Supplementary Materials for

Phylogeography of Chinese cereal cyst nematodes sheds lights on their origin and dispersal

Xue Qing, Huan Peng, Jukui Ma, Y. Miles Zhang, Hongmei Li,* Deliang Peng,* Xuan Wang,* Tengwen Long

*Corresponding authors, Emails: lihm@njau.edu.cn, dlpeng@ippcaas.cn, xuanwang@njau.edu.cn.
Part 1: Sampling information

Fig. S1. The survey of cereal cyst nematodes in the soil attached to harvester machine. (A and B) Typical machinery harvester used in Hebei and Henan provinces of China. (C and D) Sampling of soil attached to reels and wheels of harvester machine.

Table S1. The positive sampling locations and corresponding recovered cyst densities. CD = cysts number per 100 g soil. Ab = abbreviations for the sampling provinces and locations. Abbreviations: JSXZ = Xuzhou, Jiangsu; JSTC = Taicang, Jiangsu; JSNT = Nantong, Jiangsu; HN = Henan, SD = Shandong; AH = Anhui; HD = Hebei; SX = Shanxi; SS = Shaanxi; GS = Gansu; QH = Qinghai; BJ = Beijing; TJ = Tianjin; NM = Neimeng; NX = Ningxia; HB = Hubei; TZ = Tianzhu; OYR = old courses of Yellow River. Asterisk (*) donate the sites failed to acquire mtCOI.
| No. | Sampling locality               | Latitude  | Longitude  | CN  | Ab |
|-----|---------------------------------|-----------|------------|-----|----|
| 1   | Zhangjizhen, Tongshan, Xuzhou, Jiangsu | 34.2421   | 117.5826   | 16.0 |    |
| 2   | Fangcun, Tongshan, Xuzhou, Jiangsu   | 34.1206   | 117.7842   | 13.7 |    |
| 3   | Liuji, Tongshan, Xuzhou, Jiangsu    | 34.6065   | 117.0234   | 7.0  |    |
| 4   | Liuji, Tongshan, Xuzhou, Jiangsu*  | 34.6082   | 117.0013   | 17.0 |    |
| 5   | Liuji, Tongshan, Xuzhou, Jiangsu    | 34.6614   | 117.6156   | 24.0 |    |
| 6   | Liuji, Tongshan, Xuzhou, Jiangsu    | 34.6636   | 117.5997   | 33.3 |    |
| 7   | Heqiao, Tongshan, Xuzhou, Jiangsu   | 34.7483   | 117.5304   | 8.0  |    |
| 8   | Heqiao, Tongshan, Xuzhou, Jiangsu   | 34.3342   | 117.0253   | 45.0 |    |
| 9   | Heqiao, Tongshan, Xuzhou, Jiangsu   | 34.7710   | 117.3648   | 9.3  |    |
| 10  | Huangji, Tongshan, Xuzhou, Jiangsu  | 34.3926   | 116.9520   | 73.7 |    |
| 11  | Liuji, Tongshan, Xuzhou, Jiangsu    | 35.1082   | 117.5301   | 4.0  |    |
| 12  | Dashahe, Fengxian, Xuzhou, Jiangsu  | 35.1095   | 117.1234   | 8.3  |    |
| 13  | Huashan, Fengxian, Xuzhou, Jiangsu  | 35.0849   | 117.1556   | 3.0  |    |
| 14  | Huashan, Fengxian, Xuzhou, Jiangsu  | 35.0407   | 117.2444   | 2.5  |    |
| 15  | Fanlou, Fengxian, Xuzhou, Jiangsu   | 34.7888   | 117.4303   | 30.3 |    |
| 16  | Hekou, Fengxian, Xuzhou, Jiangsu    | 34.9803   | 117.3286   | 13.7 |    |
| 17  | Qishan, Fengxian, Xuzhou, Jiangsu   | 35.0946   | 117.3485   | 12.3 |    |
| 18  | Qishan, Fengxian, Xuzhou, Jiangsu   | 35.1461   | 117.3520   | 17.3 |    |
| 19  | Changdian, Fengxian, Xuzhou, Jiangsu| 35.2061   | 116.8650   | 11.0 |    |
| 20  | Zhaozhuang, Fengxian, Xuzhou, Jiangsu| 35.2159  | 116.8136   | 15.0 |    |
| 21  | Zhaozhuang, Fengxian, Xuzhou, Jiangsu| 35.2320  | 116.7126   | 9.7  |    |
| 22  | Wanggou, Fengxian, Xuzhou, Jiangsu  | 35.0413   | 116.7473   | 16.3 |    |
| 23  | Wanggou, Fengxian, Xuzhou, Jiangsu  | 35.0888   | 116.7567   | 35.7 |    |
| 24  | Songlou, Fengxian, Xuzhou, Jiangsu  | 35.0140   | 116.8334   | 81.3 |    |
| 25  | Liangzhai, Fengxian, Xuzhou, Jiangsu| 35.0792   | 116.9498   | 1.7  |    |
| 26  | Liangzhai, Fengxian, Xuzhou, Jiangsu| 35.1624   | 116.9791   | 3.7  |    |
| 27  | Xuzhuang, Fengxian, Xuzhou, Jiangsu | 34.3018   | 117.4629   | 27.0 |    |
| 28  | Xuzhuang, Fengxian, Xuzhou, Jiangsu | 34.4730   | 117.3184   | 34.3 |    |
| 29  | Liuzhuang, Fengxian, Xuzhou, Jiangsu| 35.5091   | 117.3668   | 4.0  |    |
| 30  | Xiaolizhuang, Fengxian, Xuzhou, Jiangsu| 35.0140 | 116.8334   | 4.7  |    |
| 31  | Hekou, Peixian, Xuzhou, Jiangsu     | 34.9949   | 117.3003   | 15.3 |    |
| 32  | Jingan, Peixian, Xuzhou, Jiangsu    | 34.8860   | 117.4353   | 60.0 |    |
| 33  | Lulou, Peixian, Xuzhou, Jiangsu     | 35.2348   | 117.2042   | 10.0 |    |
| 34  | Lulou, Peixian, Xuzhou, Jiangsu     | 35.3037   | 117.1677   | 9.3  |    |
| 35  | Shuanggou, Zining, Xuzhou, Jiangsu  | 34.0385   | 118.0663   | 32.0 |    |
| 36  | Wangji, Zining, Xuzhou, Jiangsu     | 34.6263   | 118.2320   | 10.3 |    |
| 37  | Lanshan, Zining, Xuzhou, Jiangsu    | 34.5122   | 118.2148   | 54.3 |    |
| 38  | Taoyuan, Zining, Xuzhou, Jiangsu    | 34.3944   | 118.3019   | 32.0 |    |
| 39  | Zhuzhai, Peixian, Xuzhou, Jiangsu   | 34.7335   | 116.8119   | 3.0  |    |
| No. | Sampling locality                      | Latitude  | Longitude | CN | Ab |
|-----|---------------------------------------|-----------|-----------|----|----|
| 40  | Zhuzhai, Peixian, Xuzhou, Jiangsu     | 34.7564   | 116.8317  | 37.7 |    |
| 41  | Yuanyanglou, Peixian.Xuzhou, Jiangsu  | 34.7827   | 116.7180  | 23.7 |    |
| 42  | Fengxian, Xuzhou, Jiangsu             | 34.7103   | 116.6994  | 6.0  |    |
| 43  | Fengxian, Xuzhou, Jiangsu             | 34.7103   | 116.6994  | 14.3 |    |
| 44  | Fengxian, Xuzhou, Jiangsu*            | 34.6776   | 116.6707  | 27.7 |    |
| 45  | Tongsan, Xuzhou, Jiangsu              | 34.6712   | 116.6537  | 53.7 |    |
| 46  | Tongsan, Xuzhou, Jiangsu              | 34.6467   | 116.7001  | 9.3  |    |
| 47  | Tongsan, Xuzhou, Jiangsu              | 34.0729   | 117.5029  | 9.7  |    |
| 48  | Zining, Xuzhou, Jiangsu               | 33.9309   | 117.8041  | 43.0 |    |
| 49  | Zining, Xuzhou, Jiangsu               | 33.9316   | 117.7472  | 16.3 |    |
| 50  | Zining, Xuzhou, Jiangsu*              | 33.9899   | 117.7829  | 8.3  |    |
| 51  | Pizhou, Xuzhou, Jiangsu               | 34.4367   | 117.9596  | 3.0  |    |
| 52  | Pizhou, Xuzhou, Jiangsu               | 34.4657   | 117.9492  | 0.7  |    |
| 53  | Pizhou, Xuzhou, Jiangsu               | 34.4685   | 117.9626  | 6.3  |    |
| 54  | Xiyi, Xuzhou, Jiangsu                | 34.2891   | 118.2845  | 2.3  |    |
| 55  | Xinyi, Xuzhou, Jiangsu               | 34.2891   | 118.2845  | 66.3 |    |
| 56  | Longhe, Suqian, Jiangsu              | 33.8666   | 118.2583  | 2.0  |    |
| 57  | Siyang, Suqian, Jiangsu              | 33.5588   | 118.3678  | 33.3 |    |
| 58  | Siyang, Suqian, Jiangsu*             | 33.6875   | 118.6284  | 1.0  |    |
| 59  | Siyang, Suqian, Jiangsu              | 33.7507   | 118.6284  | 25.3 |    |
| 60  | Siyang, Suqian, Jiangsu              | 33.8673   | 118.7365  | 33.7 |    |
| 61  | Siyang, Suqian, Jiangsu              | 33.9583   | 118.7253  | 1.7  |    |
| 62  | Tonglibeilian, Wujiang, Suzhou, Jiangsu | 31.2879 | 121.2008  | 3.2  |    |
| 63  | Yangshe, Zangjiagang, Suzhou, Jiangsu | 31.9288 | 120.5206  | 11.0 |    |
| 64  | Changyinsha, Zangjiagang, Suzhou, Jiangsu | 31.8791 | 120.7845  | 5.3  |    |
| 65  | Guli, Changsu, Suzhou, Jiangsu        | 31.5818   | 120.8730  | 2.8  |    |
| 66  | Shuangfengtangdong, Taicang, Suzhou, Jiangsu | 31.5255 | 121.0468  | 68.3 |    |
| 67  | Huangjing, Taicang, Suzhou, Jiangsu   | 31.6888   | 121.0587  | 2.7  |    |
| 68  | Yushan, Kunshan, Suzhou, Jiangsu      | 31.3556   | 120.8873  | 3.0  |    |
| 69  | Qutang, Haiian, Nantong, Jiangsu      | 32.9928   | 121.3738  | 12.0 |    |
| 70  | Qutang, Haiian, Nantong, Jiangsu      | 32.5569   | 120.4408  | 3.3  |    |
| 71  | Jiaoxie, Haiian, Nantong, Jiangsu     | 32.5569   | 120.4408  | 79.3 |    |
| 72  | Jiaoxie, Haiian, Nantong, Jiangsu     | 32.5564   | 120.4401  | 4.7  |    |
| 73  | Jiaoxie, Haiian, Nantong, Jiangsu     | 32.5564   | 120.4399  | 1.3  |    |
| 74  | Huji, Haiian, Nantong, Jiangsu        | 32.5564   | 120.4398  | 21.7 |    |
| 75  | Huji, Haiian, Nantong, Jiangsu        | 32.5693   | 120.7766  | 2.3  |    |
| 76  | Yazhou, Haiian, Nantong, Jiangsu      | 32.5693   | 120.7761  | 7.7  |    |
| 77  | Laobagang, Haiian, Nantong, Jiangsu   | 32.5693   | 120.7757  | 2.4  |    |
| 78  | Laobagang, Haiian, Nantong, Jiangsu   | 32.5693   | 120.7764  | 4.3  |    |
| 79  | Laobagang, Haiian, Nantong, Jiangsu   | 32.5693   | 120.7754  | 15.0 |    |
| No. | Sampling locality                  | Latitude  | Longitude  | CN  | Ab  |
|-----|-----------------------------------|-----------|------------|-----|-----|
| 80  | Yazhou, Haian, Nantong, Jiangsu   | 32.5693   | 120.7752   | 255.0 |    |
| 81  | Yazhou, Haian, Nantong, Jiangsu   | 32.5693   | 120.7748   | 95.0  |    |
| 82  | Sunzhuang, Haian, Nantong, Jiangsu| 32.4124   | 120.3952   | 7.0   |    |
| 83  | Sunzhuang, Haian, Nantong, Jiangsu| 32.4123   | 120.3951   | 51.3  |    |
| 84  | Sunzhuang, Haian, Nantong, Jiangsu| 32.4123   | 120.3950   | 39.7  |    |
| 85  | Sunzhuang, Haian, Nantong, Jiangsu*| 32.4167   | 120.3929   | 7.3   |    |
| 86  | Sunzhuang, Haian, Nantong, Jiangsu| 32.4219   | 120.3218   | 5.3   |    |
| 87  | Sunzhuang, Haian, Nantong, Jiangsu| 32.4219   | 120.3200   | 9.7   |    |
| 88  | Wuyou, Tinghu, Yancheng, Jiangsu   | 33.4392   | 120.2698   | 1.7   |    |
| 89  | Louwang, Yandu, Yancheng, Jiangsu   | 33.5059   | 120.4373   | 202.0 |    |
| 90  | Jiangan, Yandu, Yancheng, Jiangsu   | 32.1367   | 120.4561   | 14.3  |    |
| 91  | Banjing, Rugao, Nantong, Jiangsu   | 32.3400   | 120.3950   | 5.0   |    |
| 92  | Shigang, Tongzhou, Nantong, Jiangsu| 32.1861   | 120.9601   | 5.0   |    |
| 93  | Matang, Rudong, Nantong, Jiangsu   | 32.3250   | 121.0694   | 3.7   |    |
| 94  | Huanzhen, Nantong, Jiangsu         | 32.3201   | 121.1391   | 5.0   |    |
| 95  | Laobagang, Haian, Nantong, Jiangsu | 32.5957   | 120.8243   | 1.3   |    |
| 96  | Jiaoling, Chuzhou, Huaiian, Jiangsu| 33.7232   | 119.3084   | 95.0  |    |
| 97  | Jiaoling, Chuzhou, Huaiian, Jiangsu| 33.6920   | 119.3356   | 7.3   |    |
| 98  | Shunhe, Chuzhou, Huaiian, Jiangsu   | 33.6832   | 119.3466   | 1.0   |    |
| 99  | Shunhe, Chuzhou, Huaiian, Jiangsu*| 33.6095   | 119.2642   | 49.7  |    |
| 100 | Jiqiao, Chuzhou, Huaiian, Jiangsu   | 33.6062   | 119.2555   | 9.7   |    |
| 101 | Jiqiao, Chuzhou, Huaiian, Jiangsu   | 33.6062   | 119.2555   | 4.7   |    |
| 102 | Jiqiao, Chuzhou, Huaiian, Jiangsu   | 33.5596   | 119.2174   | 20.0  |    |
| 103 | Sanbao, Chuzhou, Huaiian, Jiangsu   | 33.4579   | 119.1337   | 2.3   |    |
| 104 | Sanbao, Chuzhou, Huaiian, Jiangsu   | 33.4579   | 119.1337   | 1.3   |    |
| 105 | Fanji, Chuzhou, Huaiian, Jiangsu    | 33.3703   | 119.0773   | 66.3  |    |
| 106 | Zhuba, Hongze, Huaiian, Jiangsu     | 33.2983   | 118.9332   | 8.7   |    |
| 107 | Chahe, Hongze, Huaiian, Jiangsu     | 33.2556   | 119.0052   | 1.0   |    |
| 108 | Qianfeng, Jinhua, Huaiian, Jiangsu  | 33.1140   | 119.1436   | 37.0  |    |
| 109 | Maba, Xuyi, Huaiian, Jiangsu        | 32.9392   | 118.7754   | 2.7   |    |
| 110 | Fanchuan, Jiangdu, Yangzhou, Jiangsi | 33.0094   | 120.1321   | 21.0  |    |
| 111 | Xianyu, Jiangdu, Yangzhou, Jiangsi  | 32.6024   | 120.1919   | 12.0  |    |
| 112 | XianYuJiangdu, Yangzhou, Jiangsi    | 32.6115   | 120.2791   | 27.3  |    |
| 113 | Shaobo, Jiangdu, Yangzhou, Jiangsi  | 32.6091   | 120.2099   | 26.3  |    |
| 114 | Daqiao, Jiangdu, Yangzhou, Jiangsi  | 32.3655   | 119.7206   | 3.7   |    |
| 115 | Fanchuan, Jiangdu, Yangzhou, Jiangsi| 32.6056   | 119.6792   | 16.3  |    |
| 116 | Hanlu, Gaoyou, Yangzhou, Jiangsu    | 32.7120   | 119.6751   | 12.3  |    |
| 117 | Sanduo, Gaoyou, Yangzhou, Jiangsu   | 32.8234   | 119.6731   | 4.7   |    |
| 118 | Longqiu, Gaoyou, Yangzhou, Jiangsu  | 32.8064   | 119.5052   | 8.0   |    |
| 119 | Longqiu, Gaoyou, Yangzhou, Jiangsu  | 32.9087   | 119.5047   | 46.0  |    |
| No. | Sampling locality                              | Latitude   | Longitude  | CN  | Ab  |
|-----|-----------------------------------------------|------------|------------|-----|-----|
| 120 | Zhouwang, Gaoyou, Yangzhou, Jiangsu           | 32.9466    | 119.5045   | 18.0|     |
| 121 | Zhouxiang, Gaoyou, Yangzhou, Jiangsu          | 33.0198    | 119.5043   | 12.3|     |
| 122 | Fanshui, Baoying, Yangzhou, Jiangsu           | 33.1112    | 119.4093   | 7.7 |     |
| 123 | Xiaoguanzhuang, Baoying, Yangzhou, Jiangsu    | 33.1956    | 119.3877   | 51.0|     |
| 124 | Anyi, Baoying, Yangzhou, Jiangsu              | 33.1964    | 119.3481   | 7.0 |     |
| 125 | Wangzhigang, Baoying, Yangzhou, Jiangsu       | 33.2463    | 119.4123   | 6.3 |     |
| 126 | Liubao, Baoying, Yangzhou, Jiangsu            | 33.1431    | 119.5217   | 8.0 |     |
| 127 | Xiaji, Baoying, Yangzhou, Jiangsu             | 33.0983    | 119.5469   | 13.3|     |
| 128 | Zhongbao, Xinghua, Taizhou, Jiangsu           | 33.0877    | 119.8555   | 20.3|     |
| 129 | Lincheng, Xinghua, Taizhou, Jiangsu           | 32.8594    | 119.8610   | 3.7 |     |
| 130 | Liulu, Xinghua, Taizhou, Jiangsu              | 32.8323    | 119.8804   | 1.0 |     |
| 131 | Liulu, Xinghua, Taizhou, Jiangsu              | 32.8262    | 119.9178   | 0.7 |     |
| 132 | Xingtai, Jiangyan, Taizhou, Jiangsu*          | 32.6816    | 120.0961   | 4.3 |     |
| 133 | Xingtai, Jiangyan, Taizhou, Jiangsu           | 32.6799    | 120.0961   | 3.0 |     |
| 134 | Shengao, Jiangyan, Taizhou, Jiangsu           | 32.5457    | 120.1033   | 2.0 |     |
| 135 | Liangxu, Jiangyan, Taizhou, Jiangsu*          | 32.4520    | 120.1491   | 28.0|     |
| 136 | Liangxu, Jiangyan, Taizhou, Jiangsu           | 32.4301    | 120.0918   | 1.0 |     |
| 137 | Zhangdian, Jiangyan, Taizhou, Jiangsu         | 32.4079    | 120.0750   | 10.0|     |
| 138 | Gugao, Jiangyan, Taizhou, Jiangsu             | 32.3655    | 120.1315   | 26.7|     |
| 139 | Jichuan, Taixing, Taizhou, Jiangsu            | 32.4751    | 120.3507   | 142.3|     |
| 140 | Yuanzhu, Taixing, Taizhou, Jiangsu            | 32.3472    | 120.1708   | 80.7|     |
| 141 | Huangqiao, Taixing, Taizhou, Jiangsu          | 32.2851    | 120.2104   | 12.7|     |
| 142 | Heshi, Taixing, Taizhou, Jiangsu              | 32.1985    | 120.1151   | 11.7|     |
| 143 | Zhangqiao, Taixing, Taizhou, Jiangsu          | 32.1052    | 120.0715   | 17.7|     |
| 144 | Bilu, Jingjiang, Taizhou, Jiangsu             | 32.0745    | 120.0952   | 8.0 |     |
| 145 | Shengci, Jingjiang, Taizhou, Jiangsu          | 32.0498    | 120.1374   | 26.3|     |
| 146 | Maqiao, Jingjiang, Taizhou, Jiangsu           | 32.0409    | 120.1904   | 6.3 |     |
| 147 | Xieqiao, Jingjiang, Taizhou, Jiangsu          | 32.0399    | 120.3428   | 8.3 |     |
| 148 | Xilai, Jingjiang, Taizhou, Jiangsu            | 32.1033    | 120.4186   | 26.3|     |
| 149 | Wuyou, Tinghu, Yancheng, Jiangsu              | 33.2811    | 120.2441   | 6.7 |     |
| 150 | Guomeng, Yandu, Yancheng, Jiangsu             | 33.2593    | 120.0698   | 0.3 |     |
| 151 | Yandan, Jianhu, Yancheng, Jiangsu             | 33.3537    | 119.7371   | 1.0 |     |
| 152 | Jinhu, Jianhu, Yancheng, Jiangsu              | 33.4194    | 119.7669   | 2.0 |     |
| 153 | Zhongzhuang, Jianhu, Yancheng, Jiangsu        | 33.5328    | 119.8515   | 3.0 |     |
| 154 | Fucheng, Funing, Yancheng, Jiangsu            | 33.7446    | 119.7720   | 12.3|     |
| 155 | Shuoji, Funing, Yancheng, Jiangsu             | 33.6854    | 119.6734   | 14.7|     |
| 156 | Banhu, Funing, Yancheng, Jiangsu              | 33.6795    | 119.6344   | 7.3 |     |
| 157 | Tongyu, Binhai, Yancheng, Jiangsu             | 33.9501    | 119.8552   | 14.7|     |
| 158 | Zhonghong, Binhai, Yancheng, Jiangsu          | 33.8824    | 119.8604   | 1.0 |     |
| 159 | Zhonghong, Binhai, Yancheng, Jiangsu          | 33.8497    | 119.8269   | 5.3 |     |
| No. | Sampling locality                        | Latitude  | Longitude | CN | Ab |
|-----|------------------------------------------|-----------|-----------|----|----|
| 160 | Liutao, Xiangshui, Yancheng, Jiangsu     | 34.1116   | 119.7880  | 8.0|    |
| 161 | Qitao, Xiangshui, Yancheng, Jiangsu     | 34.1386   | 119.8210  | 2.3|    |
| 162 | Lianyungang, Jiangsu                    | 34.2092   | 119.2260  | 2.3|    |
| 163 | Shahe, Ganyu, Lianyungang, Jiangsu      | 34.7262   | 118.9311  | 1.0|    |
| 164 | Shilianghe, Ganyu, Lianyungang, Jiangsu | 34.7648   | 118.9248  | 1.0|    |
| 165 | Hongzhuan, Donghai, Lianyungang, Jiangsu| 34.4921   | 118.5975  | 1.0|    |
| 166 | Jialou, Xuzhou, Jiangsu                 | 34.3143   | 116.9813  | 2.5|    |
| 167 | Jialou, Xuzhou, Jiangsu                 | 34.3143   | 116.9813  | 3.0|    |
| 168 | Dapeng, Xuzhou, Jiangsu                 | 34.2678   | 117.0417  | 11.3|   |
| 169 | Dapeng, Xuzhou, Jiangsu                 | 34.2512   | 117.0386  | 5.7|    |
| 170 | Dapeng, Xuzhou, Jiangsu                 | 34.2326   | 117.0416  | 2.0|    |
| 171 | Dapeng, Tongshan, Xuzhou, Jiangsu       | 34.2326   | 117.0416  | 2.0|    |
| 172 | Dapeng, Tongshan, Xuzhou, Jiangsu       | 34.2561   | 117.0809  | 3.0|    |
| 173 | Sanbao, Tongshan, Xuzhou, Jiangsu       | 34.0902   | 117.1964  | 12.0|   |
| 174 | Xiaoxian, Suzhou, Anhui                 | 34.1164   | 117.1250  | 3.0|    |
| 175 | Tangzhang, Xuzhou, Jiangsu              | 34.1017   | 117.2605  | 2.5|    |
| 176 | Tangzhang, Xuzhou, Jiangsu              | 34.1017   | 117.2605  | 16.0|   |
| 177 | Shuyang, Suqian, Jiangsu                | 34.1482   | 118.7359  | 5.3|    |
| 178 | Shuyang, Suqian, Jiangsu                | 34.1482   | 118.7359  | 2.3|    |
| 179 | Shuyang, Suqian, Jiangsu                | 34.1482   | 118.7359  | 1.0|    |
| 180 | Shuyang, Suqian, Jiangsu                | 34.1489   | 118.7418  | 32.3|   |
| 181 | Shuyang, Suqian, Jiangsu                | 34.1608   | 118.8348  | 22.3|   |
