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Resistance Response of Drought and Heat Tolerant Spring Wheat Lines against the Cereal Cyst Nematode, *Heterodera filipjevi*

Osameh ATIYA[a*], Abdelfattah DABABAT[b], Gul ERGINBAS-ORAKCI[b], Sukhwinder SINGH[c], Halil TOKTAY[a]

[a]*Niğde Ömer Halisdemir University, Faculty of Agricultural Sciences and Technologies, Niğde, TURKEY*
[b]*International Maize and Wheat Improvement Centre - Turkey office P.K. 39 Emek 06511 Ankara, TURKEY*
[c]*Geneshifters LLC, 222 Mary Jane Lane, Pullman, WA, 9916, USA*

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Corresponding Author: Osameh ATIYA, E-mail: osamehatiya@yahoo.com
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ABSTRACT
Wheat (*Triticum aestivum* L.) is extremely affected by several abiotic and biotic stress factors. Drought and/or heat alongside the parasitism of cereal cyst nematodes of the *Heterodera* genera can have a combined destructive impact on wheat. Solely, the cereal cyst nematode species *Heterodera filipjevi* can cause wheat yield losses of up to 50%. Several control measures have been implemented, yet the most economical and convenient control strategy is the use of resistant hosts. Therefore, the main aim of this study was to evaluate the resistant response of 257 spring wheat lines obtained from the International Maize and Wheat Improvement Centre to *Heterodera filipjevi* that might contain novel sources of resistance and be added as genetic resources for future breeding programs. Also, provide a base for future research to understand the relationship between nematode resistances and drought and heat tolerance. The results indicated that 11 wheat lines (4%) and 36 wheat lines (14%) were resistant and moderately resistant, respectively. High frequency of susceptible and highly susceptible lines and low frequency of resistant lines within this set was also recorded. The linear regression analysis between the number of cysts formed and the resistance response grouping showed a strong, positive, linear correlation. Log-linear regression analysis showed that there is a weak positive correlation between the yield of heat tolerant wheat lines and their resistance to the cyst nematodes as these lines showed tolerance, while there was a weak negative correlation of formed cyst nematodes on the yield of drought tolerant lines. This study was able to add new genetic sources of resistance to *Heterodera filipjevi* for upcoming breeding programs.

Keywords: Biotic stress, Breeding, Cereal crops, Plant-parasitic nematodes, Resistant source

1. Introduction

Bread wheat (*Triticum aestivum* L.) is a vital crop for many countries, contributing nearly to one-third of the total global food grain production (FAOSTAT 2020). Abiotic and biotic stress factors can interact together to adversely affect wheat yield and production worldwide (Lichtenthaler 1996; Afzal et al. 2015). In the wheat gene pool, there is an adequate genetic variation that can ensure continuous improvement of wheat adaptation to these stress factors (Lawlor & Cornic 2002; Trethowan & Mujeeb-Kazi 2008).

Climate change is a challenge facing humanity and its effects have been harmful to the agricultural industry. It is projected that countries near the equator will have a reduction in food production (Droogers & Aerts 2005). The International Water Management Institute (IWMI) study forecasts that wheat production in South Asia will decline by 50% by 2050 (De Fraiture et al. 2007). Studies indicated that increasing temperatures have negative effects on wheat yields in numerous regions of the world (Parry et al. 2004; Asseng et al. 2015; Zhao et al. 2017). It is going to be a challenge to increase or at least maintain the world's production of wheat to provide future generations with food needed to satisfy the demands of the increasing population. Also, it is a current and future challenge to find ways to reduce the impact of stress factors that decreases the yield of wheat such as plant-parasites (i.e., plant-parasitic nematodes) along with environmental factors (i.e., drought and heat).

Plant-parasitic nematodes that are the cause of agriculture production reduction, are regarded to be alarming. Despite their widespread compared to other pests, plant-parasitic nematodes are commonly very dangerous, stealthy, and costly to be managed and there is not enough detailed information or data on their economic impact (Webster 1987; Vaish 2017). Handoo (1998) valued the losses of international crop production due to nematode infection was around US$ 80 billion and McCarter (2009) estimated that the global economic loss due to nematode infection to be US$ 118 billion per year. The widespread of plant-parasitic nematodes on a majority of the vital crops, especially cereal cyst nematodes (CCNs) on wheat and their effect that dramatically reduces crop yields has caught the awareness of governments and international organizations to find methods of management.

Nicol et al. (2011) reported that environmental conditions influence losses that are caused by CCNs and may exceed 90%. In association with other biotic and abiotic factors such as fungal pathogens, water stress, and heat, CCNs can have a synergistic destructive impact (Nicol et al. 2006). The species of CCN *avenae* complex *H. avenae*, *H. filipjevi* and *H. latipons* (Rivoal & Cook 1993; Nicol & Rivoal 2008; Akar et al. 2009; Dababat et al. 2015; Seid et al. 2021) are considered the most economically important species in West Asia, North Africa, and the Mediterranean (Nicol et al. 2011; Dababat et al. 2021). *H. filipjevi* can be found generally in China, Germany, India, Iran, Norway, Poland, Russia, Spain, Syria, Sweden, Tajikistan, Turkey, and the USA (Nicol et al. 2006). In Turkey, *H. filipjevi* causes yield losses of up to 50% in winter wheat under rainfed conditions (Nicol et al. 2006; Imren et al. 2019). While Hajihasani et al. (2010) reported that in Iran *H. filipjevi* causes approximately 48% yield losses in winter wheat under rainfed conditions. Additionally, Karimipour Fard et al. (2018) reported that *H. filipjevi* in field conditions significantly had a negative effect on grain yield (23% reduction) and growth parameters (plant height, number of tillers, root dry weight, root height and aerial shoot dry weight) in all of the tested three cultivars.

