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# Identification and characterisation of resistance to the cereal cyst nematode *Heterodera filipjevi* in winter wheat

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**Summary –** The aim of this study was to search for new sources of resistance against the cereal cyst nematode, *Heterodera filipjevi*, in a collection of 290 wheat accessions. The plants were inoculated with juveniles and assessed for the number of females and cysts. One percent of the wheat accessions were ranked as resistant, 16% as moderately resistant, 41% as moderately susceptible, 26% as susceptible and 15% as highly susceptible. The infection rate and the number of females and cysts per plant were significantly lower in the resistant accession Nudakota and three moderately resistant accessions Ekonomka, Katea and Lantian 12 compared with susceptible cv. Bezostaya 1. Nematode development was reduced in resistant and moderately resistant accessions. The size of females and the total number of eggs and second-stage juveniles were reduced only in Ekonomka. No significant difference in plant height, plant weight, root length, root weight and root volume were recorded for inoculated plants compared to non-inoculated plants. This study has identified four resistant wheat accessions offering new material for breeding the resistance to *H. filipjevi*.

**Keywords –** breeding, host-nematode interaction, infection, susceptibility, *Triticum aestivum*.

Plant-parasitic nematodes significantly limit food production worldwide with at least 17 important nematode species in three major genera (*Meloidogyne*, *Heterodera* and *Pratylenchus*). Cereal cyst nematodes (CCN) are an important group of plant-parasitic nematodes attacking cereals. CCN comprise a number of closely related species that cause severe yield loss in cereals in many parts of the world including North Africa, West Asia, China, India, Australia, USA and Europe (Nicol & Rivoal, 2008). *Heterodera avenae*, *H. filipjevi* and *H. latipons* are frequently reported species in wheat and each species consists of various pathotypes (Rivoal & Cook, 1993; Holgado *et al*., 2005; Toktay *et al*., 2013). *Heterodera filipjevi* has been described in China, Estonia, India, Iran, Libya, Morocco, Norway, Pakistan, Russia, Sweden, Tadzhikistan, Tunisia, Turkey and USA (Rumpenhorst *et al*., 1996; Holgado *et al*., 2004; Smiley *et al*., 2008; Riley *et al*., 2009; Nicol *et al*., 2011). In Turkey, *H. filipjevi* has been found in 87% of the wheat-growing area in the Central Anatolian Plateau with an estimate of yield loss up to 50% in several rain-fed winter wheat locations (Nicol *et al*., 2006). Infected mature plants are stunted, have a reduced number of tillers and the roots are bushy and knotted (Nicol *et al*., 2011). Growth of the plants was retarded and their lower leaves are often chlorotic thus forming pale green patches in the field.

The life cycle of *H. filipjevi* has not been studied in detail but it is suggested to be similar to other CCN species such as *H. avenae* and *H. latipons* (Hajihasani *et al*., 2010). Morphologically, *H. filipjevi* can be distinguished by the presence of bifenestrate vulval cones, a distinct underbridge and a robust stylet with anterior concave knobs, and a hyaline terminal tail in second-stage juveniles (J2) (Abdollahi, 2008; Smiley *et al*., 2008). *Heterodera filipjevi* is a sedentary nematode and completes only one generation during each crop season (Hajihasani *et al*., 2010; Seifi *et al*., 2013). The mechanisms by which cyst nematodes invade roots have been investigated in several

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plant species (Sobczak & Golinowski, 2011). In general, the vermiform J2 of cyst nematodes invade epidermal and cortical cells behind the tips of young roots, migrate intracellularly towards the vascular cylinder and select a single cell (initial syncytial cell) in the stele into which they inject effector molecules, thereby inducing the formation of enlarged syncytial feeding structures in roots (Wyss & Grundler, 1992; Hewezi & Baum, 2013). After feeding has commenced, the juveniles become sessile and moult consecutively into the third-stage juvenile (J3), fourth-stage juvenile (J4) and eventually into the adult female or male. *Heterodera filipjevi* is sexually dimorphic and sex becomes morphologically apparent during the J3 stage. Adult males regain mobility to find females for mating, whereas females remain embedded in the root tissue and continue to feed from the syncytium. After mating, the females produce several hundred eggs and then die. Their cuticles harden during a tanning process, and the body turns into a resistant brown cyst that protects the eggs in the soil for many years.

Plant resistance is currently the most effective method to control cyst nematodes in cereals (McIntosh, 1997). Nematode resistance against cyst nematodes in plants is characterised by failure or limitation to produce functional feeding sites and female development (Williamson & Kumar, 2006). It has been described for a number of cyst nematodes that juveniles develop into females under favourable conditions in a susceptible host, whereas the number of males increases in resistant hosts (Trudgill, 1967). Accordingly, reduced numbers of females or cysts are the most common traits in nematode resistance. Reduced attraction towards roots and root structural barriers may also be important factors preventing invasion and syncytium induction. Analysis of nematode invasion, nematode development and nematode reproduction provides a detailed understanding of the active resistance mechanisms. Within CCN, most studies have been focused on *H. avenae*. More than nine single dominant genes, known as '*Cre*' have been reported in wild relatives of wheat and barley (Riley *et al*., 2009; Dababat *et al*., 2015). New sources of resistance to *H. filipjevi* were found in wheat, *Thinopyrum* (wheat grass), derivatives (Li *et al*., 2012) and the wheat landrace, Sardari, which is also a source of *Cre1* (Akar *et al*., 2009). Although the exploitation of plant resistance to CCN has great potential, only limited efforts have been made to identify new and effective sources of resistance in wheat. In fact, currently, there are no varieties providing strong and sustainable resistance to *H. filipjevi* in wheat, barley and oat.

Here, we present results of screening a large collection of wheat populations against *H. filipjevi*, which we assume could lead to the identification of new sources of resistance. In addition, detailed studies on the different stages of interaction between host and nematode during invasion, nematode development and reproduction can help us to understand the underlying mechanism of resistance.

## Materials and methods

### Wheat accessions

Two hundred and ninety-one winter wheat accessions including breeding lines, cultivars and landraces were tested (Table S1). The wheat accessions originated from Afghanistan (1), Azerbaijan (1), Bulgaria (2), Canada (2), China (7), Hungary (1), Iran (20), the International Winter Wheat Improvement Program Turkey-CIMMYT-ICARDA (95), Moldova (3), Mexico (29), Romania (1), Russia (28), Serbia (1), South Africa (26), Syria (1), Turkey (24), Ukraine (12) and the USA (36). The material was provided by the International Winter Wheat Improvement Program (http://www.iwwip.org/Nursery).

### Nematode inoculum

A pure growth room culture of *H. filipjevi* from Central Anatolian Plateau, Eskisehir (39.76665°N, 30.40552°E), was collected and cysts were extracted by Cobb's decanting and sieving method (Cobb, 1918). Cysts were picked by hand and sterilised with 0.5% NaOCl for 10 min and rinsed several times with sterile distilled water. The surface-sterilised cysts were transferred into a funnel and stored at 4°C for hatching. Freshly hatched juveniles after 2 days ($\leqslant$48 h) were used as inoculum. We performed a polymerase chain reaction-restriction fragment length polymorphism analysis to confirm the species identification shown in Figure S1 (Yan *et al*., 2010).

### Screening assay of wheat accessions

Six spikes of each of the 290 wheat accessions were picked by hand and one representative spike was selected from each accessions. A susceptible wheat cv. Bezostaya 1 was used as control. Seven seeds from each spike were germinated in moistened tissue in Petri dishes for 3 days at 22°C. After germination, five seedlings of a similar phenotype were selected. A sterilised potting mixture of sand, field soil and organic matter (70:29:1, v/v/v) was filled in RLC4-pine tubes (25 × 160 mm, Ray

Leach Cone-tainer™; Stuewe & Sons). One germinated seed was planted per tube in a 200 tube rack (RL200; Ray Leach Cone-tainer™) and plants were organised in a randomised block design. Each plant was inoculated with 250 freshly hatched J2 of *H. filipjevi* in 1 ml water into three holes around the shoot base 7 days after transplanting. Plants were grown in a growth room at 26°C and 65% RH. Twenty-five days after planting, plants were fertilised with water-soluble Nitrophoska® Solub/Hakaphos® (20:19:19 NPK including micro elements such as $P_2O_5$, $K_2O$, B, Cu, Fe, Mn, Mo and Zn; COMPO) at 1 g $l^{-1}$. Plants were harvested at 63 days post infection (dpi) to collect the cyst from the soil and the roots. The soil from each tube was collected in a 2 l beaker filled with water and the soil mixture was stirred, then left for about 30 s to allow the heavy sand and soil debris to settle down. Roots were washed very gently on the upper sieve to free any females and cysts left attached to the root system. The soil mixture was poured through 850 and 250 $\mu$m sieves. This process was repeated three times to ensure all females and cysts were collected. Females and cysts from both roots and soil were captured on a 250 $\mu$m sieve and counted under a dissecting microscope. The roots were further checked for females and cysts that had not been dislodged during the washing process. The host status of the tested wheat accessions was determined and categorised into five groups based on mean number of females and cysts present per plant (Dababat *et al.*, 2014). The following ranking was used on a per plant basis: resistant (R) = <5 females and cysts; moderately resistant (MR) = 5-10 females and cysts; moderately susceptible (MS) = 11-15 females and cysts; susceptible (S) = 16-19 females and cysts; and highly susceptible (HS) = >20 females and cysts. The widely grown winter wheat cv. Bezostaya 1 in Turkey was used as the susceptible control.

### Resistance assay

To identify potential mechanisms of resistance, nematode invasion, development and reproduction was monitored in the resistant accession Nudakota and three moderately resistant accessions Ekonomka, Katea and Lantian 12, and compared to the susceptible cv. Bezostaya 1. The experimental method described above for the screening assay of wheat accessions was used for the resistance assay. For plant growth measurements, non-inoculated (NI) and inoculated (I) plants were analysed. All treatments were repeated 18 times and performed in a completely randomised design. To monitor nematode infection and nematode development, roots were stained with acid fuchsin at 2, 5, 10 and 15 dpi (Byrd *et al.*, 1983). To determine nematode reproduction, plants were harvested at 63 dpi, female and cysts were extracted from roots and soil, and the numbers of eggs and J2 determined after gently crushing the cysts. To measure cyst size, cysts were transferred to 2% water agar and photographed with a DM2000 dissection microscope (Leica Microsystems). The largest optical section of the cysts area was calculated using LAS software (Leica Microsystems). To assess growth parameters, the plants were washed gently, remaining soil particles were removed, and the root surface was dried with soft paper towel. Immediately after drying, the fresh plant weight and root weight was recorded. Plant height was assessed as the distance from the base of the stem to the base of the spike. Root length was determined by using WinRHIZO™ software (Regent Instruments Canada); root volume was measured volumetrically (Harrington *et al.*, 1994).

### Data analysis

In the first round of wheat accession screening, mean, standard deviation and standard error of number of cysts were determined. In the following resistance assay, the data were analysed using Sigma Plot 11.0. Statistical analysis included one-way analysis of variance and post-hoc analysis by the Holm-Sidak method. Statistical differences were accepted as significant at $P \leqslant 0.05$. Regression analysis was used to relate the size of cyst to the total number of eggs and J2 developed on the different wheat accessions. A polynomial regression analysis was used to calculate the best fitting equation.