| 182 | Shuyang, Suqian, Jiangsu                | 34.1526   | 118.8603  | 20.0|   |
| 183 | Shuyang, Suqian, Jiangsu                | 34.1526   | 118.8603  | 15.3|   |
| 184 | Guannan, Lianyungang, Jiangsu           | 34.1977   | 119.2252  | 42.5|   |
| 185 | Guannan, Lianyungang, Jiangsu           | 34.1977   | 119.2252  | 35.0|   |
| 186 | Chengguanzhuang, Yongcheng, Shangqiu, Henan| 34.0275 | 116.9822  | 88.0|   |
| 187 | Huicun, Yongcheng, Shangqiu, Henan      | 34.6310   | 116.8634  | 53.0|   |
| 188 | Shibali, Yongcheng, Shangqiu, Henan     | 34.5862   | 116.5631  | 89.0|   |
| 189 | Zanyang, Yongcheng, Shangqiu, Henan     | 34.6610   | 116.3971  | 102.3|  |
| 190 | Mamu, Yongcheng, Shangqiu, Henan        | 34.0651   | 116.2936  | 36.3|   |
| 191 | Tiaohexi, Yongcheng, Shangqiu, Henan    | 34.4834   | 116.8321  | 60.0|   |
| 192 | Mangshan, Yongcheng, Shangqiu, Henan    | 34.3403   | 116.8398  | 7.3|    |
| 193 | Mangshan, Yongcheng, Shangqiu, Henan    | 34.2701   | 116.7945  | 56.0|   |
| 194 | Xuehu, Yongcheng, Shangqiu, Henan       | 34.2447   | 116.7667  | 7.7|    |
| 195 | Xuehu, Yongcheng, Shangqiu, Henan       | 34.1573   | 116.7465  | 14.0|   |
| 196 | Chenji, Yongcheng, Shangqiu, Henan      | 34.0482   | 116.7017  | 8.0|    |
| 197 | Shibali, Yongcheng, Shangqiu, Henan     | 34.5861   | 116.5633  | 19.0|   |
| 198 | Shibali, Yongcheng, Shangqiu, Henan     | 34.5931   | 116.5479  | 15.7|   |
| 199 | Shibali, Yongcheng, Shangqiu, Henan     | 34.6135   | 116.5031  | 5.0|    |
| No. | Sampling locality                     | Latitude  | Longitude  | CN | Ab |
|-----|--------------------------------------|-----------|------------|----|----|
| 200 | Zanlou, Yongcheng, Shangqiu, Henan    | 34.6112   | 116.3989   | 11.0 |     |
| 201 | Zimu, Yongcheng, Shangqiu, Henan     | 33.0421   | 116.3103   | 12.7 |     |
| 202 | Huiting, Xiayi, Shangqiu, Henan      | 34.1318   | 116.1601   | 75.3 |     |
| 203 | Jiyang, Xiayi, Shangqiu, Henan       | 34.2826   | 116.5947   | 30.7 |     |
| 204 | Huiting, Xiayi, Shangqiu, Henan      | 34.1321   | 116.1603   | 2.3  |     |
| 205 | Guodian, Xiayi, Shangqiu, Henan      | 34.2384   | 116.1507   | 35.7 |     |
| 206 | Mengdaqiao, Xiayi, Shangqiu, Henan   | 34.3150   | 116.1852   | 135.3|     |
| 207 | Zhanji, Yucheng, Shangqiu, Henan     | 34.3655   | 116.4660   | 191.7|     |
| 208 | Gushu, Yucheng, Shangqiu, Henan      | 34.4236   | 116.3411   | 118.0|     |
| 209 | Mangzhongqiao, Yucheng, Shangqiu, Henan | 34.5173 | 116.1774   | 12.7 |     |
| 210 | Wangmeng, Linying, Luohe, Henan      | 33.7896   | 113.9610   | 10.7 |     |
| 211 | Wangmeng, Linying, Luohe, Henan      | 33.7947   | 113.9859   | 18.3 |     |
| 212 | Wangmeng, Linying, Luohe, Henan      | 33.7887   | 114.0002   | 42.3 |     |
| 213 | Wangmeng, Linying, Luohe, Henan      | 33.7910   | 113.9794   | 40.0 |     |
| 214 | Wangmeng, Linying, Luohe, Henan      | 33.7865   | 113.9077   | 7.0  |     |
| 215 | Wangmeng, Linying, Luohe, Henan      | 33.7903   | 113.9694   | 14.3 |     |
| 216 | Wangmeng, Linying, Luohe, Henan      | 33.7960   | 113.9746   | 1.7  |     |
| 217 | Wangmeng, Linying, Luohe, Henan      | 33.7909   | 114.5817   | 4.7  |     |
| 218 | Wangmeng, Linying, Luohe, Henan      | 33.7973   | 114.0019   | 1.3  |     |
| 219 | Wangmeng, Linying, Luohe, Henan      | 33.7990   | 114.6077   | 4.0  |     |
| 220 | Wangmeng, Linying, Luohe, Henan      | 33.7898   | 114.6023   | 2.3  |     |
| 221 | Jiangguanchi, Xuchang, Henan         | 33.9715   | 113.8062   | 34.3 |     |
| 222 | Jiangguanchi, Xuchang, Henan         | 33.9409   | 113.7890   | 4.0  |     |
| 223 | Jiangguanchi, Xuchang, Henan         | 33.9435   | 113.7688   | 4.7  |     |
| 224 | Jiangguanchi, Xuchang, Henan         | 33.9391   | 113.7220   | 22.3 |     |
| 225 | Jiangguanchi, Xuchang, Henan         | 33.9545   | 113.7328   | 10.7 |     |
| 226 | Jiangguanchi, Xuchang, Henan         | 33.9749   | 113.7552   | 11.0 |     |
| 227 | Balitun, Weihui, Xinxiang, Henan     | 34.7490   | 114.1088   | 52.0 |     |
| 228 | Dufangdian, Weihui, Xinxiang, Henan  | 35.8239   | 114.1556   | 25.7 |     |
| 229 | Shipogu, Yanjin, Xinxiang, Henan     | 35.4447   | 114.3764   | 108.0|     |
| 230 | Yulin, Yanjin, Xinxiang, Henan       | 35.1971   | 114.0843   | 47.7 |     |
| 231 | Yuin, Yanjin, Xinxiang, Henan        | 35.1018   | 114.0156   | 50.0 |     |
| 232 | Ayang, Yuanyang, Xinxiang, Henan     | 35.1203   | 113.8842   | 54.3 |     |
| 233 | Qitang, Yuanyang, Xinxiang, Henan    | 35.4164   | 113.2963   | 49.3 |     |
| 234 | Chengguan, Yuanyang, Xinxiang, Henan | 35.3715 | 114.0350   | 87.0 |     |
| 235 | Guguzhai, Xinxiang, Henan            | 35.3230   | 114.1268   | 23.0 |     |
| 236 | Guguzhai, Xinxiang, Henan            | 35.2707   | 114.1085   | 9.3  |     |
| 237 | Beiyang, Qixian, Hebi, Henan         | 35.9271   | 114.2267   | 21.0 |     |
| 238 | Gaocun, Qixian, Hebi, Henan          | 36.1718   | 114.4029   | 12.0 |     |
| 239 | Juqiao, Qixian, Hebi, Henan          | 36.1620   | 114.5116   | 86.3 |     |
| No. | Sampling locality                              | Latitude | Longitude  | CN  | Ab |
|-----|-----------------------------------------------|----------|------------|-----|----|
| 240 | Youlicheng, Tangyin, Anyang, Henan            | 36.5910  | 114.5724   | 40.3|    |
| 241 | Zhuangying, Huaxian, Anyang, Henan            | 36.0790  | 114.9333   | 50.3|    |
| 242 | Wadian, Anyang, Henan                         | 35.8589  | 115.2277   | 37.7|    |
| 243 | Jindegu, Nanle, Puyang, Henan                 | 36.1425  | 115.2275   | 30.0|    |
| 244 | Chengguan, Nanle, Puyang, Henan               | 36.1021  | 115.2624   | 32.7|    |
| 245 | Fanbao, Qingfeng, Puyang, Henan               | 36.6443  | 115.2941   | 33.3|    |
| 246 | Shaiguzhuang, Qingfeng, Puyang, Henan         | 36.5620  | 115.2320   | 45.3|    |
| 247 | Liuge, Qingfeng, Puyang, Henan                | 36.3937  | 115.1938   | 38.3|    |
| 248 | Qinghetou, Puyangxian, Puyang, Henan          | 36.2187  | 115.1689   | 12.3|    |
| 249 | Dongmaying, Boai, Jiaozuo, Henan              | 35.2253  | 113.1439   | 14.0|    |
| 250 | Qinghua, Boai, Jiaozuo, Henan                 | 35.2897  | 113.1984   | 56.3|    |
| 251 | Xitielu, Jiaozuo, Henan                       | 35.3509  | 113.2604   | 24.3|    |
| 252 | Zhoukou, Henan                                 | 33.1378  | 113.2228   | 130.7|   |
| 253 | Qingguji, Caoxian, Heze, Shandong             | 35.0825  | 116.2775   | 9.7 |    |
| 254 | Qingguji, Caoxian, Heze, Shandong             | 35.1539  | 116.3606   | 55.7|    |
| 255 | Guocun, Shanxian, Heze, Shandong              | 35.2416  | 116.5909   | 7.7 |    |
| 256 | Shilipu, Shanxian, Heze, Shandong             | 35.4245  | 116.1931   | 3.3 |    |
| 257 | Zhongxing, Shanxian, Heze, Shandong           | 35.2371  | 116.5835   | 11.7|    |
| 258 | Zhuji, Shanxian, Heze, Shandong               | 35.1303  | 116.5869   | 44.7|    |
| 259 | Daokoupu, Dongchangfu, Liaocheng, Shandong    | 36.8106  | 116.3618   | 172.3|   |
| 260 | Yuji, Dongchangfu, Liaocheng, Shandong        | 36.3888  | 116.6633   | 18.7|    |
| 261 | Dingyuanzhai, Guanxian, Liaocheng, Shandong   | 36.5110  | 116.0179   | 97.7|    |
| 262 | Sangzhen, Guanxian, Liaocheng, Shandong       | 36.7700  | 116.0962   | 9.7 |    |
| 263 | Liangtangzhen, Guanxian, Liaocheng, Shandong  | 36.7204  | 116.0522   | 45.0|    |
| 264 | Dawangzhai, Shenxian, Liaocheng, Shandong     | 36.7078  | 115.8282   | 19.0|    |
| 265 | Dongduduzhuang, Shenxian, Liaocheng, Shandong | 36.4634  | 115.8574   | 13.0|    |
| 266 | Zhangzai, Shenxian, Liaocheng, Shandong       | 36.2226  | 115.8310   | 21.0|    |
| 267 | Zhangzai, Shenxian, Liaocheng, Shandong       | 36.1297  | 115.8280   | 38.0|    |
| 268 | Xihu, Yanggu, Liaocheng, Shandong             | 36.1025  | 115.8818   | 36.3|    |
| 269 | Chengguan, Yanggu, Liaocheng, Shandong        | 36.2741  | 116.1976   | 70.3|    |
| 270 | Huarunqiao, Yanggu, Liaocheng, Shandong       | 36.2434  | 116.2835   | 64.7|    |
| 271 | Anle, Yanggu, Liaocheng, Shandong             | 36.2451  | 116.4176   | 24.3|    |
| 272 | Qiji, Yanggu, Liaocheng, Shandong             | 36.2864  | 116.4566   | 20.7|    |
| 273 | Damiao, Lingbi, Suzhou, Anhui                 | 34.2743  | 118.1299   | 24.0|    |
| 274 | Dalu, Lingbi, Suzhou, Anhui                   | 34.3177  | 117.6368   | 10.0|    |
| 275 | Huigou, Lingbi, Suzhou, Anhui                 | 34.2447  | 117.6424   | 8.0 |    |
| 276 | Yinji, Lingbi, Suzhou, Anhui                  | 34.3062  | 117.7695   | 20.3|    |
| 277 | Xialou, Lingbi, Suzhou, Anhui                 | 34.6440  | 117.7996   | 8.3 |    |
| 278 | Tubai, Xiaoxian, Suzhou, Anhui                | 34.2293  | 117.0935   | 75.7|    |
| 279 | Dulou, Xiaoxian, Suzhou, Anhui                | 34.3462  | 117.4132   | 47.7|    |
| No. | Sampling locality                  | Latitude  | Longitude  | CN  | Ab |
|-----|-----------------------------------|-----------|------------|-----|----|
| 280 | Wangzai, Xiaoxian, Suzhou, Anhui  | 34.2606   | 117.2734   | 76.7| AH |
| 281 | Zulou, Xiaoxian, Suzhou, Anhui   | 34.1194   | 117.1639   | 5.7 |    |
| 282 | Luanlou, Dangshan, Suzhou, Anhui | 35.0256   | 116.6960   | 16.0|    |
| 283 | Huaguanying, Cixian, Handan, Hebei| 36.8246   | 114.7223   | 44.7|    |
| 284 | Matou, Cixian, Handan, Hebei     | 36.7530   | 114.6553   | 15.3|    |
| 285 | Zhangliji, Linzhang, Handan, Hebei| 36.5882  | 114.7680   | 43.7|    |
| 286 | Linzhazhe, Linzhang, Handan, Hebei| 36.5302  | 114.9685   | 7.3 |    |
| 287 | Xiyanggao, Linzhang, Handan, Hebei| 36.5683  | 115.1566   | 41.3|    |
| 288 | Yuanbao, Weixian, Handan, Hebei  | 36.5584   | 115.3506   | 63.3|    |
| 289 | Shakou, Weixian, Handan, Hebei   | 36.8309   | 115.0080   | 84.0|    |
| 290 | Shuangjing, Weixian, Handan, Hebei| 36.6087  | 115.1441   | 13.0|    |
| 291 | Shengying, Guoping, Handan, Hebei| 36.5474   | 115.0345   | 114.3|    |
| 292 | Zhanggu, Guaping, Handan, Hebei  | 36.5139   | 115.1273   | 38.7|    |
| 293 | Zhanghe, Linzhang, Handan, Hebei | 36.4413   | 115.6199   | 11.3|    |
| 294 | Ghenganzhen, Chengan, Handan, Hebei| 36.6398  | 115.4356   | 48.3|    |
| 295 | Hesha, Handanxian, Handan, Hebei | 36.7802   | 115.6086   | 102.0|    |
| 296 | Lizhuang, Daming, Handan, Hebei  | 36.6793   | 115.3728   | 76.7|    |
| 297 | Xiweiuzhuang, Daming, Handan, Hebei| 36.7181  | 115.2045   | 17.7|    |
| 298 | Jiudian, Feixiang, Handan, Hebei | 36.9506   | 115.5940   | 20.0|    |
| 299 | Anzhai, Zhouku, Handan, Hebei    | 37.1633   | 115.5957   | 43.7|    |
| 300 | Quzhou, Zhouku, Handan, Hebei    | 37.2602   | 115.5384   | 2.7 |    |
| 301 | Caohuan, Jize, Handan, Hebei     | 37.2790   | 115.4845   | 81.7|    |
| 302 | Tongcheng, Wenxi, Yuncheng, Shanxi| 35.6034  | 111.4242   | 1.7 |    |
| 303 | Guojiazhuang, Wenxi, Yuncheng, Shanxi| 35.5290 | 111.2915  | 12.7|    |
| 304 | Wexi, Yuncheng, Shanxi           | 35.5807   | 111.3062   | 44.0|    |
| 305 | Wadi, Wenxi, Yuncheng, Shanxi    | 35.7578   | 111.1968   | 5.3 |    |
| 306 | Liyuan, Wexi, Yuncheng, Shanxi   | 35.9767   | 111.5644   | 31.7|    |
| 307 | Wanan, Xiangzian, Yuncheng, Shanxi| 35.8559  | 111.5345   | 16.3|    |
| 308 | Longxing, Xinjiang, Yuncheng, Shanxi| 35.9621  | 111.2488   | 19.0|    |
| 309 | Donghua Rd., Xinjiang, Yuncheng, Shanxi| 36.0025 | 111.2747  | 11.7|    |
| 310 | Zhaokang, Xiangfen, Linfen, Shanxi| 36.0367  | 111.4005   | 54.7|    |
| 311 | Fengcheng, Houma, Linfen, Shanxi| 36.1492   | 111.4065   | 39.3|    |
| 312 | Shangma, Houma, Linfen, Shanxi   | 36.0017   | 111.6754   | 67.3|    |
| 313 | Rougu, Yangling, Xianyang, Shaanxi| 34.2705  | 108.0310   | 62.7|    |
| 314 | NWUAF Campus, Xianyang, Shaanxi  | 34.4314   | 108.1092   | 136.7|    |
| 315 | Wugong, Xianyang, Shaanxi        | 34.5566   | 108.2292   | 18.0|    |
| 316 | Wugong, Xianyang, Shaanxi        | 34.5503   | 108.3135   | 51.0|    |
| 317 | Qianxian, Xianyang, Shaanxi      | 34.6394   | 108.3477   | 23.0|    |
| 318 | Qianxian, Xianyang, Shaanxi      | 34.7440   | 108.5506   | 8.3 |    |
| 319 | Jingyang, Xianyang, Shaanxi      | 35.0061   | 109.1365   | 2.7 |    |
| No. | Sampling locality                              | Latitude  | Longitude  | CN  | Ab |
|-----|-----------------------------------------------|-----------|------------|-----|----|
| 320 | Zhouzhi, Zhouzhi, Xi'an, Shaanxi              | 34.1817   | 108.2094   | 57.0|    |
| 321 | Xinglin, Fufeng, Baoji, Shaanxi               | 34.5839   | 108.5327   | 37.7|    |
| 322 | Famen, Fufeng, Baoji, Shaanxi                 | 34.7453   | 108.5165   | 80.3|    |
| 323 | Yuechen, Meixian, Baoji, Shaanxi              | 34.4773   | 108.1135   | 32.7|    |
| 324 | Shoushan, Baoji, Shaanxi                      | 34.4301   | 108.2859   | 64.7|    |
| 325 | Fengle, Liangzhou, Wuwei, Gansu               | 38.0459   | 102.6810   | 6.0 |    |
| 326 | Fengle, Liangzhou, Wuwei, Gansu               | 38.0554   | 102.6895   | 16.7|    |
| 327 | Fengle, Liangzhou, Wuwei, Gansu               | 38.1166   | 102.6343   | 32.0|    |
| 328 | Duoyuncun, Liangzhou, Wuwei, Gansu            | 38.1181   | 102.6342   | 10.3|    |
| 329 | Wuhe, Liangzhou, Wuwei, Gansu                 | 38.1119   | 102.7793   | 55.3|    |
| 330 | Gaoba, Liangzhou, Wuwei, Gansu                | 38.0357   | 102.8482   | 31.7|    |
| 331 | Liangzhou, Wuwei, Gansu                       | 38.3574   | 103.1639   | 13.7|    |
| 332 | Liangzhou, Wuwei, Gansu                       | 38.2616   | 103.1918   | 3.7 |    |
| 333 | Liangzhou, Wuwei, Gansu                       | 38.1541   | 103.3012   | 6.0 |    |
| 334 | Huangyang, Liangzhou, Wuwei, Gansu            | 38.0888   | 103.4552   | 24.3|    |
| 335 | Shuangta, Gulang, Wuwei, Gansu                | 37.9975   | 103.4488   | 4.7 |    |
| 336 | Sishui, Gulang, Wuwei, Gansu                  | 37.9976   | 103.4487   | 1.3 |    |
| 337 | Sishui, Gulang, Wuwei, Gansu                  | 37.9939   | 103.5968   | 15.7|    |
| 338 | Laoyoubao, Xining, Qinghai                    | 38.0001   | 103.6158   | 2.3 |    |
| 339 | Xibao, Xining, Qinghai                        | 36.8303   | 101.9732   | 7.7 |    |
| 340 | Shenzhong, Xining, Qinghai                    | 36.8778   | 101.9405   | 2.7 |    |
| 341 | Bayan, Xining, Qinghai                        | 37.2107   | 101.2972   | 4.3 |    |
| 342 | Bayan, Xining, Qinghai                        | 37.2774   | 101.2247   | 11.0|    |
| 343 | Huangyuan, Xining, Qinghai                    | 37.3274   | 101.1732   | 3.3 |    |
| 344 | Tangchuan, Haidong, Qinghai                   | 36.8283   | 101.2470   | 11.0|    |
| 345 | Tangchuan, Haidong, Qinghai                   | 36.6750   | 101.8878   | 3.7 |    |
| 346 | Xiegou, Datong, Xining, Qinghai               | 37.1223   | 102.4569   | 10.3|    |
| 347 | Chengguan, Datong, Xining, Qinghai            | 37.0582   | 101.8761   | 8.0 |    |
| 348 | Lixian, Daxing, Beijing                       | 39.5900   | 116.4079   | 25.0|    |
| 349 | Lixian, Daxing, Beijing                       | 39.5980   | 116.4049   | 2.7 |    |
| 350 | Lixian, Daxing, Beijing                       | 39.5941   | 116.4066   | 3.3 |    |
| 351 | Shigezhuang, Baodi, Tianjin                   | 39.7260   | 117.2322   | 36.0|    |
| 352 | Shigezhuang, Baodi, Tianjin                   | 39.7105   | 117.2429   | 32.0|    |
| 353 | Sicundian, Wuqing, Tianjin                    | 39.5121   | 116.9430   | 26.0|    |
| 354 | Shizishan, Hongshan, Wuhan, Hubei             | 30.4759   | 114.3555   | 19.0|    |
| 355 | Liupanshan, Jingyuan, Guyuan, Ningxia         | 35.6619   | 106.2940   | 24.0|    |
| 356 | Shaogang, Qingtongxia, Wuzhong, Ningxia        | 38.1534   | 106.0649   | 7.0 |    |
| 357 | Hangjinhouqi, Bayan Nur, Inner Mongolia       | 40.7553   | 106.9924   | 5.0 |    |
| 358 | Wuchuanxian, Huhhot, Inner Mongolia           | 41.1499   | 111.3053   | 14.0|    |
| No. | Sampling locality                  | Latitude | Longitude  | CN   | Ab |
|-----|-----------------------------------|----------|------------|------|----|
| 359 | Yongnian, Tianzhu, Wuwei, Gansu   | 37.1680  | 102.8380   | 81.9 |  |
| 360 | Honggada, Tianzhu, Wuwei, Gansu  | 37.2190  | 102.7090   | 30.8 |  |
| 361 | Hongdaiganbai, Tianzhu, Wuwei, Gansu | 37.2290 | 102.6950 | 11.0 |  |
| 362 | Chaxitan, Tianzhu, Wuwei, Gansu | 37.1690  | 102.8380   | 17.7 |  |
| 363 | Anyuan, Tianzhu, Wuwei, Gansu     | 37.2050  | 102.8280   | 11.0 |  |
| 364 | Anyuan, Tianzhu, Wuwei, Gansu     | 37.2430  | 102.8440   | 9.4  |  |
| 365 | Shimen, Tianzhu, Wuwei, Gansu     | 36.9716  | 103.0113   | 1.0  | TZ |
| 366 | Dachaigou, Tianzhu, Wuwei, Gansu  | 37.0770  | 103.0060   | 17.5 |  |
| 367 | Gaza, Xiahe, Gannan, Gansu        | 35.3662  | 102.8720   | 7.2  |  |
| 368 | Lazetang, Xiahe, Gannan, Gansu    | 35.3588  | 102.8360   | 5.4  |  |
| 369 | Madang, Xiahe, Gannan, Gansu      | 35.3374  | 102.7894   | 2.0  |  |
| 370 | Wanggeertang, Xiahe, Gannan, Gansu | 35.2242 | 102.7894 | 6.3  |  |
| 371 | Damai, Xiahe, Gannan, Gansu       | 35.2179  | 102.6935   | 16.5 |  |
| 372 | Kajiaman, Hezuo, Gannan, Gansu    | 35.0420  | 102.9159   | 2.7  |  |
| 373 | Nawu, Hezuo, Gannan, Gansu        | 35.0083  | 102.9435   | 14.0 |  |
Table S2. Sampling locations and corresponding cysts recovered from the soil attached to trans-regional machinery harvesters.

