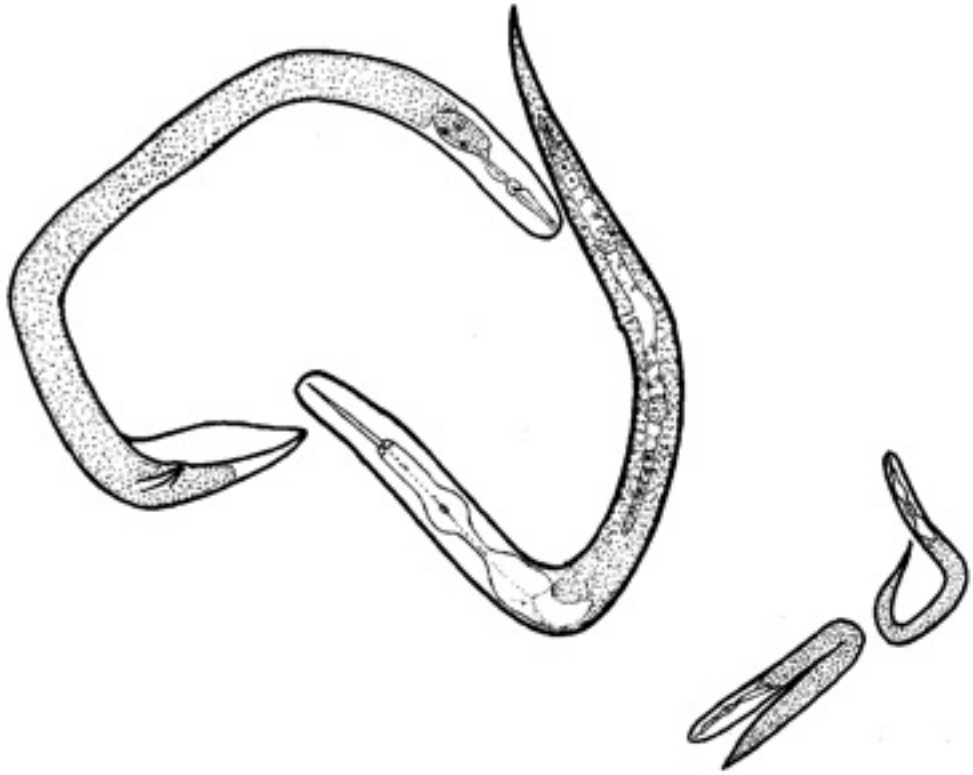

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SPECIAL ISSUE

Annotated bibliography of cereal cyst nematodes (*Heterodera avenae* and *H. filipjevi*) in China, 1991 to 2014

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Annotated bibliography of cereal cyst nematodes (*Heterodera avenae* and *H. filipjevi*) in China, 1991 to 2014

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Introduction

Cereal cyst nematodes (CCN), including *Heterodera avenae* and some closely related species, have long been recognised as serious pests of wheat and other cereals in many countries. However, in China this recognition has been relatively recent compared to the other major wheat-growing regions. In China, *H. avenae* was first reported by Chen *et al*. (1991). Whereas, in Europe CCN was in late 1800s (Meagher, 1977) and in Australia CCN has been know since the early 1900s (Riley and McKay, 2009). In North Africa CCN was reported in 1925 (Namouchi-Kachouri & B'Chir, 2005), in South and West Asia in 1950s (Meagher 1977, Nicol and Rivoal, 2008) and in North America in 1975 (Jensen, 1975). Apart from Australia and North America, where introductions will have occurred in modern times, the spread of CCN through the wheat growing areas of Africa, Asia and Europe is likely to have occurred with the spread of cereal farming in neolithic times. Assuming this, then the history of detection of CCN mostly represents the spread of scientific and agronomic skills and interest (Meagher, 1977).

In the twelve years following its detection in China, a further 25 scientific papers concerning CCN were published. Except for one (Zheng *et al*. 2000), these were all published in Chinese, so not easily accessed by the non-Chinese scientific community. However, in 2004 a focus on soilborne diseases of wheat was developed between international and Chinese scientists (Nicol *et al*. 2010), and this was followed by a significant increase in research on CCN. In 2004, survey teams visited sites in Anhui, Henan, Shandong Provinces and found the prevalence and population densities of CCN to be much greater than expected and potentially contributing to significant yield loss in wheat. This stimulated interest across the wheat growing provinces of China, and in the past decade about 100 scientific articles on CCN in China have been published (Fig. 1), with 13 of these in English.

The aim of this bibliography is to collate in English the work on CCN China published in scientific journals since its first detection twenty-three years ago. This is to improve the accessibility of this Chinese research to the wider research community. Most Chinese journals provide English titles and abstracts for their articles, which greatly facilitates this task. For other papers, a translated title and a brief summary of the content are given. Papers are listed, firstly by year of publication and then by author. Entries in the bibliography have been classified into the following subject categories: reviews, detection and distribution, biology and ecology, identification and phylogeny, impact, genetic control and pathotypes, agronomic control, chemical control, biological control and integrated management. Most entries are on *Heterodera avenae*, so the 14 papers on *Heterodera filipjevi* (first recorded in China in 2010) are also listed separately. Conference abstracts and student dissertations are not included.

Sources of references, titles and abstracts

Publication details were mostly sourced from China's Knowledge Resource Integrated Database (epub.cnki.net) or direct from authors. English titles are as given in the original publication, or if as a translation, they are included in square brackets. Abstracts are largely as given in the original paper, except for some minor edits. Therefore, the English is often non-standard. Where no English abstract was given, the Chinese abstract was translated or a summary written (these are indicated by the author's initials in square brackets). Zotero (zotero.org) was used for bibliographic data storage and formatting.

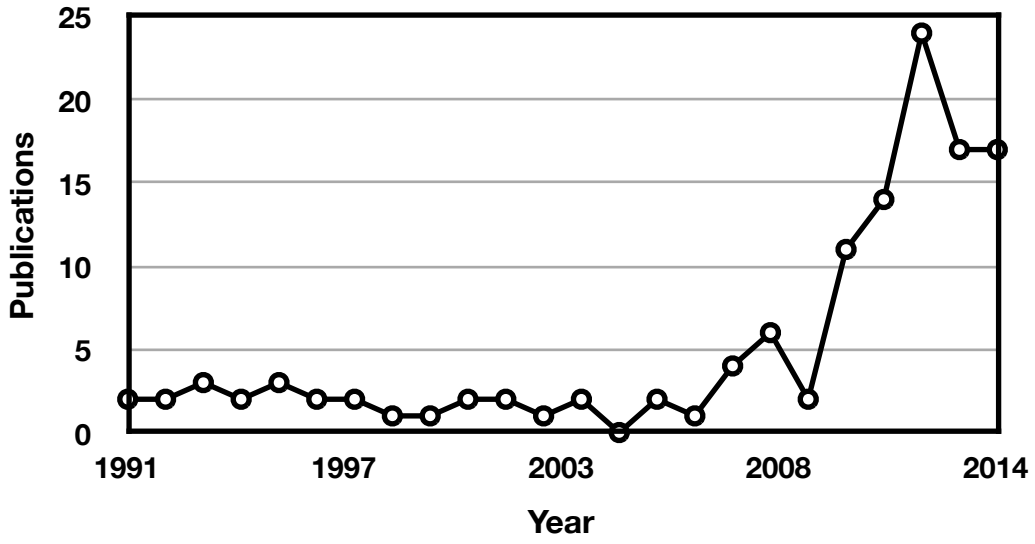

Figure 1. Publications on of cereal cyst nematodes (*Heterodera avenae* and *H. filipjevi*) in China, 1991 to 2014

Subject categories

Entries in the bibliography classified by subject area are tabulated below. Most of the papers are on *H. avenae* and a lesser number on *H. filipjevi*, so the latter is given as an additional subject category.

Reviews	3, 12, 22, 25, 27, 29, 34, 43, 58, 93
Detection and distribution	1, 4, 7, 8, 13, 26, 32, 34, 35, 39, 41, 42, 44, 46, 48, 49, 54, 55, 56, 60, 63, 80, 82, 95, 97, 103, 104, 107
Biology and ecology	6, 9, 10, 11, 14, 15, 17, 59, 73, 74, 75, 81, 86, 92, 96, 100, 101, 102, 104, 107, 109, 110, 112, 115, 118, 122, 123
Identification and phylogeny	1, 2, 4, 20, 24, 32, 33, 47, 50, 52, 60, 65, 70, 78, 85, 87, 97, 98
Research methodology	5, 14, 59, 72, 80, 85
Impact	23, 35, 86, 91, 112, 119
Genetic control and pathotypes	7, 16, 18, 19, 21, 22, 25, 28, 34, 38, 40, 51, 53, 57, 62, 67, 69, 71, 72, 76, 77, 88, 89, 90, 99, 105, 106, 111, 113, 116, 117
Agronomic control	36, 37, 45, 63, 64, 83, 84, 94, 101, 110
Chemical control	30, 68, 79, 91, 108
Biological control	31, 45, 61, 66, 114, 120, 121
Integrated management	83, 84, 119
Heterodera filipjevi	41, 44, 52, 62, 67, 69, 70, 71, 87, 88, 106, 116, 117, 118

Bibliography

1. **Chen PS, Wang MZ, Peng DL**. 1991. [Preliminary report of identification on cereal cyst nematode in China]. Scientia Agricultura Sinica **24**:89–91. [in Chinese]

   First report of *Heterodera avenae* in China, from samples collected in Tianmen County of Hubei Province. Identification was made on the basis of host and morphology. Symptoms were first observed in 1987 and the nematode identified in 1989. [ITR]

2. **Wang MZ, Peng DL, Wu XQ**. 1991. Studies on the wheat disease caused by cyst nematode I. Identification of pathogen. Journal of Huazhong Agricultural University **10**:362–365. [in Chinese]

   A same species of cyst nematodes was isolated from 128 soil samples collected from wheat field in Hubei. The population densities were 1.2 to 63 eggs/g of soil. Morphological studies showed that the characteristics of all stages of nematodes conform to the description of oat cyst nematode (*Heterodera avenae*). It was identified as *Heterodera avenae* Wollenweber. Artificial inoculation proved that the cyst nematode from 4 counties could induce typical disease symptoms (dwarfing and yellowing) on wheat and a number similar cyst nematode in or on the roots were obtained. This further confirms that the concerned nematode disease of wheat in Hubei is caused by the oat cyst nematode (*Heterodera avenae*).

3. **Chen PS, Peng DL, Wen X**. 1992. [Cereal cyst nematode]. Plant Protection **18**:37–38. [in Chinese]

   This brief summary of cereal cyst nematode (*Heterodera avenae*) covers its discovery around the world and in China, host range, symptoms, morphology, biology and control. [0 references] [ITR]

4. **Chen PS, Wang MZ, Peng DL**. 1992. A study of cereal cyst-nematode (*Heterodera avenae* Wollenweber) in China. Acta Phytophylacica Sinica **22**:339–343. [in Chinese]

   Root and soil specimens were collected from the rhizosphere of wheat in Tianmen, Qianjiang, Xiantao, Xinzhou Counties of Hubei Province. Hebei, Henan and Shanxi Provinces and the suburbs of Beijing in 1989-1990. Many similar brown and dark brown cysts with live eggs were isolated by flotation method. The observations and measures of morphological characteristics of cysts and larvae by light microscopy and scanning electron microscopy demonstrated that these cysts were *Heterodera avenae*. The major diagnostic features were widely lemon shaped cyst with the length 709 (601-913) µm and width 523 (436-612) µm, vulval cone always ambifenestrate, bullae prominent, crowded beneath vulva cone, underbridge absent; juvenile length 550 (471-602) µm, spear well developed, length 24 µm, great elongation of the oral lip disc (sub-dorsal and sub-ventral together) and it may extend across the entire width of the first head annule.

5. **Peng DL, Zhang DS, Qi SH, Chen PS**. 1993. [Period and method of investigation for cereal cyst nematode]. Plant Protection **19**:48. [in Chinese]

   The optimal time and method for examining wheat for infestation of CCN in wheat are recommended. Sampling should be done in the heading to flowering stage from areas with yellowing, reduced growth and weed infestations. Root systems should be dug up, soil gently shaken off and roots examined for white females. [ITR]

6. **Wang MZ, Yan JK**. 1993. Studies on the wheat disease caused by cyst nematode II. Hatching of the nematode *Heterodera avenae*. Journal of Huazhong Agricultural University **12**:561–565. [in Chinese]

   Wheat was planted after inoculating juveniles of *Heterodera avenae* collected from Tianmen, Hubei Province. Cysts were extracted from the inoculated soil at different times after harvesting for hatching test. The results showed that an average room temperature appropriate for juvenile emergence was 9-12°C on a ten-day period. The number of juveniles emerged at the constant temperature of 15°C, five-times wheat root juice and the lixiviation liquid of loess soils inhibited the emergence of juveniles, and ten-times and twenty-times root juice did not have significant effect on juvenile emergence. Neither did wheat root exudates suppress the emergence of juveniles. Juveniles failed to emerge outdoors from June to October. The emergence efficiency of nematodes was high when cysts were stored in freezer for 16 months, while many eggs of cysts lost their viability when stored at 7°C for 16 months. It was safe to store cysts in dry soil at room temperature for as long as four months but would have trouble if stored longer than 16 months.

7. **Wang ZY, Wang SZ, Li HL, Yuan HX**. 1993. A preliminary study on wheat cyst nematode disease (*Heterodera avenae* Wollenweber) in Henan Province. Acta Agriculturae Boreali-Sinica **8**:105–109. [in Chinese]

   Through observing the symptoms and identifying the pathogen, it was clear that the new wheat disease occurred in Henan Province was caused by cereal cyst nematode (*Heterodera avenae* Wollenweber). The results of artificial inoculation test showed that this kind of cyst nematode could also infect barley, oat and rye, but corn, rice, sorghum and millet did not express symptoms, and the nematode was not found even in their roots. The results of experiment conducted in the field indicated that furrow application of aldicarb or carbofuran at the same time of sowing could express a satisfying effect. None of the 12 main cultivars of wheat in Henan province are resistant to the disease, but their susceptibility to the disease is different.

8. **Qi SH, Peng DL, Zhang DS, Chen PD**. 1994. [First report of new host and occurrence area of *Heterodera avenae* Wollebweber in China]. Plant Protection **20**:52. [in Chinese]

   Heterodera avenae is reported in Qinghai Province and a new host, Tibetan barley [*Hordeum vulgare* var. *nudum*] [ITR]

9. **Zhang DS, Peng DL, Qi SH, Lu ZQ, Wang YY**. 1994. [Cereal cyst nematode reproduction rate in winter wheat and its effect on productivity]. Plant Protection **20**:4–6. [in Chinese]

   Outdoor pot experiments investigated the invasion and reproduction of cereal cyst nematode (*Heterodera avenae*) in winter. Initial population densities (Pi) were 0 (control), 1000, 3000, 5000, 7000 and 10,000 egg and second-stage juveniles/pot (diameter 10 cm, volume 450 ml) and final population (Pf) determined. For Pi up to 7000 the population increased, but for Pi of 10,000 the population decreased significantly. The reproduction rate (Pf/Pi) was greater than 10 for all Pi up to 70000, but there was no significant difference in Pf/Pi between these treatments. There was no significant effect on plant height and shoot dry weight (including grain) in this experiment. [ITR]

10. **Liu ZJ, Ma RX, Liu WC, Cai FL**. 1995. [Study on generation of wheat cyst cereal]. Journal of Henan Agricultural Sciences 17–19. [in Chinese]

The development of *Heterodera avenae* in wheat cv. Yumai 17 was studied in Anyang, Henan, by collecting and staining roots from November 1991 to May 1992. No penetration of roots was found before March. Adults and cysts were found in May. The nematode only completed one generation per year. A survey of other potential hosts was conducted but the nematode was only found to infest wheat. [ITR]

11. **Wang MZ, Lei ZF, Xiao YN**. 1995. [Host range of cereal cyst nematode (*Heterodera avenae*)]. Hubei Plant Protection **6**:2–3. [in Chinese]

    Five cereals, six grasses and 2 legumes were grown in pots with *Heterodera avenae* to test their host status. The nematode was able to complete its life cycle on 10 of test plants: adults developed (most to least) in *Roegneria kamoji* [*Agropyron tsukushiense* var. *transiens*], naked barley, hulless barley, wild oat, cultivated oat, *Festuca arundinacea*, wheat, *Datylis glomerata* and *Phalaris tuberosa*. [ITR]

12. **Zhang DS, Peng DL, Qi SH**. 1995. [Factors influencing hatching of the cereal cyst nematode from the northern part of Huabei Plain]. Journal of Plant Pathology **26**:158. [in Chinese]

    This article discusses the conditions needed for cereal cyst nematode (*Heterodera avenae*) to hatch; chilling but not exposure to host root exudates. The cold requirement for diapause to be broken is discussed in relation to the climatic conditions under which spring wheat is grown in China. It is postulated that although conditions promote hatch in northern Huabei Plain, where winter wheat is grown, the short growing season might not allow the nematode to cause serious damage. Investigation of its potential impact in spring wheat is nevertheless recommended as high population densities could still cause significant damage to seedlings. [0 references] [ITR]

13. **Zheng JL, Lin MS, Fang ZD**. 1996. Identification of two cyst nematode populations parasitizing wheat in Anhui, China. Jiangsu Journal of Agricultural Science **12**:31–35. [in Chinese]

    Two cyst nematode populations in wheat were collected from Anhui, China, and identified by light microscopy and scanning electron microscopy (SEM) in 1993. The cysts of both populations, with posterior protuberance, lemon shaped, vulval slit short, bifenestrate, bullae present and underbridge absent, indicating they belong to Mulvey's (1972) group 3. The stylets of their second-stage larvae averaged 24 μm in length, and the ratio between the lengths of the clear tail and the stylet was about 1.6. SEM observation showed that their lip pattern belonged to Stone's (1975) pattern 4. There were four incisures in the lateral field forming three bands, the two outer bands being areolated. Both of the cysts and the second-stage larvae morphologically conformed to those of *Heterodera avenae*. Thus, the two populations were identified as *H. avenae*.

14. **Zheng JW, Lin MS, Fang ZD**. 1996. Effect of temperature on hatching and viability of *Heterodera avenae*. Journal of Nanjing Agricultural University **19**:108–110. [in Chinese]

    The hatching characteristics of a population of cereal cyst nematode, *Heterodera avenae*, from Taigu County, Shanxi, China was examined under laboratory conditions. After exposing the eggs in cysts to cold conditions to break their diapause, 15°C was found to be the optimum temperature for hatch. At 20 and 25°C hatch occurred more quickly but overall rates were low. At 5°C the greatest number of eggs hatch but over a much longer period. It was conclude that 15°C was the best choice for experimental purposes needing a supply of *H. avenae* juveniles. [ITR]

15. **Zheng JW, Cheng HR, Fang ZD**. 1997. Hatching characteristics of cereal cyst nematode, *Heterodera avenae* in Shanxi, China. Journal of Zhejiang Agricultural University **26**:667–671. [in Chinese]

    Experiments were carried out *in vitro* on the hatching of second stage larvae for the Taigu population of *H. avenae*. The tests indicated that cysts under diapause must be pretreated at 5°C for at least four weeks in order for them to hatch; higher hatching rate was achieved when cysts were pretreated at 5°C for more than ten weeks; and low temperature, i.e. -10°C, pretreatment resulted in lower hatching rate. Leachates of five plants, wheat, barley, oats, maize and tomato, were found to have no effect on either interrupting the diapause of cysts or stimulating the hatching of cysts pretreated at 5°C. With respect to pH requirements for hatching, the highest hatching was seen at pH 6, high alkalinity (pH 12) significantly inhibited hatching. When cysts were dried and stored for a period of time, they generally hatched poorly.