Cereal cyst nematodes management methods have been mainly attained by rotation with non-host crops, such as legumes and moderately resistant cultivars. Due to the multi-year survival nature of the cyst that protects the eggs, a crop rotation period of at least 2 years is needed to maintain population densities below the economic damage threshold (Bridge & Starr 2007). This might be considered a non-feasible and non-profitable way of management due to its time and cost in cultivating practices during crop rotation. Host resistance is a desirable alternative because it is less expensive, easy to be used once identified, and it has no environmental toxicity like nematicides, despite the successful use of nematicides to control nematodes (Williamson & Kumar 2006, Dababat & Fourie 2018). Dababat et al. (2014) stated that globally, the evolution of cultivars with genetic resistance plus genetic tolerance has been accomplished. Screens (resistant tests) have been established for almost every crop to present phenotypic data for their particular breeding program. These screens aim to find and identify new sources of resistance and also the identification of resistant progeny in segregating populations. Miniaturized screening test either by using the test tube method is considered to show the greatest accuracy regarding phenotypic reaction distinction (Blok et al. 2018).

The study aims to screen and evaluate a set of drought and heat tolerant international spring wheat lines for the resistance response to *H. filipjevi*. It is believed that this set is a unique set for CCN resistance because of their drought and heat tolerant nature, which is believed to have a relation with CCN resistance in general but needs other in-depth studies to establish this theory and our study is considered to be a starting point. It is also believed that this study would provide new resistant spring wheat lines against *H. filipjevi*, which might contain novel sources of resistance and be added as genetic resources for future breeding programs. Another primary expectation of the research is to provide a base for future research to try to understand the relationship between nematode resistances and drought and heat tolerance.

2. Material and Methods

2.1. Plant Materials

A set of 257 spring wheat lines that originated from various countries were obtained from the International Maize and Wheat Improvement Center (CIMMYT) in Mexico **(Supplementary Table 1).** This set has been screened and genotyped for drought and heat tolerance traits by CIMMYT–Mexico. The set was tested for cereal cyst nematode resistance response at the Transitional Zone Agricultural Research Institute (TZARI) in Eskisehir, Turkey (39° 46' 1.2612" N, 30° 24' 10.8282" E) and has been repeated in two independent experiments. Four well-known check lines for their resistance response to *H. filipjevi* were used as reference: 2 susceptible cultivars (Bezostaya and Kutluk-94) and 2 moderate resistant cultivars (Katea-1 and Sonmez-2001).

2.2. Nematode inoculum: collection, hatching, and identification

Soil samples were collected from a wheat field historically known to be infested with *H. filipjevi* in Çiçekdağı district in the province of Kırşehir, Turkey (39° 63' 80" N; 34° 46' 72" E). Cysts were extracted using Cobb's decanting and sieving method (Cobb, 1918). Cysts were handpicked from the organic matter residue under a dissecting microscope (Olympus SZ61). Then the cysts were surface sterilized with NaOCl (0.5%) for about 10 minutes and rinsed several times with distilled H_2O before being transferred onto a fine mesh (45 µm) placed in a glass petri dish and stored at 4 °C to enhance hatching. Freshly hatched second-stage juveniles (J2s) were used as an inoculum source. Species identification was previously validated by CIMMYT-Turkey using molecular methods from random individual cysts and identified as *H. filipjevi* (Pariyar et al. 2016a). To reinsure that there were no other species, morphological identification was done by using a light microscope (LEICA DM5500 B) along with imaging software Leica Application Suite (LAS V4.12) in the labs of the Faculty of Agricultural Sciences and Technology of Nigde Omer Halisdemir University (37° 56' 36.2" N; 34° 37' 42.4" E), as the fenestra of the cyst was the main aspect of species determination. The morphological measurements and characteristics were compared to previously published data of Siddiqi (2000); Handoo (2002); Subbotin & Baldwin (2010).

2.3. Assessment of wheat lines

Three representative spikes of a single wheat line were selected and threshed. About 15-20 similar and healthy seeds per line were selected and germinated on a moist filter paper in a Petri dish for 3 days at 22 °C and 70-80% of relative humidity. A single germinated seed of each line with identical sized radicles was selected and transplanted into RLC4-pine tubes (25 mm × 160 mm Ray Leach Cone-tainer™; Stuewe & Sons, Inc., USA) containing 100 g of a sterilized growing mixture containing sand, organic matter, and field soil (70:29:1, v/v/v). The tubes were placed in a 200-cell tray (RL200; Ray Leach Cone-tainer™; Stuewe & Sons, Inc., USA) with 3 replications per line arranged in a randomized block design. One day after transplanting, each tube was inoculated with 250 freshly hatched J2s suspended in 1 ml of water and injected into 3 holes of 2 cm depth made by a thin plastic rod around the stem base. Plants were kept under controlled conditions (25 °C, 70% RH and a photoperiod of 16 h) at TZARI. Fourteen weeks after nematode inoculation, plants were uprooted and cysts were extracted from both roots and soil of each plant as per Dababat et al. (2014). The resistance response of the screened wheat lines was determined and classified into five groups based on the mean number of cysts and females per plant (Dababat et al. 2016). The following grouping was used: 1) R = Resistant (fewer cysts and females/plant than the moderately resistant checks). 2) MR = Moderately resistant (as few cysts and females/plant as the moderately resistant checks). 3) MS = Moderately susceptible (significantly more cysts and females/plant than in the moderately resistant check, but not as many as in the susceptible checks). 4) S = Susceptible (as many cysts and females/plant as in the susceptible check and the number of cysts per root system considered damaging). 5) HS = Highly susceptible (more cysts and females/plant than in the susceptible check).

2.4. Statistical analysis

Descriptive statistical parameters (mean, standard error (SE) and standard deviation (SD)) of the number of cysts and females per line were calculated and compared with the check cultivars for their resistant response evaluation. Regression analysis was conducted to assess the correlation between the mean number of cysts and females and the sorting of the resistance response grouping and to calculate the best fitting equation, a polynomial regression analysis was used. Log-linear regression analysis was conducted to assess the correlation between the yield of drought and heat tolerant wheat lines and the mean number of formed cysts.