| No. | Sampling locality | Harvester transportation background | Coordination | Altitude | Weight of soil attached | Recovered cysts No. |
|-----|-------------------|-------------------------------------|--------------|----------|-------------------------|---------------------|
| 1   | Wulitou Village, Linying Chengguan Town, Luohe, Henan | From Zhumadian, Henan | 33.79486, 113.92392 | 53 m | 200 g | 0 |
| 2   | Shi Village, Linying Chengguan Town, Luohe, Henan | From Luohe, Wuyang, Henan | 33.79708, 113.92639 | 54 m | 200 g | 0 |
| 3   | Shi Village, Linying Chengguan Town, Luohe, Henan | From Luohe, Wuyang, Henan | 33.80044, 113.92700 | 52 m | 100 g | 0 |
| 4   | Shi Village, Linying Chengguan Town, Luohe, Henan | From Zhumadian, Henan | 33.79914, 113.92992 | 52 m | 100 g | 0 |
| 5   | Shi Village, Linying Chengguan Town, Luohe, Henan | From Zhumadian, Henan | 33.79927, 113.93047 | 52 m | 100 g | 0 |
| 6   | Xuchang, Changchun Zhang Town, Henan | From Sheqi, Nanyang | 33.98325, 113.82794 | 63 m | 100 g | 0 |
| 7   | Zhengzhou Agricultural Science Institute, Henan | Local harvester | 34.76922, 113.46622 | 159 m | 200 g | 0 |
| 8   | Baizhuang Town, Anyang, Henan | Local harvester | 36.19420, 114.34173 | 59 m | 100 g | 1 |
| 9   | Baizhuang Town, Anyang, Henan | Local harvester | 36.20218, 114.36090 | 78 m | 50 g | 13 |
| 10  | Jin Xiaozhuang, Baizhuang Town, Anyang, Henan | Local harvester | 36.20263, 114.36085 | 78 m | 100 g | 0 |
| 11  | Dongfanghong Village, Baizhuang, Anyang, Henan | Local harvester | 36.18922, 114.35917 | 79 m | 50 g | 0 |
| 12  | Taojiaying, Baizhuang Town, Anyang, Henan | From Nanyang and Xuchang | 36.17603, 114.36302 | 73 m | 200 g | 1 |
| 13  | Taojiaying, Baizhuang Town, Anyang, Henan | From Nanyang and Xuchang | 36.17600, 114.36282 | 76 m | 50 g | 0 |
| 14  | Gaozu, Baizhuang Town, Anyang, Henan | Local harvester | 36.16823, 114.36043 | 72 m | 100 g | 3 |
| 15  | Gaozu, Baizhuang Town, Anyang, Henan | Local harvester | 36.16682, 114.35917 | 68 m | 200 g | 2 |
| 16  | HouBaibi Town, Anyang, Henan Province | Local harvester | 36.08923, 114.50917 | 94 m | 100 g | 4 |
| 17  | HouBaibi Town, Anyang, Henan Province | Local harvester | 36.09143, 114.51452 | 70 m | 200 g | 3 |
| 18  | Gaopan Village, Baibi Town, Anyang, Henan | Local harvester | 36.09563, 114.51317 | 66 m | 100 g | 13 |
| 19  | Gaopan Village, Baibi Town, Anyang, Henan | Local harvester | 36.09448, 114.51333 | 65 m | 100 g | 0 |
| 20  | Chuwang Town, Anyang, Henan | From Changyuan, Hua to Wei | 36.06878, 114.87225 | 49 m | 100 g | 0 |
| No. | Location                          | Origin                  | Latitude         | Longitude        | Distance | Weight (g) | Notes |
|-----|----------------------------------|-------------------------|------------------|------------------|----------|------------|-------|
| 21  | Chuwan Town, Anyang, Henan       | From Changyuan, Hua to Wei | 36.06875, 114.87227 | 50 m             | 100 g    | 7          |
| 22  | Chuwan Town, Anyang, Henan       | From Changyuan, Hua to Wei | 36.06897, 114.87230 | 51 m             | 100 g    | 19         |
| 23  | Dongguan Village, Chengguan Town, Nanle, Henan | From Pingdingshan, Henan | 36.06498, 115.23398 | 56 m             | 100 g    | 19         |
| 24  | Dongguan Village, Chengguan Town, Nanle, Henan | From Pingdingshan, Henan | 36.06598, 115.23518 | 54 m             | 100 g    | 0          |
| 25  | Dongguan Village, Chengguan Town, Nanle, Henan | From Pingdingshan, Henan | 36.06327, 115.23603 | 53 m             | 50 g     | 0          |
| 26  | Nanjie Village, Zhanggutunp, Nanle, Henan | From Pingdingshan, Henan | 36.04250, 115.29872 | 50 m             | 200 g    | 0          |
| 27  | Nanjie Village, Zhanggutun, Nanle, Henan | From Xinxiang, Henan    | 36.04287, 115.29818 | 49 m             | 150 g    | 3          |
| 28  | Nanjie Village, Zhanggutun, Nanle, Henan | From Xinxiang, Henan    | 36.05118, 115.32978 | 48 m             | 100 g    | 0          |
| 29  | Henan Nanle, Hanzhang Town, Hangutuan | From Xinxiang, Henan    | 36.05127, 115.32872 | 49 m             | 100 g    | 3          |
| 30  | Lijiatun Village, Gujinlou Township, Nanle, Henan | From Puyang, Henan | 36.07587, 115.25035 | 48 m             | 250 g    | 15         |
| 31  | Lijiatun Village, Gujinlou Township, Nanle, Henan | From Puyang, Henan | 36.07595, 115.24980 | 48 m             | 100 g    | 0          |
| 32  | Xifu Village, Xifu Township, Daming, Hebei | Local harvester, Henan | 36.29625, 115.11517 | 67 m             | 100 g    | 0          |
| 33  | Xifu Village, Xifu Township, Daming, Hebei | Local harvester, Henan | 36.29672, 115.1149 | 66 m             | 100 g    | 1          |
| 34  | Xifu Village, Xifu Township, Daming, Hebei | Local harvester, Henan | 36.32367, 115.03942 | 54 m             | 200 g    | 64         |
| 35  | Dayang Zhuang, Shakou Ji Township, Wei, Hebei | From Henan direction | 36.32373, 115.03945 | 53 m             | 100 g    | 5          |
| 36  | Dayang Zhuang, Shakou Ji Township, Wei, Hebei | From Henan direction | 36.32573, 115.04022 | 52 m             | 200 g    | 113        |
| 37  | Wangdonglibao, Heshan Town, Handan, Hebei | From Henan direction | 36.49232, 114.61418 | 58 m             | 100 g    | 3          |
| 38  | Jinchao, Hesha Town, Handan, Hebei | From Henan direction | 36.51073, 114.59927 | 56 m             | 100 g    | 0          |
| 39  | Jinchao, Hesha Town, Handan, Hebei | From Henan direction | 36.50978, 114.59982 | 57 m             | 100 g    | 0          |
| 40  | Yaozhuan, Shahe, Xingtai, Hebei   | From Xinxiang, Henan    | 36.89260, 114.49845 | 63 m             | 100 g    | 5          |
| 41  | Yaozhuan, Shahe, Xingtai, Hebei   | From Xinxiang, Henan    | 36.89352, 114.49842 | 63 m             | 100 g    | 3          |
| 42  | Yaozhuan, Shahe, Xingtai, Hebei   | From Xinxiang, Henan    | 36.89402, 114.49835 | 64 m             | 100 g    | 19         |
| 43  | Yaozhuan, Shahe, Xingtai, Hebei   | From Xinxiang, Henan    | 36.89422, 114.49845 | 64 m             | 100 g    | 9          |
|   | Location                               | Origin                  | Coordinates               | Depth (m) | Mass (g) | Number |
|---|----------------------------------------|-------------------------|---------------------------|-----------|----------|--------|
| 44| Anxia, Zhengding Town, Zhengding, Shijiazhuang, Hebei | From Handan, Hebei     | 38.18268, 114.57807       | 62        | 100      | 3      |
| 45| Anxia, Zhengding Town, Zhengding, Shijiazhuang, Hebei | Unknown                 | 38.18372, 114.57635       | 64        | 100      | 0      |
| 46| Anxia, Zhengding Town, Zhengding, Shijiazhuang, Hebei | Unknown                 | 38.18412, 114.57307       | 67        | 50       | 4      |
| 47| Yong'an, Zhengding Town, Zhengding, Shijiazhuang, Hebei | Unknown                 | 38.18275, 114.56247       | 71        | 50       | 1      |
Table S3. The GenBank accession of obtained sequences and their corresponding haplotypes, host and origin. Multiple sequences were submitted for same haplotype as they are either in different lengths, or recognized as same haplotype in PopART. Sample codes are corresponding for the locations presented in table S1. Abbreviations: W=wheat, G=grass.