16. **Zheng JW, Cheng HR, Fang ZD**. 1997. Pathotype of cereal cyst nematode (*Heterodera avenae*) on wheat in Shanxi and Anhui, China. Acta Phytopathologica Sinica **27**:309–314. [in Chinese]

    Two populations of *H. avenae* from Taigu, Shanxi and Guzhen, Anhui were treated for their pathotype identities. They exhibited identical reaction to the 11 cultivars of cereals in group A of the international test collection, i.e. except for the wheat cultivar, Capa. They were avirulent to the 4 barley cultivars, 4 oat cultivars and the other 2 wheat cultivars. The reaction demonstrated that the two populations are of a new pathotype, different from all the 13 pathotypes that have been described and nominated. The pathogenicity of the two Chinese population are somewhat similar to that of the two Swedish populations, Knislinge and Ringsasen. The Swedish populations are virulent on the barley cultivar Morocco, but the two Chinese populations are not.

17. **Wang MZ, Li SB**. 1998. Characteristics of cereal cyst nematode population in active period in Hubei. Acta Phytophylacica Sinica **25**:37–40. [in Chinese]

    The quantified cereal cyst nematode (CCN) (*Heterodera avenae*) were inoculated at the same time as the wheat sowing. The life cyst was observed after rooting. The result indicated that *H. avenae* accomplished one generation in one wheat growth season. The peak period for the nematode larvae entering into pod-shaped within 100-120 days. The sexes of larvae could be distinguished in 110-130 days. The white cyst (females) appeared in 130-150 days. The intruding points of the roots turned slightly brown in colour, then swelled and became slightly abnormal. There were excessive branches. There were more nematode cysts in soil where the content of phosphorus and potassium were naturally rich and where the water capacity was higher. Most nematodes inhabited the 5-30 cm cultivated horizon.

18. **Zheng JW, Lin MS, Cheng HR, Fang ZD**. 1999. Resistance of cereal cultivars to cereal cyst nematode, *Heterodera avenae*. Acta Phytophylacica Sinica **26**:250–254. [in Chinese]

    Twenty-five resistance accessions of cereals from Australia and 22 cultivars of wheat from eight provinces of China were assessed for resistant to the Taigu population of cereal cyst nematode, *Heterodera avenae*, from Shanxi Province, China. It was found that six synthetic allihexaploid wheat accessions derived from *Triticum turdigum* var. *durum* (genome AABB), "Langdon", and *H. avenae* resistant accessions in *T. tauschii* (genome DD) were highly resistant to the Taigu population of *H. avenae*. Some wheat cultivars containing resistance gene *Ccn1*, such as Festiguay and Aus 10894, which are resistant to pathotype Ha13, are

susceptible to the Chinese population, and 6 oats and 5 barley accessions from Australia were highly resistant. Most Chinese wheat cultivars tested were moderately susceptible, however Yangzhou 5 and Zhengzhou 831 were resistant.

19. **Deng HX, Yang XJ, Deng GB, Chen J, Pan ZF, Yu MQ**. 2000. Study on RAPD molecular markers of the resistance gene to CCN in wheat. Journal of Sichaun University (Natural Science Edition) **37 Sup**:38–42. [in Chinese]

    The factors that influencing RAPD (Random Amplified polymorphic DNA) reaction, including the concentration of Mg^{2+}, Taq DNA polymerase and template DNA were examined in the study. The results indicated that the optimum RAPD condition for wheat were: Mg^{2+} concentration 2.0 mmol/L, Taq DNA polymerase 2U, template DNA concentration 15-20 ng in 25 μL reaction system. The RAPD analysis was made in CCN (cereal cyst nematode) resistance gene near isogenic lines (NILs) with 100 random primers. Three primers the NILs. Only OPB12 showed the same discriminating results in more than four replications. The polymorphic DNA marker was $OPB12_{-1350}$. It was amplified only in NILs E-10 and the parent carrying the CCN resistance gene from *Ae. variabilis*, but not found in the back cross parent Kutin. The authors are studying the polymorphic DNA molecular marker $OPB12_{-1350}$ to confirm the relation of the CCN resistance gene in wheat.

20. **Zheng JW, Subbotin SA, Waeyenberge L, Moens M**. 2000. Molecular characterisation of Chinese *Heterodera glycines* and *H. avenae populations* based on RFLPs and sequences of rDNA-ITS regions. Russian Journal of Nematology **8**:109–113. [in English]

    Restriction profiles and sequences of the ITS region of Chinese populations of *Heterodera glycines* and *H. avenae* are given. In *H. glycines*, heterogeneity was detected after restriction of the PCR product with *Ava* I. This is the principal identification enzyme for this species, and usually yields four fragments of 552, 478, 367 and 112 bp. Restriction of the PCR product from the Chinese *H. avenae* population by *Hin*f I and *Tru*9 I produced RFLP profiles that differentiated it from other cereal cyst nematode populations.

21. **Deng HX, Yang XJ, Deng GB, Yu MQ**. 2001. Cloning and sequencing of the coding region of nucleotide-binding site in cereal cyst nematode resistance gene from *Ae. variabilis*. Chinese Journal of Biochemistry and Molecular Biology **17**:751–755. [in Chinese]

    Most of plant disease resistance (R) genes cloned so far belong to NBS LRR group which contains nucleotide binding sites (NBS) and a leucine rich repeat (LRR). Specific primers were derived from the conserved motif of NBS sequence at the *Cre3* locus, which conferred resistance to cereal cyst nematode (CCN) in the wild wheat (*Triticum tauschii*), and the specific primers were used in isolating a cereal cyst nematode resistance gene through a polymerase chain reaction (PCR) cloning approach. Only one band of approximately 530 bp in size was amplified from wheat E-10 conferring the resistance to cereal cyst nematode from *Aegilops variabilis*. This target fragment was cloned and sequenced,and coding region of this clone (Rccn4) was 528 bp in size, which contained an incomplete open reading frame without initiation codon, terminator codon and exon encoding a peptide of 176 amino acid residues.The molecular weight of the protein from the amino acid was 20.4 kD. The amino acid sequence of Rccn4 contained conserved motifs: I(V)LDD, T(T/S)R, G(L/S), PLA(A/I/L) and RCF(A/L)Y, present in known R gene containing NBS from other plants. Rccn4 shares 99.4% nucleotide sequence and 98% amino acid sequence identity with the NBS sequence at the *Cre3* locus. It is a novel gene containing NBS resistance to cereal cyst nematode.

22. **Zheng JW**. 2001. Genetics of resistance to cereal cyst nematodes (*Heterodera avenae*) in cereal crops. Journal of Shenyang Agricultural University **32**:244–227. [in Chinese]

The history and progress on virulence of *Heterodera avenae*, the resistant test methods for cereal crop to *H. avenae*, and the major resistant genotypes or cultivars that were used in the cereal crop production were reviewed. It also provided the characteristics of pathotypes of *H. avenae* reported in China, especially the new rDNA ITS type, Type C, and the resistance of some cereal cultivars from China were also summarized. [16 references]

23. **Sha GL, Xing CY, Hu R, Fu XL, Li YR**. 2002. Effects of root knot density of *Heterodera avenae* Woll. disease on seedling growth in wheat. Acta Agriculturae Boreali-Sinica **17**:66–69. [in Chinese]

The cereal cyst nematode disease and its influence on seedling growth in wheat were studied in this paper. The typical symptom of the disease appeared that root knots (nematode gall) are formed at branching part of roots. The result of investigation on root knots caused by the nematode disease showed a highly significant negative correlation between root knot densities and seedling growth vigor in wheat. As root knot density gradually increased from 0 21 to 1 83, the height of main stem, length of roots,no.of tiller, leave and secondary root per plant have decreased by 27.5-45.4%, 8.0-71.9%, 4.3-77.0%, 7.9-65.7% and 1.3-61.6%, respectively. When the density reached 4.22 above, the seedlings becoming very weak and yellow cannot produce tiller and secondary roots and died early.

24. **Peng DL, Subbotin S, Moens M**. 2003. rDNA restriction fragment length polymorphism of *Heterodera avenae* in China. Acta Phytopathologica Sinica **33**:323–329. [in Chinese]

The amplification of the rDNA-ITS region of *Heterodera avenae* (CCN) from China and Morocco with the current primers AB28 and TW81 yielded one fragment of approximately 1060 bp. A total 27 scored fragments were obtained with 11 restriction enzymes. Intraspecific polymorphism was revealed within *H. avenae* by *Alu* I, *Rsa* I and *Hin*f I digestion. *Alu* I and *Rsa* I digestion of ITS products of seven Chinese CCN populations yielded 2 fragments respectively (560, 500 bp; 720, 320 bp); but both *Alu* I and *Rsa* I could not digest ITS product of Morocco. Those RFLP profiles revealed by *Alu* I and *Rsa* I classified the ITS of Chinese populations as “type B” and Morocco population as “type B” according to Subbotin *et al*. (2000). Digestion by *Alu* I also showed heterogeneity in ITS regions of Morocco population, and two additional bands were obtained, the sum of the three fragments was approximately 2120 bp. *Hin*f I digested PCR amplified ITS products of Chinese populations obtained 2 fragments (860, 200 bp), but obtained 3 fragments (520, 340 and 200 bp) from Morocco population. The results showed that Chinese populations may be distinctly different from Morocco population. Six enzymes, *Cfo* I, *Bsh*1236 I, *Msr*F I, *Scr*F I, *Hae* III and *Mva* I, produced restriction profiles identical for all CCN populations. *Hin*d III and *Ava* I did not digest the ITS products of Chinese and Morocco CCN populations.

25. **Yan NH, Chen J, Yu MQ**. 2003. Progress of study on resistance to cereal cyst nematode in wheat. Journal of Triticeae Crops **23**:90–94. [in Chinese]

Cereal cyst nematode (CCN) is a serious pest of cereal crops in many wheat growing regions of the world. The best way to decrease crop damage is breeding the resistance cultivars. Since the disease was reported at first in China in 1989, CCN has been found in wheat growing areas of many provinces, such as Henan and Hebei, and its distribution is spreading. Though CCN was divided into 13 types of pathogencity according to the poisonous difference of CCN to the resistance genes, some other new types had been found. The loci of more than 10 resistance genes to CCN had been identified in wheat. Most of these genes

were dominant. They had different levels of resistance to different types of CCN. The technology of molecular markers could available for the found of resistance gene loci and offer some good conditions to breeders. At the same time, the range of resistance resource was developed through gene cloning. It was favorable that many new genes would be found and invented for it. [34 references]

26. **Liu WZ, Liu XY, Luan ZJ**. 2005. The detection of *Hetebodera avenae* Wollenweber, 1924 from the wheat field in Heze City of Shandong Province. Journal of Laiyang Agricultural College **22**:266–269. [in Chinese]

    The soil samples were collected from the wheat field in Heze City of Shandong Province in May, 2005, the nematode population was identified as *Heterodera avenae* Wollenweber, 1924. This nematode was found in Shandong Province for the first time. The main morphological characters for this nematode were that: a pair of semifenestra on vulval cone, the vulval underbridge not obvious, bullae obvious, the length of the vulval slit 11.9 ± 1.1 (10.5 - 15.0) μm. For the second - stage juvenile (J2), the stylet knobs extrude or horizontal anteriorly, the length of tail hyaline portion 44.6 ± 3.3 (37. 5 - 54.0) μm, the end slightly blunt.

27. **Wang ZY, Li HL, Yuan HX**. 2005. [Occurrence, damage and control strategy of wheat cereal cyst nematode]. Journal of Henan Agricultural Sciences 54–55. [in Chinese]

    Cereal cyst nematode is a new disease for China, being only discovered in the late 1980's, and its impact has become increasingly serious. Research results and other relevant information obtained the years since its discovery in China are summarised, including occurrence, damage, symptoms, prevention and control. [4 references] [ITR]

28. **Wang XY**. 2006. [The resistance of different wheat cultivars to cereal cyst nematode]. Journal of Henan Agricultural Sciences 50–52. [in Chinese]

    To screen for resistance to cereal cyst nematode in wheat, ten lines with good agronomic characteristics were assessed in the field for resistance and yield. The cultivars had significant differences in resistance and yield, but none were fully resistant. Line CD01 was the most resistant with an average is 19.3 cysts per plant. Cultivar Yuzhan 1 and line CD99205 were most susceptible with average cysts per plant of 41.6 and 40.0, respectively, and significantly lower yield than than the other cultivars. There was no clear relationship between cysts per plant or disease index and yield. [ITR]

29. **Gao J, Wang CH, Zhang SM**. 2007. Research progress on cereal cyst nematode. China Plant Protection **27**:10–12. [in Chinese]

    The paper reviewed research progress on pathogen distribution, taxonomy, occurring rules, symptoms, yield losses, identification of pathotype and control measures of cereal cyst nematode at home and abroad, and reported that the damages of cereal cyst nematode became more and more serious. [6 references]

30. **Wu XJ, Yang WX, Sun BJ, Xing XP, Wang ZY, Li HL, Yuan HX**. 2007. Effect of different nematicides on the controlling cereal cyst nematode and wheat growth. Journal of Henan Agricultural Sciences 57–60. [in Chinese]

    The effects of 4 kinds of nematicides, Temik, Phosim, Ethoprophos and Fosthiazate, on the cereal cyst nematode in wheat were tested in the field. The results showed that the control effect of Temik 22.5 kg/ha was the best one in all treatments, its control effect on cereal cyst

nematode was 54.0, 60.8 and 52.5% in the seedling stage, flowering stage and filling stage, respectively, and the population of cysts after harvest was 2.67 per 100 g dry soil dry soil, reduced to 95.3% of the check. The effects of Ethoprophos 30 kg/ha and Temik 15 kg/ha in controlling cereal cyst nematode were less then Temik 22.5 kg/ha, but better than the others, and the population of cyst after harvest was reduced to 82.9 and 76.5% of the check, respectively. The effects of Ethoprophos 15 kg/ha, Fosthiazate 30 kg/ha, Fosthiazate 22.5 kg/ha and Phosim 22.5 kg/ha on controlling disease was poor compared to Temik, but the population of cyst in these treatments also decreased remarkably after harvest. In the effects of nematicides, Temik promoted wheat growth, but Ethoprophos and Fosthiazate had the opposite effect on wheat growth. Phosim have no significant effect.

31. **Xiang MC, Le XH, Wang ZX, Liu XZ, Chen SY, Xiao QM**. 2007. Variability of morphology, parasitism, and nucleotide sequences among isolates and species of nematophagous *Hirsutella*. Biological Control **41**:110–119. [in English]

    Three nematode-endoparasitic, *Hirsutella rhossiliensis* (18 isolates), *Hirsutella minnesotensis* (8 isolates) and *Hirsutella vermicola* (3 isolates) were studied for their variability in morphology, nematode parasitism, and DNA sequences of internal transcribed spacer (ITS) of ribosomal DNA (rDNA) and mitogen-activated protein kinase (MAPK) gene fragments. There were differences in length and width of conidiogenous cells and conidia among the three *Hirsutella* species and among isolates within species of *H. rhossiliensis* and *H. minnesotensis*. Most isolates of *H. rhossiliensis* and *H. minnesotensis* parasitized higher percentages of the cyst nematodes, *Heterodera glycines* and *Heterodera avenae*, than the four non-cyst nematodes, *Meloidogyne hapla*, *Bursaphelenchus xylophilus*, *Heterorhabditis bacteriophora*, and *Steinernema carpocapsae*. *H. vermicola* had no or weak parasitism on the six assayed nematode species. The phylogenetic trees of ITS region, MAPK gene fragments and their combination revealed that there was genetic variability among species and isolates, but there was no apparent relationship between the genetic variability and their host or geographic origin.

32. **Zhao HH, Wu X, Gao HX, Wang XM, Huang XC, Liu WZ**. 2007. Report on the distribution of *Heterodera avenae* in Shandong Province. Journal of Qingdao Agricultural University (Natural Science) **24**:20–22. [in Chinese]

    Forty-seven samples of wheat roots and rhizosphere soil were collected from part regions of Shandong Province during 2006-2007 and *Heterodera avenae* Wollenweber, 1924 was detected in 29 samples. The result indicated *H. avenae* had occurred in certain place of Jinan, Liaochen, Dezhou, Binzhou, Zibo and Weifang cities and there was a chance that its distribution expanded year after year. The Jinan population of *H. avenae* was systematically observed, measured and described in morphology in this paper.

33. **Ou SQ, Peng DL, Li Y, Wang YJ**. 2008. Restriction fragment length polymorphism and sequences analysis of rDNA—ITS region of cereal cyst nematode (*Heterodera avenae*) on wheat from Zhengzhou. Acta Phytopathologica Sinica **38**:407–413. [in Chinese]

    The amplification of the rDNA-ITS region of *Heterodera avenae* (CCN) populations collected from Zhengzhou, Henan Province with the current primers AB28 and TW81 yielded one fragment of approximately 1040 bp. The result of ITS sequences analysis and alignments between *H. avenae* populations from Zhengzhou and related species *H. australis* and *H. pratensis* using UPGM A showed that it was clustered in a same group with close relationship. A total 23 scored fragments were obtained with 8 restriction enzymes. *Hin*d III and *Ava* I could not digest the ITS products of nine CCN populations from Zhengzhou. *Alu* I digested PCR amplified ITS products of 9 populations obtained 2 fragments (560 and 480

bp). *Hin*f I and *Rsa* I digested ITS products of 9 populations yielded 3 fragments respectively (820, 180 and 40 bp, and 700, 320 and 20 bp). Digestion by *Cfo* I obtained 4 fragments (740, 150, 110 and 40 bp). Digestion by *Hae* III and *Mva* I could observe 3 fragments (420, 350 and 180 bp, and 400, 340 and 280 bp) but not small fragments. Eight restriction enzymes produced restriction profiles identical for all CCN populations. The results showed that 9 populations might be type C of *H. avenae* and different from type A of European populations and type B of Indian populations.

34. **Ou SQ, Peng DL, Li Y**. 2008. Research progress on molecular diagnosis and resistance genes of the cereal cyst nematode, *Heterodera avenae*. Plant Protection **34**:7–11. [in Chinese]

The cereal cyst nematode (CCN), *Heterodera avenae*, is a serious pest of cereal crops in many wheat growing regions of the world. This paper introduced the research progress on molecular diagnoses, isoenzyme variance and resistance genes of cereal cyst nematode worldwide. The rational management strategies for controlling cereal cyst nematodes were also discussed. [32 references]

35. **Yang CG, Wu HP, Tan GJ, Wang YY**. 2008. Investigation on the distribution of and damages caused by cereal cyst nematode in Anhui. Plant Protection **34**:107–110. [in Chinese]

Check plots were designed by soil-treated application of Temik against cereal cyst nematode (CCN) before sowing. Plant height, fresh weight and ear number were use as growth indices to stimulate the damage of the affected wheat plants. The damage caused by CCN to three different wheat varieties were compared. The results showed that the distribution pattern of CCN in the field was a clustered one. The egg densities in soil averaged 6.5 eggs/g soil, ranging from 0 to 42.8 eggs/g soil. Wheat growth investigations indicated that CCN did not cause significant damage during seedling stages, but cause a significant reduction in ear number and fresh weight. The damage varied significantly among the three varieties. Analyses of the control effects of Abamectin indicated that it was not effective against CCN.