3. Results and Discussion

3.1. Assessment of wheat lines

The results of the screening evaluation of the 257 spring wheat lines showed that 11 lines (4.28%) were resistant, 36 lines (14%) were moderately resistant, 72 lines (28.02%) were moderately susceptible, 79 lines (30.74%) were susceptible and 59 lines (22.96%) were highly susceptible, as shown in Figure 1 which also indicates a high frequency of susceptible and highly susceptible lines and low frequency of resistant lines within this set of drought and heat tolerant lines and represents a histogram distribution of the mean number of cysts formed on the root systems and estimated kernel density plot of the mean number of cysts formed per plant.

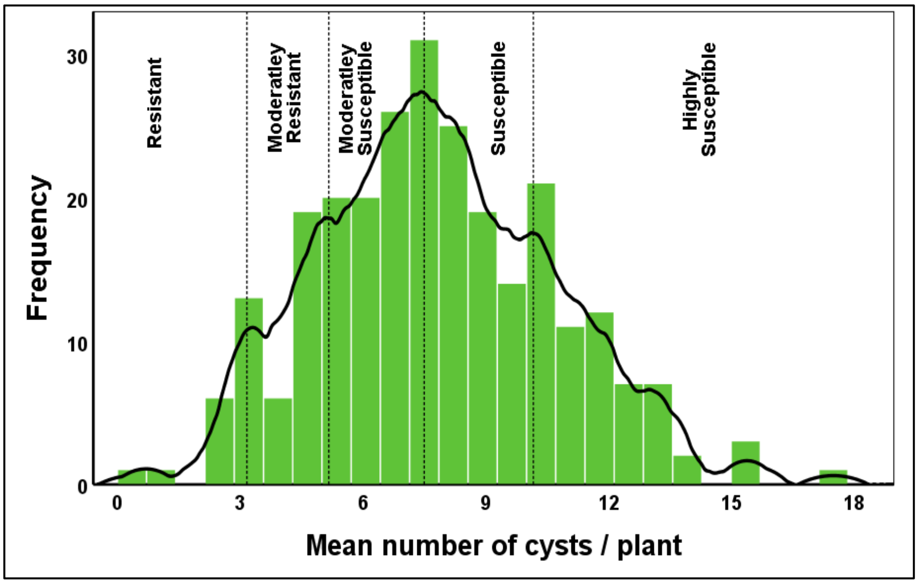

Figure 1- Histogram distribution and estimated kernel density plot of the mean number of cysts formed per plant, Frequency represents the number of wheat lines that cysts have formed on their root system between 0 – 18

3.2. Wheat lines resistant response grouping

To further assess the correlation between the mean number of cysts and females and the resistance response grouping of the wheat lines, linear regression analysis was used ($P < 0.05$, $R^2 = 0.958$). The data points to a strong, positive, linear correlation between the number of cysts and females formed and the resistance response grouping (Figure 2), which shows that the increase of the number of cysts formed leads to the categorization of the wheat lines from resistant to highly susceptible.

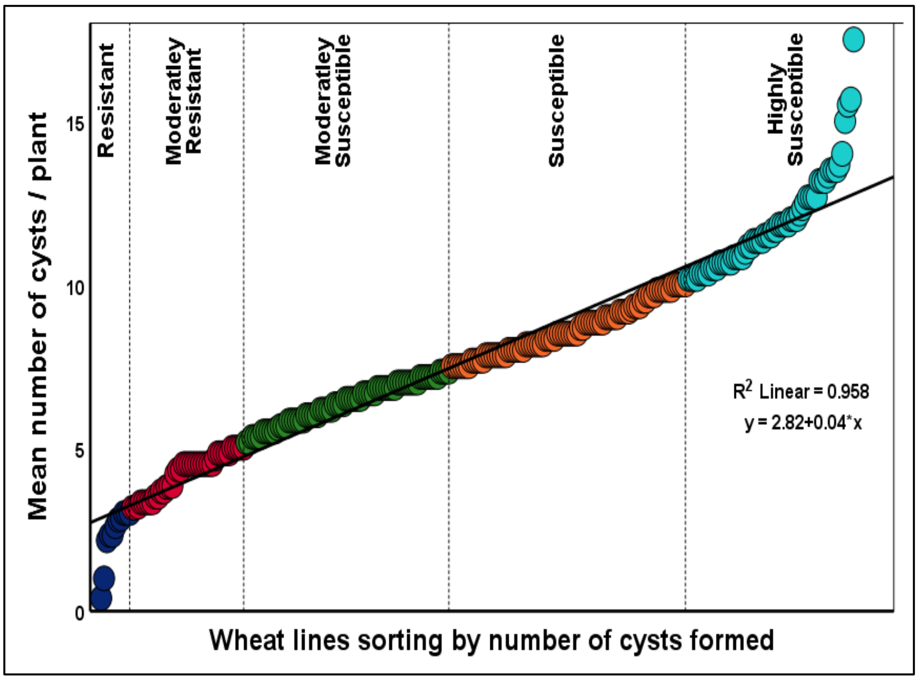

Figure 2- Linear regression of the mean number of cysts formed per plant and wheat lines sorting. Values are a mean of 2 trials, each with 3 replications. (P<0.05)

3.3. Source of resistance

After examining and comparing the parent materials of the wheat lines that have shown resistant and moderately resistant responses to all the spring wheat lines within this set, it has been found that there is no coherent pattern or indication that one parent tends to pass down resistance traits to their pedigree over another. As the parent material of the resistant and moderately resistant lines can be also found in the moderately susceptible, susceptible, and highly susceptible lines. So, the source of resistance of this set is due to different factors other than the dominant traits of a certain parent in resistant and moderately resistant lines (data not presented). Further analysis is required to be conducted to get a better idea of what the resistant sources are.

3.4. Effect of cyst nematodes on yield

In order to assess the effect of drought and heat on the relation between wheat yield and the mean number of formed cysts, Log-linear regression analysis was conducted (Figure 3). A negative relationship was noted between the number of formed cyst nematodes and the yield of drought tolerant wheat lines ($R^2 = 0.11$), while heat tolerant wheat lines seem to be more tolerant to the effect of cyst nematode formation as wheat yield values that were positively related to the number of formed cysts ($R^2 = 0.15$). Moreover, despite the noted negative effect of the number of formed cysts, the yield of drought tolerant lines was considered to be higher than the heat tolerant lines.