## Results

### Screening assay of wheat accessions

The screening of 290 winter wheat accessions resulted in identifying 1% as resistant, 16% as moderately resistant, 41% as moderately susceptible, 26% as susceptible and 15% as highly susceptible to *H. filipjevi* (Table S1).

### Resistance assay

*Nematode invasion*

The time-course of juvenile infection in selected wheat accessions Nudakota Katea, Ekonomka, Lantian 12 and cv. Bezostaya 1 at 2, 5 and 10 dpi is shown in Figure 1. No significant difference in nematode penetration among

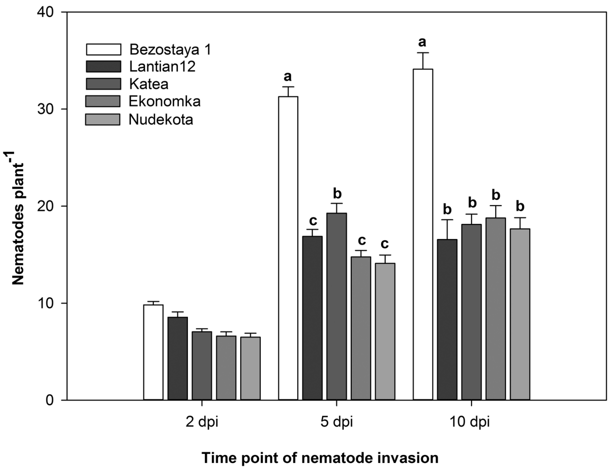


**Fig. 1.** Nematode infection in different selected wheat accessions at 2, 5 and 10 days post inoculation (dpi). Columns with different letters are significantly different based on one way analysis of variance (Holm-Sidak) analysis at ($P \leqslant 0.05$, n = 18) and a > b. Bar indicates the standard error of the mean.

the tested wheat accessions was found at 2 dpi. The number of J2 in the root was generally low, around 5-10. However at 5 dpi, nematode penetration was significantly greater, about 32 J2 in cv. Bezostaya 1 and up to about, 19 J2 in Ekonomka, Katea, Lantian 12 and Nudakota. The highest nematode infection was observed at 10 dpi in all accessions, with a significantly lower number in resistant and moderately resistant accessions compared to the susceptible cv. Bezostaya 1.

*Nematode development*

In Ekonomka, Katea, Lantian 12 and Nudakota, the number of J3 and J4 juveniles was found to be much lower at 10 dpi than in cv. Bezostaya 1 (Fig. 2A), reflecting the lower number of invading J2. At 15 dpi, the number of J3 in Katea, Ekonomka, Nudakota and Lantian 12 were significantly lower than in cv. Bezostaya 1 (Fig. 2B). At the same time point, the number of J4 females resulted from the development of J3. It was high in cv. Bezostaya 1, but significantly lower in all four resistant accessions. In addition, the number of males in Katea and Nudakota was significantly higher than in cv. Bezostaya 1.

*Nematode reproduction*

In addition to reduced and delayed nematode invasion and development in Ekonomka, Katea, Lantian 12 and Nudakota, the numbers of mature cysts were also significantly lower when counted at 63 dpi (Table 1). In this experiment, Lantian 12 was regarded as MS, due to slightly higher number of females per plant (Table 1).

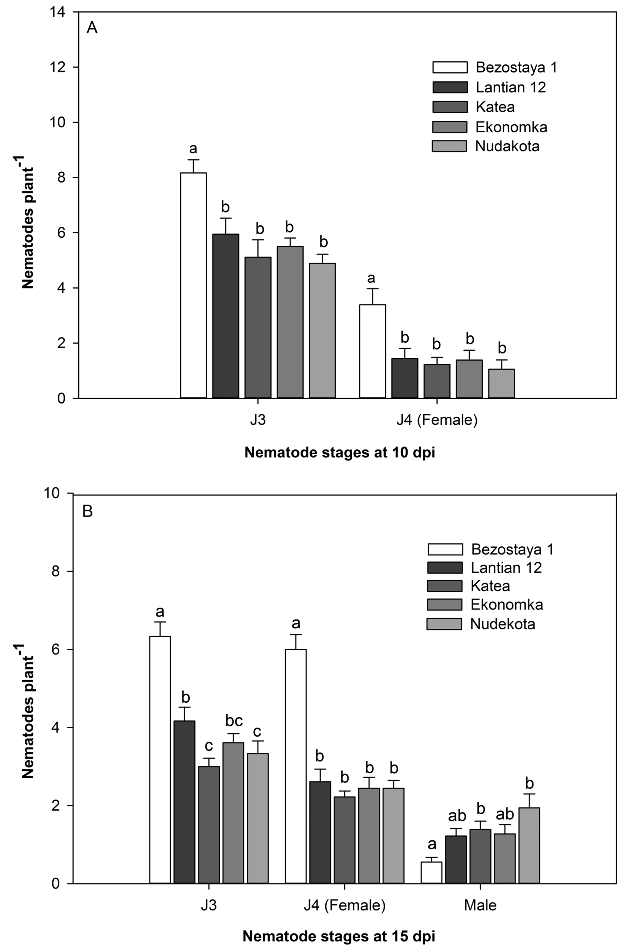


**Fig. 2.** Nematode development in selected wheat accessions at: A: 10 days post inoculation; B: 15 days post inoculation. Columns with different letters are significantly different based on one way ANOVA (Holm-Sidak) analysis at ($P \leqslant 0.05$, n = 18) and a > b. Bar indicates the standard error of the mean.

However, the mean number of cysts per plant was significantly less than in cv. Bezostaya 1. Cyst sizes in Katea and Ekonomka were significantly smaller, whilst there were no significant difference in Lantian 12 and Nudakota compared with cv. Bezostaya 1. Ekonomka and Nudakota contained significantly fewer eggs and juveniles per cyst compared with cv. Bezostaya 1. The regression analysis revealed no correlation between total number of eggs and juveniles to the cyst size in all wheat accessions (Fig. 3).

*Plant growth*

For analyses of basic plant growth parameters, we monitored plant height, plant fresh weight, root length, and root fresh weight at 63 dpi of inoculated and non-

**Table 1.** Selected winter wheat accessions and their response to *Heterodera filipjevi* development and reproduction.

| Wheat genotype | Pedigree | Origin | Cysts per plant | SD | SE | Cyst size ($mm^2$) | Eggs per cyst | J2 per cyst | Total (eggs+J2) | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| Bezostaya 1 | LUT17/SRS2 | Russia | 25.47[a] | 4.7 | 1.1 | 0.232[a] | 164 | 23 | 187[a] | HS |
| Lantian 12 | Qingnong-4/ Xiannong-4 | China | 10.45[b] | 3.3 | 0.8 | 0.198[ab] | 145 | 11 | 156[ab] | MS |
| Katea | Hebros/Bez-1 | Bulgaria | 7.98[bc] | 2.5 | 0.6 | 0.178[b] | 140 | 16 | 156[ab] | MR |
| Ekonomka | – | Ukraine | 6.39[bc] | 1.8 | 0.4 | 0.183[b] | 96 | 10 | 106[b] | MR |
| Nudakota | Jagger/ Romanian | USA | 3.52[c] | 1.2 | 0.3 | 0.200[ab] | 128 | 11 | 139[b] | R |

Columns with different letters are significantly different based on one way ANOVA (Holm-Sidak) analysis at ($P \leqslant 0.05$, n = 18) and a > b > c.
Abbreviations: HS: highly susceptible; R: resistant: MR: moderately resistant; J2: second-stage juveniles; SD: standard deviation; SE: standard error.

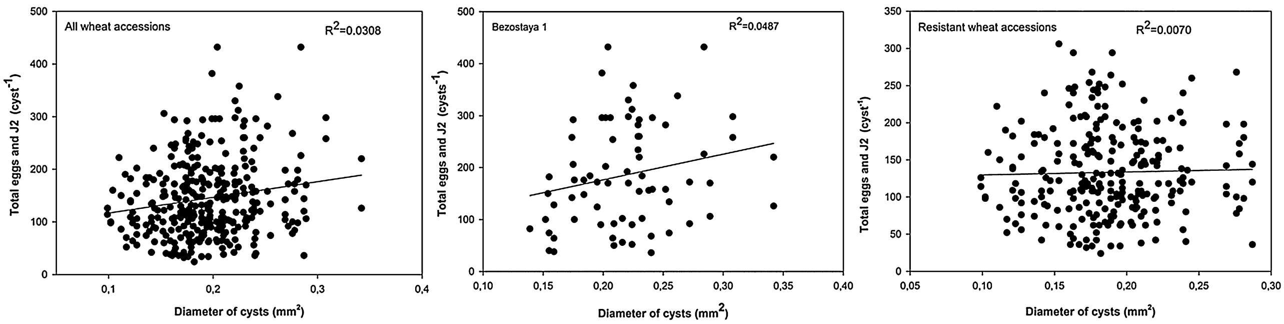


**Fig. 3.** Regression coefficient ($R^2$) for relation between cyst sizes (mm) to total number of eggs and juveniles in five wheat accessions ($P \leqslant 0.05$, n = 67).

inoculated plants. No significant differences were found in plant height, plant weight, root length, root weight and root volume between inoculated and non-inoculated Katea, Ekonomka and Nudakota (Fig. 4).

## Discussion

Resistant wheat cultivars can be very effective in controlling cyst nematodes. Research to identify resistance sources and to characterise molecular markers for resistant phenotypes is ongoing in wheat and its wild relatives. However, there are very few studies focusing on the mechanism of resistance in wheat-nematode interactions. Wheat landraces and domesticated genotypes possess genetic variation including resistance to biotic and abiotic stresses (Kimber & Feldman, 1987). Here, we analysed wheat populations with wide geographical distribution and diverse genetic background to identify a new sources of resistance that can be introduced into wheat breeding. Two hundred and ninety-one wheat accessions used in this study responded differentially to *H. filipjevi* infection and damage. Seventeen percent of the wheat accessions led to significant reduction in nematode numbers compared to Bezostaza 1 and were therefore classified as R (1%) and MR (16%) (Table S1). In these wheat accessions, nematode infection and development was suppressed and relatively few females developed to maturity. The frequency of resistant accessions observed in this study varied significantly among the different geographical origin (Table 1). Two winter wheat cvs Silverstar (source of *Cre1*) and Frame (source of *Cre8*) were reported to confer moderate resistance to *H. filipjevi* (Imren *et al.*, 2012). The Iranian bread wheat landrace Sardari carrying the *Cre1* gene was reported to confer moderate resistance to *H. filipjevi* (Akar *et al.*, 2009). However, the Sardari (accession number (ACCNO) 951009, Table S1) was only moderately susceptible in our study. The experimental method used by Akar *et al.* was different and the inoculum density (20 J2) was low compared to our study. A screening, performed in a glasshouse, and field