36. **Yang WX, Yuan HX, Sun BJ, Xing XP, Zhang FY, Yin XP, Wang ZY, Li HL**. 2008. Effects of fertilization on cereal cyst nematode of wheat. Acta Phytopathologica Sinica **38**:613–618. [in Chinese]

The effects of four fertilizers namely urea, superphosphate, potassium sulphate (PS) and phosphorus-potassium nitrate fertilizer (PPNF) at 10 dosages on cereal cyst nematode (CCN) of wheat were tested in the plots and pots. In pots, the control effect of urea 375 kg/ha was the best and the effects of urea 300 kg/ha, urea 225 kg/ha and superphosphate 900 kg/ha were lower than the former but higher than other treatments; The effects of PS 270 kg /ha, PPNF 525 kg /ha and PPN F 525 kg /ha + potassium sulphate 120 kg /ha treatments were all negative. In plots, the control effects of urea 300, 225 kg/ha and superphosphate 900 kg/ha treatments were better than other treatments. The effects of PS 270 kg/ha, PPNF 525 kg/ha and PPNF 525 kg/ha + PS 120 kg/ha treatments were poor. In suppressing the reproduction of CCN, PPNF 525 kg/ha + urea 75 kg/ha was the best in all treatments and the Superphosphate 900 kg/ha and urea 300 kg/ha treatments also suppress the reproduction of CCN, whereas PS 270 kg/ha, PPNF 525 kg/ha and PPNF 525 kg/ha + PS 120 kg/ha promoted the reproduction of CCN. The yield-increasing effects of superphosphate 900 kg/ha, urea 300 kg/ha and PPN F 525 kg/ha + superphosphate 187.5 kg/ha treatments were all above 10%, but that of PS 270 kg/ha, PPNF 525 kg/ha and PPNF 525 kg/ha + PS 120 kg/ha treatments were all below 5%.

37. **Yang WX, Yuan HX, Xing XP, Wang ZY, Li HL**. 2008. Effect of soil constituents and soil moisture on cereal cyst nematode of wheat. Henan Science **26**:672–675. [in Chinese]

The effects of 5 soil constituents and 6 soil moisture contents on cereal cyst nematode (CCN) of wheat were tested in the pots. The result showed that the clay soil was not suitable for the occurrence and development of CCN with the lowest disease index in 5 testing soil constituents. The disease index in clay soil and the clay:sand = 3:1 treatment were all below 25, whereas the disease index of the clay:sand = 1:3 treatment, the sand treatment, the clay:sand 1:1 treatment were all above 60; The diseased plant rate of the clay:sand 3:1 treatment and the clay treatment were all below 70% and the diseased plant rate of the clay:sand 1:1 treatment and the sand treatment were all above 85%, the diseased plant rate of the clay:sand 1:3 treatments were 100%. Result showed that too high or too low soil moisture was not suitable for the occurrence and development of CCN. In the 6 soil moisture treatments, the disease index of the 29.7% and the 4.7% treatments were all below 60. The disease index of the 12.8, 14.3 and 6.9% treatments were between 75 to 85, and the 9.6% treatment was most suitable for the occurrence and development of CCN with the highest index of 88.7 in all of the testing soil moisture treatments.

38. **Zhai XG, Zhao T, Liu YH, Long H, Deng GB, Pan ZF, Yu MQ**. 2008. Characterization and expression profiling of a novel cereal cyst nematode resistance gene analog in wheat. Molecular Biology **42**:960–965. [in English]

Based on the conserved regions of known resistance genes, an NBS-LRR-type CCN resistance gene analog was isolated from the CCN resistant E-10 near isogenic lines (NILs) of wheat, designated as *CreZ* (GenBank accession number: EU327996). It contained a complete ORF that was 2775 bp in length and encoded 924 amino acids. Sequence comparison indicated that it shared 92% nucleotide and 87% amino acid identity with those of the known CCN-resistance gene *Cre3* and had similar characteristic conserved motifs to those in other established NBS-LRR disease resistance genes. The expression profiling of *CreZ* indicated that it was specifically expressed in the roots of resistant plants and real-time PCR analysis demonstrated that expression levels drastically increased when the plants were inoculated with cereal cyst nematodes. It could be inferred, then, that *CreZ* belongs to the NBS-LRR resistance gene family and is a candidate gene for potential resistance to the cereal cyst nematode.

39. **Chen X, Zhou HY, Ma X**. 2009. Distribution of *Heterodera avenae* in the middle and west regions of Inner Mongolia, China. Plant Protection **35**:114–117. [in Chinese]

Through sampling, extracting and identifying, it was found that *Heterodera avenae* was distributed in Hohhot, Baotou, Wulanchabu, Bayannur, Erdos and Xilinghaote. There were more cysts in Chahaerzhongqi of Wulanchabu, Inner Mongolia Academy of Agricultural Sciences and the farmlands of Inner Mongolia Agricultural University than in other places, and the average number of cysts was 38.4, 29.4 and 16.4 per 250 g of soil, respectively.

40. **Wu XJ, Yuan HX, Zhang GL, Xing XP, Sun BJ, Li HL**. 2009. A preliminary study on the resistance mechanism of wheat cultivars to cereal cyst nematode. Journal of Henan Agricultural Sciences 73–77. [in Chinese]

The resistance mechanism of wheat cultivars to CCN were analyzed by observing root shape and cell structure, and testing the effect of root secretion on egg hatching. The results suggested that there was a negative relationship between the resistance and the number of lateral root. The number of resistant cultivars' lateral roots were much less than susceptible cultivars. The coat cell structure of resistant and susceptible cultivars was observed by

paraffin slice up. The results showed that the coat parenchyma cells of resistant cultivar in seedling stage and tillering stage were more compact than susceptible cultivar. The shape of lateral root coat parenchyma cell of resistant cultivar was smaller, ellipse or brick, but susceptible cultivar's was bigger and circular. Study on the effects of root secretion from resistant and susceptible cultivar on the egg hatch indicated that there were no difference in the effect of root secretion between the susceptible cultivars and resistance cultivars for egg hatching.

41. **Li HL, Yuan HX, Sun JW, Fu B, Nian GL, Hou XS, Xing XP, Sun BJ**. 2010. First record of the cereal cyst nematode *Heterodera filipjevi* in China. Plant Disease **94**:1505–1505. [in English]

Cereal cyst nematode (CCN) is now recognized as a widespread and often damaging parasite of wheat in China. Only *Heterodera avenae* has been reported in China (4). However, molecular analysis of four samples from Beijing and one from Shanxi Province indicated genetic differences from *H. avenae* and other named species (3). Here we report the detection of *H. filipjevi* at a site in Henan Province that was not included in any previous study or report. The infested crop was rainfed winter wheat (*Triticum aestivum*) cv. Wenmai 19 in a field near Banpopu Village in Xuchang County (34.0447°N, 113.7415°E) with a long-established maize-wheat semiannual crop rotation. During the winter growing season, the crop was patchy with uneven growth and cyst nematode females were observed on the roots. In June 2009, soil was collected and mature cysts were extracted for morphological and molecular identification. Cysts were also kept at 4°C for 2 months and then incubated in shallow water at 15°C for a month to obtain second-stage juveniles (J2). Measurements (range; mean ± sd) of 10 cysts were body length including neck (569 to 786 μm; 699 ± 56), body width (403 to 600 μm; 523 ± 55), length:width ratio (1.3 to 1.5; 1.3 ± 0.1), neck length (61 to 125 μm; 106 ± 19) and width (49 to 83 μm; 69 ± 13), fenestra length (52 to 59 μm; 57 ± 2.9) and width (24.5 to 34.4; 27.9 ± 3.5), underbridge (64 to 101 μm; 85 ± 10), and vulval slit (7.4 to 10.0 μm; 9.6 ± 1.0). Lemon-shaped cysts were brown with a surface zigzag pattern. The vulval cone was bifenestrate with horseshoe-shaped semifenestra, with heavy underbridge and many bullae. The J2 (n = 22) measurements were body length (496 to 590 μm; 552 ± 24), body width (20.0 to 23.8; 21.5 ± 0.9), stylet (22.8 to 25.3; 24.0 ± 1.0) with anchor-shaped basal knobs, tail (47 to 64; 61.6 ± 4.4), and hyaline tail terminus (32 to 43; 40.2 ± 3.0). The J2 had up to four lateral lines, but the inner two were often the only lines clearly visible, and the shape of the stylet knobs, tail, and tail terminus were consistent with *H. filipjevi*. All morphological data and characters were consistent with *H. filipjevi* (1). Specimens have been lodged with the Australian National Insect Collection. DNA from single cysts was extracted to amplify the internal transcribed spacer region of rDNA by PCR with forward primer TW81 (5′-GTTTCCGTAGGTGAACCTGC-3′) and reverse primer AB28 (5′-ATATGCTTAAGTTCAGCGGGT-3′) (2). The PCR product was sequenced (Genbank Accession No. HM027892) and digested by restriction enzymes (*Alu* I, *Cfo* I, Hae I, *Hin*f I, *Pst* I, *Rsa* I, *Taq* I, and *Tru*9 I) to obtain restriction fragment length polymorphism profiles (2). Profiles for the Xuchang population consistently matched those published for *H. filipjevi* and were distinct from those of *H. avenae* and other species (3). Phylogenic analysis of the sequence further indicated conspecificity with *H. filipjevi*. These morphological and molecular data confirmed that the specimens from Xuchang were *H. filipjevi*, which represents the first detection of *H. filipjevi* in China, and extends the known distribution of the species from Europe, North America, South Asia, and West Asia to East Asia. This finding adds complexity to the management of CCN in China, especially for control by host resistance, which now must consider both species and pathotype diversity.

42. **Li HM, Wang X, Pei SA, Le XH, Liang ZW**. 2010. A preliminary survey of the cereal cyst nematode *Heterodera avenae* on wheat in Jiangsu Province of China. Plant Protection **36**:172–175. [in Chinese]

In May of 2009, a preliminary survey of the cereal cyst nematode (CCN) was carried out in wheat fields in 22 counties of Jiangsu Province in China. A total of 76 samples with roots and soil were collected. The results of extraction and identification demonstrated that *Heterodera avenae* was distributed in Xuzhou, Lianyungang, Suqian and Yancheng districts .The incidence rate was 35%. The CCN incidence rates in wheat growing areas of Peixian, Fengxian, Pizhou and Suining Counties of Xuzhou were higher than 90%. The cyst densities in the fields in Huashan Town (Fengxian), Hekou Town (Peixian) and suburban Fengxian were higher than that in other areas investigated. The average cyst and egg numbers in these areas were 161, 159 and 112 cysts/100 mL soil, respectively, and 187, 190 and 174 eggs/cyst, respectively. This is the first report of CCN distribution in Jiangsu Province.

43. **Liu J, Wu HY, Peng DL**. 2010. Thinking on the occurrence, prevention and control strategies of cereal cyst nematode. Journal of Anhui Agricultural Sciences **38**:1629–1632. [in Chinese]

Based on the introduction of the host plant, physiologic race and damage of the cereal cyst nematode, the latest research progress on hatching characteristics, pathotype and control measures at home and abroad were reviewed, and thought about and prospected control strategy of the nematode. [54 references]

44. **Peng DL, Ye WX, Peng H, Gu XC**. 2010. First report of the cyst nematode (*Heterodera filipjevi*) on wheat in Henan Province, China. Plant Disease **94**:1262–1262. [in English]

During a survey for cereal cyst nematodes from May to June of 2009, cyst nematodes were detected in four wheat-growing areas (Liying, Xuchang, Weihui, and Yanjing) of Henan Province, China. The main wheat cultivar affected was Wenmai No.4. Almost 5.3 million ha of winter wheat are grown in Henan Province and 73% of the fields surveyed were found to be infested with *Heterodera avenae* (2). The affected wheat fields had stunted patches. Stunted seedlings had chlorotic or necrotic lower leaves, few or no tillers, and bushy, light brown roots leading to typical witches'-broom symptoms resulting from increased rootlet emergence at the nematode invasion sites. Individual roots had a knotted appearance. Cyst nematodes obtained from soil samples and plant samples at these four locations differed from those of *H. avenae* and had uniform morphological and molecular characteristics. Cysts were lemon shaped and bifenestrate, with an underbridge and strongly developed bullae. The lateral field of second-stage juveniles (J2) consisted of four incisures. These characteristics indicated that the four populations were *H. filipjevi*, a member of the "*H. avenae* Group" of cereal cyst nematodes (1). Key morphological features were determined for cysts and J2. Cysts (n = 15) had the following characteristics, in addition to those described above: light brown color; bifenestrate vulval cone with horseshoe-shaped fenestrate; body length (not including the neck) ranged from 690 to 790 µm (mean of 750 µm); body width ranged from 410 to 640 µm (mean of 540 µm); neck length ranged from 86 to 100 µm (mean of 96 µm); fenestrate length of 59 to 70 µm (mean of 67.7 µm) and width of 31.3 to 36.7 µm (mean of 35.2 µm); underbridge length from 59 to 71 µm (mean of 68 µm); and vulval slit from 6.9 to 8.6 µm (mean of 7.9 µm). J2 (n = 10) had the following characteristics: body length ranged from 540 to 580 µm (mean of 550 µm); stylet length from 22.5 to 24.5 µm (mean of 23.5 µm) with anchor-shaped basal knobs; tail length of 52.5 to 62.5 µm (mean of 57.7 µm); and hyaline terminal tail ranged from 32 to 39 µm (mean of 33.8 µm). The tail had a sharp terminus. Amplification of the rDNA-internal transcribed spacer (ITS) region with primers

TW81 and AB28 yielded a PCR fragment of 1,054 bp (3). Amplification of the D2/D3 fragments of the 28S RNA with universal primers D2A (5′-ACA AGT ACC GTG AGG GAA AGT TG-3′) and D3B (5′-TCG GAA GGA ACC AGC TAC TA-3′) yielded a PCR fragment of 782 bp. Digestion patterns of the ITS PCR fragments with *Alu* I, *Cfo* I, *Hin*f I, *Sat* I, *Pst* I, *Rsa* I, *Taq* I, and *Tru*9 I showed restriction profiles identical to that of *H. filipjevi* (3,4). Four ITS sequences (GU083595, GU083596, HM147944, and HM147945) and four D2D3 sequences (GU083592, GU083593, GU083594, and GU083597) from nematode samples collected in Liying, Xuchang, Weihui, and Yanjing, respectively, were submitted to GenBank. These sequences exhibited 99.4% similarity with that of *H. filipjevi* isolates from Germany (AY148400), Italy (AY347922), Russia (AY148401), Spain (AY148399), Tadzhikistan (AY148402), Turkey (AY148398 and AY148397), the United Kingdom (AY148403 and AF274399), and the United States (GU079654). To our knowledge, this is the first report of *H. filipjevi* in China.

45. **Riley IT, Hou SY, Chen SL**. 2010. Crop rotational and spatial determinants of variation in *Heterodera avenae* (cereal cyst nematode) population density at village scale in spring cereals grown at high altitude on the Tibetan Plateau, Qinghai, China. Australasian Plant Pathology **39**:424–430. [in English]

Cereal cyst nematode (*Heterodera avenae*) population densities were determined in spring cereals after harvest in three high-altitude villages in Qinghai, China in order to examine the effect of crop rotations. Two villages were sampled intensively to allow examination of between-field spatial variation. The previous season's crop, including fields where two host crops had been grown in succession, did not appear to influence the final nematode density. A high degree of variation in population density and significant spatial variation appeared to be strongly influenced by the occurrence of hyperparasites, thus masking any possible crop rotation effects. Nevertheless, a third of the fields had final egg densities of greater than 10 eggs/g soil, creating a risk of yield loss if an intolerant host was to be grown in the next year. From the findings, it is suggested that future research should focus on developing locally adapted resistant cultivars and examining factors that determine the efficacy of natural biocontrol.

46. **Wang AL, Hou SY, Peng DL, Zhang G, Huang WK, Yao Q**. 2010. Studies on occurrence and distribution of cereal cyst nematode of wheat in Qinghai Province. Journal of Anhui Agricultural Sciences **38**:13231–13233. [in Chinese]

The distribution of wheat cereal cyst nematode in 24 counties (cities) of 7 areas of Qinghai Province was surveyed. The results showed that the wheat cereal cyst nematode disease occurred in different elevations and different ecological zones of Qinghai Province. The average incidence of cyst samples was 72.7%. In the barley growing areas of 3501-3900 m above sea level, the highest incidence of cyst samples was 100%. In 2501-3500 m above sea-level areas, the unit number of cyst was the highest, the average number were 36.1-35.1 in 200 g soil. The survey findings for the different ecological zones suggests that the unit number of Asayama zones cyst were higher, followed by Naoshan region, the cyst number of units in Qianshan and Naoshan regions were significantly larger than the Chuanshui region. Its main damage hosts were wheat and barley.

47. **Wang X, Liang ZW, Pei SA, Le XH, Li HM, Peng DL**. 2010. Sequences analysis of rDNA-ITS region of cereal cyst nematodes on wheat from Jiangsu Province. Journal of Nanjing Agricultural University 55–62. [in Chinese]

ITS region of ribosomal DNA was amplified from 15 populations of cereal cyst nematodes (CCN) on wheat from 4 district (Xuzhou, Suqian, Lianyungang and Yancheng) of Jiangsu

Province, China. The ITS-RFLP patterns revealed that all populations showed the same fragments after digestion with 8 restriction enzymes. The Jiangsu populations not only obtained the same patterns as the "B" type (Indian populations) by *Alu* I and *Rsa* I digestions, but also the "C" type by *Hin*f I and *Tru*9 I digestions which were specialised for the Chinese populations. The phylogeny trees were constructed by Neighbor-Joining (MEGA 4.0) based on ITS sequences and revealed that all of Jiangsu populations were grouped with the species from *Heterodera avenae* complex, which was one of the branches of the *H. avenae* group. Most of the Jiangsu populations were genetically closed to the Russian and German populations of *H. pratensis*. Comparisons of ITS sequences between Jiangsu populations with other CCN populations from China and abroad revealed the close relationship between Zhengzhou populations and *H. australis*. The regional identities were clearly showed in the populations from Qinghai Province and Zhengzhou, Henan Province. The rich genetic diversities in CCN populations from Jiangsu and other provinces in China were demonstrated in this study.

48. **Wu HP, Yang CG, Chen LH, Tan GJ, Wang XY**. 2010. Identification and distribution of rhizosphere nematodes of wheat in Anhui Province. Journal of Anhui Agricultural University **37**:189–195. [in Chinese]

In order to identify species and investigation of distribution of cereal cyst nematode (CCN) and other nematodes of wheat in Anhui Province, soil and wheat roots were sampled from wheat fields with zig-zag method in 22 counties. Cysts and migratory nematodes were isolated by Fenwick Oostenbrink method and Baermann method respectively. Identification was carried out depends on nematode morphological data measured by de Man method, and combination with comparison of morphology of female vulva cone of CCN. CCN in Xiao County was identified as *Heterodera avenae*, the maximum density of CCN reached 42.8 egg·g^{-1} soil in Xiao county, plain distribution of CCN in field obeys clustered distribution judged by diffusion coefficient method. CCN second-stage juveniles (J2) concentrated in 0 to 100 mm soil layer, the J2 population accounted for 36.1%, and J2 density reached 2.8 head·g^{-1} soil in this layer. CCN widely occurs in Xiao county, where 70.6% investigation sites was found. And, other economic plant nematodes, include root lesion nematode and dagger nematode, were found in the wheat rhizosphere.