| Accession | Haplotype | Length | Host | Regions | Sample code |
|-----------|-----------|--------|------|---------|-------------|
| ON357397  | H8        | 791    | W    | HN, NM, SD | 188-190,192 (2), 357, 255 (3) |
| ON357398  | H7        | 791    | W    | BJ, TJ   | 348 (15), 351 (9) |
| ON357399  | H6        | 791    | W+G  | GS, QH, TZ | 325-330, 331 (3), 332 (3), 333, 334 (3), 338 (2), 339, 340, 359, 360 (2) |
| ON357400  | H7        | 791    | W    | SD       | 253 (5) |
| ON357401  | H5        | 791    | W    | JSNT, JSTC | 62, 63, 95-99, 120, 121 |
| ON357402  | H3        | 791    | W    | SS       | 313 |
| ON357403  | H1        | 791    | W+G  | AH, BJ, HB, HD, PN, JSNT, JSTC, NM, SX, SS, SD, TZ, TJ, OYR, JSXZ | 273-277, 278 (3), 279 (3), 280 (3), 281 (2), 282 (2), 350 (8), 354 (10), 283 (4), 284 (4), 285 (2), 286 (2), 200, 227, 230, 234 (3), 249 (2), 250 (2), 102 (3), 153 (2), 157 (2), 68 (6), 358 (8), 355 (10), 356 (7), 316 (5), 317 (4), 318 (4), 319 (2), 323 (2), 257-272, 302-310, 311 (3), 312 (7), 351 (4), 352 (3), 353 (3), 166-173, 11-13 |
| ON357404  | H1        | 791    | W    | HN       | 236, 239, 245 |
| ON357405  | H4        | 791    | W    | JSNT     | 105, 110, 118, 153 (2) |
| ON357406  | H2        | 791    | W    | HD       | 288, 300 (2) |
| ON357407  | H1        | 791    | W    | HD       | 287, 299 |
| ON357408  | H1        | 791    | W    | HD       | 290, 296, 297, 298 |
| ON357409  | H1        | 791    | W    | TJ       | 353 |
| ON357410  | H13       | 791    | G    | TZ       | 361-363, 364 (3) |
| ON357411  | H13       | 791    | G    | TZ       | 366 (3), 367 (3), 368 (2), 369 (2) |
| ON357412  | H17       | 791    | W    | JSTC     | 67 |
| ON357413  | H17       | 791    | W    | HD, JSNT, JSTC | 287 (2), 288 (3), 293, 294, 111, 64 (3) |
| ON357414  | H17       | 791    | W    | JSTC     | 65 |
| ON357415  | H19       | 791    | W    | QH       | 340, 343, 346 (2) |
| ON357416  | H18       | 791    | G    | TZ       | 364, 370 (2), 371 (2) |
| ON357417  | H20       | 791    | G    | TZ       | 365 (4) |
| ON357418  | H20       | 791    | G    | TZ       | 370-373 |
| ON357419  | H11       | 791    | W    | NM, QH   | 358 (3), 342 (2), 343-345, 347 |
| ON357420  | H5        | 445    | W    | JSTC     | 67 (3), 68 |
| ON357421  | H19       | 445    | W    | QH       | 346 (1) |
| ON357422  | H1        | 445    | W    | HD       | 292, 64 (3) |
| ON357423  | H11       | 445    | W+G  | GS, TZ, QH | 329 (2), 330 (2), 333 (2), 360, 361, 338 (2), 339, 341 (2) |
| ON357424  | H9        | 445    | G    | TZ       | 361 (6) |
| ON357425  | H6        | 445    | W    | GS, QH   | 335, 346 (2) |
| ON357426  | H4        | 445    | W    | JSTC     | 66 (3) |
| ON357427  | H2        | 445    | W    | HD       | 290, 294 (3) |
Table S4. The pairwise nucleotide difference between newly recovered mtCOI haplotypes.