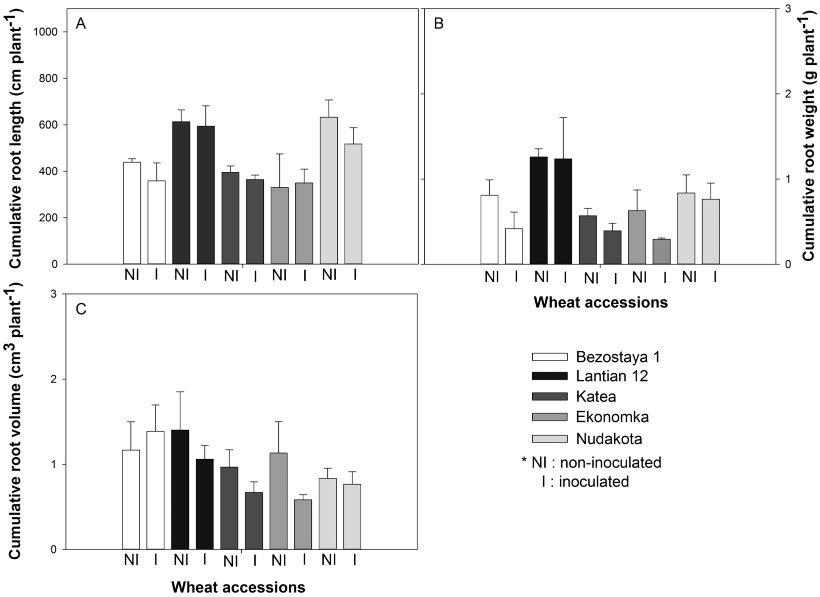


**Fig. 4.** Effect of *Heterodera filipjevi* on wheat growth determined as cumulative root length (A), root volume (B) and root weight (C) on different wheat accessions. Columns with different letters are significantly different based on one way ANOVA (Holm-Sidak) analysis at ($P \leqslant 0.05$, n = 18) and a > b. Bar indicates the standard error of the mean.

trials revealed one resistant wheat germplasm (6R(6D)) and two moderately resistant wheat germplasm (Mackller and CROC_1/AE.SQUARROSA(224)//OPATA) (Yuan *et al*., 2011). The two wheat accessions ES 84.24/GRK and Suzen 97 (ACCNO 000374 and 950283, Table S1) tested in this study (Yuan *et al*., 2011) were found to be highly susceptible, thus confirming our results.

Several mechanisms of resistance to cyst nematodes have been reported in host plants, including prevention of nematode infection and interruption of nematode development (Montes *et al*., 2004; Reynolds *et al*., 2011). Our data suggest that in resistant accessions nematode development is impaired at three phases: early invasion, nematode development, and reproduction, *i.e.*, the number of eggs and J2. Nematode invasion was very low in all four lines at the infection stage (2 dpi), gradually but moderately increased at 5 and 10 dpi due to juveniles that needed more time to find and invade the roots. We therefore conclude that in these accessions resistance is at least partially based on reduced invasion. This is consistent with other studies in wheat with *H. filipjevi* and *H. avenae* (Sağlam *et al*., 2009; Seifi *et al*., 2013). Other authors also found low invasion of *H. avenae* in resistant wheat cultivars Raj MR 1, CCNRV 4 and AUS 15854 (Pankaj *et al*., 2008). J2 are attracted to host plants by root exudates. Differences in the composition of root exudates might explain lower or higher attraction to roots and may alter nematode behaviour (Zhao *et al*., 2000; Robinson, 2002). J2 use their stylets as tools to pierce cell walls mechanically (Wyss & Zunke, 1986; Wyss, 2002) and to release secretions containing cell wall modifying enzymes facilitate ingress to roots (De Boer *et al*., 1996; Davis *et al*., 2000, 2008; Long *et al*., 2013). The composition of cell walls, therefore, may also determine invasion success by forming a more or less strong physical or physiological obstacle (reviewed by Bohlmann & Sobczak, 2014). Syncytia developed by *H. avenae* in susceptible wheat cv. Meering were metabolically active, while the syncytium of resistant wheat (*Triticum aestivum* cv. AUS10894) remained extensively vacuolated and less active at 13 dpi (Seah *et al*., 2000). A similar report revealed *H. avenae* female development was arrested in resistant wheat near isogenic line AUS10894 × Prins and metabolically active syncytia in the susceptible cv. Prins was reported (Williams & Fisher, 1993). At this stage, we cannot state whether the studied wheat accessions differ in chemical composition of root exudates and cell wall. Our results, however, show that the development of J3, J4 female and male does not differ between susceptible and resistant wheat accessions. We therefore conclude that the resistant accessions do not suppress growth and development of invaded nematodes by limitation or failure of the function of the induced syncytia. This mechanism has often been observed in other host-nematode interactions *e.g.*, in tomato containing *Hero A* gene conferring resistance to potato cyst nematode *Globodera rostochiensis* (Sobczak *et al*., 2005), potato containing *Gpa2* gene to *G. pallida* (Koropacka, 2010) and sugar beet containing *HS1*$^{pro1}$ gene to *H. schachtii* (Holtmann *et al*., 2000). Deterioration of the syncytia in these cases prevents successful completion of the nematode life cycle.

In this study, we examined cyst size as a possible indicator of resistance expecting the size of cysts to be related to the number of eggs and J2 they contain. In fact, cyst size was reduced in two resistant accessions (Katea and Ekonomka). However, counting the number of eggs and J2 revealed no clear correlation between these two traits (Fig. 3). Whereas in Katea, cyst size was reduced, the number of eggs and J2 was not significantly different compared to cv. Bezostaya 1. By contrast, both traits showed significantly reduced values in Ekonomka. Since there is no clear correlation between cyst size and number of eggs and J2, we conclude that cyst size is not a reliable trait to determine nematode resistance. Further studies are needed to verify whether and which plant factors determine these nematode traits.

Among all results achieved by analysing plant growth parameters, only root length and root weight in Lantian 12 and root weight in cv. Bezostaya 1 showed reduction after nematode infection. The fact that in most accessions none of the parameters was changed after inoculation indicates that the plants are tolerant to low nematode infection. The question rises why the susceptible cv. Bezostaya 1 obviously also shows this type of response. Since Bezostaya 1 is a cultivar which is grown extensively in Turkey, it might well be that is has been selected unintentionally by the farmers to maintain or improve wheat production under nematode infestation. Our data, however, do not imply that the studied accessions would show tolerance under field conditions. This trait is much more complex and can finally only be measured through monitoring yield under different conditions. However, here we focused on those parameters that can easily be monitored in a growth room trial. Extensive trials currently in progress will show how the selected accessions perform under field conditions. The challenge will then be to differentiate between effects that can be attributed to resistance from those that are based on tolerance.

From our results, we confirmed that wheat accessions Nudakota, Katea, Ekonomka and Lantian 12 possess resistance and can subsequently be crossed with high-yielding cultivars improving their genetic resistance to CCNs. Currently, we are working on the identification of markers and QTLs that are related to nematode resistance. Therefore, 161 wheat accessions have been included in a genome-wide association study to identify loci/genes conferring resistance to *H. filipjevi* (Pariyar *et al*., 2015). Marker-assisted selection will further improve the development of resistant cultivars. Isolation of candidate genes associated with specific markers will greatly facilitate this process.

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**Table S1.** List of 291 winter wheat accessions with accession number, common name, selection history, origin and host response to *Heterodera filipjevi*.