Breeding wheat for resistance against CCNs started in the 1970s (Brown & Ellis 1976) and has become one of the most effective and desirable methods of control especially against *H. filipjevi* to prevent yield losses. The use of resistant lines is desirable and the only enduring method present to control CCNs due to its low cost, being user-friendly and is acknowledged to not be harmful to the environment (Dababat et al. 2014; Williamson & Kumar 2006). Different control methods can be used but have limitations and there are very few reports related to wheat-nematode interaction. Goverse & Smant (2018) pointed out that the complete mechanism of resistance is still an enigma with incomplete knowledge on plant immunity to plant-parasitic nematodes. Specific genes for the resistance against *H. filipjevi* are yet to be identified despite some of the *Cre* genes have shown certain degrees of success against the nematode such as; *Cre8* and *CreR* which showed some levels of resistance (Imren et al. 2012). Toktay et al. (2012) screened resistant wheat lines containing the *Cre1* gene which showed different resistance responses to *H. filipjevi*. It has been recognized that some of the identified 12 *Cre* genes that are known as a resistant source in wheat to *H.*

avenae can show resistance to *H. filipjevi* and have shown success against other CCNs (Blok et al. 2018). To date, 16 different resistance genes to *H. avenae*, including 12 *Cre* genes; *Cre1*, *Cre2, Cre3, Cre4, Cre5, Cre6, Cre7, Cre8*, *Cre9 CreR*, *CreY* and *Cre3S* in wheat and its wild relatives and *Ha1*, *Ha2*, *Ha3*, *Ha4* genes in barley were reported (Bakker et al. 2006; Zhai et al. 2008; Smiley & Nicol 2009; Moens et al. 2018; Cui et al. 2020), which also might have resistance to *H. filipjevi*. Kimber & Feldman (1987) mentioned that wheat varieties showing resistance or tolerance responses have shown to provide resistance against a wide range of biotic and abiotic stress factors. There are some assumptions that there might be a strong connection between drought and heat tolerance with CCN resistance and is yet to be proven. Dababat et al. (2018) has addressed this matter, as it was mentioned that water stressed crops grown in arid and semi-arid regions that have the ability to secure adequate amounts of water can be severely weakened due to the effect of nematodes on the crops root system. Correspondingly, with our current findings, it has been found that there is a weak positive correlation between wheat lines with heat tolerance and the number of formed cysts (resistance response), as these lines showed more tolerance without negatively affecting their yield. Our findings also indicated that there is a weak negative correlation between drought tolerant wheat lines and number of formed cysts. This is most likely due to the genetic background of these lines.

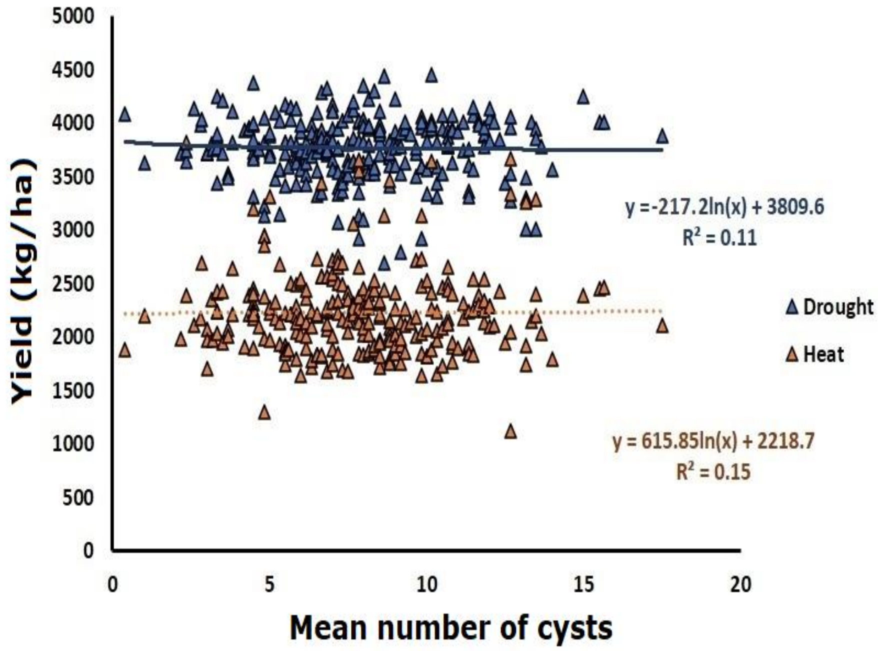

Figure 3- Log-linear regressions of wheat yield and mean number of formed cysts in 2 experiments. All R^2 values were significant at P<0.05. Values are means of 1 years, each with 6 replicates per line. The link represents the predicted logarithmic regression model. Equations were represented on kg ha^{-1}

The study has managed to find 11 resistant and 36 moderately resistant spring wheat lines, noting that the screened wheat set originates from a diverse genetic background. Different screening studies that have been done on wheat accessions originating from different sources have shown resistance to *H. filipjev*i (Toktay et al. 2012; Dababat et al. 2014; Pariyar et al. 2016a, b; Yavuzaslanoglu et al. 2016; Dababat 2019).

There is a difficulty to truly compare the result of this study to other similar or related studies despite using the same experimental setup, as there are a lot of variables between the experiments. One of the main reasons regarding the difficulty in comparison is due to different categorizing of the resistant response groups that rely on the average number of formed cysts and females on the root system per plant and comparing them to the check wheat cultivars with known resistance response. Pariyar et al. (2016b) and Yavuzaslanoglu et al. (2016) have used a different arrangement of the average number of formed cysts and females/plant assigned to the resistant groups with reliance on the check wheat cultivars response. Zhang et al. (2012) even used a different method of sorting which relied on the relative resistance index (RRI); RRI = [1 – (the mean number of white females per plant on a tested line/the mean number of white females per Wenmai 19 check plant).

Also, a point of difference is the experiment setup conditions, Dababat (2019) conducted his experiment under field conditions, Hajihasani et al. (2010) experiment was conducted in pots under field conditions, while Zhang et al. (2012) conducted his experiment in greenhouse conditions. Toktay et al. (2012) and (Pariyar et al. 2016a, b) conducted their study in a growth chamber under a controlled condition and with resembling methodology, so this can be a point of similarity to compare the results.