49. **Yang YY, Zhao HH, Peng DL**. 2010. New distribution report of cereal cyst nematode on wheat in Shandong Province. Journal of Qingdao Agricultural University (Natural Science) **27**:17–20. [in Chinese]

In May and June of 2009, 115 samples of wheat roots and rhizosphere soil were collected from 61 counties/districts of 13 regional cities in Shandong province,and cereal cyst nematode (CCN) was detected in 76 samples with the detection ratio of 66.1% and the cyst density range of 0 - 326 per 200 mL soil. The result indicated that CCN had occurred in 47 counties/districts under the 11 regional cities of Heze, Jining, Zaozhuang, Liaocheng, Jinan, Dezhou, Bingzhou, Dongying, Zibo, Weifang and Qingdao; the CCN occurrence situations were much different among regions: the first five cities for detection ratio were Zaozhuang, Liaocheng, Qingdao, Jining and Heze, and the first five cities for average cyst density were Liaocheng, Qingdao, Dezhou, Heze and Dongying; CCN cysts were not detected in 14 counties/districts of the 13 regional cities and were not found in all the 15 samples from 7 counties/districts of Rizhao and Linyi regional cities. The results indicated additionally that there were some indications showing that the long distance spreading of CCN might be resulted from the trans-regional operations of wheat combine harvesters and the water flowing of large rivers. The CCN cyst densities were high enough to cause heavy damage to wheat production in some wheat blocks.

50. **Ye WX, Xu BL, Peng DL, Huang WK**. 2010. Sequence and RFLP analysis of rDNA-ITS and 28S rDNA-D2/D3 regions of *Heterodera avenae* on wheat from Gansu Province in China. Plant Protection **36**:58–65. [in Chinese]

Cereal cyst nematode (CCN), as an important pathogen of cereal crops, has occurred in a number of wheat-growing areas in China. Amplification of 28S rDNA-D2/D3 and rDNA-ITS regions of *Heterodera avenae* (CCN) populations collected from Gansu, Anyang county of Henan and Bangbu county of Anhui in China, yielded a fragment of 28S rDNA-D2/D3 with the length of approximately 780 bp and one fragment of rDNA-ITS of approximately 1040 bp. The results of D2/D3 and ITS sequences analysis and alignment showed that they were clustered in the same group. A total of 22 scored fragments were obtained from ITS PCR-RFLP of CCN populations collected from Gansu. The 9 restriction enzymes produced identical restriction profiles for the population of Gansu. 28S rDNA-D2/D3 and rDNA-ITS analysis and ITS RFLP analysis showed that 7 populations of Gansu Province might be type C of *H. avenae*, different from type A of European populations and type B of Indian populations.

51. **Yuan HX, Sun JW, Yang WX, Xing XP, Wang ZY, Riley IT, Li HL**. 2010. New pathotypes of *Heterodera avenae* (cereal cyst nematode) from winter wheat in Zhengzhou, Henan, China. Australasian Plant Pathology **39**:107–111. [in English]

A growing recognition of the importance of the cereal cyst nematode, *Heterodera avenae* in winter wheat in China has highlighted the need to better understand local pathotype diversity, as this knowledge is needed to effectively deploy host resistance. Two populations of *H. avenae*, one each from Xushui and Xingyuang, villages near Zhengzhou, Henan, on the Huang Huai flood plain where 50% of China's wheat is grown, were typed using 23 standard international differentials and a common local cultivar Wenmai 19. These populations were found to be previously undescribed pathotypes. It is proposed that the pathotype code, Ha43, be applied to the population from Xushui, which was consistently characterised over two seasons and differs from the most similar pathotype, Ha13, by being avirulent in oat cv. Sivan and wheat cvv. Loros and Iskamish K-2-light. Wenmai 19 was found to be susceptible to both populations.

52. **Fu B, Yuan HX, Zhang Y, Hou XS, Nian GL, Zhang P, Xing XP, Sun BJ, Riley IT, Li HL**. 2011. Molecular characterisation of cereal cyst nematodes in winter wheat on the Huang-Huai floodplain of China using RFLP and rDNA-ITS sequence analyses. Australasian Plant Pathology **40**:277–285. [in English]

In response to the recent discovery of *Heterodera filipjevi* central Henan and the uncertain taxonomic status of *Heterodera avenae* more widely in China, heteroderid specimens from winter wheat at 21 locations in Henan and adjacent provinces were subjected to RFLP and rDNA- ITS sequence analysis. *H. filipjevi* was found in six locations in Henan, including two mixed with *H. avenae*; *H. avenae* being found at all other locations. A new RFLP profile type was found for *H. filipjevi*, three new types for *H. avenae* and the Australian type (*Heterodera australis*) were found for the first time in China (at two locations). Otherwise, *H. avenae* and *H. filipjevi* were of RFLP types previously reported in China. Phylogenic analysis of the rDNA sequences showed *H. filipjevi* in China was less diverse than *H. avenae*, with greatest similarity to specimens from Italy and the USA, which is consistent with a more recent introduction. In contrast, *H. avenae* in China was clearly distinct from *H. avenae* found elsewhere, except for the discovery of the Australian types. Although the Australian types clustered together, this fell within the variation found for the remainder of the specimens from China, which may represent a single species. These data reveal additional genetic

diversity within the two cereal cyst nematode species in China, which is likely to have implications for the development of their control by host resistance.

53. **Gu XC, Peng DL, Peng H, Long HB, Wang GF, Huang WK, He YQ**. 2011. Molecular cloning and sequencing of cellulose binding protein gene (Ha-cbp-1) from the cereal cyst nematode (*Heterodera avenae*). Acta Phytopathologica Sinica **41**:240–246. [in Chinese]

The cereal cyst nematode, *Heterodera avenae*, is an important nematode pathogen of wheat in China. The cellulose binding protein genes are the important parasitism genes for invasion of plant parasitic nematodes. The cDNA sequence of *Ha-cbp-1* (GenBank accession GQ178086) was cloned by RACE kit based on homologous cloning method. The results showed that the cDNA sequence of *Ha-cbp-1* contained an open reading frame, which encoding 131 amino acids with a predicted signal peptide sequence for secretion and a cellulose-binding domain. The DNA sequence of *Ha-cbp-1* contained two introns with the length of 932 bp. The predicted HA-CBP-1 amino acid sequence had 60% identity and 75-76% similarity with HS-CBP-1 and HGCBP-1.

54. **Hou SY, Wang AL, Zhang G, Peng DL, Wang WK**. 2011. Occurrence and distribution of *Heterodera avenae* in Qinghai Province. Plant Protection **37**:139–141. [in Chinese]

Heterodera avenae (cereal cyst nematode, CCN) is one of the main diseases of wheat and barley in Qinghai Province. The occurrence and distribution of CCN was investigated in Qinghai during 2007-2010. The results of horizontal distribution showed that CCN occurred seriously in Xining, Haidong, Haibei, Huangnan, Yushu and Haixi in Qinghai. CCN could occur at different altitudes and in different ecological areas from 1700 m to 3900 m. The incidence rate was significantly different between different ecological regions and different plots in the same region. The results of vertical distribution showed that CCN mainly occurred in soil over 20 cm in depth in the same plots.

55. **Huang WK, Ye WX, Wang GF, Long HB, Ou SQ, Peng DL**. 2011. Occurrence and distribution of *Heterodera avenae* Wollenweber in Ningxia Hui Autonomous Region. Journal of Huazhong Agricultural University **30**:74–77. [in Chinese]

The occurrence and distribution of this nematode was investigated by random sampling in 16 cities of five regions of Ningxia Hui Autonomous Region. The pathogen was identified with the morphological and morphometric examination. The results showed that the cereal cyst nematode distributed in most areas of five the regions of Ningxia Hui Autonomous Region and the detection ratio of CCN was 59.8% in all samples. The highest cyst number existed in Yinchuan City and the lowest one existed in Shizuishan City. The number of eggs per cyst in Guyuan City, Zhongwei City, Wuzhong City and Qingtongxia City were significantly higher than that of Shizuishan City. The pathogen of wheat was identified as *H. avenae* by morphological examination.

56. **Ma J, Li XH, Yu HB, Chen SL**. 2011. Identification of cereal cyst nematode isolated from Hebei Province. Acta Agriculturae Boreali-Sinica **26**:168–173. [in Chinese]

The cereal cyst nematode disease caused serious damage to the production of wheat in recent years. Accurate diagnosis is the basis for controlling this disease. 37 cereal cyst nematode populations were extracted from different areas of Hebei province in this study. The morphological and molecular characters of the nematodes were systemically studied. The difference of ITS-rDNA sequences of all the tested nematode was small and these sequences are less than 1% differences between local populations and *Heterodera avenae*. The main morphological and morphometric characteristics of different populations were studied. They

were mostly close to *H. avenae* in morphology. We confirmed that the nematode populations that extracted from Hebei province are *Heterodera avenae* based on morphological, morphometric and molecular characters.

57. **Ou SQ, Peng DL, Li Y**. 2011. rDNA-ITS restriction fragment length polymorphism of cereal cyst nematodes in some regions of Qinghai, Shaanxi and Henan Province, China. Acta Phytopathologica Sinica **41**:411–420. [in Chinese]

    Eleven populations of cereal cyst nematode (CCN) from wheat were collected in collected in Qinghai and Shaanxi Province, all morphologically identified as *Heterodera avenae*. The rDNA-ITS regions of the populations were amplified with the universal primers AB28 and TW81, a fragment of approximately 1060 bp was yielded. The fragments were digested with *Hin*f I,*Taq* I, *Hpa* II, *Hae* III, *Pst* I and *Alu* I. The identical digestion patterns were obtained from CCN populations (YBT10A, HY65A, HY61B, ZHZ162B, HY5B, HHX8A, GH132A, HY92A, HY127B and DT142A) of Qinghai and which were the same species. The digestion patterns were the same between YL4A population of Shaanxi and the ones of Qinghai by *Hae* III,*Hin*f I and *Hpa* II. The digestion patterns of *Pst* I and *Alu* I showed that the YL4A CCN population was differed from the ones of Qinghai, because it had an extra 1060 bp fragment. The *Taq* I restriction pattern of YL4A CCN population was complex. The obvious difference could be observed in the *Taq* I RFLP pattern, a 520 bp fragment was not presented in the Qinghai CCN populations but in the Henan populations. According to the known conclusions, the analysis results restriction profiles showed that 10 populations of Qinghai were the identical RFLP patterns of *H. avenae* from China. *Alu* I profile of YL4A population was the same as *H. avenae* from France, then digestion of YL4A population by *Pst* I and *Taq* I were different with either members of Avenae group because of its complex profiles. The Henan CCN populations were the similar as Qinghai ones except RFLP profile by *Taq* I, and identical with *H. avenae* from Australia.

58. **Wang AL, Hou SY**. 2011. Happen and Identification on *Heterodera avenae* in Qinghai Province. Science and Technology of Qinghai Agriculture and Forestry 68, 74. [in Chinese]

    Heterodera avenae happening in Qinghai province distribution situation, field disease symptoms were introduced, some integrated control method were put forward to provide the reference for identification, prevention and controlling in the field.

59. **Wang X, Liu BL, Sun CG, Wang P, Xiang GL, Song ZQ, Li HL**. 2011. Hatching characterisation of cereal cyst nematode (*Heterodera avenae*) in Jiangsu Province and optimization of the pathotype bioassay. Journal of Nanjing Agricultural University **34**:71–76. [in Chinese]

    In lab condition, the hatching characters of *Heterodera avenae* from Yanji Town in Peixian, Jiangsu Province were studied under the influence of temperature and time,and the number of white females produced on wheat seedlings was evaluated by the influences of container size and inoculum density. The results showed that the hatching of juveniles from Jiangsu population was stimulated by cold temperature. The second stage juveniles hatched at 10, 15 and 25°C after cysts pre-treated at 5°C for 8 weeks. Juveniles hatched the most at 15°C. However, a few juveniles hatched at 25°C and no juveniles at 28 and 30°C. Juvenile hatching was also improved by the extension of cold pre-treated period. When the cysts pre-treated at 5°C for 14 weeks was incubated at 15°C, the juveniles hatched during one week interval was the highest with the number of 322 and the cumulative hatching rate was 62%. In pathotype bioassay, the number of white females produced on wheat seedling was significantly different in different inoculum densities. The wheat seedlings planted in different size of containers and inoculated with density of 4 juveniles per cm^3 soil produced

the largest number of white females. The optimized conditions for pathotype bioassay not only decreased the number of nematode inoculum, but also increased the evaluation accuracy for resistance/susceptible by differentiate hosts.

60. **Wei LH, Zhao L, Zhang HY, Wang JW, Cheng ZB, Chen HG, Zhou YJ**. 2011. Survey of cereal cyst nematodes in wheat fields of Jiangsu, Anhui, Shandong and Henan Provinces and characterization of their rDND-ITS region sequence. Journal of T **31**:1158–1163. [in Chinese]

This paper aims at probing the distribution of cereal cyst nematode (CCN) occurring in the wheat fields of Jiangsu, Anhui, Shandong and Henan Provinces and the relationship of those populations. During 2010, investigations were carried out on cereal cyst nematodes growing in 30 fields from those areas and the rDNA-ITS region of those CCN populations were amplified by PCR and the sequences were analyzed. The results indicated that CCN was detected in all 30 samples and the cyst density range was 1-80 per 100 g soil.The similarities of nucleotide sequences of 30 isolates are 97.7 to 100%.The phylogenetic tree of 30 CCN populations and other related species of Heterodera spp. reported in GenBank was constructed based on its rDNA-ITS sequences. The 30 CCN populations and the published CCN populations from China (Y148382, EU106175), Australia (AY148395) and Russia (AY148351) were clustered in the same group, showing high homology level in evolution.

61. **Yuan HX, Chen L, Zhang FY, Li HL**. 2011. Isolation and identification of fungal parasites of cyst nematodes in *Heterodera avenae* group. Acta Phytophylacica Sinica **38**:52–58. [in Chinese]

Cereal cyst nematodes (CCN) in the *Heterodera avenae* group are recognised as the important pest of wheat in Huanghuai area. So far, there is no effective control method for CCN in this area. In order to seek for the biocontrol agents for CCN, 42 parasitic fungi were isolated from CCN cysts from different locations in Henan. The biocontrol potential of these isolates was evaluated in pots and in the field (Xuchang, 2008-2009). Eleven isolates (F03, F04, F08, F11, F13, F15, F20, F25, F26, F33 and F37) provided good control of CCN in pots, with average control efficacy more than 50% (based on disease index value). Five isolates provided good control in the field with control efficacy of over 35%. Based on morphology and rDNA-ITS PCR sequence analyses, five isolates (F04, F08, F20, F26 and F37) can be identified as *Chaetomium* sp., *Fusarium solani*, *Penicillium oxalicum*, *Stemphylium solani*, and *F. proliferatum*, respectively.

62. **Yuan HX, Zhang FX, Zhang JJ, Hou XS, Li HJ, Li HL**. 2011. Resistance of CIMMYT wheat germplasm to *Heterodera filipjevi* Xuchang population from Henan Province, China. Acta Agronomica Sinica **37**:1956–1966. [in Chinese]

The cereal cyst nematode (CCN) of wheat has become a severe disease in recent years. *Heterodera filipjevi* is a new pathogenic nematode of CCN in China. For screening resistant resources in breeding to *H. filipjevi*, the resistance of 75 wheat germplasm cultivars or lines from CIMMYT was evaluated in the greenhouse and field using relative resistance index (RRI) and Pf/Pi ratios, with the nematode from Xuchang population, Henan Province, China. No cultivar was immune to *H. filipjevi*. However, line 6R(6D) was highly resistant in two test conditions. CROC_1/AE.SQUARROSA (224)//OPATA*1, CROC_1/AE.SQUARROSA (224)//OPATA*2, MACKELLER, CPI 133842, CPI 133814, and TRIDENT were moderately resistant to *H. filipjevi* in greenhouse. In the field test, CPI 133842, CPI 133814, DURATI and TURCAN#39 showed a high resistance with RRI values ranging from 0.90 to 0.96. Fourteen lines including ID-2150, BAXTER and MACKELLER were moderately resistant to *H. filipjevi*. The disease severity was heavier in greenhouse than in the field, and

resistance identification in the greenhouse is much easier and reliable. The results indicated that relative resistance index is an efficient index for evaluating the resistance of wheat cultivars to CCN.

63. **Zhao HH, Yang YY, Peng DL, Liu F**. 2011. New report of distribution and analysis of occurring characteristics analysis for cereal cyst nematode on wheat in Shandong Province. Journal of Qingdao Agricultural University (Natural Science) **28**:261–266. [in Chinese]

Seventy-eight and 68 soil samples were collected in Shandong Province from wheat rhizosphere during the maturing stage in year of 2010 and 2011, respectively. Cereal cyst nematode (*Heterodera avenae* group, CCN) was detected in 59 samples from the ones of year 2010 with the detection ratio of 75.6% and the cyst density average (range) of 22.1 (0-210) per 100 g soil; CCN was detected in 26 samples from the ones of year 2011 with the detection ratio of 38.2% and the cyst density average (range) of 7.4 (0-95) per 100 g soil. The six cities of Linyi, Rizhao, Laiwu, Tai'an, Yantai and Weihai were firstly found to be CCN-occurring regional cities of which 17 counties/districts were found to be the ones of CCN new distribution in Shandong Province. The occurring characteristics of CCN in Qingdao, Yantai and Weihai were analyzed, the occurring situations of CCN in Shandong, the controlling factors on CCN and the spreading ways of CCN were discussed. It was proposed that rotation was the most effective agricultural practice for controlling of CCN in the current agricultural system; CCN could be carried and disseminated by the Yellow River.

64. **Zhao J, Niu XY, Zhang GQ, Peng DL, Kang ZS**. 2011. Occurrence and distribution of cereal cyst nematode (*Heterodera avenae*) in central-south Shaanxi Province. Acta Agriculturae Boreali-occidentailis Sinica **20**:181–185. [in Chinese]

Investigation on occurrence and distribution of *Heterodera avenae* in central-south Shaanxi province were carried out during wheat heading to milking stage in April to May 2010. Soil sampling were taken in 5 to 20 cm under ground around the infected wheat plants in filed based on random sampling method of five-point. Cysts were isolated from 100 g of the mixed soil by Fenwick's method. Identification of nematode was performed based on morphology characters of *H. avenae*. Of 39 counties in central-south Shaanxi were investigated on occurrence of *H. avenae*, 20 counties were found infection of *H. avenae* on wheat. In south parts of Shaanxi, there were no distribution of *H. avenae*, but severe infection in counties in the central Shaanxi. A higher density of cysts were focused in the following counties including Zhouzhi, Qishan, Lintong in Xi'an, Fufeng, Meixian, Yangling, Sanyuan, Gaoling, Jingyang, and Huaxian. The average number of cysts/100 g was ranged from 8.9 to 63. The occurrence of *H. avenae* in Shaanxi has a trend of rapid spread with a large scale distribution and severe damage. This survey was helpful to understand status of distribution of *H. avenae* in central-south Shaanxi, and to provide scientific basis for controlling wheat cyst nematode in Shaanxi.