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11CBWF | 951327 | KINACI97 | -7M-0M-8M-1M-3WM-0WM-4WM-2WM-0WM | SWM12289 | MX-BD | 24.0 | 4.25245 | 2.12623 | HS |
| 2 | 11CBWF | 010580 | KROSHKA | | | RUS | 18.0 | 5.04975 | 2.52488 | S |
| 3 | 11CBWF | 030689 | POBEDA 50 | | | RUS | 21.3 | 4.90465 | 2.45232 | HS |
| 4 | 11CBWF | 080951 | OBRII/DNESTREANCA25//ILICIOVCA/OD.CRASNOCOLOS | | | MOL | 19.5 | 2.04124 | 1.02062 | HS |
| 5 | 11CBWF | 080932 | DRAGANA | | | SERBIA | 15.8 | 4.08928 | 2.04464 | S |
| 6 | 11CBWF | 020966 | L 4224 K 12 | | | KR-RUS | 10.3 | 1.88562 | 0.94281 | MS |
| 7 | 11CBWF | 000017 | 8023.16.1.1/KAUZ | -0SE-0YC-1YE-0YC-2YC-0YC | C3W92WM00378S | MX-TCI | 10.0 | 1.77951 | 0.88976 | MR |
| 8 | 11CBWF | 070404 | CUPRA-1/3/CROC1/AE.SQUARROSA (224)//2*OPATA/4/PANTHEON | -030YE-0E-2E-0E-2E-0E | TCI992280 | TCI | 24.8 | 5.07171 | 2.53585 | HS |
| 9 | 11CBWF | 070028 | TCI | | | | 24.3 | 10.1434 | 5.07171 | HS |
| 10 | 11CBWF | 050150 | KAUZ//ALTAR 84/AOS/3/F10S-1 | -0SE-0YC-0YE-7YE-0YE-2YE-0YE | TCI971281 | TCI | 15.8 | 1.31233 | 0.65617 | S |
| 11 | 11CBWF | 050179 | BONITO//KAREE/TUGELA | -0AP-0AP-0YE-5YE-0YE-3YE-0YE | TCI97AP 039 | TCI | 19.8 | 4.49691 | 2.24846 | HS |
| 12 | 11CBWF | 010634 | CETINEL 2000 | -6H-0YC-0R-1YC-0YC-0E | OWC852672 | TR-ESK | 18.2 | 4.08928 | 2.04464 | S |
| 13 | 11CBWF | 040569 | OR941611 | | | USA-OR | 14.7 | 1.92931 | 0.96465 | MS |
| 14 | 11CBWF | 030164 | KS82W409/SPN//TAM106/TX78V3630 | -0SE-0YC-0E-1YE-0YE-2YM-0YM | TCI951385 | TCI | 16.8 | 1.43372 | 0.71686 | S |
| 15 | 11CBWF | 040347 | MAHON DEMIAS/3/HIM/CNDR//CA8055 | -0AP-0YC-4E-0E-3K-0YK | TCI960471 | TCI | 21.3 | 4.36527 | 2.18263 | HS |
| 16 | 11CBWF | 020135 | AGRI/NAC//KAUZ/3/1D13.1/MLT | -0SE-0YC-*-1YE-1YC-0YC-3YM-0YM | CIT937146 | TCI | 15.7 | 2.65623 | 1.32811 | S |
| 17 | 11CBWF | 000008 | KOLLEGA | | | RUS | 20.2 | 6.40746 | 3.20373 | HS |
| 18 | 11CBWF | 090730 | LANTIAN 22 | | | PRC | 16.2 | 5.94886 | 2.97443 | S |
| 19 | 11CBWF | | aMOSKVICH | | | RUS-KRAS | 11.3 | 3.39935 | 1.69967 | MS |
| 20 | 11CBWF | | POSTROCK | | | US-AGRIPRO | 12.5 | 1.08012 | 0.54006 | MS |
| 21 | 11CBWF | 090874 | Alamoot/3/Alvd//Aldan“s”/IAS58/4/Alamoot/Ga spard | | | IR-KARAJ | 20.3 | 2.35702 | 1.17851 | HS |
| 22 | 11CBWF | 100019 | KS2016/Trego | | ARS05-1034 | US-ARS-NC | 6.3 | 3.39935 | 1.69967 | MR |
| 23 | 11CBWF | 100733 | MV-TOLDI | | | HUN | 18.0 | 2.27303 | 1.13652 | S |
| 24 | 11CBWF | 100668 | LCR/SERI/3/MEX-DW/BACA//VONA/4/TAM200/JI5418 | -0AP-DH16 | ICWH99018 | SYR | 12.3 | 5.90668 | 2.95334 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | 11CBWF | 100676 | LCR/SERI/3/MEX-DW/ BACA//VONA/4/TAM200/ JI5418 | -0AP-DH16 | ICWH99018 | SYR | 21.0 | 5.11534 | 2.55767 | HS |
| 26 | 11CBWF | 980135 | VICTORYA | | | UKR | 22.3 | 7.02772 | 3.51386 | HS |
| 27 | 11CBWF | 060050 | ATTILA/3/AGRI/NAC//MLT | -0E-0E-2E-0E-1E-0E | TCI981026 | TCI | 17.3 | 2.24846 | 1.12423 | S |
| 28 | 11CBWF | 060074 | TX69A509.2//BBY/FOX/3/ GRK//NO64/PEX/4/ CER/5/CHIL/2*STAR | -0E-0E-5E-0E-2E-0E | TCI981148 | TCI | 17.7 | 1.64992 | 0.82496 | S |
| 29 | 11CBWF | 000261 | VORONA/KAUZ//1D13.1/MLT | -0SE-0YC-*-3YE-3YC- 0YC | CIT937111 | TCI | 19.3 | 5.57275 | 2.78638 | S |
| 30 | 11CBWF | 090068 | RSK/CA8055//CHAM6/4/ NWT/3/TAST/SPRW// TAW12399.75 | -0AP-0AP-25AP-0AP- 4AP-0AP | TCI-02-47 | TCI | 17.3 | 2.01384 | 1.00692 | S |
| 31 | 11CBWF | 090270 | TAM200/KAUZ//YUMAI30 | -030YE-30E-5E-0E- 4AP-0AP | TCI011017 | TCI | 18.3 | 1.0274 | 0.5137 | S |
| 32 | 11CBWF | 090350 | HBA142A/HBZ621A// ABILENE/3/CAMPION/ 4/F6038W12.1 | -030YE-30E-3E-0E-1E- 0E | TCI012144 | TCI | 12.0 | 1.87083 | 0.93541 | MS |
| 33 | 11CBWF | 090432 | 4WON-IR-257/5/YMH/ HYS//HYS/TUR3055/3/DGA/ 4/VPM/MOS | -0AP-0AP-46AP-0AP- 1AP-0AP | TCI-02-80 | TCI | 11.3 | 1.92931 | 0.96465 | MS |
| 34 | 11CBWF | 090495 | PYN/BAU/3/KAUZ//KAUZ/ STAR | -030YE-30E-6E-0E-1E- 0E | C3W01WM00586S | MX-TCI | 21.5 | 4.44175 | 2.22088 | HS |
| 35 | 11CBWF | | VEE#8//JUP/BJY/3/F3.71/ TRM/4/BCN/5/KAUZ/6/163 | -030YE-0E-1E-0E-2E- 0E | TCI992192 | TCI | 25.7 | 2.01384 | 1.00692 | HS |
| 36 | 11CBWF | | DORADE-5/3/BOW“S”/GEN// SHAHI | -0AP-0AP-6AP-0AP- 3AP-0AP | TCI-02-522 | TCI | 20.0 | 9.09212 | 4.54606 | HS |
| 37 | 11CBWF | 010004 | 494J6.11//TRAP#1/BOW | -0YC-0YC-0YC-8YC- 0YC-1SE-0YC-2YC- 0YC | C3W90M200 | MX-CIT | 24.0 | 2.25462 | 1.12731 | HS |
| 38 | 11CBWF | 020321 | SAULESKU#44/TR810200 | -03Y-0B-0SE-3YE- 0YC-2YM-0YM | C3W94WM00586S | MX-TCI | 20.2 | 3.00925 | 1.50462 | HS |
| 39 | 11CBWF | 950513 | GUN91 | -1A-1A-1A-0A | SWM7155 | MX-YA | 14.2 | 0.62361 | 0.3118 | MS |
| 40 | 11CBWF | 070158 | CHEN/AE.SQUARROSA (TAUS)//BCN/4/RAN/ NE701136//CI13449/CTK/ 3/CUPE/5/130L1.11/ GUN91//KINACI97 | -030YE-0E-1E-0E-1E- 0E | TCI992198 | TCI | 14.5 | 5.30723 | 2.65361 | MS |
| 41 | 11CBWF | 950377 | DOGU88 | | | TR-ERZ | 19.0 | 1.77951 | 0.88976 | S |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 42 | 11CBWF | 070676 | KS92H363-2/COUGAR SIB(=NE85707/TBIRD) X NE94632(=ABILENE/ NORKAN//RAWHIDE) | | | US-UNL | 20.2 | 5.10446 | 2.55223 | HS |
| 43 | 11CBWF | 090779 | SAR-30 | | | IR-DARI | 18.3 | 3.32499 | 1.66249 | S |
| 44 | 11CBWF | 090781 | RASAD | | | IR-DARI | 17.5 | 1.47196 | 0.73598 | S |
| 45 | 11CBWF | 050117 | KS82142/PASTOR | -0P-0YC-0YE-3YE-0YE-1YE-0YE | C3W97WM00399S | OR-CIT | 13.5 | 7.11805 | 3.55903 | MS |
| 46 | 11CBWF | 990857 | BURBOT-6 | -9H-0YC-1YC-0YC-0YC-2YC-0YC-3YC-0YC | WXD880137A | OR-CIT | 17.0 | 1.87083 | 0.93541 | S |
| 47 | 11CBWF | 000374 | ES84.24/GRK | -0SE-0YC-1YE-0YC-2YC-0YC | CIT932135 | TCI | 24.7 | 0.84984 | 0.42492 | HS |
| 48 | 11CBWF | 950283 | SUZEN 97 | -7E-1E-0E | YE2957 | TR-ESK | 21.0 | 1.87083 | 0.93541 | HS |
| 49 | 11CBWF | 050696 | TAM105/3/NE70654/BBY// BOW“S”/4/Century*3/TA2450 | | AP01T1112 | US-AgriPro South | 17.8 | 3.68179 | 1.84089 | S |
| 50 | 11CBWF | 050751 | MILLENNIUM/NE93613 | | SD00258 | US-SDSU | 5.8 | 3.92287 | 1.96143 | MR |
| 51 | 11CBWF | 010027 | TAM200/KAUZ | -0SE-0YC-1YC-0YC-3YC-0YC-1YC-0YC | C3W91M00414S | MX-CIT | 18.8 | 7.26101 | 3.6305 | S |
| 52 | 11CBWF | 040237 | PYN/BAU/3/AGRI/BJY//VEE | -0SE-0YC-17E-0E-1K -0YK | TCI961547 | TCI | 19.0 | 3.24037 | 1.62019 | S |
| 53 | 11CBWF | 950369 | DAGDAS94 | -10A-0A | YA15662 | YA-BD | 16.2 | 2.35702 | 1.17851 | S |
| 54 | 11CBWF | 050728 | TREGO/BTY SIB | | KS01HW152-6 | Kansas State-Hays | 16.3 | 3.47211 | 1.73606 | S |
| 55 | 11CBWF | 070676 | NE04424 | HRW | | US-UNL | 22.8 | 4.17 | 2.085 | HS |
| 56 | 11CBWF | 090783 | KOHDASHT | | | IR-DARI | 15.5 | 1.77951 | 0.88976 | S |
| 57 | 11CBWF | 070603 | ICDW-21122 | BW | | AFG | 6.8 | 1.43372 | 0.71686 | MR |
| 58 | 11CBWF | 951009 | SARDARI | | | IR-DARI | 14.7 | 1.31233 | 0.65617 | MS |
| 59 | 11CBWF | 030243 | SABALAN/GRK//PYN/BAU | -0YC-0E-1YE-0YE-3YM-0YM | TCI952089 | TCI | 23.3 | 3.42377 | 1.71189 | HS |
| 60 | 11CBWF | 030323 | CA8055/4/ROMTAST/BON/3/ DIBO//SU92/CI13645/5/ AGRI/BJY//VEES | -0SE-0YC-0E-7YE-0YE-1YM-0YM | TCI951084 | TCI | 20.3 | 1.88562 | 0.94281 | HS |
| 61 | 11CBWF | 000330 | BILINMIYEN96.7 | -0SE-3YA-3YC-0YC | F2.96.7 | TCI | 20.2 | 5.94886 | 2.97443 | HS |
| 62 | 11CBWF | 000029 | RIPPER | | | US-COL | 16.0 | 1.08012 | 0.54006 | S |
| 63 | 11CBWF | 000031 | SNOWMASS | | | US-COL | 16.5 | 2.85774 | 1.42887 | S |
| 64 | 11CBWF | 070671 | 2180*K/2163//?/3/ W1062A*HVA114/W3416 | KS980554-12-∼9 | | USA | 11.5 | 2.82843 | 1.41421 | MS |
| 65 | 11CBWF | 040320 | BULEVREDIKA/STOZHER/4/ TAST/SPRW//CA8055/3/CSM | -0AP-0YC-2E-0E-2K-0YK | TCI96T151 | TCI | 13.2 | 9.56847 | 4.78423 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 66 | 11CBWF | 090169 | TAM200/KAUZ/3/SPN/NAC// ATTILA/4/F885K1.1/SXL | -030YE-30E-3E-0E-1E-0E | TCI012021 | TCI | 18.5 | 2.48328 | 1.24164 | S |
| 67 | 11CBWF | 090194 | ZCL/3/PGFN//CNO67/ SON64(ES86-8)/4/ KA../4/BEZ/NAD//KZM (ES85.24)/3/F900K | -030YE-30E-6E-0E-2E-0E | TCI011392 | TCI | 16.2 | 6.32895 | 3.16447 | S |
| 68 | 11CBWF | 080893 | CDC FALCON | | | CAN | 16.7 | 7.71722 | 3.85861 | S |
| 69 | 11CBWF | 080991 | Bulava | | | RUS | 15.3 | 2.49444 | 1.24722 | MS |
| 70 | 11CBWF | 090748 | MIRONIVSKA RANNOSTYGLA | | | UKR-MIR | 20.7 | 6.84755 | 3.42377 | HS |