Generally, when screening wheat accessions for their resistant response almost all studies have obtained a low percentage of resistant accessions from the total screening. This study managed to find a total of 4.28% resistant lines from 257 lines, Dababat

(2019) tested 35 resistant lines that were obtained from the previous screening of thousands of wheat accessions. Pariyar et al. (2016a) found only 1% resistant accessions from a total of 161 accessions and in another study by Pariyar et al. (2016b) found only 1% resistance of wheat accessions from a total of 291 accessions.

In this type of study, it is expected to find a very low percentage of resistance among the screened accessions. When comparing the results of this study in terms of the percentage of resistance accessions found with the other studies, this study is considered to have a noticeably high percentage of success.

A possible reason for our current finding is the possibility that resistant and moderately resistant lines may have a relationship with the drought and heat tolerant QTLs as assumed. The screened set may also contain a source of *Cre* genes; like *Cre1* as in Toktay et al. (2012) study, *Cre8* or *CreR* in Imren et al. (2012) study, *Cre5* as in Dababat et al. (2014) study, or the same QTLs Pariyar et al. (2016a) has identified or due to the presence of new sources of resistance. This matter cannot be confirmed in this study but future analysis is required to obtain a clearer idea of why these specific lines showed a resistant response to *H. filipjevi*.

4. Conclusions

It is notable that despite the abundance of screening studies related to nematode resistance, this study is the first to evaluate the resistant response of *H. filipjevi* against wheat genotyped with drought and heat tolerance. It has been managed to add 11 wheat lines with resistance and 36 lines with moderate resistance to *H. filipjevi* as genetic resources for future wheat breeding programs. This might be good for helping advance resistance studies to CCNs in general but specifically to improve resistance against *H. filipjevi*. It is expected that the study can provide supplementary data with previous work by Pariyar et al. (2016a) for future studies concerned with finding resistant genes to *H. filipjevi*.

Although resistant and moderately resistant lines to *H. filipjevi* were found, it should be noted that further assessment of these lines is recommended to fully verify their resistant and moderately resistant status. Also, it is recommended that these lines should be screened for resistance response to other *Heterodera* species, mainly *H. avenae* and *H. latipons* to obtain wheat lines with resistance to more than one *Heterodera* species.

This study supports Dababat et al. (2018) remarks, statistically, that there is a correlation between drought and heat tolerance with CCN resistance despite being a weak one but establishes a foundation for more detailed studies.

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Supplementary Table1: List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
265	620759	PERSIA-88/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/ QUAIU #1	SDSS13Y00190T-0B-0Y-0M-0Y-0B-71Y	0.40	0.55	3.11	R
210	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-113Y	1.00	0.89	0.37	R
70	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-31Y	2.17	1.33	1.14	R
203	620683	H-1601/NAVJ07//KACHU	SDSS13Y00114T-0B-0Y-0M-0Y-0B-106Y	2.33	1.21	0.84	R
264	620749	IG 122743/NAVJ07//KACHU	SDSS13Y00180T-0B-0Y-0M-0Y-0B-33Y	2.33	0.82	0.33	R
54	620613	IG 1505/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ ROLF07/5/NELOKI	SDSS13Y00044T-0B-0Y-0M-0Y-0B-31Y	2.60	2.41	2.56	R
49	620609	DOY1/AE.SQUARROSA (447)/4/PRL/2*PASTOR// PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00040T-0B-0Y-0M-0Y-0B-43Y	2.80	2.28	2.83	R
263	620748	IG 122741/NAVJ07//KACHU	SDSS13Y00179T-0B-0Y-0M-0Y-0B-28Y	2.83	1.72	1.14	R
42	620600	H-1357/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST /7/TACUPETO F2001/9/KAUZ//ALTAR 84/AOS/3/ PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI	SDSS13Y00031T-0B-0Y-0M-0Y-0B-41Y	3.00	1.79	1.32	R
251	620729	IG 122139/NAVJ07//KACHU	SDSS13Y00160T-0B-0Y-0M-0Y-0B-38Y	3.00	1.90	1.18	R
254	620736	IG 122627/6/KAUZ//ALTAR 84/AOS/3/PASTOR/4/ MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/ BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00167T-0B-0Y-0M-0Y-0B-38Y	3.00	1.41	1.51	R
128	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE. SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-58Y	3.17	1.60	0.65	MR
KATEA (MR)		KHEBROS/BEZOSTAYA-1		3.17	2.71	1.11	MR
81	620631	H-1699/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00062T-0B-0Y-0M-0Y-0B-23Y	3.20	2.28	2.76	MR
69	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-30Y	3.33	1.97	0.80	MR
157	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-65Y	3.33	2.07	2.03	MR
225	620690	GAN/AE.SQUARROSA (206)//KACHU/3/BAJ #1	SDSS13Y00121T-0B-0Y-0M-0Y-0B-83Y	3.33	1.51	1.41	MR
250	620729	IG 122139/NAVJ07//KACHU	SDSS13Y00160T-0B-0Y-0M-0Y-0B-34Y	3.33	2.07	1.58	MR
257	620746	IG 122738/3/PBW343*2/KUKUNA*2//FRTL/ PIFED/4/QUAIU #1	SDSS13Y00177T-0B-0Y-0M-0Y-0B-54Y	3.33	2.16	0.88	MR
57	620615	IG 122145/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ ROLF07/5/NELOKI	SDSS13Y00046T-0B-0Y-0M-0Y-0B-38Y	3.50	2.35	1.41	MR
256	620736	IG 122627/6/KAUZ//ALTAR 84/AOS/3/PASTOR /4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.527 7/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00167T-0B-0Y-0M-0Y-0B-43Y	3.50	1.64	1.28	MR
208	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-101Y	3.67	4.97	2.03	MR
261	620748	IG 122741/NAVJ07//KACHU	SDSS13Y00179T-0B-0Y-0M-0Y-0B-22Y	3.67	2.50	1.23	MR
SONMEZ (MR)		BEZOSTAYA-1//BEZOSTAYA-1/TEVERE/3/ KREMENA/LOVRIN-29/4/KATYA-1[3669]		3.80	2.17	0.97	MR
87	620633	IG 131672/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00064T-0B-0Y-0M-0Y-0B-60Y	3.83	2.23	1.68	MR
227	620693	D67.2/PARANA 66.270//AE.SQUARROSA (506)/3/ KACHU/4/BAJ #1	SDSS13Y00124T-0B-0Y-0M-0Y-0B-49Y	3.83	1.47	0.60	MR