65. **Zhao J, Zhang GQ, Niu XY, Peng DL, Zhang XS**. 2011. Sequence and RFLP analysis of rDNA-ITS region of cereal cyst nematode on wheat from Shaanxi Province. Acta Phytopathologica Sinica **41**:561–569. [in Chinese]

The amplification of rDNA-ITS region of *Heterodera avenae* (CCN) populations collected from twenty counties of Shaanxi Province with the universal primers TW81 and AB28 produced a single fragment of 1045 base pairs. The results of ITS sequence analysis and multi-alignment among Shaanxi CCN populations and its related species including Chinese CCN populations (GenBank accession number EU106175 for Henan population, AY148382 for Beijing population and HM370427 for Shandong population), Australian population (AY148395, *H. australis*) and Russian population (*H. pratensis*, AY148351) with UPGMA

(software Mega) showed that they were clustered in the same group with close relationship, and that all of CCN populations from Shaanxi were the same species shared high homology (99.56%) except for the difference of three base pairs. A total of 22 scored fragments were produced by 8 restriction enzymes including *Ava* I (*Eco*88 I), *Alu* I, *Hha* I (*Cfo* I), *Hae* III (*Bsu*R I), *Hin*d III, *Hin*f I, *Rsa* I, and *Mva* I (*Bst*N I), which yield restriction profiles identical for all CCN populations. This demonstrated that 20 populations might be type C of *H. avenae* in accordance with the reported Chinese CCN populations type C, and were distinguished from type A of European populations and type B of Indian populations. This is the first report on molecular characterization of *H. avenae* populations from Shaanxi.

66. **Bao LL**. 2012. Isolation of fungal parasites of cyst nematodes in *Heterodera avenae* group and biological characteristics. Inner Mongolia Agricultural Science And Technology 86–88. [in Chinese]

Cereal cyst nematodes in the *Heterodera avenae* group are recognized as one of the important pest of wheat in China. In order to seek for the biocontrol agents for CCN, 20 parasitic fungi were isolated from CCN cysts and eggs, which was evaluated in pots. Eleven isolates (Z2 and Z4) provided good control of CCN in pots, with average control efficacy reach 50%. Z2 and Z4 strains respectively belonged to *Pleosporales* and *Paecilomyces* species through morphological characteristics observation and ITS sequence assayed. Then it preliminary studied on the biological characteristics of the two strains.

67. **Cui L, Gao X, Wang XM, Jian H, Tang WH, Li HL, Li HJ**. 2012. Characterization of interaction between wheat roots with different resistance and *Heterodera filipjevi*. Acta Agronomica Sinica **38**:1009–1017. [in Chinese]

Heterodera filipjevi is a newly identified pathogenic species of cereal cyst nematode that invades wheat (*Triticum aestivum* L.) in central China. A two-year field test (2009–2011) conducted in Xuchang County, Henan Province, China, where *H. filipjevi* has severely damaged wheat for several years, demonstrated that the wheat-rye (*Secale cereale* L.) chromosome substitution line 6R(6D) (carrying gene *CreR* for resistance to *Heterodera* spp.) was highly resistant (HR) to the nematode. The wheat cultivar Taikong 6 was moderately resistant (MR) and its parental cultivar Yumai 49 was highly susceptible (HS). Attraction of *H. filipjevi* juveniles to root tips of wheat differed in resistance to *H. filipjevi* was studied using Pluronic F-127 gel as a medium. Although root tips from wheat cultivars with different resistance were able to attract juveniles of nematode alone, the number of juveniles around the root tip from line 6R(6D) was obviously less than that from Taikong 6 (MR) and Yumai 49 (HS) when they were challenged together concurrently by *H. filipjevi*. The juveniles were capable to penetrate into wheat roots regardless of their resistance as revealed by acid fuschin-sodium hypochlorite staining of infected roots. However, significantly smaller number of nematodes in the roots of 6R(6D) and Taikong 6 were observed compared to those of Yumai 49 at later stage of wheat-*H. filipjevi* interaction. These findings demonstrate that some of the *H. filipjevi* juveniles are not able to continue to reproduce themselves although they can penetrate the roots of resistant wheat cultivars 6R(6D) and Taikong 6. The results from this study provide experimental evidence on mechanism of host resistance to *H. filipjevi*.

68. **Gao DL, Miao JQ, Liu F**. 2012. Susceptibilities of cereal cyst nematode from different regions to different types of nematicides. Journal of Triticeae Crops **32**:168–172. [in Chinese]

In order to realize the susceptibilities of cereal cyst nematode to different types of nematicides, the toxicities of ethoprophos, fosthiazate, aldicarb, carbosulfan, abamectin and

emamectin benzoate against the second-stage juveniles (J2) of cereal cyst nematodes from five wheat-growing regions were determined by contact assay in the laboratory. The results indicated that the toxicity of six nematicides to cereal cyst nematode J2 was ranked as that emamectin, benzoate, abamectin, ethoprophos, aldicarb, fosthiazate and carbosulfan. The susceptibilities of cereal cyst nematode to ethoprophos, fosthiazate, aldicarb and carbosulfan were relatively low and there were some difference among those cereal cyst nematode from different regions.The values of LC50 were all above 582.7 mg·L-1,but the relative toxicity indexes were all below 1.31. The LC50 values of abamectin to cereal cyst nematode were between 26.0 and 66.3 mg·L-1,and the LC50 values of emamectin benzoate were between 20.1 and 35.3 mg·L-1, in addition, there were greater differences among those cereal cyst nematode from different regions, and the largest relative toxicity index reached to 2.55.

69. **Gao X, Cui L, Li HL, Wang XM, Tang WH, Conner RL, Lin XH, Li HJ**. 2012. Resistance of *Triticum durum* cultivars Waskana and Waskowa to cereal cyst nematode, *Heterodera filipjevi* and *H. avenae*. Acta Agronomica Sinica **38**:571–577. [in Chinese]

Cereal cyst nematodes (CCN) are a group of important soil-borne pathogens of wheat. *Heterodera avenae* and *H. filipjevi* are the major species of CCN that have limited wheat (*Triticum aestivum*) production in China in recent years. Since the CCN-resistant resource is short, it is important to develop new sources with resistance for breeding purpose in China. Based on the results of a 3-year field test and controlled environment tests, we found that two Canadian *Triticum durum* cultivars, Waskana and Waskowa, were highly resistant to both *Heterodera filipjevi* (pathotype Hfc-1) and *H. avenae* (pathotype HA43) populations from Henan Province, China. The number of white females per plant in Waskana and Waskowa was significantly smaller than that in the susceptible common wheat cultivars Aikang 58, Shi 4185, and Wenmai 19. Although the juveniles of *H. filipjevi* and *H. avenae* populations were able to penetrate into the roots of Waskana and Waskowa, the number of juveniles inside the roots was significantly smaller than that of Aikang 58, Shi 4185, and Wenmai 19, resulting in smaller numbers of females on the roots of these *durum* wheat cultivars. Waskana and Waskowa with resistance to *H. filipjevi* and *H. avenae* are useful in developing wheat cultivars with enhanced resistance to CCN in China. Based on the results from the DNA-based soil testing service operated by South Australian Research and Development Institute, the number of eggs of nematodes in the rhizospheric soil samples from the CCN-resistant cultivars Waskana and Waskowa was less than that in the soil samples from the susceptible wheat cultivars. This indicates that application of resistant cultivars might reduce the risk of damage caused by CCN in soil.

70. **Huang WK, Ye WX, Jiang HY, Long HB, Peng H, Wang GF, Peng DL**. 2012. Genetic variation analysis of *Heterodera avenae* Wollenweber (Nematoda: Heteroderidae) using ISSR marker and ITS-rDNA sequence. Asian Journal of Nematology **1**:1–12. [in English]

Heterodera avenae is distributed in 13 provinces of China and causes considerable yield losses of wheat. Inter-Simple Sequence Repeats (ISSR) fingerprint patterns and sequence analysis of the ITS region were used for the comparative study of genetic variation of *H. avenae*. DNAs of second-stage juveniles from 16 populations of *H. avenae* and one population of *Heterodera filipjevi* in 4 provinces were analysed with 3 ISSR primers. Results of ISSR revealed a high genetic diversity (the percentage of polymorphic bands was 78.6%) within *H. avenae* on a large geographical scale. The analysis of molecular variance (ANOVA) indicated that about 74.8% of the variations resulted from genotypic variations within region and the remaining 25.2% were due to variances among regions. Base transition of ITS-rDNA sequence revealed low intraspecific variation in rDNA of *H. avenae*. The alignment of 16 sequences in *H. avenae* covered altogether 1045 nucleotide positions with 4 polymorphic bases. ISSR dataset grouped all populations into two clusters according to their

geographical origin. These results suggested two different pathotypes or biological entities existing in the *H. avenae* species. Hybridization, multiple introductions, passive dispersal by anthropogenic activities and some natural means would probably be responsible for the genetic variation of *H. avenae*.

71. **Li HG, Cui L, Li HL, Wang XM, Murray TD, Conner RL, Wang LJ, Gao X, Sun Y, Sun SC, Tang WH**. 2012. Effective resources in wheat and wheat–*Thinopyrum* derivatives for resistance to *Heterodera filipjevi* in China. Crop Science **52**:1209–1217. [in English]

Cereal cyst nematode (CCN) is becoming one of the important soil-borne pathogens in wheat (*Triticum aestivum* L.) monocropping or wheat–maize (*Zea mays* L.)–wheat cropping systems of central China. *Heterodera filipjevi* (Madzhidov, 1981) Stelter, 1984 was recently recognized as a causal agent of CCN in China, but little information is available on sources of resistance against this nematode species. The present study was initiated to determine the current status of resistance in wheat cultivars against *H. filipjevi* and to identify effective resources for improvement of CCN resistance in China. A 3-yr field study of CCN resistance that involved 174 wheat cultivars or wheat–*Thinopyrum* derivatives was conducted in a wheat field in Xuchang, Henan Province, China, where *H. filipjevi* had been present for years. Greenhouse experiments were conducted with representative resistant entries from each group of accessions. None of the 78 wheat cultivars and breeding lines from China was resistant in field tests. Wheat cultivar Madsen from Washington State was most resistant among the entries tested both in field and under controlled environment. New sources of resistance to *H. filipjevi* were identified in some wheat–intermediate wheatgrass [*Thinopyrum intermedium* (Host) Barkworth & D. R. Dewey] and wheat–tall wheatgrass [*Thinopyrum ponticum* (Podp.) Barkworth & D. R. Dewey] partial amphiploids, which will diversify resistance resources in enhancing resistance of wheat against CCN.

72. **Li XH, Gu SJ, Wang WL, Chen SL**. 2012. Effect of different factors on number of *Heterodera avenae* cysts produced on the wheat. Journal of Agricultural University of Hebei **35**:56–61. [in Chinese]

The criterion of wheat resistance to *Heterodera avenae* was based on the number of the cysts produced on the roots. To optimize the evaluation technique on wheat resistance to *Heterodera avenae* effect of soil texture, times of inoculation, inoculum densities and seeding age on the number of *H. avenae* cysts formed on the roots were evaluated in the lab. The results showed the highest number of cysts was produced in the wheat planted in sandy clay loam; although the number of cysts produced with 4 times of inoculation was higher than those with 1-3 times of inoculation, its resistant reaction was not significantly influenced by the times of inoculation based on the resistance criterion. A set of cultivars with different resistance could be effectively differentiated at the density of 1000 second stage juveniles (J2) per plant. The numbers of cysts in wheat inoculated in 3-6 d after sowing is higher than those in 9-15 d. We suggest that to obtain an optimum evaluation technique for wheat resistance to *H. avenae* the wheat should be planted in a sandy clay loam soil and 1000 J2 were inoculated in 3-6 d after sowing.

73. **Li XH, Ma J, Chen SL**. 2012. Effect of temperature on the hatch of *Heterodera avenae* field population. Acta Phytophylacica Sinica **39**:260–264. [in Chinese]

The effect of temperature on the hatch of *Heterodera avenae* population sampled in early of October at wheat sowing period and in end of December before soil freezing was evaluated *in vitro* for understanding *H. avenae* hatching characteristics with different temperature experiences. The results showed that the hatching peak of *H. avenae* collected in wheat sowing period was 10-12 weeks after treatment at constant temperature of 5°C. It is about 4

week's delay comparing to that at constant temperature of 15°C. For the treatments of pre-incubation at 5°C, then transferring to 15°C, the longer the incubation time at 5°C, the more delay the hatching peak; the total hatch increased with increasing incubation time at 5°C. It proved that the low temperature at 5°C was favorable for the total hatch. *H. avenae* collected before soil freezing (experienced <10°C for seven weeks) could hatch at 5-30°C, but the optimum temperature for its hatch is 20°C. The highest hatch rate was observed at this temperature and its hatching period was shorter than those at other temperatures. The hatch was significantly inhibited at the temperature of over 25°C.

74. **Li XH, Ma J, Chen SL**. 2012. Effect of temperature on the penetration and development of *Heterodera avenae*. Journal of Triticeae Crops **32**:977–981. [in Chinese]

Effects of temperature on the penetration, development and cyst forming of *Heterodera avenae* were tested in controlled environments. The results showed that the number of nematodes penetrated in the root at 18°C were the highest in 3 d after inoculation, while it was higher at 16°C than those at other temperatures tested in 6-9 d after inoculation.The numbers of nematodes penetrated in root at 12 and 14°C were the most in 15 and 12 d after inoculation respectively. It needed 34, 30, 27 and 18 d to complete a life cycle at 16-18, 20, 22 and 24°C, respectively. There was not female found in the root at 10-12°C even after two months. In the second experimental the plants were first inoculated and incubated at 16°C for 7 d, afterwards incubated at different temperatures. Cysts formed at 18-22°C were higher than those at other temperatures. We suggested the optimum temperature for penetration is 16°C and the optimum temperature for cyst forming is 18-22°C based on the number of nematodes penetrated and the time of penetration.

75. **Liang C, Yang YY, Zhao HH, Peng DL**. 2012. Study of wheat field infection of cereal cyst nematode in Jiaodong Region of Shandong Province. Shandong Agricultural Sciences **44**:80–84. [in Chinese]

The samples were periodically collect from three wheat sampling fields in Chengyang, Jiaozhou and Laiyang from October 2010 to May 2011, and the cysts and 2-instar larva (J2s) in soil and various stages of cereal cyst nematode (CCN) in root tissue were detected in the laboratory. It was found that the free J2s in the soil or their infection of roots were not detected in autumn and winter of 2010; the beginning for J2s entering soil was in early March 2011 and the peak phase was from the last ten days or March to the first 10 days of April. For the adverse conditions such as severe drought, the root infection of J2s did not occur until early April in Chengyang sampling field, while this were delayed about 20 and 30 days in Jiaozhou and Laiyang, respectively. CCN development from J2s to J4s in roots occurred during late April to mid May in Chengyang and Jiaozhou, and during mid and late May in Laiyang. The adults protruded out of the root in mid May in Chengyang and Jiaozhou, and in late May in Laiyang. The results indicated that the severe drought inhibited CCN infection strongly.

76. **Liu BL, Sun CG, Wang X, Xiang GL, Song ZQ, Gao FF, Li HM**. 2012. Evaluation of the resistance of wheat cultivars to Peixian population of *Heterodera avenae* from Jiangsu Province, China. Journal of Triticeae Crops **32**:563–568. [in Chinese]

In order to screen the resistant wheat cultivars to cereal cyst nematode (*Heterodera avenae*), 40 cultivars from 5 provinces were evaluated by two test methods of second juvenile inoculation under greenhouse and eggs inoculation under natural conditions and one field trial, with the nematode population from Peixian, Jiangsu province, China. The greenhouse test with juvenile inoculation revealed no cultivar was immune to *H. avenae*. However, cultivars Huamai 1, Wenliang 58 and Yumai 66-18 were highly resistant, Yangmai 13 and

Xumai 7086 were moderately resistant. Yannong 5158 was the most susceptible cultivar with 104.7 white females per plant in average. In field trial, only Huamai 1 of the resistant cultivars above mentioned was evaluated as resistant. The sustainable test results demonstrated that Huamai 1 could be used as the prospective resistant cultivar for wheat cultivation in CCN heavily infested areas and as resistant resource for plant breeding. The resistance results evaluated by eggs inoculation test were more variable when compared with those from juvenile test and field trial, therefore, it was not suitable for the evaluation of wheat cultivars resistance to CCN.

77. **Liu J, Wu HY, Peng DL**. 2012. Evaluation of the main wheat varieties from Shandong for resistance to *Heterodera avenae*. Crops 111–114. [in Chinese]

Thirty-one wheat varieties from Shandong Province were evaluated for resistance to *Heterodera avenae* with pot experiment in illumination incubator. The results showed that most of the tested varieties were high susceptible (HS), and none were resistant. Zimai 12 and Shannong 8355 were moderately susceptible (11-20 cysts/root), account for 6.5% of the tested varieties. Other 29 varieties were all high susceptible (more than 20 cysts/root), account for 93.5% of the tested varieties. Furthermore, no relationship between the growth character of wheat root and number of cyst nematodes was observed.

78. **Liu K, Xi TY, Zhang YF, Zheng JW**. 2012. Morphological and molecular characterization of cyst-forming nematodes on wheat from Shanxi Province. Journal of Zhejiang University (Agriculture and Life Sciences) **38**:566–574. [in Chinese]

Cyst-forming nematode parasitizing on wheat is a serious problem in the world. The first report of cyst nematode infecting wheat in China was in 1989, and since then the nematodes were reported in 13 provinces of China. In Shanxi Province no systematic survey were made for the distribution and species identification of the cyst-forming nematodes parasitizing in wheat. During 2010 to 2011, an extensive survey and investigation on cyst-forming nematodes parasitizing wheat in Shanxi Province was carried out. Key morphological characteristics and morphometrics of cysts and second-stage juveniles of major populations were systematically observed and measured, and molecular data of rDNA-ITS region of the populations were analyzed. The cysts were characterized by lemon-shaped, with posterior protuberance, vulval silt short, bifenestrate, bullae present and under bridge absent. Morphometric comparison of cysts and second stage juveniles showed that all the cyst-forming nematode populations from Shanxi were *Heterodera avenae*. The phylogenic analysis of the rDNA-ITS sequences based on nine cereal cyst nematode (CCN) populations from Shanxi Province showed a close genetic relationship with the *H. avenae* populations from China including Anhui, Jiangsu, Henan, Beijing, Hebei and Qinghai, and India, and *H. australis* population from Australia, however, the CCN populations from China had a distant genetic relationship with *H. avenae* from European countries including Germany, Morocco, Spain, United Kingdom and France. Amplification of rDNA-ITS region of *H. avenae* populations collected from Shanxi yielded a fragment with the length of 1045 bp. Both morphological and molecular identification of cyst-forming nematode populations parasitizing on wheat in Shanxi confirm that all the populations collected in this study are *H. avenae*, and no other species are detected.