| 71 | 11CBWF | 100701 | PEREGRINE | | | CAN | 16.0 | 3.08221 | 1.5411 | S |
| 72 | 11CBWF | 090079 | GRECUM 84//PYN/BAU | -0AP-0AP-18AP-0AP-1E-0E | TCI-02-726 | TCI | 14.5 | 2.44949 | 1.22474 | MS |
| 73 | 11ELITE-IRR | 980825 | AGRI/NAC//ATTILA | C3W92WM00232S | -0SE-0YC-4YE-0YC | MX-TCI | 14.7 | 4.24918 | 2.12459 | MS |
| 74 | 11ELITE-IRR | 980960 | TAM200/JI5418 | CIT930099 | -0SE-0YC-2YE-0YC | TCI | 18.8 | 8.02427 | 4.01213 | S |
| 75 | 11ELITE-IRR | 950055 | BESKOPRU | | | TR | 22.3 | 0.62361 | 0.3118 | HS |
| 76 | 11ELITE-IRR | 990149 | 885K4.1//MNG/SDV1/3/ 1D13.1/MLT | CIT925099 | -0SE-0YC-3YC-0YC-3YC-0YC | TCI | 17.8 | 3.51979 | 1.75989 | S |
| 77 | 11ELITE-IRR | 990932 | STAR/BWD | C3W93WM0137 | -0AP-0YC-11YE-0YC | MX-TCI | 13.3 | 2.09497 | 1.04748 | MS |
| 78 | 11ELITE-IRR | 990414 | FRTL//AGRI/NAC | C3W93WM0071 | -0AP-0YC-29YE-0YC | MX-TCI | 14.8 | 4.00694 | 2.00347 | MS |
| 79 | 11ELITE-IRR | 232 | SW89-3218//AGRI/NAC | C3W93WM0184 | -0AP-0YC-*-3YE-3YC-0YC | MX-TCI | 14.0 | 2.27303 | 1.13652 | MS |
| 80 | 11ELITE-IRR | 10831 | ID800994.W/MO88 | CMWS92Y00272S | -030WM-1WM-05WM-015WM-7WM-0WM | MX-TCI | 20.7 | 4.10961 | 2.0548 | HS |
| 81 | 11ELITE-IRR | 991101 | VORONA/HD2402 | SWM17702 | -0SE-9YC-0YC-1YC-0YC-4YC-0YC-34YC-0YC | MX-CIT | 16.2 | 4.49691 | 2.24846 | S |
| 82 | 11ELITE-IRR | 33 | AGRI/NAC//KAUZ | C3W92WM00231S | -0SE-0YC-0YC-*-5YE-5YC-0YC | MX-TCI | 15.3 | 2.95334 | 1.47667 | MS |
| 83 | 11ELITE-IRR | 10246 | ESKINA-8 | CIT925080 | -0SE-0YC-7YC-0YC-2YC-0YC-3YC-0YC | CIT | 13.3 | 3.85861 | 1.92931 | MS |
| 84 | 11ELITE-IRR | 30158 | AGRI/BJY//VEE/3/KS82142/ CUPE | TCI951027 | -0SE-0YC-0E-1YE-0YE | TCI | 20.5 | 4.02078 | 2.01039 | HS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 85 | 11ELITE-IRR | 40007 | F130-L-1-12/ MV12(ATILLA-12) | TCI961246 | -0SE-0YC-0E-1YE-0YE-2YM-0YM | TCI | 17.7 | 4.49691 | 2.24846 | S |
| 86 | 11ELITE-IRR | 50073 | AGRI/BJY//VEE/3/AKULA/4/ F10S-1 | TCI972515 | -0SE-0YC-0YE-4YE-0YE-1YE-0YE | TCI | 13.5 | 1.22474 | 0.61237 | MS |
| 87 | 11ELITE-IRR | 50111 | SHI#4414/CROW“S”// GK SAGVARI/CA8055 | TCI97AP 539 | -0SE-0YC-0YE-26YE-0YE-1YE-0YE | TCI | 16.7 | 5.79272 | 2.89636 | S |
| 88 | 11ELITE-IRR | 60119 | VORONA/HD2402// ALBATROSS ODESSKIY | TCI960735 | -0AP-0AP-0YE-5YE-0YE-1YE-0YE | TCI | 17.0 | 4.60072 | 2.30036 | S |
| 89 | 11ELITE-IRR | 60074 | TX69A509.2//BBY/FOX/ 3/GRK//NO64/PEX/4/ CER/5/CHIL/2*STAR | TCI981148 | -0E-0E-5E-0E-2E-0E | TCI | 11.5 | 1.87083 | 0.93541 | MS |
| 90 | 11ELITE-SA | 950412 | KARAHAN | | | TR | 20.0 | 2.85774 | 1.42887 | HS |
| 91 | 11ELITE-SA | | MUFFITBEY | | | TR | 17.0 | 2.27303 | 1.13652 | |
| 92 | 11ELITE-SA | 980671 | LFN/VOGAF//LIRA/5/ K134(60)/4/TOB/BMAN// BB/3/CAL/6/F339P1.2 | CIT935039 | -0SE-0YC-5YE-0YC | TCI | 7.8 | 3.85861 | 1.92931 | MR |
| 93 | 11ELITE-SA | 980639 | FLAMURA85//F134.71/NAC | CIT930037 | -0SE-0YC-1YE-0YC | TCI | 16.2 | 1.31233 | 0.65617 | S |
| 94 | 11ELITE-SA | 990276 | ORKINOS-1 | | -0YA-0YA-5YC-0YC | YA-TCI | 21.3 | 2.4608 | 1.2304 | HS |
| 95 | 11ELITE-SA | 990277 | ORKINOS-2 | | -0YA-0YA-6YC-0YC | YA-TCI | 7.2 | 1.69967 | 0.84984 | MR |
| 96 | 11ELITE-SA | 990818 | PMF/MAYA//YACO/3/ CO693591/CTK | CIT90095T | -0YC-0YC-0YC-3YC-0YC-1YC-0YC | CIT | 22.8 | 3.39935 | 1.69967 | HS |
| 97 | 11ELITE-SA | 990125 | 777TWWON87/3/F12.71/ SKA//CA8055 | CIT922247 | -0SE-0YC-3YC-0YC-3YC-0YC | CIT | 10.8 | 0.62361 | 0.3118 | MS |
| 98 | 11ELITE-SA | 990084 | 1D13.1/MLT//TUI | C3W90M398 | -0YC-0YC-0YC-1YC-0YC-6YC-0YC | MX-CIT | 12.8 | 0.94281 | 0.4714 | MS |
| 99 | 11ELITE-SA | 990593 | KVZ/HB2009/5/CNN/ KHARKOV//KC66/3/ SKP35/4/VEE | ICWH87046 | -0YC-0R-2YC-0YC-1YA-0YC | CIT | 10.8 | 5.03874 | 2.51937 | MS |
| 100 | 11ELITE-SA | 010027 | TAM200/KAUZ | C3W91M00414S | -0SE-0YC-1YC-0YC-3YC-0YC-1YC-0YC | MX-CIT | 14.0 | 2.04124 | 1.02062 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 101 | 11ELITE-SA | 010037 | JI5418/MARAS | CIT922142 | -0SE-0YC-3YC-0YC-6YC-0YC-1YC-0YC | CIT | 20.8 | 3.29983 | 1.64992 | HS |
| 102 | 11ELITE-SA | 020323 | SAULESKU#44/TR810200 | C3W94WM00586S | -03Y-0B-0SE-3YE-0YC-4YM-0YM | MX-TCI | 24.2 | 3.42377 | 1.71189 | HS |
| 103 | 11ELITE-SA | 020319 | SAULESKU#44/TR810200 | C3W94WM00586S | -03Y-0B-0SE-1YE-0YC-1YM-0YM | MX-TCI | 17.8 | 5.4365 | 2.71825 | S |
| 104 | 11ELITE-SA | 020226 | BILINMIYEN96.27 | F2.96.27 | -0SE-0YC-1YE-0YC-2YM-0YM | TCI | 19.2 | 1.84089 | 0.92045 | S |
| 105 | 11ELITE-SA | 020293 | TAST/SPRW/4/ROM-TAST/BON/3/DIBO//SU92/CI13645/5/F130L1.12 | CIT932182 | -0SE-0YC-7YE-0YC-1YM-0YM | CIT | 18.7 | 2.77889 | 1.38944 | S |
| 106 | 11ELITE-SA | 030311 | GUN91/POBEDA//F900K | CIT945243 | -030SE-0YC-2YE-0YC-2YM-0YM | TCI | 20.7 | 1.24722 | 0.62361 | HS |
| 107 | 11ELITE-SA | 030418 | CA8055//KS82W409/STEPHENS | TCI950547 | -0SE-0YC-0E-4YE-0YE-1YM-0YM | TCI | 13.8 | 1.43372 | 0.71686 | MS |
| 108 | 11ELITE-SA | 030423 | YE2453//PPBB68/CHRC | TCI950019 | -3AP-0AP-0E-2YE-0YE-3YM-0YM | TCI | 15.3 | 2.3214 | 1.1607 | MS |
| 109 | 11ELITE-SA | 060161 | TX69A509.2//BBY/FOX/3/GRK//NO64/PEX/4/CER/5/KAUZ//ALTAR 84/AOS | TCI981143 | -0E-0E-6E-0E-1E-0E | TCI | 12.5 | 0.70711 | 0.35355 | MS |
| 110 | 11ELITE-SA | 060287 | BOW/NKT//KATIA1/3/AGRI/BJY//VEE | TCI982234 | -030YE-0E-3E-0E-1E-0E | TCI | 19.5 | 7.17635 | 3.58818 | HS |
| 111 | 11ELITE-SA | 060417 | TIRCHMIR1//71ST2959/CROW/4/NWT/3/TAST/SPRW//TAW12399.75 | TCI98-IC-0097 | -0AP-0AP-4E-0E-2E-0E | TCI | 21.8 | 2.09497 | 1.04748 | HS |
| 112 | 11ELITE-SA | 991540 | YILDIZ | | | TR | 13.2 | 1.64992 | 0.82496 | MS |
| 113 | 18FAWWON-IRR | 080009 | DORADE-5/CAMPION | TCI001049 | -030YE-030YE-2E-0E-4E-0E | TCI | 10.2 | 0.4714 | 0.2357 | MS |
| 114 | 18FAWWON-IRR | 080056 | T 98-9//VORONA/HD2402 | TCI001530 | -030YE-030YE-11E-0E-3E-0E | TCI | 23.5 | 6.01387 | 3.00694 | HS |
| 115 | 18FAWWON-IRR | 080533 | SHARK-1/GK.PINKA | TCI001359 | -030YE-030YE-10E-0E-3AP-0AP | TCI | 18.5 | 0.70711 | 0.35355 | S |
| 116 | 18FAWWON-IRR | 080684 | BOW/CROW/3RSH//KAL/BB/3/GUN91 | TCI011508 | -030YE-30E-0YK | TCI | 16.8 | 1.69967 | 0.84984 | S |
| 117 | 18FAWWON-IRR | 070256 | HK1/6/NVSR3/5/BEZ/TVR/5/CFN/BEZ//SU92/CI13645/3NAI60 | ICWH99158 | -0AP-0AP-0AP-4YE-0YE | TCI | 15.5 | 2.16025 | 1.08012 | S |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 118 | 18FAWWON-IRR | | TAST/SPRW//LT176.73/7/SOTY/SUT//LER/4/2*RFN/3/FR//KAD/GB/5/TMP64../8/BOUHOUTH6 | TCI97AP 212 | | TCI | 15.8 | 4.87055 | 2.43527 | S |
| 119 | 18FAWWON-IRR | | SN64//SKE/2*ANE/3/SX/4/BEZ/5/SERI/6/CHERVONA/7/KLEIBER/2*FL80//DONSK.POLUK. | TCI962126 | | TCI | 16.7 | 1.43372 | 0.71686 | S |
| 120 | 18FAWWON-IRR | 070250 | HK1/4/TAST/SPRW//CA8055/3/CSN | ICWH99157 | -0AP-1AP-2AP-0AP-2AP-0AP | TCI | 13.5 | 0.70711 | 0.35355 | MS |
| 121 | 18FAWWON-IRR | 080031 | TX71A1039.V1*3/AMI/3/BEZ/NAD//KZM(ES85-24)/4/SHARK-1 | TCI001213 | -030YE-030YE-7E-0E-3E-0E | TCI | 13.7 | 4.92161 | 2.4608 | MS |
| 122 | 18FAWWON-IRR | 080052 | GANSU-1//VORONA/HD2402 | TCI001499 | -030YE-030YE-5E-0E-2E-0E | TCI | 14.3 | 7.72802 | 3.86401 | MS |
| 123 | 18FAWWON-IRR | 080595 | T 98-9//VORONA/HD2402 | TCI001530 | -030YE-030YE-22E-0E-4AP-0AP | TCI | 13.5 | 3.34166 | 1.67083 | MS |
| 124 | 18FAWWON-IRR | 080702 | CRR/ATTILA/4/WA476/391/3/NUM//W22/TA M200 | TCI-01-419 | -0AP-0AP-25AP-0AP-4AP-0AP | TCI | 11.5 | 6.33772 | 3.16886 | MS |
| 125 | 18FAWWON-IRR | 080660 | DANA/3/SPN/NAC//ATTILA/4/SHARK-1 | TCI002097 | -030YE-030YE-1E-0E-1E-0E | TCI | 17.5 | 2.67706 | 1.33853 | S |
| 126 | 18FAWWON-IRR | 100671 | LCR/SERI/3/MEX-DW/BACA//VONA/4/TAM200/JI5418 | ICWH99018 | -0AP-DH16 | TCI | 13.0 | 5.88784 | 2.94392 | MS |
| 127 | 18FAWWON-IRR | 100673 | HK92/L 3676 K 11-20 | ICWH99019 | -0AP-DH14 | TCI | 14.3 | 0.84984 | 0.42492 | MS |
| 128 | 18FAWWON-IRR | 100664 | SHAHRIAR | | | IR-ARD | 5.3 | 2.59272 | 1.29636 | MR |
| 129 | 18FAWWON-IRR | 090861 | Alamoot/4/Bloudan/3/Bb/7c*2//Y50E/Kal*3 | | | IR-KARAJ | 14.0 | 2.54951 | 1.27475 | MS |
| 130 | 18FAWWON-IRR | 081138 | Owl//Ombul/Alamo | | | IR-KARAJ | 12.8 | 4.78423 | 2.39212 | MS |
| 131 | 18FAWWON-IRR | 081161 | Alvd//Aldan/Ias58/3/Col.No.3193/4/Zarrin | | | IR-KARAJ | 16.8 | 7.70642 | 3.85321 | S |
| 132 | 18FAWWON-IRR | 090902 | Bow“s”/Crow“s”//Kie“s”/Vee“s”/3/MV17 | | | IR-MIANDOAB | 14.8 | 3.32499 | 1.66249 | MS |