|     | H9  | H13 | H7  | H8  | H6  | H2  | H3  | H4  | H5  | H1  | H19 | H20 | H18 | H17 | H11 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| H9  | 2   |     | 3   | 4   | 2   | 3   | 3   | 3   | 3   | 2   | 6   | 6   | 6   | 5   | 3   |
| H13 | 2   |     |     |     | 8   | 13  | 13  | 13  | 13  | 12  | 12  | 12  | 11  | 11  | 10  |
| H7  | 3   | 9   | 1   | 1   | 6   | 6   | 6   | 6   | 5   | 9   | 9   | 8   | 8   | 7   |
| H8  | 4   | 10  | 1   | 2   | 7   | 7   | 7   | 7   | 6   | 10  | 10  | 9   | 9   | 8   |
| H6  | 2   | 8   | 1   | 2   | 5   | 5   | 5   | 5   | 4   | 8   | 8   | 7   | 7   | 6   |
| H2  | 3   | 13  | 6   | 7   | 5   | 2   | 2   | 2   | 1   | 13  | 13  | 12  | 12  | 10  |
| H3  | 3   | 13  | 6   | 7   | 5   | 2   | 2   | 2   | 1   | 13  | 13  | 12  | 12  | 10  |
| H4  | 3   | 13  | 6   | 7   | 5   | 2   | 2   | 2   | 1   | 13  | 13  | 12  | 12  | 10  |
| H5  | 3   | 13  | 6   | 7   | 5   | 2   | 2   | 2   | 1   | 13  | 13  | 12  | 12  | 10  |
| H1  | 2   | 12  | 5   | 6   | 4   | 1   | 1   | 1   | 1   | 12  | 12  | 11  | 11  | 9   |
| H19 | 6   | 12  | 9   | 10  | 8   | 13  | 13  | 13  | 13  | 12  | 2   | 1   | 5   | 6   |
| H20 | 6   | 12  | 9   | 10  | 8   | 13  | 13  | 13  | 13  | 12  | 2   | 1   | 5   | 6   |
| H18 | 5   | 11  | 8   | 9   | 7   | 12  | 12  | 12  | 12  | 11  | 1   | 1   | 4   | 5   |
| H17 | 3   | 11  | 8   | 9   | 7   | 12  | 12  | 12  | 12  | 11  | 5   | 5   | 4   | 5   |
| H11 | 2   | 10  | 7   | 8   | 6   | 10  | 10  | 10  | 10  | 9   | 6   | 6   | 5   | 5   |
Part 2: Morphometric