79. **Pei SA, Wang X, Geng LX, Chi YK, Liu BL, Sun CG, Le XH, Li HL**. 2012. Effects of different nematicides on cereal cyst nematode of wheat. Plant Protection **38**:166–170. [in Chinese]

The cereal cyst nematode (CCN) has been widely distributed in wheat growing areas of 13 provinces in China. The fast spread of the disease can threaten the food production and

economic security of China. Therefore, the systematic control studies are urgently needed. The control efficacy of 3 different uses from 5 granular nematicides (GR) with efficient components of aldicarb, carbofuran, cadusafos, fenamiphos and abamectin were evaluated on CCN in wheat fields at regreening stage. The results showed that the numbers of cysts in soil collected from different treatments were clearly dropped after nematicide application. However,there was no significant difference in the adjusted cyst reduction rates between different nematicide treatments. Significant differences were demonstrated in wheat height, root weight and fresh plant weight between different treatments, and their yields were increased compared with the control. The adjusted cyst reduction rate from the treatment with 30 kg/ha of 0.5% abamectin GR was the highest at 55.1%, and wheat yield was increased by 18.5% compared with the control. The treatment with 60 kg/ha of 0.5% abamectin GR achieved the highest wheat growth at 59.3 cm compared with those from other treatments. Due to the inhibitory effects of 0.5% abamectin GR on nematode reproduction and promotive effects on wheat growth, the usage of 30 kg/ha was suggested for regreening fields heavily infested with CCN, which might decrease the yield loss caused by CCN to some extent.

80. **Qi XL, Peng DL, Peng H, Long HB, Huang WK, He WT**. 2012. Rapid molecular diagnosis based on scar marker system for cereal cyst nematode. Scientia Agricultura Sinica **45**:4388–4395. [in Chinese]

The objective of this study is to build a SCAR marker system for rapid molecular detection of cereal cyst nematode (*Heterodera avenae*) from mixtures of different nematodes. With the method of RAPD and SCAR, a single-step PCR was used to specially detect *H. avenae*. Using the SCAR marker system established in this study, the target fragment was amplified from the DNA templates of *H. avenae* only, from other 8 species including 32 populations. The SCAR marker system could detect cysts and the J2 of *H. avenae*, and the specific fragment could be clearly identified when the dilution was 1/2000 of a cyst or 1/80 of a J2 for all replicates. The establishment of the SCAR marker system for rapid molecular detection of *H. avenae* can be used to detect the *H. avenae* from the mixed nematode samples rapidly, and the detection is accurate and highly sensitive.

81. **Song XL, Gao DL, Chen Y, Miao JQ, Liu F**. 2012. Juvenile emergence characteristics of the cereal cyst nematode, *Heterodera avenae*, in Tai'an area of Shandong. Plant Protection **38**:95–97. [in Chinese]

In order to obtain enough second stage juveniles of *Heterodera avenae*, the effects of the pretreatment conditions, emergence temperature, cyst pretreatment time and the time of field collecting on their emergence characteristics of Tai'an population of *H. avenae* were studied *in vitro*. The results indicated that treatment by dipping cysts in water could benefit juvenile emergence at 5°C. For the pretreated cysts at 5°C, there was significant increase in juvenile emergence rate at 15°C as compared to 20°C. The cysts pretreated at 5°C for eight weeks had the highest emergence rate. The juvenile emergence rate of the cysts collected from fields in June and August was significantly higher than that of the cysts collected in July and September, but August was the best field collecting period.

82. **Tao L, Wu HP, Peng DL, Wu XH, Zhang S**. 2012. Distribution and identification of cereal cyst nematodes on wheat in Anhui Province, China. Journal of Anhui Agricultural University **39**:257–262. [in Chinese]

The purpose of this paper is to survey distribution, species of cereal cyst nematode (CCN) and relationship among CCN species in Anhui Province. White female of wheat root system in Huaibei wheat areas were investigated; soil samples of wheat rhizosphere were collected

with zig-zag method in Huaiyuan County and other counties; cysts were separated by Fenwick & Oostenbrink method from those samples; second-stage juveniles (J2) were obtained by hatching cyst; CCN was identified based on morphologic characteristics of cyst perineal pattern and de-Man data; and the genetic relationships were analyzed by amplified ITS characteristic fragment and phylogenetic tree built with MEGA5.05. The results showed that CCN was detected from 52% sample sites, from all the samples of wheat areas in the northern part of the Huai River, and from 7% sample sites in Jianghuai wheat areas. No CCN was detected from wheat areas in the southern part of the Changjiang River. Occurrence of CCN in Yingshang and other 4 counties were identified as *Heterodera avenae*, and occurrence area of *H. avenae* was up to 41.6% of wheat areas in the northern part of the Huai River. Huaiyuan population of *H. avenae* is distantly related with other 4 *H. avenae* populations, and certain morphological differences exist among the 5 *H. avenae* populations, but with no consistency to the genetic relationships.

83. **Wang T, Qi RD, Wu XH, Zhao W, Gao TC, Zhang L, Wu HP**. 2012. A preliminary study on diffusion ways of the cereal cyst nematode. Plant Protection **38**:98–100. [in Chinese]

The study aimed to investigate the diffusion ways of cereal cyst nematode (CCN). The cyst numbers of CCN in the soil sticked to agricultural machinery in wheat fields and in the water around were investigated in the CCN epidemic areas. The detection rates of cysts in the soil collected from harvester, rotary tiller and seeder were 27.1, 51.6 and 44.0%, respectively. In wheat-rice rotation fields, the detection ratio of cysts was 58.3% in the floating leftovers. In ploughed wheat fields, the detection rates of cysts in the field accumulated water, in the water ditches and in the running water were 33.3, 22.7 and 7.7%, respectively. The results indicated that the agricultural machinery operation across different areas and running water might be one of the main ways of CCN diffusion.

84. **Wang X, Sun CG, Fang YM, Xiang GL, Liu BL, Song ZQ, Gao FF, Li HM**. 2012. Analyses of distribution and population density of cereal cyst nematodes on wheat in Jiangsu Province based on GIS. Acta Phytopathologica Sinica **42**:515–524. [in Chinese]

A survey of cereal cyst nematodes (CCN) on wheat was carried out in 290 towns from 59 counties of 13 districts in Jiangsu Province during 2009 to 2011, and the vector graphics of geographical relationships between the distribution of disease, the population density of CCN and the soil types were analyzed by geographic information system software (ArcGIS). The results showed 301 out of 580 investigated fields, which from 152 towns of 47 counties, were detected with CCN. It was widely distributed in wheat growing areas of Xuzhou district in northern part of the Province, Taizhou and Yangzhou in middle part and Zhenjiang in southern part. The average population densities of CCN varied in different districts. The population densities of Xuzhou, Yangzhou and Taizhou district was 34.4, 17.5 and 17.1 cysts per 100 mL soil, respectively, and the districts of Liangyungang, Nantong and Suzhou were 3-5 cysts per 100 mL soil. The vector graphics made by ArcGIS revealed the close relationships between the population density of CCN and the soil types in infested fields. The population densities were generally higher in sandy and sandy-clay soil than those in clay soil. The population density in Wangdian Town of Peixian, Xuzhou district was 191 cysts per 100 mL sandy soil. The research not only benefited the macroscopical understanding of CCN distribution in whole province and the inspecting dynamics of population density in seriously infested areas, but also provided the basis knowledge for CCN integrated management.

85. **Wei Z, Li HX, Li MQ**. 2012. Comparison and improvement in genomic DNA extraction methods of cereal cyst nematode. Journal of Gansu Agricultural University **47**:63–67. [in Chinese]

Heterodera avenae is a hazardous plant parasitic nematode for wheat, oats and barley. Isolation of genomic DNA from single cyst is the one of crucial obstacles for identifying cyst nematodes and diversity research. SDS-proteinase K method (SDS-PK), TE-proteinase K method (TE-PK), PCR buffer-proteinase K method (PCR B-PK) and guanidine hydrochloride method (Gu·HCl) were used to extract genomic DNA from single cyst. The efficiency and the success rate of amplification of ribosomal DNA using the extracted genomic DNA were compared. The results indicated that SDS-PK method was the most effective, the success rate was 85.71%, then was Gu·HCl method, and less effective of TE-PK method. Microwaving treatment improved the extraction success rate of the four methods. A microwaving combined with SDS-PK method showed the optimum of extraction, the success rate reached 96.97%.

86. **Yu X, Wu HP, Ma J, Wang LP**. 2012. Occurrence of and damages caused by the cereal cyst nematode *Heterodera avenae* in Yingshang County of Anhui Province. Plant Protection **38**:124–127. [in Chinese]

Totally 60 soil samples were collected by zig-zag method from different wheat areas in north Anhui Province to investigate wheat cereal cyst nematode (CCN) occurrence and wheat damage caused by CCN. Occurrence frequency of egg density was assessed based on egg density of cysts separated by Fenwick & Oostenbrink method. CCN occurred at Yingshang wheat area was identified according to morphological characteristics of cyst vulva cone and J2. Field plain distribution type of CCN was determined by disperse coefficient method, and J2 population of CCN in soil depth of 0-300 mm was dynamically monitored during wheat growing season by systematic observations. Early infection was monitored by acid fuchsin staining method; differences of plant height and yield between aldicarb-control plots with soil treatment before sowing and non-control plots were compared on a selective field with medium egg density of CCN. The results showed that occurrence frequency of the egg density ranging from 1 to 10 eggs/g soil was 62% in north Anhui wheat area. CCN occurred in Yingshang was identified as *Heterodera avenae*, and field distribution in Shuanglou of Huangqiao in Yinshang County belonged to cluster type. The earliest infection of J2 in wheat root system was observed on18 March in the test year, and yield loss caused by *H. avenae* ranged between 9.8-14.9% when egg density ranged from 2.5-20.5 eggs/g soil. “Fanmai-5” yield decreased significantly by 14.9%.

87. **Yuan HX, Hou XS, Fu B, Sun JW, Zhang FX, Xing XP, Li HL**. 2012. Identification on the species of cereal cyst nematode from Northern Henan and Southern Hebei, China. Acta Phytopathologica Sinica **42**:219–224. [in Chinese]

Four cereal cyst nematode (CCN) populations of wheat were collected from Boai, Qingfeng, Anyang counties in Henan Province and Handan county in Hebei Province in 2009. The cyst of Boai population had distinct underbridge in the vulval cone area, but other three tested populations had not. The main morphological characteristics and measurements of the cyst and the second juvenile of Boai population conformed to *Heterodera filipjevi*, and that of the populations from Qingfeng, Anyang and Handan conformed to *H. avenae*. The result of ITS sequence analysis and alignment indicated that Boai population and related species *H. filipjevi* from America and Italy were clustered in the same group with close relationship by MP of MEGA 4 and the three populations from Qingfeng, Anyang, Handan and the related species *H. avenae* from Tongzhou and Zhengzhou were clustered in the same group. Based on the morphological and molecular characteristics, the Boai population was identified as *H. filipjevi* and the other three populations were identified as *H. avenae*.

88. **Zhang JJ, Yuan HX, Zhang RQ, Xing XP, Dai JL, Niu JS, Li HL, Chen PD**. 2012. Analysis of resistance to *Heterodera filipjevi* in *Triticum aestivum–Dasypyrum villosum* germplasm. Acta Agronomica Sinica **38**:1969–1976. [in Chinese]

Heterodera filipjevi is a new pathogenic species of cereal cyst nematode (CCN) in China, which has a potential threat to wheat production security. Wheat relatives are important resources of multiple resistance genes to many biotic and abiotic stresses, including CCN resistance genes. Using relative resistance index (RRI) as the evaluation indicator, we screened resistant resources against *H. filipjevi* from 20 wheat relatives after artificial inoculation, and found *Dasypyrum villosum* highly and stably resistant to *H. filipjevi* Xuchang population. Three sets of common wheat (*Triticum aestivum* L. cv. Chinese Spring) chromosome addition lines with individual *D. villosum* chromosome 1V to 7V, as well as 6VS translocation lines from different origins, were evaluated for CCN resistance. The *Triticum aestivum–D. villosum* 6V chromosome addition line showed high resistance to CCN with RRI higher than 0.90 in all sets of addition lines; however, the translocation lines 6VS were susceptible to CCN with RRI ranging from 0.43 to 0.51. Therefore, the CCN resistance gene is most probably located on chromosome 6VL.

89. **Zhao HH, Yang YY, Peng DL**. 2012. Preliminary evaluation on resistance of main wheat cultivars from Shandong Province to cereal cyst nematode. Shandong Agricultural Sciences **44**:80–83. [in Chinese]

The resistance of wheat to cereal cyst nematode (CCN) were evaluated with 15 and ten cultivars respectively for outdoor pot test and field plot experiment. The results indicated that the tested wheat cultivars from Shandong Province were all susceptible to CCN with different degrees. Yannong 24 showed the highest resistance, while Weimai 8 the worst. Their performance was basically same in pot and field plot trials. The factors affecting resistance evaluation such as inoculation volume and extreme weather were also discussed.

90. **Dai JL, Cui L, Liu K, Zong YY, Yuan HX, Xing XP, Li HJ, Li HL**. 2013. Genetic analysis of common wheat cultivar Taikong 6 for resistance to *Heterodera avenae* Zhengzhou population. Acta Agronomica Sinica **39**:642–648. [in Chinese]

Taikong 6 is a common wheat (*Triticum aestivum* L.) cultivar with high-yield and good agronomic performance bred by Henan Academy of Agricultural Sciences with satellite-loaded mutation breeding. This cultivar was shown to be resistant to *H. avenae* Zhengzhou population in the conditions of repeated inoculation and field tests. In this study, Taikong 6 was crossed with the susceptible cultivars Yumai 47 to produce an F2 segregating population. Reactions of the F2 progeny to *H. avenae* Zhengzhou population was investigated in the field and inoculation tests. The results of genetic analysis showed that the cyst number of F2 population was the quantitative character with a continuous and skewed distribution, indicating that there are major genes in Taikong 6. The method of joint segregation analysis of single generation of major gene plus polygene mixed inheritance model was used to analyze the inheritance of resistance to *H. avenae* Zhengzhou population in Taikong 6, showing that the genetic model B-2 was the most fitted genetic model for the resistance for the cross of Yumai 47 × Taikong 6 in the conditions of inoculation and field tests. This indicates that the resistance to cereal cyst nematode in Taikong 6 is controlled by two major genes with additive-dominant effects plus polygene effect. The major gene heritability of resistance for the cross of Yumai 47 × Taikong 6 to *H. avenae* Zhengzhou population in the conditions of inoculation and field tests was 73.5% and 86.9%, indicating the two major genes with the dominant role to resistance of Taikong 6 to *H. avenae* Zhengzhou population.

91. **Feng WT, Wang TQ, Fang ZD, Xie YF**. 2013. The occurrence and control technique of cereal cyst nematodes on wheat in Xingping, Shaanxi Province. Acta Agriculturae Boreali-occidentailis Sinica **22**:94–98. [in Chinese]

Cereal cyst nematode is a new disease of wheat production in Xingping, Shanxi province. In order to control the disease, investigation on occurrence and control technique of cereal cyst nematode was carried out; the results showed that wheat growing in the city was slightly infected by cereal cyst nematode. The number of cyst per plant was less than 20. There was no severe infection field. Seed dressing with imidacloprid and tebuconazole, imidacloprid and isofenphos-methyl, soil treatment with avermectin, carbofuran and chlorpyrifos before sowing of wheat, could reduce the disease index of cereal cyst nematode, and increase the wheat yield. Seed dressing with imidacloprid and tebuconazole could inhibit cereal cyst nematode, could not affect physiological index of wheat seeding rate, tillers and roots. Among soil treatments with avermectin, carbofuran and chlorpyrifos before sowing of wheat, wheat yield increase rate under treatment with chlorpyrifos was the highest, 20.1%; followed by carbofuran; the lowest was 4.23%, obtained in the treatment of avermectin. Wheat yield of soil stamping after sowing was significantly higher than that of the CK, the increasing rate was 1.73%. The disease index of cereal cyst nematode of plots treatment with carbofuran was significantly lower than other plots. The control effect of carbofuran on the cereal cyst nematode was significant.

92. **Hou SY, Zhang G, Wang X, Wang AL**. 2013. Infection dynamics of *Heterodera avenae* on spring wheat in Qinghai province. Journal of Qinghai University (Natural Science Edition) **31**:1–3. [in Chinese]

The infection period,development progress, dynamics and generation of *Heterodera avenae* on spring wheat in Qinghai province was investigated by seedling observation combined by field work. The results show that J2 hatched out of the overwintering cyst in soil infected the wheat seedling roots by the rise of temperature since the middle of April. The larvae completed three stages from two age to four age in wheat root late April to early July and the white female adults exposed on the root surface in July. From August to September the new cyst fell into the soil, and the wintering period is from the middle of October to next April. *Heterodera avenae* occurs one generation during the whole growth period of spring wheat.

93. **Huang ZQ, Wang B, Zhou XG, Feng GH**. 2013. Occurrence, identification and control strategies of cereal cyst nematode in wheat. Journal of Triticeae Crops **33**:200–206. [in Chinese]

Cereal cyst nematode (CCN) is an important plant parasitic nematode in the world, which causes great damage in cereal crops, such as wheat, barley, oats and pasture. It has been widely distributed in more than 40 countries all over the world. In China, cereal cyst nematode spread quickly and extended its occurrence in 13 provinces. Here we overviewed the occurrence, the identification methods of cereal cyst nematode by morphology and molecular techniques. The comprehensive control strategies including quarantine, resistance breeding, agricultural control, chemical control and biological control were put forward, which could provide valuable information for the control of cereal cyst nematode to the wheat production in China. [45 references]

94. **Li XH, Gao B, Ma J, Wang RY, Chen SL**. 2013. Effect of fallow and rotation on the population dynamics of *Heterodera avenae*. Journal of Triticeae Crops **33**:1048–1053. [in Chinese]

Effect of fallow, rotation and continuous cropping of wheat on the population dynamics of *Heterodera avenae* were tested in pot experiment and natural disease field to understand the control efficacy of fallow and rotation on the cereal cyst nematode.The results showed that the hatching of *H. avenae* was not affected by the hosts. The population dynamics of the second stage juveniles (J2) in soil and nematode density within cyst were similar in all the treatments. Hatching peak of *H. avenae* was in the period of March to April in the area of Hebei Province. Population of *H. avenae* reduced by 89.8% after one year's fallow, and it was reduced by 93.8% after rotation with eggplant for one year, while it was reduced by 90.7% after rotation with the muskmelon or melon for one year, and by 98.8% after rotation for two years. In the natural disease field, the population of the nematodes increased by 36.8% and by 49.2% after continuous wheat cropping for one and two years, respectively. In conclusion, the disease may become more and more severe after continuous wheat cropping, while the population of *H. avenae* could be significantly reduced by fallow or rotation one year or more.

95. **Li XH, Ma J, Chen SL**. 2013. Occurrence and distribution of cyst nematodes of wheat in Hebei Province. Plant Protection **39**:162–165. [in Chinese]

A systematic survey on the occurrence of cyst nematodes of wheat in 55 counties of Hebei was carried out during 2009-2011. A total of 719 soil samples were collected. The results showed that the total incidence of cyst nematodes of wheat in Hebei was 52.7%, whereas the incidence of cyst nematodes in winter wheat and spring wheat were 61.2 and 0%, respectively. The incidence of cyst in Shijiazhuang Region is 90% and is the highest among al the regions investigated in Hebei. Ranking of cyst incidence from high to low was Shijiazhuang, Xingtai, Baoding, Handan, Langfang, Hengshui, Tangshan, Cangzhou, Zhangjiakou, Chengde. A higher densities of cysts occurred in Luannan County of Tangshan and in Renqiu City, with the densities of more than 40 cysts/100 mL soil in 11.8 and 7.7% fields, respectively. The incidence of cysts in sandy loam soil was 63.0%, while those were 60, 50 and 0 in loam soil, clay soil and sandy soil, respectively. All the cyst nematodes of wheat in Hebei were identified as *Heterodera avenae* based on the morphological characteristics.