| 133 | 18FAWWON-IRR | 090914 | Owl/Soissons//Zarrin | | | IR-MIANDOAB | 11.7 | 1.0274 | 0.5137 | MS |
| 134 | 18FAWWON-IRR | 090920 | Spb“s”//K134(60)/Vee“s”/3/Druchamps/4/Alvan d | | | IR-MIANDOAB | 6.3 | 1.24722 | 0.62361 | MR |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 135 | 18FAWWON-IRR | 090911 | PODOIMA | | | MOL | 13.5 | 5.01664 | 2.50832 | MS |
| 136 | 18FAWWON-IRR | 090915 | AVANTAJ | | | MOL | 16.8 | 4.78423 | 2.39212 | S |
| 137 | 18FAWWON-IRR | 080189 | TX71A1039.V1*3/AMI//TRAP#1/4/KAUZ//ALTAR 84/AOS/3/KAUZ | C3W00WM440 | -030YE-030YE-6E-0E-5E-0E | MX | 13.2 | 3.32499 | 1.66249 | MS |
| 138 | 18FAWWON-IRR | 080840 | SIRKKU/PRINIA | C3S97Y00247S | -040Y-050M-020Y-030M-41Y-1M-0Y | MX | 15.3 | 2.35702 | 1.17851 | MS |
| 139 | 18FAWWON-IRR | 080829 | CHIL/PRL//BAV92/3/MILAN/KAUZ | C3S97M03230T | -040Y-020Y-030M-040SY-020M-24Y-0M-0SY | MX | 13.3 | 1.69967 | 0.84984 | MS |
| 140 | 18FAWWON-IRR | 100710 | NUDELA | | | RO | 18.8 | 3.39935 | 1.69967 | S |
| 141 | 18FAWWON-IRR | 100704 | CH-111.14098 | | | UN | 14.5 | 2.16025 | 1.08012 | MS |
| 142 | 18FAWWON-IRR | 070632 | MIT/TX93V5722//W95-301 | TX04M410164 | | USA | 11.3 | 6.54896 | 3.27448 | MS |
| 143 | 18FAWWON-IRR | 100006 | TX98D1170*2/TTCC365 | WX02ARS171-3-14 | ARS05-0043 | US-ARS-NC | 9.7 | 3.06413 | 1.53206 | MR |
| 144 | 18FAWWON-IRR | 100031 | IN97395B1-4-3-8/AWD99*5725 | | ARS07-0723 | US-ARS-NC | 9.5 | 1.08012 | 0.54006 | MR |
| 145 | 18FAWWON-IRR | 080486 | ORACLE/PEHLIVAN | TCI00125703 | -030YE-030YE-2E-0E-4AP-0AP | TCI | 14.0 | 3.34166 | 1.67083 | MS |
| 146 | 18FAWWON-SA | 080710 | BUC/PVN//MILAN/3/TX96V2427 | TCI-01-436 | -0AP-0AP-28AP-0AP-3AP-0AP | TCI | 7.0 | 0.8165 | 0.40825 | MR |
| 147 | 18FAWWON-SA | 080217 | SST44//K4500.2/SAPSUCKER/3/ALTAY | TCI001581 | -030YE-030YE-2E-0E-5E-0E | TCI | 17.5 | 0.8165 | 0.40825 | S |
| 148 | 18FAWWON-SA | 080229 | KAROUS-4/7/NECOMP1/5/BEZ//TOB/8156/4/ON/3/TH*6/KF//LEE*6/K/6/TAST/SPRW.. | TCI001744 | -030YE-030YE-2E-0E-3E-0E | TCI | 7.0 | 2.85774 | 1.42887 | MR |
| 149 | 18FAWWON-SA | 080271 | TAM200/KAUZ//Ltg-164 | TCI-01-135 | -0AP-0AP-18AP-0AP-3AP-0AP | TCI | 11.2 | 2.86744 | 1.43372 | MS |
| 150 | 18FAWWON-SA | 080335 | VORONA/HD2402/3/RSK/CA8055//CHAM6 | TCI-01-61 | -0AP-0AP-14AP-0AP-4AP-0AP | TCI | 15.8 | 3.47211 | 1.73606 | S |
| 151 | 18FAWWON-SA | 080364 | DOGU88//TX71A374.4/TX71A1039.V1/3/1502W9.1/4/MIRLEBEN | TCI991247 | -0YE-0YK-0YO-0YK | TCI | 16.2 | 3.29983 | 1.64992 | S |
| 152 | 18FAWWON-SA | 080221 | HBA142A/HBZ621A//ABILENE/3/BURBOT-6 | TCI001619 | -030YE-030YE-1E-0E-4E-0E | TCI | 12.2 | 0.4714 | 0.2357 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 153 | 18FAWWON-SA | 080157 | 8030VERSAILLES/EDCH//CD/3/[SAULESKU 17] | C3W00WM540 | -030YE-030YE-3E-0E-2E-0E | MX-TCI | 11.5 | 9.35414 | 4.67707 | MS |
| 154 | 18FAWWON-SA | 080402 | CM98-79/3/T67/X84W063-9-45//K92 | X990439 | -0E-030YE-2E-0E-3E-0E | KSU-TCI | 11.5 | 4.24264 | 2.12132 | MS |
| 155 | 18FAWWON-SA | 080403 | CM98-112/4/HAWK/81PYI9641//MESA MOTHER LINE/3/KS82W418/SPN | X990457 | -0E-030YE-1E-0E-1E-0E | KSU-TCI | 6.7 | 0.62361 | 0.3118 | MR |
| 156 | 18FAWWON-SA | 070653 | HBK0935-29-15/KS90W077-2-2/VBF0589-1 | AP06T3832 | | USA | 8.5 | 2.85774 | 1.42887 | MR |
| 157 | 18FAWWON-SA | 070671 | 2180*K/2163//?/3/W1062A*HVA114/W3416 | KS980554-12-∼9 | | USA | 7.7 | 1.84089 | 0.92045 | MR |
| 158 | 18FAWWON-SA | 080218 | ARLIN/ALTAY | TCI001606 | -030YE-030YE-1E-0E-3E-0E | TCI | 14.7 | 4.08928 | 2.04464 | MS |
| 159 | 18FAWWON-SA | 080298 | YE2453/KA//1D13.1/MLT/3/VORONA/TR810200 | TCI-01-422 | -0AP-0AP-27AP-0AP-1AP-0AP | TCI | 9.3 | 3.29983 | 1.64992 | MR |
| 160 | 18FAWWON-SA | 080313 | DORADE-5/4/HK96/3/CHAM6//1D13.1/MLT | TCI-01-505 | -0AP-0AP-13AP-0AP-1AP-0AP | TCI | 10.3 | 4.24918 | 2.12459 | MS |
| 161 | 18FAWWON-SA | 080400 | CM98-64/4/HAWK/81PYI9641//MESA MOTHER LINE/3/KS82W418/SPN | X990434 | -0E-030YE-2E-0E-2E-0E | KSU-TCI | 8.3 | 4.6428 | 2.3214 | MR |
| 162 | 18FAWWON-SA | 080833 | RL6043/4*NAC//PASTOR/3/BABAX | C3S97M03173T | -040Y-030M-040SY-030M-040SY-11M-0Y-0SY | MX | 16.5 | 1.77951 | 0.88976 | S |
| 163 | 18FAWWON-SA | 080398 | JUP/4/CLLF/3/II14.53/ODIN//CI13431/WA00477/5/GK Aron/AgSeco 7846//2180 | OCW00S436S | -0YA-2E-0E-2E-0E | OK-TCI | 13.7 | 1.64992 | 0.82496 | MS |
| 164 | 18FAWWON-SA | 070668 | HBK1064-3/KS84063-9-39-3-4W//X960103 | KS970093-8-9-#1 | | USA | 6.0 | 0.40825 | 0.20412 | MR |
| 165 | 18FAWWON-SA | 090713 | JAGGER/ALLIANCE | NE02558 | | USA | 7.3 | 3.68179 | 1.84089 | MR |
| 166 | C19FAWWON-INT | | LANTIAN 12 | | | PRC | 6.0 | 1.5456 | 0.7728 | MR |
| 167 | C19FAWWON-INT | | LANTIAN 14 | | | PRC | 10.5 | 3.89444 | 1.94722 | MS |
| 168 | C19FAWWON-INT | | LANTIAN 15 | | | PRC | 14.3 | 0.84984 | 0.42492 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 169 | C19FAWWON-INT | | LANTIAN 17 | | | PRC | 13.0 | 2.67706 | 1.33853 | MS |
| 170 | C19FAWWON-INT | | LANTIAN 00-30 | | | PRC | 24.0 | 4.08928 | 2.04464 | HS |
| 171 | C19FAWWON-INT | | BOGDANA | | | UKR-MIR | 15.3 | 0.94281 | 0.4714 | MS |
| 172 | C19FAWWON-INT | | VESTA | | | UKR-MIR | 12.7 | 3.47211 | 1.73606 | MS |
| 173 | C19FAWWON-INT | | VOLODARKA | | | UKR-MIR | 21.5 | 5.71548 | 2.85774 | HS |
| 174 | C19FAWWON-INT | | ECONOMKA | | | UKR-MIR | 5.2 | 3.92287 | 1.96143 | MR |
| 175 | C19FAWWON-INT | | KRYZHYNKA | | | UKR-MIR | 10.7 | 6.73713 | 3.36856 | MS |
| 176 | C19FAWWON-INT | | KOLOS MYRONIVSCHYNY | | | UKR-MIR | 14.0 | 6.37704 | 3.18852 | MS |
| 177 | C19FAWWON-INT | | KALINOVA | | | UKR-MIR | 13.8 | 4.32692 | 2.16346 | MS |
| 178 | C19FAWWON-INT | | SNIZHANA | | | UKR-MIR | 10.0 | 3.89444 | 1.94722 | MR |
| 179 | C19FAWWON-INT | | KATIA | | | BUL | 8.3 | 2.01384 | 1.00692 | MR |
| 180 | C19FAWWON-INT | | Gariep | | | SA | 15.0 | 3.18852 | 1.59426 | MS |
| 181 | C19FAWWON-INT | | Komati | | | SA | 16.0 | 4.81318 | 2.40659 | S |
| 182 | C19FAWWON-INT | | Limpopo | | | SA | 10.7 | 4.02768 | 2.01384 | MS |
| 183 | C19FAWWON-INT | | T06/11 | | | SA | 13.5 | 1.22474 | 0.61237 | MS |
| 184 | C19FAWWON-INT | | T07/09 | | | SA | 16.3 | 5.8642 | 2.9321 | S |
| 185 | C19FAWWON-INT | | T08/03 | | | SA | 10.8 | 4.92161 | 2.4608 | MS |
| 186 | C19FAWWON-INT | | SONMEZ | | | TR | 7.3 | 2.77889 | 1.38944 | MR |
| 187 | C19FAWWON-INT | | T03/17 | | | SA | 8.2 | 2.49444 | 1.24722 | MR |
| 188 | C19FAWWON-INT | | KS98HW518(93HW91/93HW255)//KS98H245(IKE/TA2460//*3T200)/TREGO | KS05HW136-3 | KSU-HAYS | SA | 11.7 | 7.19182 | 3.59591 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 189 | C19FAWWON-INT | | T03/01 | | | SA | 13.5 | 6.68331 | 3.34166 | MS |
| 190 | C19FAWWON-INT | | T04/25 | | | SA | 16.3 | 4.08928 | 2.04464 | S |
| 191 | C19FAWWON-INT | | T04/17 | | | SA | 4.3 | 2.09497 | 1.04748 | R |
| 192 | C19FAWWON-INT | | EC-P | | | SA | 8.0 | 0.70711 | 0.35355 | MR |
| 193 | C19FAWWON-INT | | Kariega | | | SA | 8.8 | 3.68179 | 1.84089 | MR |
| 194 | C19FAWWON-INT | | Olifants | | | SA | 5.5 | 4.63681 | 2.3184 | MR |
| 195 | C19FAWWON-INT | | KONYA | | | TCI | 11.0 | 4.63681 | 2.3184 | MS |
| 196 | C19FAWWON-INT | | BSP01/19 (Krokodil) | | | SA | 13.0 | 8.19553 | 4.09776 | MS |
| 197 | C19FAWWON-INT | | BSP01/18 (Duzi) | | | SA | 9.5 | 2.94392 | 1.47196 | MR |
| 198 | C19FAWWON-INT | | BSP06/06 | | | SA | 10.3 | 6.53622 | 3.26811 | MS |
| 199 | C19FAWWON-INT | | BSP06/08 | | | SA | 8.8 | 2.24846 | 1.12423 | MR |
| 200 | C19FAWWON-INT | | BSP06/17 | | | SA | 7.2 | 2.0548 | 1.0274 | MR |
| 201 | C19FAWWON-INT | | BSP07/11 | | | SA | 18.8 | 2.86744 | 1.43372 | S |
| 202 | C19FAWWON-INT | | BSP08/02 | | | SA | 15.5 | 0.40825 | 0.20412 | S |
| 203 | C19FAWWON-INT | | BSP08/06 | | | SA | 12.2 | 2.65623 | 1.32811 | MS |
| 204 | C19FAWWON-INT | | BSP08/10 | | | SA | 13.2 | 2.49444 | 1.24722 | MS |
| 205 | C19FAWWON-INT | | BSP08/11 | | | SA | 13.0 | 2.44949 | 1.22474 | MS |
| 206 | C19FAWWON-INT | | BSP08/12 | | | SA | 13.8 | 1.92931 | 0.96465 | MS |
| 207 | C19FAWWON-INT | | BSP08/13 | | | SA | 17.7 | 1.92931 | 0.96465 | S |
| 208 | C19FAWWON-INT | | BSP08/17 | | | SA | 11.7 | 4.36527 | 2.18263 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 209 | C19FAWWON-INT | | BC01138-S | | | US-AGRIPRO | 13.8 | 5.03874 | 2.51937 | MS |