Supplementary Table2(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
174	**620655**	**CETA/AE.SQUARROSA (872)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRT L/PIFED**	**SDSS13Y00086T-0B-0Y-0M-0Y-0B-58Y**	**4.20**	**2.49**	**3.58**	**MR**
143	620646	IWA8611400/BORL14//COPIO	SDSS13Y00077T-0B-0Y-0M-0Y-0B-112Y	4.33	2.66	1.09	MR
219	620689	CROC_1/AE.SQUARROSA (176)//KACHU/3/BAJ #1	SDSS13Y00120T-0B-0Y-0M-0Y-0B-87Y	4.33	2.73	1.63	MR
127	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE. SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-57Y	4.50	2.95	1.54	MR
144	620646	IWA8611400/BORL14//COPIO	SDSS13Y00077T-0B-0Y-0M-0Y-0B-113Y	4.50	3.02	1.89	MR
145	620647	T.DICOCCON PI94624/AE.SQUARROSA (454)// COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00078T-0B-0Y-0M-0Y-0B-71Y	4.50	2.74	1.69	MR
168	620653	PERSIA-21/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00084T-0B-0Y-0M-0Y-0B-75Y	4.50	2.88	1.61	MR
169	620653	PERSIA-21/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00084T-0B-0Y-0M-0Y-0B-77Y	4.50	2.81	1.96	MR
189	620665	GARZA/BOY//AE.SQUARROSA (281)/3/ PBW343*2/KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00096T-0B-0Y-0M-0Y-0B-62Y	4.50	2.81	1.34	MR
199	620680	IG 41243/NAVJ07//KACHU	SDSS13Y00111T-0B-0Y-0M-0Y-0B-58Y	4.50	2.88	1.18	MR
239	620699	IG 41506/3/PBW343*2/KUKUNA*2//FRTL/ PIFED/4/QUAIU #1	SDSS13Y00130T-0B-0Y-0M-0Y-0B-71Y	4.50	3.15	1.28	MR
247	620718	IG 43238/NAVJ07//KACHU	SDSS13Y00149T-0B-0Y-0M-0Y-0B-5Y	4.50	2.88	1.48	MR
273	620785	IWA8614378/NAVJ07//KACHU	SDSS13Y00216T-0B-0Y-0M-0Y-0B-119Y	4.50	2.35	0.96	MR
SONMEZ (MR)		BEZOSTAYA-1//BEZOSTAYA-1/TEVERE/3/ KREMENA/LOVRIN-29/4/KATYA-1[3669]		4.50	2.07	0.85	MR
160	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-71Y	4.67	2.34	0.95	MR
170	620653	PERSIA-21/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00084T-0B-0Y-0M-0Y-0B-81Y	4.83	3.37	1.92	MR
215	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-137Y	4.83	4.45	1.82	MR
229	620694	INDIA-59/KACHU//BAJ #1	SDSS13Y00125T-0B-0Y-0M-0Y-0B-79Y	4.83	2.56	1.05	MR
246	620710	IG 41735/NAVJ07//KACHU	SDSS13Y00141T-0B-0Y-0M-0Y-0B-78Y	4.83	4.79	1.96	MR
278	620786	IWA8612701/6/KAUZ//ALTAR 84/AOS/3/PASTOR /4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.527 7/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00217T-0B-0Y-0M-0Y-0B-75Y	4.83	2.32	0.95	MR
165	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-79Y	5.00	2.76	1.53	MR
166	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-81Y	5.00	2.76	1.13	MR
221	620689	CROC_1/AE.SQUARROSA (176)//KACHU/3/BAJ #1	SDSS13Y00120T-0B-0Y-0M-0Y-0B-100Y	5.00	3.03	1.81	MR
241	620699	IG 41506/3/PBW343*2/KUKUNA*2// FRTL/PIFED/4/QUAIU #1	SDSS13Y00130T-0B-0Y-0M-0Y-0B-75Y	5.00	5.14	2.10	MR
KATEA (MR)		KHEBROS/BEZOSTAYA-1		5.00	2.58	1.29	MR
20	620583	H-1624/BAJ #1//SUP152	SDSS13Y00014T-0B-0Y-0M-0Y-0B-32Y	5.17	2.64	1.97	MS
29	620588	H-1311/3/FRET2*2/SHAMA//KACHU/4/ HUW234+LR34/PRINIA*2//KIRITATI	SDSS13Y00019T-0B-0Y-0M-0Y-0B-4Y	5.17	2.32	0.95	MS
30	620588	H-1311/3/FRET2*2/SHAMA//KACHU/4/ HUW234+LR34/PRINIA*2//KIRITATI	SDSS13Y00019T-0B-0Y-0M-0Y-0B-7Y	5.33	3.14	1.61	MS
114	620640	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (628)/5/BORL14/6/COPIO	SDSS13Y00071T-0B-0Y-0M-0Y-0B-46Y	5.33	3.61	1.48	MS
137	620645	IWA8612416/BORL14//COPIO	SDSS13Y00076T-0B-0Y-0M-0Y-0B-46Y	5.33	3.01	1.91	MS
244	620710	IG 41735/NAVJ07//KACHU	SDSS13Y00141T-0B-0Y-0M-0Y-0B-67Y	5.33	2.80	1.15	MS
148	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)// COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-102Y	5.50	3.15	1.61	MS
159	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-69Y	5.50	3.78	1.54	MS
184	620662	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (477)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/ KUKUNA*2//FRTL/PIFED	SDSS13Y00093T-0B-0Y-0M-0Y-0B-87Y	5.50	6.47	2.64	MS