96. **Li XH, Ma J, Gao B, Wang RY, Chen SL**. 2013. The dynamics of *Heterodera avenae* in winter wheat areas in Hebei Province. Acta Phytophylacica Sinica **40**:315–319. [in Chinese]

To understand the invasive and developmental characteristics of the cereal cyst nematode *Heterodera avenae*, the number of cysts and second stage juveniles (J2) in soil and nematodes in roots were investigated systematically in the main winter wheat areas in Hebei from 2009 to 2012 using floating method, extraction tray method and acid fuchsin staining method, respectively, and the egg hatching in the cysts was also checked. The results showed that J2 could be extracted from soil all year round except early and mid-June. There was a low peak of hatch with the densities of 12.3-18.6 J2 per 100 mL soil before soil freezing. Most nematodes hatched in early and mid-April, and the J2 densities were 52-65 per 100 mL soil. J2 that invaded the plants could develop to third stage juveniles (J3) before soil freezing. The number of J3, fourth stage juveniles and females in roots peaked in early, mid- to late, and late May, respectively. The total hatch per year for the nematodes was 86.5%. In conclusion, *H. avenae* had one generation per year and its main invasion period was in late March to mid-April.

97. **Liu CJ, Huang WK, Cui JK, Peng DL, Li HM**. 2013. Distribution and rDNA-ITS analysis of cereal cyst nematode in Shandong Province. Journal of Huazhong Agricultural University **32**:55–60. [in Chinese]

The cereal cyst nematode (*Heterodera avenae* Wollenweber) is the most threatening nematode on wheat and cereal crops in China. The occurrence and distribution of *Heterodera* spp. were investigated by random sampling method from 19 town or counties of Shandong Province. The species was identified as *Heterodera avenae* with the morphological and rDNA-ITS analysis. The cereal cyst nematode was detected from 70.9 percent samples collected from Linyi City, Laiwu City, Zibo City ,Weifang City, Dongying City, Weihai City and Yantai City. The highest cyst and egg number appeared in Dongying City and Weifang City, the lowest cyst and egg number appeared in Yantai City.

98. **Liu J, Xu J, Dai JL, Li HM**. 2013. RAPD Markers of *Heterodera avenae* Xingyang population from Huang-huai floodplain in China. Journal of Triticeae Crops **33**:1294–1299. [in Chinese]

Wheat disease caused by cereal cyst nematode (CCN), *Heterodera avenae*, has been the important disease in Henan province, and it is becoming the enormous threat to wheat production. Pathotype characterization is important for breeding and utilization of disease-resistant varieties. Traditional procedure of pathotype identification is time-consuming. In this research, RAPD technique was used to build the molecular marker related to the pathotype of CCN. 147 random primers were screened and 3 random primers with RAPD method S10, S43 and S112 were found relating to Xingyang population of CCN with polymorphic bands of 780, 1300 and 875 bp respectively. The results of PCR amplification with S10, S43 and S112 in other CCN pathotype from the wheat region of Huang-Huai Floodplain in China showed that the Polymorphic bands appeared only in Xingyang population of CCN. The three RAPD markers related to Xingyang population of CCN can be used to detect and identify the CCN pathotype of Xingyang population.

99. **Long H, Peng D, Huang W, Peng H, Wang G**. 2013. Molecular characterization and functional analysis of two new β-1,4-endoglucanase genes (*Ha-eng-2*, *Ha-eng-3*) from the cereal cyst nematode *Heterodera avenae*. Plant Pathology **62**:953–960. [in English]

Parasitism genes encoding secretory proteins expressed in the pharyngeal glands of plant-parasitic nematodes play a crucial role in nematode parasitism of plants. Two new β-1,4-endoglucanase genes (*Ha-eng-2* and *Ha-eng-3*) expressed in the pharyngeal glands of the sedentary cyst nematode, *Heterodera avenae*, were cloned. Both of the predicted proteins have a putative signal peptide for secretion and a catalytic domain. Neither peptide linkers nor cellulose binding domains were present. *In situ* hybridization showed that the transcripts of *Ha-eng-2* and *Ha-eng-3* accumulated specifically in the two subventral gland cells of *H. avenae*. RT-PCR analysis confirmed that their transcriptions were strong in the pre-parasitic and early parasitic second-stage juveniles, and were undetectable at the late parasitic stages of the nematode. Cellulase activities of the recombinant proteins HA-ENG-2 and HA-ENG-3 were confirmed *in vitro*. Knocking down *Ha-eng-2* using RNA interference reduced nematode infectivity by 40%. The results indicate that these β-1,4-endoglucanases can be secreted into plant tissues and play an important role in the wall degradation of plant cells during penetration and the migration of second-stage juveniles in host roots.

100. **Su ZH, Huang WK, Zheng GD, Zhang HJ, Liu SY, Peng DL**. 2013. Investigation on the occurrence of *Heterodera avenae* in Beijing. Plant Protection **39**:116–120. [in Chinese]

Cereal cyst nematode (*Heterodera avenae*) caused serious yield losses of wheat. Occurrence and life cycle of *H. avenae* were investigated in Daxing district of Beijing from December 2010 to December 2011. The results showed that *H. avenae* has one generation per year in Beijing. The peak of egg hatching occurred in April, infection peak of second stage juvenile (J2) occurred in early April, development peak of third stage juvenile (J3) occurred in late

April to early May development peak of J4 occurred in early May, development peak of adult females occurred in late May to early June. J2 could infect young wheat roots in end of October and developed into J3 before winter. The results would beneficial for *H. avenae* control in Beijing.

101. **Wang ZY, Shi Y, Yuan HX, Yang WX, Li HL**. 2013. The effects of nutrient elements on the hatching of cyst and vitality of secondary stage juvenile of cereal cyst nematode. Acta Phytopathologica Sinica **43**:333–336. [in Chinese]

    The impacts of soil nutrient elements on cereal cyst nematode were studied. The results showed that the mortality rate of secondary stage juvenile (J2) treated with N or P at different concentrations as well as 6 fold concentration of K was obviously higher than that of control, while the other three elements showed no difference. With respect to the minor elements, the mortality rate was higher than control when treated with Mn at a concentration over 5 fold and the mortality raised by the increase of concentration. Each Cu treatment increased the mortality significantly as compared with the control.

102. **Xiang GL, Song ZQ, Liang XD, Hu XB, Qi ZR, Wang X, Li HM**. 2013. Life cycle and vertical distribution of *Heterodera avenae* on wheat in Peixian, Jiangsu Province, China. Journal of Triticeae Crops **33**:789–794. [in Chinese]

    The information of life cycle and vertical distribution for cereal cyst nematode (CCN) in wheat field is critical to making strategies for integrated control of this disease. During two winter wheat growth seasons of October 2010 to June 2011 and October 2011 to June 2012, the life cycle and vertical distribution of CCN (*Heterodera avenae*) in wheat field in Peixian, Jiangsu Province was investigated systematically. The results showed that *Heterodera avenae* population completed only one life cycle during the whole growth season. Before wheat over-wintering, a few second stage juveniles (J2) of *H. avenae* were hatched, but only a few of them infected the root systems and none of them developed in normal. During the re-greening period, the hatching peak of J2 was appeared in soil and massive infection to roots was happened. In heading period, the white females appeared on roots which could be seen by naked eyes and some of males could be observed in roots and soil. During wheat maturation period, white females changed into brown cysts and fell into soil for over-summering. The results for vertical distribution revealed that cysts mainly distributed in soil under 10 cm layer. The hatched J2 also aggregated in the same layer and the peaks were appeared in re-greening period, which was in coincide with the life cycle CCN in field.

103. **Zhang S, Wang LP, Tan GJ, Wang XY, Jin P, Wu HP**. 2013. Occurrence and distribution of cereal cyst nematode in Xiao County of Anhui Province. Plant Protection **39**:148–152. [in Chinese]

    A field survey was carried out from 2007 to 2010 in Xiao County of Anhui Province to investigate the occurrence and distribution of cereal cyst nematode (CCN) under different altitudes, soil types and cultural practice, such as crop rotation. Cysts were isolated by float method from 360 soil samples collected by random survey method. Number of white females and cysts, and the nematode occurrence rate were calculated. Egg density was determined based on 30 cysts from each sample site. Egg density occurrence quantity (EDQ) frequency was analyzed by frequency statistic, and EDQ values under different altitude, soil type and cultural practice were compared by variance analysis. CCN species was identified based on the morphological characters of the female vulva cone and de Man data.The results showed that the nematodes occurred in wheat fields in Majing Town, Xiao County was identified as *Heterodera avenae*. CCN occurred in 87% sampling fields. In wheat fields, EDQ of higher altitude (31-40 m) was significantly higher than that of lower altitude (21-30

m) ($P < 0.05$). EDQ with soybean as pre-crop was significantly higher than that with maize as pre-crop in sandy soils ($P<0.05$). There was no significant difference among the EDQ in different soil type fields. This paper indicated CCN occurrence and distribution follow certain rules in Xiao County, which provided theory evidence for the local CCN control.

104. **Zhao J, Zhang GQ, Kang ZS**. 2013. New occurrence regions and field infection regularity of cereal cyst nematode on wheat in Shaanxi Province. Scientia Agricultura Sinica **46**:3496–3503. [in Chinese]

The objective of this study is to determine current status of cereal cyst nematode (CCN) on wheat and their field infection regularity in Northern Shaanxi Province and northern areas of Weihe River, and to provide a scientific basis for integrated control of CCN in this area. Field surveys of CCN on wheat were performed by sampling with five-point method in field at the booting to milking stages of wheat, isolating CCN cysts with Fenwick flotation method, and identifying CCN species using morphological method. A periodic sampling method in wheat field was used to acquire that the amount and life stage of juvenile (J2) of *Heterodera avenae* from roots stained by sodium hypochlorite-acid fuchsin solution using a microscope. Pathogenic CCN species attacking wheat in twenty-four counties in the two areas was *H. avenae*. Linyou, Yongshou, Liquan, and Wugong Counties were first time to be reported the occurrence of CCN on wheat. On the average, the amount of CCN was the highest with 32.0 cysts/100 g air-dried soil in Linyou County, and the lowest with 5.5 cysts/100 g air-dried soil in Yongshou County. No CCN were found in the investigated wheat fields in the Northern Shaanxi Province. No CCN infection was found in the investigated wheat field in the Northern Shaanxi Province. Second-stage juvenile (J2) of *H. avenae* hatching from survival cysts in the soil were detected within young roots of autumn-sown winter wheat. Following the next year, J2 attacking the roots of seedling plants could be observed when wheat started regreening. A peak of J2 infection on wheat emerged at time-span from late March to early April. The third-stage juvenile (J3) generated in middle April and started swelling in late April. Obvious white cysts of *H. avenae* could be seen on the outside of roots of wheat plants by naked-eyes in early May. Linyou, Yongshou, Liquan, and Wugong counties were new occurrence areas of CCN on wheat. Two infection periods of CCN on wheat occur after autumn-sown winter wheat and regreening in the following year. One generation of *H. avenae* took place in growing season of wheat in a year in Shaanxi Province.

105. **Zhao J, Zhang GQ, Peng DL, Kang ZS**. 2013. *Aegilops tauschii* and *Phleum paniculatum*, two new hosts of *Heterodera avenae*. Acta Phytophylacica Sinica **40**:379–380. [in Chinese]

Field studies was conducted in Shaanxi Province, China to determine the host status of four species of grass for cereal cyst nematode (*Heterodera avenae*). Species surveyed included *Aegilops tauschii* and *Phleum paniculatum*, which were both confirmed to be hosts for the first time. Wild oats and barley had about 9 and 10 cysts per sample compared to 13 and 11 for the two new hosts, respectively. The new host were not considered to be major host but given they both occur in fields were susceptible cereals are grown, they should be considered in integrated management of *H. avenae*. [ITR]

106. **Zong YY, Dai JL, Yuan HX, Xing XP, Sun BJ, Li HL**. 2013. Genetic analysis of resistance to cereal cyst nematode in common wheat variety Zhongyu 6. Journal of Triticeae Crops **33**:249–254. [in Chinese]

Based on previous research, the relatively high level of resistance to *Heterodera filipjevi* (Bo'ai population) and *H. avenae* (Xingyang population) had been observed in Zhongyu 6. The objectives of this research were to analyze the genetic characteristics of resistance to the

two races of cereal cyst nematode in a F2 population derived from the cross of Wenmai 19 and Zhongyu 6 by using the major gene plus polygene mixed genetic model. The results showed that the resistance of Zhongyu 6 to *H. filipjevi* (Bo'ai population) and *H. avenae* (Xingyang population) appeared to be quantitatively inherited. The resistance to *H. filipjevi* (Bo'ai population) and *H. avenae* (Xingyang population) in Zhongyu 6 was controlled by one major gene with the heritability of 38.1 and 59.4%, respectively. Both additive and dominant genetic effects controlled the resistance to *H. avenae* (Xingyang population), among which, the additive effect was the main in gene effect with negative partial dominance. While the major gene resistance to *H. filipjevi* (Bo'ai population) was displayed as completely negative dominance.

107. **Chen P, Xiang N, Xiao YN, Zhang CL, Shi L, Yu QH, Huang CY, Wang CQ**. 2014. Study on life cycle and infection dynamics of cereal cyst nematode (*Heterodera avenae*) in Xiangyang City. Acta Agriculturae Jiangxi **26**:114–117. [in Chinese]

    The occurrence and distribution of cereal cyst nematode (CCN) (*Heterodera avenae*) were investigated in Hubei Province. Through sampling in seriously diseased wheat field in Xiangyang city, we observed the morphology of *H. avenae* at different developmental stages, and studied its population dynamics. The results showed that this nematode distributed in Xiangyang, Tianmen, Qianjiang, Zhongxiang and Hanchuan. The most serious CCN disease occurred in Xiangyang, in which there were 12.5 living cysts in 100 mL soil sample. The J2 of CCN began to intrude into the young wheat roots on the 20th day after sowing,and the larvae density in the roots reached a peak on the 143rd day after sowing. The larvae in wheat roots fed, did harm, and developed to white females on the 158th day after sowing. The developed white female came out from wheat roots, and its density reached the maximum on the 174th day after sowing.

108. **Hao R, Huang WK, Liu CJ, Peng DL, Li HM, Li HX**. 2014. Effect of seed-coatings on controlling cereal cyst nematode (*Heterodera avenae*) of wheat. Plant Protection **40**:182–186. [in Chinese]

    Effects of six kinds of seed-coatings, Gannong seed coating I, Gannong seed coating II, Gannong seed coating III, abamectin seed coating AV1, abamectin seed coating AV2 and 5.7% emamectin benzoate, on controlling cereal cyst nematode (*Heterodera avenae*) of wheat, were evaluated in this study. Wheat seeds were treated with eight different seed-coatings before sowing and the changes in number of cysts in soil and wheat yield were compared after harvesting. The results showed that the numbers of cysts in soil with different treatments were clearly dropped after seed-coating. When treated by Gannong seed coating III (1:35), Gannong seed coating I (1:50) and Gannong seed coating II (1:35), the cyst reducing rates were 56, 53 and 47%, respectively. Compared with control, the wheat yields increased 37.6, 19.4, 17.9 and 17.7% treated by Gannon seed coating III (1:35), Gannon seed coating I (1:50), Gannon seed coating II (1:35) and Gannon seed coating I (1:35) respectively. Gannon seed coating III demonstrated the best control efficacy, with the characteristics of environmental safety, lower toxicity, labor and cost saving, which is suitable for wide application in practical disease control.

109. **Jing BX, He Q, Wu HY, Peng DL**. 2014. Seasonal and temperature effects on hatching of *Heterodera avenae* (Shandong population, China). Nematology **16**:1209–1217. [in English]

    The cereal cyst nematode (CCN; *Heterodera avenae*) is a serious nematode pest, causing yield losses in cereals. This research aimed to investigate the effect of season on the aging of cysts and hatching of *H. avenae* in laboratory and field experiments. In the laboratory experiment, no second-stage juveniles (J2) emerged from white cysts that were incubated at

different temperatures. However, the aging of cysts was related to temperature, since the browning of white cysts accelerated at higher temperatures. In the field experiment, hatching peaked from November to March with hatching from 84.5% of cysts sampled during this period. The population of J2 in soil samples peaked during March. Although the hatching pattern from encysted eggs was similar to that recorded from free eggs (eggs released from cysts), their hatching rate was higher than that of free eggs. In a field that was naturally infested with CCN, the number of eggs that were present in cysts was significantly greater from soil samples obtained from May to November than in cysts from samples obtained during other periods of the year. Although cysts were extracted from soil samples from the nematode-infested soil all year round, no eggs or J2 were present in cysts that were obtained during April. The number of cysts recorded from soil samples substantially increased during May. The information available as a result of this study will be useful for the application of control methodologies to decrease field populations of *H. avenae* below the economic damage threshold.

110. **Li XH, Ma J, Chen SL, Gao B, Wang RY**. 2014. Vertical and horizontal distribution of *Heterodera avenae* in the field. Plant Protection **40**:140–143. [in Chinese]

In order to understand the vertical and horizontal distribution of *Heterodera avenae* in the field, the field plots was intensively sampled according to Z pattern for *Heterodera avenae* to quantify the vertical and horizontal distribution of the population after and before soil tillage, respectively. The results showed that the horizontal distribution of *H. avenae* in field was aggregated distribution, and tillage had little effect on the horizontal distribution. Before soil tillage, the vertical distribution of *H. avenae* was mainly in 5-10 cm of sampling soil, accounting for 35.8% of the total number of cysts. After tillage, the number of cysts of *H. avenae* mainly changed in 0-15 cm soil in the vertical distribution of field, dropped in 0-10 cm but increased in 10-15 cm. In the upper soil layer of 0-20 cm, cysts before tillage and after tillage accounted for the total number of 89.4 and 88.6%, respectively.

111. **Li XH, Ma J, Gao B, Wang RY, Chen SL**. 2014. Characterization of the pathotypes of the cereal cyst nematode, *Heterodera avenae*, in Hebei Province. Plant Protection **40**:127–131. [in Chinese]

The pathotypes of four populations of the cereal cyst nematode *Heterodera avenae* Wolenweber in Handan, Baoding, Renqiu and Tangshan, the primary wheat production areas in Hebei Province, were identified using 27 cultivars of international differential host set and two susceptible cultivars, namely Shixin733 and Wenmai 4. The results showed that the pathotypes of these populations were different from the 16 pathotypes which had been nominated. Tangshan population was a pathotype that was similar to the pathotype reported from Taigu population in Shanxi and Guzhen population in Anhui. Handan population, Baoding population and Renqiu population belonged to the same pathotype, similar to the pathotype reported from Dingzhou population. Cultivar Shixin 733 and cultivar Wenmai 4 used as the control were susceptible to all four populations.

112. **Liang XD, Zhang L, Guan TL, Hu XB, Wang X, Li HM**. 2014. Effects of initial population density of *Heterodera avenae* on nematode reproduction and wheat growth and yield. Journal of Triticeae Crops **34**:1136–1140. [in Chinese]

Cyst nematode *Heterodera avenae* is an important parasitic nematode on cereal crops. Clarifying the relationship between its initial population density (Pi) and wheat growth is critical to designing the integrated strategies for its control. During two growth seasons of winter wheat in year 2011-2013, the effects of initial population density of *H. avenae* on nematode reproduction and growth of wheat were evaluated in pot experiments under nature

condition.The results showed that the reproduction factor (Rf) of *H. avenae* was decreased with the increasing density of *H. avenae*. The reproduction factor was 8.7 when Pi was 0.5 egg·mL^{-1} soil, while Rf was 2.8 when Pi was 64 eggs·mL^{-1} soil. The plant height, aerial shoot dry weight, root dry weight and grain yield were also decreased, which showed a negative relationship Pi. The wheat growth and grain yield decreased significantly when Pi was higher than 8 eggs·mL^{-1} soil. Therefore, control measures should be carried out in wheat field when nematode density is higher than this economic limit value.