Table S5. Morphometrics of cyst and vulval cone of newly recovered Chinese cereal cyst nematode haplotypes. The morphometrics of eight haplotype H1 populations were compared, as they have different isolation origin. All measurements are in μm and in the form: mean ± s.d. (range).

| Haplotype | H1 | H1 | H1 | H1 | H1 | H1 | H1 | H1 | H4 |
|-----------|----|----|----|----|----|----|----|----|----|
| **Cyst (n)** | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 17 | 17 |
| Length excl. neck | 571 ± 31 | 603 ± 54 | 574 ± 55 | 578 ± 60 | 599 ± 97 | 591 ± 52 | 570 ± 58 | 583 ± 62 | 580 ± 56 |
| (511-623) | (520-685) | (454-644) | (480-684) | (412-765) | (479-658) | (468-661) | (463-667) | (473-651) |
| Width | 352 ± 50 | 361 ± 26 | 356 ± 49 | 375 ± 40 | 379 ± 63 | 381 ± 37 | 352 ± 37 | 437 ± 43 | 411 ± 56 |
| (256-473) | (296-419) | (287-457) | (322-430) | (290-514) | (308-447) | (290-411) | (333-520) | (330-517) |
| Length/Width | 1.6 ± 0.2 | 1.7 ± 0.2 | 1.6 ± 0.14 | 1.6 ± 0.2 | 1.6 ± 0.1 | 1.56 ± 0.1 | 1.6 ± 0.2 | 1.3 ± 0.2 | 1.4 ± 0.2 |
| (1.3-2.3) | (1.5-2) | (1.4-1.9) | (1.4-1.9) | (1.3-1.8) | (1.4-1.9) | (1-1.6) | (1.2-1.8) | |
| **Vulval cone (n)** | 10 | 12 | 11 | 12 | 9 | 10 | 8 | 14 | 12 |
| Fenestral length | 39 ± 2.5 | 40 ± 3.2 | 41 ± 3.1 | 43 ± 3.8 | 45 ± 2.8 | 42 ± 2.9 | 40 ± 1.6 | 44 ± 3.9 | 39 ± 5.4 |
| (34-44) | (35-45) | (37-47) | (33-48) | (40-50) | (38-46) | (38-42) | (37-50) | (31-48) |
| Mean semifenestral width | 21 ± 1.6 | 20 ± 1.2 | 19 ± 1.4 | 22 ± 1.7 | 21 ± 0.9 | 20 ± 1.4 | 22 ± 1.3 | 22 ± 2.7 | 21 ± 3.9 |
| (17-22) | (17-21) | (17-22) | (20-25) | (20-23) | (18-22) | (20-24) | (18-27) | (14-27) |
| Vulval bridge width | 7.0 ± 0.8 | 6.3 ± 1.01 | 6.6 ± 0.7 | 8 ± 0.7 | 7.1 ± 1.1 | 7.5 ± 1.0 | 6.93 ± 0.6 | 9.0 ± 1.6 | 8.4 ± 1.9 |
| (5.6-8.0) | (4.5-7.8) | (6-7.7) | (6.7-9.3) | (5.9-1) | (6.7-9.5) | (5.9-7.6) | (6.2-11.3) | (5.3-10.9) |
| Vulval slit length | 10 ± 1.3 | 9.3 ± 1.2 | 10 ± 1.4 | 11 ± 1.4 | 10.2 ± 1.3 | 9.4 ± 1.1 | 9.6 ± 1.02 | 8.9 ± 1.3 | 8.6 ± 1.6 |
| (7.4-12) | (7.6-11.5) | (7.1-12) | (8.9-13) | (7.7-11.8) | (7.8-11) | (8.2-11) | (6.4-11) | (5.3-11.1) |
| Vulval-anus distance | 48 ± 6.0 | 46 ± 4 | 45 ± 3.8 | 47. ± 4.6 | 46 ± 1.9 | 44 ± 4.4 | 46 ± 4.3 | 47 ± 6.1 | 46 ± 4.9 |
| (39-56) | (38-52) | (40-54) | (39-53) | (43-49) | (37-51) | (38-52) | (36-55) | (38-53) |
### Haplotype

| Haplotype | H5 | H13 | H9 | H20 |
|-----------|----|-----|----|-----|
| H. avenae Fangshan, China* | | | | |
| H. avenae Ha-hoola, Israel** | | | | |
| H. avenae Cukurova, Turkey** | | | | |
| H. avenae Taaken, Germany** | | | | |
| H. pratensis Otterndorf, Germany* | | | | |

### Cyst (n)

| Cyst (n) | H5 | H13 | H9 | H20 |
|----------|----|-----|----|-----|
| Length excl. neck | 593 ± 47 (511-687) | 671 ± 35 (618-691) | 594 ± 24 (575-627) | 533 ± 95 (425-607) |
| Width | 427 ± 52 (332-554) | 510 ± 65 (456-580) | 445 ± 80 (356-550) | 403 ± 90 (335-550) |
| Length/Width | 1.4 ± 0.1 (1.2-1.8) | 1.3 ± 0.14 (1.2-1.6) | 1.3 ± 0.18 (1.1-1.6) | 1.3 ± 0.19 (1.1-1.6) |

### Vulval cone (n)

| Vulval cone (n) | H5 | H13 | H9 | H20 |
|----------------|----|-----|----|-----|
| Fenestral length | 43 ± 5.1 (36-52) | 46 ± 2.8 (43-49) | 47 ± 0.49 (46-47) | 39 ± 7.6 (31-45) |
| Semifenestral width | 21 ± 3.9 (14-26) | 25 ± 4.1 (21-28) | 27 ± 2.6 (24-30) | 24 ± 5.3 (20-30) |
| Vulval bridge width | 9.2 ± 1.6 (6.5-12.2) | 7.0 ± 0.79 (6.0-7.6) | 6.4 ± 0.7 (5.4-6.9) | 6.4 ± 0.76 (5.3-7.1) |
| Vulval slit length | 9.6 ± 1.5 (7.4-11.5) | 10.0 ± 1.6 (8.3-12) | 10.4 ± 0.53 (5.4-6.9) | 10 ± 1.2 (8.5-11) |
| Vulva to anus distance | 49 ± 5.9 (40-59) | 49 ± 6.6 (39-58) | 46 ± 3.5 (42-50) | 48 ± 5.6 (44-52) |