Supplementary Table3(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
262	**620748**	**IG 122741/NAVJ07//KACHU**	**SDSS13Y00179T-0B-0Y-0M-0Y-0B-27Y**	**5.50**	**2.59**	**1.06**	**MS**
271	620783	IWA8612134/NAVJ07//KACHU	SDSS13Y00214T-0B-0Y-0M-0Y-0B-88Y	5.50	3.78	1.89	MS
110	620638	LOCAL RED/AE.SQUARROSA (223)//BORL14/3/COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-62Y	5.60	3.85	3.83	MS
47	620603	IG 42147/6/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00034T-0B-0Y-0M-0Y-0B-48Y	5.67	3.20	1.31	MS
181	620661	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (460)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/KUKUNA*2//FRTL/PIFED	SDSS13Y00092T-0B-0Y-0M-0Y-0B-99Y	5.67	3.56	1.45	MS
234	620695	INDIA-107/KACHU//BAJ #1	SDSS13Y00126T-0B-0Y-0M-0Y-0B-108Y	5.67	3.83	1.56	MS
88	620633	IG 131672/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00064T-0B-0Y-0M-0Y-0B-70Y	5.83	3.76	1.92	MS
99	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-62Y	5.83	3.71	1.51	MS
216	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-139Y	5.83	4.17	1.70	MS
248	620726	IG 107128/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00157T-0B-0Y-0M-0Y-0B-47Y	5.83	3.60	1.68	MS
270	620777	IWA 8602098/NAVJ07//KACHU	SDSS13Y00208T-0B-0Y-0M-0Y-0B-46Y	5.83	5.95	2.43	MS
272	620785	IWA8614378/NAVJ07//KACHU	SDSS13Y00216T-0B-0Y-0M-0Y-0B-116Y	5.83	4.02	2.32	MS
33	620594	INDIA-223/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.71/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00025T-0B-0Y-0M-0Y-0B-24Y	6.00	6.51	2.66	MS
41	620600	H-1357/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001/9/KAUZ//ALTAR 84 /AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI	SDSS13Y00031T-0B-0Y-0M-0Y-0B-40Y	6.00	6.39	2.61	MS
67	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-23Y	6.00	8.27	3.38	MS
202	620683	H-1601/NAVJ07//KACHU	SDSS13Y00114T-0B-0Y-0M-0Y-0B-104Y	6.00	4.15	2.35	MS
222	620690	GAN/AE.SQUARROSA (206)//KACHU/3/BAJ #1	SDSS13Y00121T-0B-0Y-0M-0Y-0B-54Y	6.00	3.95	1.61	MS
204	620684	MEX94.30.10/NAVJ07//KACHU	SDSS13Y00115T-0B-0Y-0M-0Y-0B-98Y	6.17	3.37	1.38	MS
206	620685	ARLIN/AE.SQUARROSA (283)//KACHU/3/BAJ #1	SDSS13Y00116T-0B-0Y-0M-0Y-0B-68Y	6.17	4.26	1.74	MS
218	620688	AE.SQUARROSA (1029)/DVERD_2//KACHU/3/BAJ #1	SDSS13Y00119T-0B-0Y-0M-0Y-0B-69Y	6.17	3.97	2.06	MS
220	620689	CROC_1/AE.SQUARROSA (176)//KACHU/3/BAJ #1	SDSS13Y00120T-0B-0Y-0M-0Y-0B-92Y	6.17	4.17	1.70	MS
275	620785	IWA8614378/NAVJ07//KACHU	SDSS13Y00216T-0B-0Y-0M-0Y-0B-123Y	6.17	3.31	1.94	MS
34	620594	INDIA-223/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.71/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00025T-0B-0Y-0M-0Y-0B-27Y	6.33	6.47	2.64	MS
60	620620	IG 122193/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00051T-0B-0Y-0M-0Y-0B-71Y	6.33	4.23	1.73	MS
78	620630	H-1694/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00061T-0B-0Y-0M-0Y-0B-48Y	6.33	4.32	1.76	MS
130	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-62Y	6.33	3.44	1.89	MS
23	620583	H-1624/BAJ #1//SUP152	SDSS13Y00014T-0B-0Y-0M-0Y-0B-43Y	6.50	4.55	2.69	MS
64	620621	IG 122196/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00052T-0B-0Y-0M-0Y-0B-88Y	6.50	8.02	3.27	MS
77	620630	H-1694/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00061T-0B-0Y-0M-0Y-0B-39Y	6.50	4.51	1.84	MS
155	620650	IG 41620/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00081T-0B-0Y-0M-0Y-0B-64Y	6.50	1.05	0.43	MS
158	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-66Y	6.50	4.51	2.40	MS