| 210 | C19FAWWON-INT | | NUDAKOTA | | | US-AGRIPRO | 4.0 | 1.92931 | 0.96465 | R |
| 211 | C19FAWWON-INT | | ART | | | US-AGRIPRO | 9.8 | 1.31233 | 0.65617 | MR |
| 212 | C19FAWWON-INT | | JAGARENE | | | US-AGRIPRO | 9.0 | 2.27303 | 1.13652 | MR |
| 213 | C19FAWWON-INT | | HAWKEN | | | US-AGRIPRO | 10.3 | 1.31233 | 0.65617 | MS |
| 214 | C19FAWWON-INT | | SARATOVSKAYA90 | | | RUS-SAR | 18.3 | 6.11465 | 3.05732 | S |
| 215 | C19FAWWON-INT | | SARATOVSKAYA OSTISTAYA | | | RUS-SAR | 22.0 | 5.01664 | 2.50832 | HS |
| 216 | C19FAWWON-INT | | SARATOVSKAYA17 | | | RUS-SAR | 15.3 | 4.58863 | 2.29432 | MS |
| 217 | C19FAWWON-INT | | ZHEMCHUZHINA POVOLZHJYA | | | RUS-SAR | 12.7 | 2.4608 | 1.2304 | MS |
| 218 | C19FAWWON-INT | | M808/BRIGANTINA | 23 | | RUS-SAR | 15.3 | 3.27448 | 1.63724 | MS |
| 219 | C19FAWWON-INT | | SARATOVSKAYA90/ UKRAINA | 30 | | RUS-SAR | 10.2 | 3.96513 | 1.98256 | MS |
| 220 | C19FAWWON-INT | | LUTESCENS329/ UROZHAINAYA | 33 | | RUS-SAR | 21.2 | 2.01384 | 1.00692 | HS |
| 221 | C19FAWWON-INT | | GUBERNIYA/ SARATOVSKAYA17 | 15 | | RUS-SAR | 11.8 | 0.94281 | 0.4714 | MS |
| 222 | C19FAWWON-INT | | GUBERNIYA/ SARATOVSKAYA18 | 16 | | RUS-SAR | 13.8 | 9.10433 | 4.55217 | MS |
| 223 | C19FAWWON-INT | | BEZENCHUKSKAYA616 | | | RUS-SAM | 17.8 | 4.02768 | 2.01384 | S |
| 224 | C19FAWWON-INT | | BIRYUZA | | | RUS-SAM | 17.3 | 2.39212 | 1.19606 | S |
| 225 | C19FAWWON-INT | | MALAHIT | | | RUS-SAM | 11.5 | 1.87083 | 0.93541 | MS |
| 226 | C19FAWWON-INT | | BEZENCHUKSKAYA380 | | | RUS-SAM | 10.0 | 1.41421 | 0.70711 | MR |
| 227 | C19FAWWON-INT | | TANYA | | | RUS-KRAS | 10.2 | 6.78642 | 3.39321 | MS |
| 228 | C19FAWWON-INT | | KUMA | | | RUS-KRAS | 13.0 | 4.24264 | 2.12132 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 229 | C19FAWWON-INT | | PAMYAT | | | RUS-KRAS | 7.7 | 1.64992 | 0.82496 | MR |
| 230 | C19FAWWON-INT | | MOSKVICH | | | RUS-KRAS | 9.2 | 5.66176 | 2.83088 | MR |
| 231 | C19FAWWON-INT | | KRASNODAR99 | | | RUS-KRAS | 11.2 | 4.98888 | 2.49444 | MS |
| 232 | C19FAWWON-INT | | STARSHINA | | | RUS-KRAS | 12.8 | 7.36357 | 3.68179 | MS |
| 233 | C19FAWWON-INT | | MASCOT | | | UK | 6.3 | 0.2357 | 0.11785 | MR |
| 234 | C19FAWWON-INT | | LINE 39 | | | UKR | 16.3 | 8.33 | 4.165 | S |
| 235 | C19FAWWON-INT | | Prost/Unk95-3 | TE5644 | -1T-1T-1T-1T-0T | TE-TR | 9.3 | 3.56682 | 1.78341 | MR |
| 236 | C19FAWWON-INT | | Vorona/Parus//Hatusha/3/ Lut112/4/Pehl//Rpb8-68//Chrc | TE6035 | -1T-1T-4T-0T | TE-TR | 16.5 | 1.63299 | 0.8165 | S |
| 237 | C19FAWWON-INT | | Srz95/Gyaurs1//Sana | TE5720 | -3T-1T-2T-1T-1T-0T | TE-TR | 13.2 | 7.35225 | 3.67612 | MS |
| 238 | C19FAWWON-INT | | Bez//Bez/Tvr/3/Krmn/Lov29/ 4/Kate/5/Mom | TE5446 | -5T-1T-3T-1T-0T | TE-TR | 9.7 | 4.47834 | 2.23917 | MR |
| 239 | C19FAWWON-INT | | Mex65/Momt/4/Cor71-11460/3/ Pkg/Lov13//Jsw3/5/Bul5052-1 | TE5542 | -1T-3T-1T-2T-0T | TE-TR | 15.2 | 3.85861 | 1.92931 | MS |
| 240 | C19FAWWON-INT | | 8272-1-1/4/ Temu39.76/Chat// Cupe/3/M1223.3D.1D/Ald | TE5694 | -4T-3T-1T-1T-0T | TE-TR | 15.2 | 2.0548 | 1.0274 | MS |
| 241 | C19FAWWON-INT | | AHMETAGA | | | TR | 10.7 | 1.0274 | 0.5137 | MS |
| 242 | C19FAWWON-INT | | Zarrin/Shiroodi/6/Zarrin/5/ Omid/4/Bb/Kal//Ald/ 3/Y50E/Kal*3//Emu"s" | | | Karadj | 12.7 | 2.3214 | 1.1607 | MS |
| 243 | C19FAWWON-INT | | 1-68-120/1-68-22//Mirtos/ 3/1-68-120/1-68-22 | | | Karadj | 15.0 | 0.70711 | 0.35355 | MS |
| 244 | C19FAWWON-INT | | Alamoot/Sids8 | | | Mashhad | 10.0 | 1.87083 | 0.93541 | MR |
| 245 | C19FAWWON-INT | | Zarrin*2/Shiroodi/3/Zarrin// Vee/Nac | | | Miandoab | 8.7 | 4.02768 | 2.01384 | MR |
| 246 | C19FAWWON-INT | | Owl/Shiroodi/3/Owl//Opata*2/ Wulp | | | Miandoab | 8.5 | 2.67706 | 1.33853 | MR |
| 247 | C19FAWWON-INT | | 1-68-120/1-68-22/4/Kal/Bb// Cj"s"/3/Hork"s" | | | Ardebil | 11.0 | 0.8165 | 0.40825 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 248 | C19FAWWON-INT | | OVERLEY*3/AMADINA | KS06O3A~57-1 | | KSU-Man | 18.2 | 2.09497 | 1.04748 | S |
| 249 | C19FAWWON-INT | | 2145/X940786-6-7 | TX05A001822 | | Texas A&M | 10.5 | 1.63299 | 0.8165 | MS |
| 250 | C19FAWWON-INT | | NE93407/TX86V1115/4/T107//TX78V3620/Ctk78/3/TX87V1233 | TX05A001398 | | Texas A&M | 15.5 | 3.89444 | 1.94722 | S |
| 251 | C19FAWWON-INT | | NE96644(=ODESSKAYA P./CODY)//PAVON/*3SCOUT66/3/WAHOO SIB | NI04420 | | UNL | 17.3 | 3.00925 | 1.50462 | S |
| 252 | C19FAWWON-INT | | Wesley/NE93613 | SD05118-1 | | SDSU | 12.2 | 3.09121 | 1.5456 | MS |
| 253 | C19FAWWON-INT | | BEZOSTAYA | | | RUS | 14.0 | 2.85774 | 1.42887 | MS |
| 254 | C19FAWWON-TCI | 090008 | F12.71/SKA//FKG15/3/F483/4/CTK/VEE/5/SHARK/F4105W2.1 | -030YE-30E-2E-0E-1E-0E | TCI011134 | TCI | 17.2 | 3.79327 | 1.89663 | S |
| 255 | C19FAWWON-TCI | 090015 | 55.1744/MEX67.1//NO57/3/KAUZ/4/SHARK/F4105W2.1/5/TX96V2427 | -030YE-30E-3E-0E-2AP-0AP | TCI012335 | TCI | 7.5 | 1.47196 | 0.73598 | MR |
| 256 | C19FAWWON-TCI | 090019 | ZANDER-6/5/YE2453/4/KS831024/3/AUR/LANC//NE7060 | -0AP-0AP-16AP-0AP-1E-0E | TCI-02-257 | TCI | 12.2 | 2.35702 | 1.17851 | MS |
| 257 | C19FAWWON-TCI | 090057 | GRECUM 84//PYN/BAU | -0AP-0AP-18AP-0AP-1E-0E | TCI-02-726 | TCI | 12.5 | 2.54951 | 1.27475 | MS |
| 258 | C19FAWWON-TCI | 090049 | SWON98-124/3/AGRI/NAC//ATTILA | -0AP-0AP-0AP-2E-0E-3E-0E-1E-0E | ICWH99353 | TCI | 17.8 | 0.62361 | 0.3118 | S |
| 259 | C19FAWWON-TCI | 090051 | VORONA/HD2402/4/TAST/SPRW//BLL/3/NWT | -030YE-30E-8E-0E-1E-0E | TCI011030 | TCI | 13.5 | 3.34166 | 1.67083 | MS |
| 260 | C19FAWWON-TCI | | PYN/PARUS/3/VPM/MOS83-11-4-8//PEW/4/Bluegil | -030YE-30E-2E-0E-1E-0E | TCI011322 | TCI | 17.2 | 1.17851 | 0.58926 | S |
| 261 | C19FAWWON-TCI | 90295 | JI5418/MARAS//SHARK/F4105W2.1 | -030YE-30E-7E-0E-1E-0E | TCI011194 | TCI | 16.5 | 6.16441 | 3.08221 | S |
| 262 | C19FAWWON-TCI | 90350 | HBA142A/HBZ621A//ABILENE/3/CAMPION/4/F6038W12.1 | -030YE-30E-3E-0E-1E-0E | TCI012144 | TCI | 9.7 | 3.51979 | 1.75989 | MR |
| 263 | C19FAWWON-TCI | 90353 | BLUEGIL-2/BUCUR//SIRENA | -030YE-30E-3E-0E-1E-0E | TCI012159 | TCI | 15.5 | 0.40825 | 0.20412 | S |
| 264 | C19FAWWON-TCI | 90493 | PYN/BAU/3/KAUZ//KAUZ/STAR | -030YE-30E-4E-0E-1E-0E | C3W01WM00586S | MX-TCI | 12.8 | 1.64992 | 0.82496 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 265 | C19FAWWON-TCI | 90532 | BR1284//BH114686/ALD/3/CAZO/4/KS940786-6-7 | -30E-1E-0E-2E-0E | X011602 | KS-TCI | 13.7 | 3.42377 | 1.71189 | MS |
| 266 | C19FAWWON-TCI | 90572 | LOV26/LFN/SDY(ES84-24)/3/SERI/4/FDL49../5/LAGOS-6 | -030YE-30E-1E-0E-1E-0E | TCI011046 | TCI | 19.3 | 4.40328 | 2.20164 | S |
| 267 | C19FAWWON-TCI | 90590 | ADMIS//MILAN/DUCULA | -030YE-30E-1E-0E-1E-0E | C3W01WM00331S | MX-TCI | 19.2 | 3.32499 | 1.66249 | S |
| 268 | C19FAWWON-TCI | 90614 | AGRI/BJY//VEE/3/BUCUR/4/DOGU88//TX71A374.4/TX71A1039.V1/3/1502W9.1 | -030YE-30E-1E-0E-2E-0E | TCI012082 | TCI | 20.0 | 3.62859 | 1.8143 | HS |
| 269 | C19FAWWON-TCI | 50852 | VO1225 | | | TCI | 11.8 | 1.31233 | 0.65617 | MS |
| 270 | C19FAWWON-TCI | 108 | FRTL/NEMURA | -0AP-0YC-*-1YE-1YC-0YC | C3W93WM0073 | MX-TCI | 11.8 | 1.0274 | 0.5137 | MS |
| 271 | C19FAWWON-TCI | 60585 | 338-K1-1//ANB/BUC/3/GS50A | -0SE-0YC-0YE-4YE-0YE-4YE-0YE | TCI971351 | TCI | 16.7 | 2.95334 | 1.47667 | S |
| 272 | C19FAWWON-TCI | 90216 | BEZ/NAD//KZM(ES85.24)/3/MILAN/4/SPN/NAC//ATTILA | -030YE-30E-1E-0E-1E-0E | TCI011486 | TCI | 11.3 | 5.2015 | 2.60075 | MS |
| 273 | C19FAWWON-TCI | 90240 | RAN/NE701136//CI13449/CTK/3/CUPE/4/TAM200/KAUZ/5/BWD | -030YE-30E-3E-0E-1E-0E | TCI012234 | TCI | 21.2 | 7.48703 | 3.74351 | HS |
| 274 | C19FAWWON-TCI | 90181 | CTY*3/TA2460//LAGOS-6 | -030YE-30E-1E-0E-2E-0E | TCI011059 | TCI | 9.3 | 4.47834 | 2.23917 | MR |
| 275 | C19FAWWON-TCI | | TOSUNBEY | | | TR | 12.8 | 1.84089 | 0.92045 | MS |
| 276 | 11CBWF | 950590 | KATIA1 | | | BUL | 10.5 | 2.12132 | 1.06066 | MS |
| 277 | 11CBWF | 050670 | STARSHINA | | | RUS | 14.0 | 4.49073 | 2.24537 | MS |
| 278 | 11CBWF | 000033 | AGRI/NAC//KAUZ | -0SE-0YC-0YC-*-5YE-5YC-0YC | C3W92WM00231S | MX-TCI | 15.3 | 1.5456 | 0.7728 | MS |
| 279 | 11CBWF | 060075 | TX69A509.2//BBY/FOX/3/GRK//NO64/PEX/4/CER/5/CHIL/2*STAR | -0E-0E-5E-0E-3E-0E | TCI981148 | TCI | 13.7 | 5.83571 | 2.91786 | MS |