**Note:** n = Number of specimens;
* Measurements according to Subbotin et al. (2015).
** Measurements according to Subbotin et al. (2003).
Table S6. Morphometrics for second-stage juveniles of newly recovered Chinese CCN haplotypes. The morphometrics of eight haplotype H1 populations were compared, as they have different isolation origin. All measurements are in μm and in the form: mean ± s.d. (range).

| Haplotype | H1 | H1 | H1 | H1 | H1 | H1 | H1 | H1 | H4 | H5 |
|-----------|----|----|----|----|----|----|----|----|----|----|
| n         | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 12 | 12 |
| L         | 538 ± 21 (502-566) | 558 ± 17 (536-593) | 532 ± 22 (491-560) | 535 ± 30 (501-584) | 524 ± 21 (501-563) | 519 ± 18 (486-543) | 527 ± 17 (493-554) | 512 ± 10 (454-542) | 560 ± 10 (542-575) | 514 ± 23 (554-583) |
| a         | 23 ± 0.01 (20-25) | 20 ± 1.2 (18-22) | 23 ± 1.6 (20-25) | 21.9 ± 1.8 (20-24) | 24 ± 1.6 (21-27) | 23 ± 1.7 (20-25) | 21 ± 0.01 (20-24) | 25 ± 1.6 (20-24) | 25 ± 0.2 (20-24) | 25 ± 0.9 (20-24) |
| b         | 5.9 ± 0.3 (5.6-6.5) | 5.8 ± 0.3 (5.3-6.5) | 5.7 ± 0.4 (5.1-6) | 5.7 ± 0.2 (5-5-6) | 5.7 ± 0.3 (4.8-6-4) | 5.7 ± 0.3 (4.8-6-4) | 5.6 ± 0.3 (5-5-8) | 5.4 ± 0.3 (5-5-8) | 5.3 ± 0.4 (5-5-8) | 5.3 ± 0.4 (5-5-8) |
| c         | 8.6 ± 0.6 (7.9-9.7) | 8.6 ± 0.5 (7.7-9.3) | 8.2 ± 0.2 (7.8-8.6) | 8.8 ± 0.23 (8-4-9.2) | 8.6 ± 0.5 (7.8-9.2) | 8.4 ± 0.4 (7.8-9.0) | 8.7 ± 0.5 (7.8-9.6) | 9.3 ± 0.7 (8.5-11.1) | 8.2 ± 0.5 (7.7-9.1) | 9.0 ± 0.6 (8.4-10.3) |
| Stylent length | 24 ± 0.6 (23-25) | 25 ± 0.7 (24-25) | 24 ± 0.7 (23-25) | 24 ± 0.9 (23-26) | 23 ± 0.7 (22-25) | 24 ± 0.6 (23-25) | 24 ± 0.9 (23-26) | 25 ± 0.7 (23-26) | 25 ± 0.6 (24-26) | 25 ± 0.9 (24-26) |
| Lip region width | 9.8 ± 0.3 (9.3-10) | 9.9 ± 0.5 (9.3-10) | 9.6 ± 0.3 (9.2-10) | 9.8 ± 0.5 (9.1-10) | 9.7 ± 0.4 (9-10) | 9.3 ± 0.3 (9-10) | 9.6 ± 0.4 (9.1-9) | 9 ± 0.4 (8.2-9.6) | 9.5 ± 0.3 (9.1-9.4) | 9.2 ± 0.5 (9-10.1) |
| Lip region height | 3.5 ± 0.2 (3.3-3.9) | 3.6 ± 0.2 (3.3-3.9) | 3.4 ± 0.2 (3-3-7) | 3.3 ± 0.2 (3.1-3.7) | 3.4 ± 0.3 (3.1-3.8) | 3.4 ± 0.2 (3.1-3.8) | 3.6 ± 0.2 (3.1-3.8) | 3.6 ± 0.3 (3.3-3.8) | 4.1 ± 0.2 (3.4-4.1) | 4.0 ± 0.4 (3.6-4.8) |
| DGO | 5.4 ± 0.2 (5.1-5.9) | 5.5 ± 0.2 (5.1-5.8) | 5.5 ± 0.2 (5-5-8.4) | 5.3 ± 0.2 (5-5-7) | 5.2 ± 0.2 (5-5-6.6) | 5.3 ± 0.2 (5-5-6.6) | 5.2 ± 0.2 (5-5-6.6) | 5.7 ± 0.4 (5-5-6.6) | 6.2 ± 0.6 (5-5-6.6) | 6.6 ± 0.8 (5-5-6.6) |
| Anterior end to excretory pore | 104 ± 6.5 (91-113) | 112 ± 4.12 (104-119) | 105 ± 3.3 (101-112) | 110 ± 4.8 (102-112) | 106 ± 3.65 (98-110) | 103 ± 2.7 (98-108) | 109 ± 3.3 (102-115) | 113 ± 4.2 (105-121) | 110 ± 2.7 (105-114) | 105 ± 3.6 (101-111) |
| BWA | 15 ± 0.8 (14-16) | 18 ± 1.4 (15-19) | 16 ± 0.9 (15-19) | 17 ± 0.4 (14-16) | 16 ± 0.6 (15-17) | 17 ± 1.7 (14-17) | 16 ± 0.9 (17-17) | 16 ± 0.6 (15-17) | 14 ± 0.7 (14-17) | 12 ± 0.7 (14-17) |
| Tail length | 63 ± 4.8 (52-68) | 65 ± 4.4 (58-72) | 65 ± 3.5 (60-70) | 61 ± 3.5 (57-67) | 61 ± 3.5 (56-67) | 61 ± 3.5 (56-67) | 61 ± 3.5 (56-67) | 61 ± 3.5 (56-67) | 61 ± 3.5 (56-67) | 61 ± 3.5 (56-67) |
| Hyaline tail length | 39 ± 3.7 (35-47) | 40 ± 3.8 (33-46) | 41 ± 4.5 (35-48) | 39 ± 3.3 (34-44) | 39 ± 2 (34-42) | 39 ± 2 (34-42) | 37 ± 2 (32-40) | 37 ± 2 (34-42) | 38 ± 2 (34-42) | 44 ± 3.1 (40-48) |
| Tail length/BWA | 4.1 ± 0.2 (3.8-4.4) | 3.6 ± 0.4 (3.1-4.2) | 4.2 ± 0.3 (3.4-4.5) | 3.7 ± 0.12 (3.5-3.9) | 3.9 ± 0.2 (3.6-4-3) | 3.9 ± 0.2 (3.6-4-3) | 3.5 ± 0.4 (3.2-4-2) | 3.5 ± 0.4 (3.3-4-4) | 4.3 ± 0.3 (3.9-4-9) | 4.1 ± 0.3 (3.7-4-6) |

Note: n = Number of specimens; L = Total body length; a = Body length/body width; b = Body length/distance from anterior end to junction of oesophagus and intestine; c = Body length/tail length; BWA = Body width at anus; DGO = Dorsal pharyngeal gland opening from stylet konbs.
Part 3: Analysis of genetic structure for Chinese *Heterodera avenae* populations based on SSR microsatellite markers

**Material and methods**

*DNA extraction*

The cysts were recovered from wheat root samples collected at different locations (Table S1). Prior to DNA extraction, the identity of recovered Chinese *Heterodera avenae* population (CHA) were confirmed both by morphology and molecular barcoding using COI gene. The cysts were incubated at 4 °C for 6 weeks then at 16 °C to stimulate the hatching of pre-parasitic second-stage juveniles (J2s). For each population, J2s from 32 individual cysts were extracted separately following the protocol described by Adam et al. (2007), resulting a total of 416 individual cysts from 371 samples were used further analyses (Table S1).

*SSR amplification and genotyping*

A total of 9 pair primers were used for SSR amplification (Table S7), and subsequently divided into three groups according fragment size, i.e. (1) CS-19, CS-20, CS-31; (2) CS-60, CS-137, CS-170; (3) CS-179, CS-8384, CS-174. PCR was performed following the method detailed in Wang et al. (2018). Briefly, a 20 μL reaction mixture was used containing three primers and 2 μL of the template DNA of each cyst, 0.2mM dNTP, 1 × PCR buffer and 0.2 μL TaKaRa Ex Taq DNA Polymerase (Takara Bio, Dalian, China). PCR products were analyzed using an ABI 3730 sequencer (Applied Biosystems, Carlsbad, CA, USA) according to the manufacturer’s instructions. Allele sizes were determined using GENEMAPPER version 4.0 (Applied Biosystems, Carlsbad, CA, USA), using LIZ-500 (−250) as the size standards.

| Table S7 Primer sequence and features of nine microsatellite loci used in this study |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| Locus  | Motif  | Primer sequence (5'-3') | T_a (℃) | Size range (bp) |
|--------|--------|--------------------------|---------|-----------------|
| CS-19  | (AGG)_5| F: ATGAGCAGCAACAACAGCAG | 56      | 147－151        |
|        |        | R: ACTTCTCATCGTGTCCGTATG |         |                 |
| CS-20  | (TG)_10| F: ATTCGAATACTTCTCGCTTTCCC | 56      | 128－155       |
|        |        | R: GAATGGAAGGCTAACTAAGGTT |         |                 |
| CS-31  | (CTG)_6| F: ACAGTATGGTATCGCAAAAGG | 56      | 164－168        |
|        |        | R: TTCTGTCTCAATTGTTCTTTC |         |                 |
**Data analyses**

The FSTAT 2.9.3 program (Goudet, 1995) was used to calculate the fixation index ($F_{ST}$) and the individual inbreeding coefficient ($F_{is}$) among and within the population. The MSAnalyzer 4.05 (Dieringer & Schlötterer, 2003) was used to calculate the genetic distance between J2 individuals based on shared alleles, and GenAlex 6.5 (Peakall & Souse, 2006) was used for PCoA analysis using the genetic distance matrix. STRUCTURE v2.3.4 was used to analyze the population structure based on the Bayesian clustering method (Pritchard et al., 2000), and the mixed ancestry model and the allele frequency association model were used to carry out $10^6$ repeated Markov Monte Carlo Chain (MCMC) search, and discard the first $10^5$ clustering results to determine the optimal number of clusters (K). The K value is set from 1 to 13, and each K value is run 20 times to calculate the LnP(D) corresponding to each K value, and then calculate the $\Delta K$ value through LnP(D) to obtain the difference between the K value and $\Delta K$ (Evanno et al., 2005). The 20 replicates were aligned and integrated using CLUMPP v1.1.2 software (Jakobsson & Rosenberg, 2007), and finally plotted using DISTRUCT (Rosenberg, 2004). The ARLEQUIN v3.5 (Excoffier et al., 2010) was used to calculate the Analysis of Molecular Variance (AMOVA), and the three types were compared: variation between groups, between populations but within a group, and among individuals but within a population. Neighbor-joining phylogenetic tree was constructed using POPULATION v1.2.30 (http://bioinformatics.org/~tryphon/populations) based on Cavalli-Sforza and Edwards genetic distances (Cavalli-Sforza & Edwards, 1967). The
Wilcoxon signed-rank test method in BOTTLENECK v1.2.02 (Cornuet & Luikart, 1996) was used to test whether each population had experienced bottleneck effect, based on infinite allele model (IAM) and two-phase model (TPM) and stepwise mutation model (SMM), and three models were tested separately (Cristescu et al., 2010). In order to clarify whether geographic isolation aggravates the graminearum cyst nematode Genetic differentiation of populations. The Mantel test implied R package “ade4” was used to test the fixation index $F_{ST}$ among populations based on microsatellite data and the average geographic distance of the sampling area.
Results

Genetic diversity of the CHA population

In general, we recovered a low genetic diversity among studied population (Table S8). The result showed that the 13 CHA populations have the allelic richness ranging from 1.889 to 3.111, with an average of 2.453. The observed heterozygosity was ranging from 0.163 to 0.344 with an average of 0.253 while the expected heterozygosity was between 0.180 and 0.414 with an average was 0.276. Testing for Hardy-Weinberg equilibrium found that 8 out of 13 populations deviate from the equilibrium and the main reason for the deviation is the loss of heterozygotes. The inbreeding coefficient ($F_{is}$) ranged from -0.115 to 0.220, and the rest of the populations were deviate significantly from equilibrium ($P < 0.05$) except for the Gansu population (GS), Qinghai population (QH), Hebei population (HH), Shandong population (SD) and Hubei population (HB).