113. **Liu YK, Huang WK, Long HB, Peng H, He WT, Peng DL**. 2014. Molecular characterization and functional analysis of a new acid phosphatase gene (*Ha-acp1*) from *Heterodera avenae*. Journal of Integrative Agriculture **13**:1303–1310. [in English]

For sedentary endo-parasitic nematodes, parasitism genes encoding secretory protein expressed in the subventral glands cells always play an important role during the early parasitic process. A new acid phosphatase gene (*Ha-acp1*) expressed in the subventral glands of the cereal cyst nematode (*Heterodera avenae*) was cloned and the characteristics of the gene were analyzed. Results showed that the gene had a putative signal peptide for secretion and *in situ* hybridization showed that the transcripts of *Ha-acp1* accumulated specifically in the subventral gland cells of *H. avenae*. Southern blot analysis suggested that *Ha-acp1* belonged to a multigene family. RT-PCR analysis indicated that this transcription was strong at the pre-parasitic juveniles. Knocking down *Ha-acp1* using RNA interference technology could reduce nematode infectivity by 50%, and suppress the development of cyst. Results indicated that *Ha-acp1* could play an important role in destroying the defense system of host plants.

114. **Wang XK, Zhao HH, Li M, Liu RJ**. 2014. Interactions between arbuscular mycorrhizal fungi and cereal cyst nematode. Acta Phytopathologica Sinica **44**:97–106. [in Chinese]

Arbuscular mycorrhizal fungi (AMF), as one kind of the environmental functioning organisms, have the dual role of biocide and fertilizer, which not only enhance nutrient absorption and utilization by host plants, but also antagonize soil-borne pathogens and improve plant disease resistance. In recent years, cereal cyst nematode (CCN) disease on wheat (*Triticum aestivum*) become serious and the new biocontrol approach needs to be explored. The purpose of this study was to clarify the interaction relationship between AMF and CCN; evaluate the effects of different AMF suppressing CCN and reducing disease. Pot experiments were carried with 12 treatments: inoculation with AMF *Gigaspora margarita* (Gi.m), *Glomus mosseae* (G.m), *Glomus intraradices* (G.i), *Glomus versiforme* (G.v), Gi.m +G.m+G.i+G.v, CCN, CCN+Gi.m, CCN+G.m, CCN+G.i, CCN+G.v, CCN+Gi.m+G. m+G.i +G.v and non-inoculation control (CK). The results showed that the treatments with AMF reduced CCN infection rate, cyst numbers in the soil and J2 numbers in the root and Gi. m treatment was the best. CCN reduced the numbers of AMF entry points and spores. The arbuscule colonization percentage in Gi.m and CCN +Gi.m treatments was the highest. The activity of superoxide dismutase (SOD), phenylalanine ammonia-lyase (PAL), and catalase (CAT) in roots inoculated with CCN+Gi.m were significantly higher than that in the other treatments, while the content of malondialdehyde (MDA) was lower than that in the other CCN+AMF treatments. The plant height, stems and leaves dry weight of plants inoculated with Gi.m or G.i were higher than that in the other treatments; the weight per ear and yield per plant treated with Gi. m, or CCN +Gi.m were higher than other treatments. That showed AMF could inhibit CCN, enhance wheat growth and increase yield in some degree, and Gi.m was superior. It was suggested there was negative interactions between AMF and CCN; and AMF can antagonize CCN through inducing defense reactions.

115. **Wu HY, He Q, Liu J, Luo J, Peng DL**. 2014. Occurrence and development of the cereal cyst nematode (*Heterodera avenae*) in Shandong, China. Plant Disease **98**:1654–1660. [in English]

The cereal cyst nematode (CCN), *Heterodera avenae*, has been found in 16 provinces of China, including the Shandong winter-wheat-growing region. This study investigated the population dynamics of *H. avenae* in the winter wheat "Jimai 22" and "Tainong 18" for two consecutive years in the field. Soil and root samples were collected during the winter-wheat-growing season and *H. avenae* population densities and life-stages determined. *H. avenae* population dynamics in roots and soil of the two winter wheat cultivars were similar over the 2-year period. Second-stage juvenile (J2) population densities in wheat roots were greatest during booting stage (April), when mean soil temperature was between 11.8 and 14.4°C. Cysts in rhizosphere soil increased significantly when new cysts were formed after Zadoks (Z) 47 (booting stage). There was a peak in J2 population densities in soil during Z23 and Z30 (tillering and stem elongation, respectively) whereas J2 population densities were the lowest at Z13 (seedling stage). This research provides important information indicating that J2 populations in roots and soil increased after the wheat winter dormancy period. Knowledge of when different life stages of *H. avenae* occur in winter wheat in Shandong will provide valuable insights to enable the development of an integrated approach to manage this plant-parasitic nematode.

116. **Xing XP, Yang J, Yuan HX, Zhang JJ, Li HL, Liu WZ**. 2014. Resistance to *Heterodera filipjevi* in *Triticum aestivum-Aegilops geniculata* germplasm. Acta Agronomica Sinica **40**:1956–1963. [in Chinese]

Heterodera filipjevi is a pathogenic nematode of wheat newly discovered in Huang-Huai Plain of China. However, germplasm resistant to *H. filipjevi* has been rarely found in genus *Triticum*. To mine resistance genes from wheat relative species, we identified the resistance to *H. filipjevi* in 34 accessions of *Aegilops geniculata* by inoculating *H. filipjevi* Xuchang population with mean of female number per plant method and relative resistance index method in greenhouse. Six candidates of germplasm were identified including PI542187 with high resistance and other five accessions (PI564186, PI573396, PI374365, PI361880 and PI374365) with resistance. A set of Chinese Spring (CS) *Ae. geniculata* addition lines were used to chromosomally locate the resistance gene(s). Lines 7Ug and 5Mg showed obviously fewer females per plant than CS. In two consecutive years, 17 CS *Ae.geniculata* 5Mg-5D translocation lines were further tested for resistance against *H. filipjevi*. Lines 5Mg464, 5Mg466, and 5Mg457 exhibited resistance to *H. filipjevi*.

117. **Xing XP, Yuan HX, Sun JW, Zhang J, Sun BJ, Li HL**. 2014. Resistance to two species of cereal cyst nematode and evaluation methods in major wheat cultivars from Henan Province, China. Acta Agronomica Sinica **40**:805–815. [in Chinese]

Resistance to cereal cyst nematode (CCN) is an important breeding target in wheat. In this study, we evaluated the resistance to CCN Xingyang population (*Heterodera avenae*) and Xuchang population (*H. filipjevi*) in 47 wheat cultivars from Henan Province, China through greenhouse and field tests. The CCN resistance was evaluated by the methods of average number of white female per plant, relative resistance index (RRI) and Pf/Pi ratio. All cultivars were susceptible to *H. avenae* and *H. filipjevi* evaluated by average number of white female per plant after artificial inoculation in greenhouse. However, Taikong 6, Xinmai 11, Zhongyu 6, and Xinmai 18 showed resistance to *H. avenae* based on RRI evaluation. In field test, when evaluated with average number of white female per plant, there were a few resistant cultivars, including Taikong 6 and Xinmai 18 with high resistance and 10 cultivars (such as Zhongyu 6 and Xinmai 11) with moderate resistance to *H. avenae*, and Zhongyu 6

and Taikong 6 with high resistance and three cultivars (Yanzhan 4110, Pumai 9 and Yunong 201) with moderate resistance to *H. filipjevi*. The result of RRI evaluation showed that Taikong 6 was highly resistant to *H. avenae*, and Xinmai 18, Zhongyu 6 and Xinmai 11 were resistant to *H. avenae*; Zhongyu 6 and Taikong 6 were highly resistant to *H. filipjevi* and 4 cultivars (Yanzhan 4110, Pumai 9, Yunong 201 and Yunong 949) were resistant to *H. filipjevi*. Using Pf/Pi ratio as the evaluation index, four cultivars (Taikong 6, Xinmai 11, Zhongyu 6, and Xinmai 18) were resistant to *H. avenae*, and four cultivars (Taikong 6, Zhongyu 6, Pumai 9, and Puyou 938) were resistant to *H. filipjevi*. The resistance evaluation based on RRI method was partially identical to that based on white female number per plant method, and RRI method has the advantage to reduce the great evaluation error among susceptible cultivars. This method can be considered in CCN resistance evaluation in wheat.

118. **Yuan HX, Yan HT, Sun BJ, Xing XP, Li HL**. 2014. Infection dynamics of two species of cereal cyst nematode in Zhengzhou, Henan Province. Acta Phytopathologica Sinica **44**:74–79. [in Chinese]

The cereal cyst nematode has become one of the serious diseases of wheat in recent years in China. The basic work for disease control is to clarify the infection dynamics of pest nematodes. In this study, the infection dynamics of two species of cereal cyst nematode, *Heterodera avenae* and *H. filipjevi* were assessed under field conditions in Zhengzhou of Henan. The results indicated that the wheat roots were infected by the second stage juveniles (J2s) two weeks after planting. A few of J2s developed into J3 subsequently. The first infection peak of J2s appeared at the sixth weeks after planting, and a few of the fourth stage juveniles were found in wheat roots at the same time. As the temperature decreased after 60 days of planting in the winter, the number of juvenile at different stages remained stable. As the temperature increased in the spring at 120 days after planting, the number of the second stage juveniles in roots started to increase and reached the second peak in late March and early April (150 days after planting), with fewer nematodes than those in the first infection peak. Duration of the second peak is also much shorter than the first one. Finally the larva gradually developed into white females and cysts. The infection dynamics of two CCN species are almost same, but J3, J4 and white females of *H. filipjevi* appeared one week earlier than *H. avenae*. These results provided the essential information for the control of cereal cyst nematode of wheat.

119. **Zhang J, Li SX, Ren YP, Liu F**. 2014. Effect of the cereal cyst nematode, *Heterodera avenae*, on wheat yield in Shandong Province. Acta Phytophylacica Sinica **41**:242–247. [in Chinese]

The pot and field trials were conducted to evaluate the impact of *Heterodera avenae* Wollenweber on wheat yield, and the yield loss of conventional wheat cultivars in Shandong Province under different initial inoculation density of *H. avenae* was measured. The results indicated that, in pot trials, agronomic traits of wheat were significantly influenced by *H. avenae*. When the initial inoculation density of eggs/g of soil ranged from 5 to 30, the chlorophyll contents of wheat leaves, dry weight of roots, dry weight of stems, number of spikes, grain numbers, weight of 1000 kernels and weight of spikes reduced from 10.9 to 34.5%, 30.7 to 74.0%, 13.9 to 58.7%, 30.5 to 53.3%, 4.0 to 36.9%, -3.7 to 1.3% and -0.7 to 35.1%, respectively, compared with the untreated control. However, under ideal field conditions (e.g., abundant water and fertilizer), no significant impact of *H. avenae* on production indexes of wheat was found,indicating that the propagation coefficient of *H. avenae* was negatively correlated with the initial egg density. Overall, the occurrence of *H. avenae* was a potential threat to wheat production, and when control measures were proposed, water and fertilizer conditions should be seriously considered, with an eye to their effects on the medium- and low-yield fields.

120. **Zhang SW, Xu BL, Xue YY, Gu LJ**. 2014. Lethal effects of *Trichoderma longibrachiatum* on *Heterodera avenae*. Chinese Journal of Applied Ecology **25**:2093–2098. [in Chinese]

The lethal effect of the conidia suspension of *Trichoderma longibrachiatum* against second stage juveniles of *Heterodera avenae* was observed under microscopic conditions and studied *in vitro* to preliminarily determine the potential and mechanism of the conidia suspension of *T. longibrachiatum* against *H. avenae*. Microscopic observation results showed that the conidia suspension of *T. longibrachiatum* adhered to or parasitized on the surface of second stage juveniles, even some parasitized nematodes were deformed at the initial stage. Later, the second stage juveniles were wrapped and the integuments were penetrated by a large number of hyphae germinated from the conidia suspension of *T. longibrachiatum*. Even the body of dead second stage juveniles was completely lysed. In vitro studies showed that different concentrations (1.5×10^5 - 1.5×10^7) cfu·mL-1) of *T. longibrachiatum* (conidia suspension) had strong lethal and parasitic effects on the second stage juveniles of *H. avenae*, and significant differences existed among the treatments with different concentrations of *T. longibrachiatum*. In addition, the lethal and parasitic effects increased with increasing the *T. longibrachiatum* concentration. The mortality and corrected mortality of the second stage juveniles treated with the concentrations of 1.5×10^7 cfu·mL-1 were 91.3 and 90.4% after 72 hours, and the second stage juveniles were parasitized by 88.7% after 14 days. Therefore, the conidia suspension of *T. longibrachiatum* had a great lethal effect on *H. avenae*,and the strain could be considered as a potential bio-control agent against *H. avenae*.

121. **Zhang SW, Xu BL, Xue YY, Liu J**. 2014. Parasitic and lethal action of *Trichoderma longibrachiatum* against *Heterodera avenae*. Acta Microbiologica Sinica **54**:793–802. [in Chinese]

To evaluate the potential of *Trichoderma longibrachiatum* spore suspension against *Heterodera avenae*. The parasitic and lethal effects of *T. longibrachiatum* spore suspension against the cysts of *H. avenae* were studied *in vitro* and observed under microscope. Microscopic observation showed that the spore suspension of *T. longibrachiatum* parasitized on the cyst surface, germinated a large number of hyphae, and grew on the surface of the cyst at the initial stage. Later, the cysts were completely surrounded by dense mycelium, and the contents of digestion in cysts was lysed, even some cysts produced vacuoles, and some were split up and finally the cyst was dissolved by the metabolite of *T. longibrachiatum*. In vitro studies showed that high concentrations of *T. longibrachiatum* spores had strong parasitic and lethal effects on the cysts of *H. avenae*, and the probable mechanism of parasitic and lethal effects of *T. longibrachiatum* against *H. avenae* were mainly by inducing and increasing chitinase, glucanase and caseinase activity. The cysts were parasitized by 93.3% at 18 days, the hatching of cysts were inhibited by 93.6% at 10 days when treated with the concentrations (1.5×10^8 CFU/mL) of *T. longibrachiatum*. *Trichoderma longibrachiatum* had strong parasitic and lethal effects on the cysts of *H. avenae*, and has the potential as a new biocontrol agent.

122. **Zhao HH, Ding HY, Peng DL**. 2014. Variation of population dynamics of *Heterodera avenae* in wheat field in Jiaozhou of Shandong Province among different years. Journal of Triticeae Crops **34**:563–567. [in Chinese]

In order to detect the field infection process and the population dynamics of cereal cyst nematode(*Heterodera avenae*, CCN) in different years,and to know the relationships between them and temperature/humidity, the soil and root samples were collected periodically from a positioned wheat block in Jiaozhou City, Shandong Province during the two wheat growing seasons of 2011-2012 and 2012-2013. The population densities (PD) and

dynamics were ascertained through the microscopic examination of the cysts and juveniles extracted from soil and stained in roots. The results showed that the cyst PD in soil reduced by 85.9% after wheat harvesting in 2013 than in 2012. Compared with the same stage of 2012, the 2nd stage juveniles (J2) of CCN emerged into soil earlier in the spring of 2013, but they penetrated into wheat roots later, with much higher PD in soil and much lower PD in roots. The juvenile development performed abnormally in roots by the 3rd and 4th stage juveniles occurring later, lasting a shorter period of time, without obvious occurrence peak and with prolonged lower PD. By the comparative analysis between the meteorological data and CCN population dynamics, it was indicated that the soil drought condition was related to the delayed penetration and lower penetration ratio of J2 in March and April, the lower air temperatures were related to the abnormal development of the juveniles inside roots in April and May. It was inferred to be the drought and lower temperatures occurring in the critical stages of CCN invasion and development respectively that caused the obvious reduction of CCN cyst PD in 2013.

123. **Zhao J, Ding HY**. 2014. Investigation on the occurrence of *Heterodera avenae* during fall and winter seasons in Shandong Province. Journal of Qingdao Agricultural University (Natural Science) **31**:100–104. [in Chinese]

In order to probe into the emergence and infection situations of cereal cyst nematode (*Heterodera avenae*, CCN) during fall (autumn) and winter seasons in Shandong Province, fixed-block systematic monitoring was carried out in one CCN-diseased field of Chengyang district, Qingdao city from October to December in the years of 2009-2013, and non-systematic investigations were proceeded with random sampling for 52 CCN-diseased field times in 2009, 2012 and 2013 in partial regions of Shandong province. The results of the systematic monitoring showed that the second stage juvenile (J2) of CCN emerged into soil the earliest in December in 2009, 2012 and 2013, but no emergence occurred from October to December in 2010 and 2013. It was indicated that there was a certain relationship between CCN emergence in December and air temperature of November, emergence would occur or its probability would be high in the years which had a mean temperature below 10°C in November. It was found in the non-systematic investigations that there was no emergence of J2 in the total 10 diseased fields from October to December in 2010, but J2 emerged into soil in partial diseased fields in December of 2012 and 2013 with the J2 emerging field ratio of 90% and 59%, respectively. The J2 emerging field ratios were much different among prefecture-level cities in 2013, being high in Heze and Yantai and low in Qingdao and Weifang cities. Wheat root penetrated J2 was detected neither in the systematic monitoring nor in the non-systematic investigations.

Additional references

References cited but not included in the bibliography.

Jensen HJ, Eshtiaghi H, Koepsell PA, Goetze N. 1975. The oat cyst nematode, *Heterodera avenae*, occurs in oats in Oregon. Plant Disease Reporter **59**:1–3.

Meagher JW. 1977. World dissemination of the cereal-cyst nematode (*Heterodera avenae*) and its potential as a pathogen of wheat. Journal of Nematology **9**:9–15.

Namouchi-Kachouri N, B'Chir MM. 2005. Identification morphometrique et moleculaire de quelques populations Tunisiennes d'*Heterodera avenae* associées aux céréales. Nematologia Mediterranea **33**:3–9.

Nicol JM, Burgess LW, Riley IT, Wallwork H. 2010. The ATSE Crawford International Master Class Series on soil-borne pathogens of wheat, p. 97–111. *In* Gupta, VVSR, Ryder, M, Radcliff, J (eds.), The Rovira Rhizosphere Symposium - Celebrating 50 years of Rhizosphere research. ATSE Crawford Fund, Deakin ACT, Australia.

Nicol JM, Rivoal R. 2008. Global knowledge and its application for the integrated control and management of nematodes on wheat, p. 251–294. *In* Ciancio, A, Mukerji, KG (eds.), Integrated Management and Biocontrol of Vegetable and Grain Crops Nematodes. Springer, Dordrecht, the Netherlands.

Riley IT, McKay AC. 2009. Cereal cyst nematode in Australia: biography of a biological invader, p. 23–28. *In* Riley, IT, Nicol, JM, Dababat, AA (eds.), Cereal cyst nematodes: status, research and outlook. CIMMYT, Ankara, Turkey.

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