**Table S1.** (Continued.)

| Entry | Nursery | ACCNO | CName | SELHX | CID | Origin | Female/ 5 rep | SD | SE | Host status |
|---|---|---|---|---|---|---|---|---|---|---|
| 280 | 11CBWF | 060074 | TX69A509.2//BBY/FOX/3/ GRK//NO64/PEX/4/ CER/5/CHIL/2*STAR | -0E-0E-5E-0E-2E-0E | TCI981148 | TCI | 8.7 | 5.31246 | 2.65623 | MR |
| 281 | 11CBWF | 090552 | ES14/SITTA//AGRI/NAC/3/ BURBOT-4 | -030YE-30E-2E-0E- 4AP-0AP | TCI011118 | TCI | 15.2 | 1.69967 | 0.84984 | MS |
| 282 | 11CBWF | 991760 | Caledon | | | TCI | 11.2 | 3.96513 | 1.98256 | MS |
| 283 | C19FAWWON- INT | | Alamoot/Sids8 | | | Mashhad | 12.7 | 3.00925 | 1.50462 | MS |
| 284 | C19FAWWON- INT | | TOSUNBEY | | | TR | 7.7 | 3.29983 | 1.64992 | MR |
| 285 | C19FAWWON- INT | | KARAHAN | | | TR | 11.7 | 3.47211 | 1.73606 | MS |
| 286 | C19FAWWON- INT | | Alamoot/Shiroodi | | | Mashhad | 15.5 | 4.54606 | 2.27303 | S |
| 287 | C19FAWWON- INT | | Alamoot/Sids8 | | | Mashhad | 11.8 | 1.24722 | 0.62361 | MS |
| 288 | C19FAWWON- TCI | 090028 | RSK/CA8055//CHAM6/4/NWT/ 3/TAST/SPRW//TAW12399.75 | -0AP-0AP-25AP-0AP- 4AP-0AP | TCI-02-47 | TCI | 15.5 | 3.18852 | 1.59426 | S |
| 289 | C19FAWWON- TCI | | EXCALIBUR/WBLL1 | -0P0Y-040M-040SY- 030M-8ZLM-0ZTY | C3A00Y00600S | MX | 22.3 | 7.26101 | 3.6305 | HS |
| 290 | C19FAWWON- INT | | Bezostaya 1 | LUT17/SRS2 | | RUS | 23.2 | 2.4608 | 1.2304 | HS |
| 291 | C19FAWWON- INT | | Katea | Hebros/Bez-1 | | BUL | 5.3 | 1.24722 | 0.62361 | MR |

Abbreviations: ACCNO: accession number; CBWF: cross block winter facultative; CName: common name; CID: cross identification; ELITE: semi-arid; FAWWON: facultative and winter wheat observation nursery; HS: highly susceptible; IRR: irrigated; INT: international; MR: moderately resistant; MS: moderately susceptible; SELHX: selection history; SD: standard deviation; SE: standard error; R: resistant; S: susceptible; SA: South Africa; TCI: Turkey-CIMMYT-ICARDA.

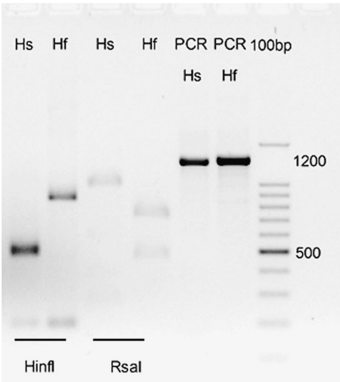


**Fig. S1.** Polymerase chain reaction restriction fragment length polymorphism patterns of *Heterodera filipjevi* (*Hf*) and *H. schachtii* (*Hs*) based on restriction with *Hinf*I or *Rsa*I.