Table S8 Statistics of genetic diversity for 13 CHA populations based on nine microsatellite markers

| Population | N  | Na   | Ne   | Ho   | He   | uHe   | HWE  | Fis |
|------------|----|------|------|------|------|-------|------|-----|
| TJ         | 32 | 3.111| 1.900| 0.344| 0.414| 0.421  | ***  | 0.185|
| BJ         | 32 | 2.677| 1.827| 0.319| 0.386| 0.393  | ***  | 0.187|
| GS         | 32 | 1.889| 1.451| 0.264| 0.239| 0.243  | ns   | -0.088|
| QH         | 32 | 2.778| 1.242| 0.192| 0.180| 0.183  | ns   | -0.044|
| SS         | 32 | 2.333| 1.164| 0.281| 0.339| 0.345  | *    | 0.187|
| NX         | 32 | 2.000| 1.368| 0.163| 0.205| 0.208  | **   | 0.219|
| SX         | 32 | 2.333| 1.449| 0.205| 0.228| 0.231  | ***  | 0.115|
| HH         | 32 | 2.111| 1.426| 0.260| 0.230| 0.234  | ns   | -0.115|
| SD         | 32 | 2.333| 1.442| 0.243| 0.238| 0.242  | ns   | -0.004|
| AH         | 32 | 2.111| 1.469| 0.188| 0.236| 0.240  | **   | 0.220|
| HN         | 32 | 3.000| 1.743| 0.299| 0.342| 0.347  | ***  | 0.143|
| HB         | 32 | 2.333| 1.480| 0.267| 0.257| 0.261  | ns   | -0.023|
| JS         | 32 | 2.889| 1.507| 0.271| 0.299| 0.304  | **   | 0.110|
| Mean       |    | 2.453| 1.534| 0.253| 0.276| 0.281  |      |     |

Sample size ($N$), average number of alleles per locus ($Na$), the effective number of alleles ($Ne$), the observed heterozygosity ($Ho$), the expected heterozygosity ($He$), unbiased expected heterozygosity ($uHe$), deviation from HWE for heterozygosity deficit and estimator of the fixation index ($F_{is}$); ns, not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Population structure of CHA
Genetic structure of studied population suggested a moderate to high $F_{ST}$ value, with the average fixation index as 0.162, and the 95% confidence interval is between 0.094 and 0.224 (Table S9). The smallest fixation index ($F_{ST} = 0.004$) was found between Beijing (BJ) and Tianjin (TJ) while the largest ($F_{ST} = 0.435$) was between Qinghai (QH) and Ningxia (NX) population. Mantel test was performed using $F_{ST}$ as the genetic distance against their geographic distance. The results suggested that there was a significant positive correlation between genetic distance and geographic distance ($r = 0.284$, $P = 0.038$), and the CHA population followed the isolation-by-distance pattern (IBD) pattern (Fig. S2).

Table S9 Pairwise comparison of $F_{ST}$ values between different CHA populations

| Population | TJ | BJ | GS | QH | SS | NX | SX | HD | SD | AH | HN | HB |
|------------|----|----|----|----|----|----|----|----|----|----|----|----|
| BJ         | 0.004 |    |    |    |    |    |    |    |    |    |    |    |
| GS         | 0.122* | 0.117* |    |    |    |    |    |    |    |    |    |    |
| QH         | 0.129* | 0.153* | 0.117* |    |    |    |    |    |    |    |    |    |
| SS         | 0.109* | 0.101* | 0.172* | 0.239* |    |    |    |    |    |    |    |    |
| NX         | 0.234* | 0.209* | 0.350* | 0.435* | 0.075* |    |    |    |    |    |    |    |
| SX         | 0.252* | 0.249* | 0.381* | 0.395* | 0.132* | 0.182* |    |    |    |    |    |    |
| HH         | 0.202* | 0.191* | 0.331* | 0.364* | 0.130* | 0.142* | 0.084* |    |    |    |    |    |
| SD         | 0.120* | 0.120* | 0.247* | 0.239* | 0.110* | 0.140* | 0.156* | 0.050* |    |    |    |    |
| AH         | 0.159* | 0.185* | 0.343* | 0.346* | 0.150* | 0.209* | 0.226* | 0.182* | 0.129* |    |    |    |
| HN         | 0.095* | 0.068* | 0.170* | 0.261* | 0.052* | 0.086* | 0.166* | 0.085* | 0.073* | 0.114* |    |    |
| HB         | 0.134* | 0.124* | 0.262* | 0.322* | 0.063* | 0.055* | 0.153* | 0.070* | 0.045* | 0.088* | 0.024* |    |
| JS         | 0.060* | 0.061* | 0.175* | 0.190* | 0.042* | 0.119* | 0.142* | 0.125* | 0.057* | 0.079* | 0.045* | 0.039* |

* $P < 0.05$
Fig. S2 Mantel test of correlation between geographic distance and genetic distance of CHA populations

Fig. S3 Scatterplot of the principal coordinate (PcoA) of CHA populations based on SSR data

The PcoA (Fig. S3) showed that the CHA populations were clustered into three groups, *i.e.*: Beijing-Tianjin region, central region and northwest region. With the coordinate 1 explains 52.78% and coordinate 2 explains 15.29% of variance, two axes explain a total of 68.07% variance. We further constructed the NJ phylogenetic tree based on the Cavalli-Sforza & Edwards genetic distance and resulted topology was generally consistent with the clustering in principal coordinate analysis (Fig. S4).
In Bayesian cluster analysis based on STRUCTURE, the highest $\Delta K$ value was achieved when $K = 2$ (Figure 5a), but $\Delta K$ remain relatively high when $K = 3$. Only after the LnP(K) value greater than 3 both $\Delta K$ and LnP(K) tends to be stable (Fig. 5a,4b).

When $K = 2$, the studied populations can be clustered into two groups, namely the Beijing-Tianjin-Northwest (green, Group I) and the central region (red, Group II), and the gene mixing is more obvious. When $K = 3$, the populations were clustered into three groups, namely the
Beijing-Tianjin region (Clade I), northwest region (Clade II) and central region (Clade III). All groups within Clade II and Clade II groups had mixed genotypes (Fig. S6).

Fig. S6 The distribution of genotype in different clustering K value

The analysis of molecular variation model

The results of AMOVA (Table S10) showed that 83.77% of the variation came within the population (intra-population) in the case of no grouping. When the population was clustered into two groups (K = 2), the intra-population variation rate accounted for 78.03%, the inter-groups variation rate was 12.72%, and the inter-populations variation rate was 9.25%. When the population was clustered into 3 groups (K = 3), the population variation rate was similar to that of the two groups, the intra-population variation rate accounted for 78.09%, and the inter-group variation rate was 13.91%, and the variation rate between populations was 7.99%.
Table S10 AMOVA analysis of CHA populations

| Source of variation | df  | Sum of squares | Variance components | Percentage of variation (%) | $F_{ST}$ |
|---------------------|-----|----------------|---------------------|-----------------------------|---------|
| Overall             |     |                |                     |                             |         |
| Inter-population    | 12  | 203.215        | 0.245 Va            | 16.23                       | 0.162*  |
| Intra-population    | 819 | 1035.031       | 1.264 Vb            | 83.77                       |         |
| Two groups (k=2)    |     |                |                     |                             |         |
| Inter-groups        | 1   | 83.891         | 0.206 Va            | 12.72                       | 0.220*  |
| Inter-population    | 11  | 119.324        | 0.150 Vb            | 9.25                        | 0.110*  |
| Intra-population    | 819 | 1035.031       | 1.264 Vc            | 78.03                       | 0.127*  |
| Three groups (k=3)  |     |                |                     |                             |         |
| Inter-groups        | 2   | 107.778        | 0.225 Va            | 13.91                       | 0.139*  |
| Inter-population    | 10  | 95.438         | 0.129 Vb            | 7.99                        | 0.093*  |
| Intra-population    | 819 | 1035.031       | 1.264 Vc            | 78.09                       | 0.219*  |

* $P<0.001$.

Detection of possible bottleneck effect

The BOTTLENECK software was used to detect the bottleneck effect was calculated based on the three models of IAM, TPM and SMM. The data are shown in Table S11.

Table S11 Bottleneck effect of CHA populations based on Wilcoxon test

| Population | IAM | TPM | SMM |
|------------|-----|-----|-----|
| AH         | 0.406| 0.531| 0.656|
| BJ         | 0.082| 0.282| 0.410|
| GS         | 0.039*| 0.219| 0.344|
| HB         | 0.422| 0.680| 0.963|
| HH         | 0.234| 0.531| 0.813|
| HN         | 0.422| 0.629| 0.844|
| JS         | 0.752| 0.898| 0.982|
| NX         | 0.344| 0.719| 0.781|
| QH         | 0.998| 0.999| 0.999|
| SS         | 0.027*| 0.125| 0.371|
| SD         | 0.680| 0.844| 0.963|
| SX         | 0.727| 0.844| 0.981|
| TJ         | 0.102| 0.285| 0.590|
| Beijing-Tianjin | 0.203| 0.734| 1.000|
In general, no significant bottleneck effect was found in across populations according to TPM and SMM model. However, signals were detected under the IAM model suggesting the GS and SS populations may recently experience bottleneck effects. Under the SMM model and three clustering groups, only the northwest region has a certain bottleneck effect, while neither the Beijing-Tianjin region nor the central region has experienced the bottleneck effect.

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Part 4: Material and method

1. Morphological analyses

Cysts were extracted from approximately 500 g of soil samples using standard flotation and sieving technique. To examine the floating cysts in water, a 100 mesh sieve was placed under water for 2-4 h. For morphological analyses, second-stage juveniles (J2) were extracted from soil using Baermann tray, killed and fixed in hot TAF and processed to glycerin dehydration (De Grisse, 1969). The J2s were mounted in glycerin and vulval cones were mounted in gelatine. The permanent slides were examined, measured and photographed with Olympus BX51 microscopy equipped with Olympus DP72 camera.

2. PCR amplification and sequencing

Two primer pairs were used for COI gene amplification. A shorter primer pairs JB3 (5’-TTTT GGG CAT CCT GAG GTT TAT-3’) and JB4.5 (5’-TAA AGA AAG AAC ATA ATG AAA ATG-3’) (Bowles et al., 1992), and a newly designed longer primer pairs COI442F (5’-CAT TTA GCA GGA ATT AGT TC-3’) and COI1326R (5’-CAC TAT AAT CTA AAT ATT TAC G-3’). Reaction mixture is 25 μl in volume containing the following: 2.5 μl 10× buffer, 1.5 μl 50 mM MgCl2, 2.0 μl 2.5 mM dNTP, 1 U Taq DNA polymerase (TaKaRa, China), 1 μl 10 μM of each primer, 2-4 μl genomic DNA (50 ng/μl), and double-distilled water was added to make a final volume of 25 μl. PCR reaction was conducted at 95°C for 3 min, followed by 35 cycles of 30 s at 95°C, 30 s at 45°C, 30 s at 72°C, and finally at 72°C for 10 min. The amplified products were examined by agarose gel electrophoresis and subsequently sent to TsingKe Biotechnology (Nanjing, China) for sequencing.