Supplementary Table4(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
274	**620785**	**IWA8614378/NAVJ07//KACHU**	**SDSS13Y00216T-0B-0Y-0M-0Y-0B-121Y**	**6.50**	**3.73**	**1.52**	**MS**
124	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-51Y	6.67	3.67	1.50	MS
146	620647	T.DICOCCON PI94624/AE.SQUARROSA (454)//COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00078T-0B-0Y-0M-0Y-0B-85Y	6.67	3.72	2.17	MS
211	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-123Y	6.67	6.65	2.72	MS
249	620726	IG 107128/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00157T-0B-0Y-0M-0Y-0B-50Y	6.67	8.89	3.63	MS
277	620786	IWA8612701/6/KAUZ//ALTAR84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00217T-0B-0Y-0M-0Y-0B-63Y	6.67	4.41	1.80	MS
39	620595	CHIH95.4.6/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.71/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS QUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00026T-0B-0Y-0M-0Y-0B-52Y	6.83	7.55	3.08	MS
82	620631	H-1699/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00062T-0B-0Y-0M-0Y-0B-26Y	6.83	4.40	2.14	MS
109	620638	LOCAL RED/AE.SQUARROSA (223)//BORL14/3/COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-56Y	6.83	7.33	2.99	MS
139	620645	IWA8612416/BORL14//COPIO	SDSS13Y00076T-0B-0Y-0M-0Y-0B-49Y	6.83	3.87	2.21	MS
217	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-145Y	6.83	3.43	1.40	MS
236	620698	IG 41474/NAVJ07//KACHU	SDSS13Y00129T-0B-0Y-0M-0Y-0B-46Y	6.83	4.31	2.14	MS
253	620736	IG 122627/6/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00167T-0B-0Y-0M-0Y-0B-37Y	6.83	5.04	2.06	MS
18	620583	H-1624/BAJ #1//SUP152	SDSS13Y00014T-0B-0Y-0M-0Y-0B-29Y	7.00	3.69	2.11	MS
45	620600	H-1357/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001/9/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI	SDSS13Y00031T-0B-0Y-0M-0Y-0B-50Y	7.00	4.69	2.38	MS
51	620612	IG 41489/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00043T-0B-0Y-0M-0Y-0B-40Y	7.00	4.52	1.84	MS
52	620612	IG 41489/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00043T-0B-0Y-0M-0Y-0B-54Y	7.00	2.97	2.50	MS
55	620613	IG 41505/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00044T-0B-0Y-0M-0Y-0B-34Y	7.00	4.82	3.40	MS
56	620615	IG 122145/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00046T-0B-0Y-0M-0Y-0B-36Y	7.00	4.00	1.63	MS
62	620620	IG 122193/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00051T-0B-0Y-0M-0Y-0B-75Y	7.00	3.10	1.26	MS
97	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-60Y	7.00	3.22	1.32	MS
84	620631	H-1699/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00062T-0B-0Y-0M-0Y-0B-30Y	7.17	4.45	1.82	MS
90	620634	INDIA-38/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00065T-0B-0Y-0M-0Y-0B-48Y	7.17	7.36	3.00	MS
98	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-61Y	7.17	4.62	2.18	MS
106	620638	LOCAL RED/AE.SQUARROSA (223)//BORL14/3/COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-40Y	7.17	3.87	1.58	MS
197	620678	H-1491/ROLF07//NAVJ07	SDSS13Y00109T-0B-0Y-0M-0Y-0B-73Y	7.17	2.32	0.95	MS
245	620710	IG 41735/NAVJ07//KACHU	SDSS13Y00141T-0B-0Y-0M-0Y-0B-68Y	7.17	8.45	3.45	MS
255	620736	IG 122627/6/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00167T-0B-0Y-0M-0Y-0B-41Y	7.17	3.31	1.89	MS
74	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-49Y	7.33	4.89	2.68	MS
83	620631	H-1699/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00062T-0B-0Y-0M-0Y-0B-28Y	7.33	3.61	1.48	MS
154	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)//COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-113Y	7.33	4.50	2.33	MS

Supplementary Table5(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
267	620768	H-1659/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/ QUAIU #1	SDSS13Y00199T-0B-0Y-0M-0Y-0B-39Y	7.33	3.14	1.28	MS
131	620642	D67.2/PARANA 66.270//AE.SQUARROSA (1085)/3/ BORL14/4/COPIO	SDSS13Y00073T-0B-0Y-0M-0Y-0B-73Y	7.50	5.24	2.14	S
136	620645	IWA8612416/BORL14//COPIO	SDSS13Y00076T-0B-0Y-0M-0Y-0B-40Y	7.50	4.81	1.96	S
205	620684	MEX94.30.10/NAVJ07//KACHU	SDSS13Y00115T-0B-0Y-0M-0Y-0B-102Y	7.50	3.78	1.54	S
223	620690	GAN/AE.SQUARROSA (206)//KACHU/3/BAJ #1	SDSS13Y00121T-0B-0Y-0M-0Y-0B-59Y	7.50	3.39	1.38	S
226	620692	D67.2/PARANA 66.270//AE.SQUARROSA (448)/3/ KACHU/4/BAJ #1	SDSS13Y00123T-0B-0Y-0M-0Y-0B-122Y	7.50	2.59	1.06	S
243	620699	IG 41506/3/PBW343*2/KUKUNA*2//FRTL/ PIFED/4/QUAIU #1	SDSS13Y00130T-0B-0Y-0M-0Y-0B-83Y	7.50	4.76	1.95	S
BEZOST AJA (S)		LUT17/SRS2		7.50	2.65	1.32	S
37	620595	CHIH95.4.6/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.7 1/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/C NDO/R143//ENTE/MEXI_2/3/AEGILOPS QUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00026T-0B-0Y-0M-0Y-0B-24Y	7.67	2.80	1.15	S
38	620595	CHIH95.4.6/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.7 1/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/C NDO/R143//ENTE/MEXI_2/3/AEGILOPS QUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00026T-0B-0Y-0M-0Y-0B-34Y	7.67	4.32	1.76	S
119	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-43Y	7.67	8.87	3.62	S
201	620683	H-1601/NAVJ07//KACHU	SDSS13Y00114T-0B-0Y-0M-0Y-0B-100Y	7.67	5.13	3.12	S
231	620695	INDIA-107/KACHU//BAJ #1	SDSS13Y00126T-0B-0Y-0M-0Y-0B-87Y	7.67	4.23	1.73	S
4	620575	DOY1/AE.SQUARROSA (488)//BAJ #1/3/SUP152	SDSS13Y00006T-0B-0Y-0M-0Y-0B-57Y	7.83	4.26	1.74	S
9	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-55Y	7.83	8.16	3.33	S
11	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-61Y	7.83	3.76	1.54	S
149	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)// COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-105Y	7.83	3.54	1.45	S
182	620661	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (460)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/ KUKUNA*2//FRTL/PIFED	SDSS13Y00092T-0B-0Y-0M-0Y-0B-100Y	7.83	5.38	2.20	S
212	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-124Y	7.83	2.40	0.98	S
228	620694	INDIA-59/KACHU//BAJ #1	SDSS13Y00125T-0B-0Y-0M-0Y-0B-73Y	7.83	5.04	2.80	S
242	620699	IG 41506/3/PBW343*2/KUKUNA*2//FRTL/ PIFED/4/QUAIU #1	SDSS13Y00130T-0B-0Y-0M-0Y-0B-78Y	7.83	5.04	2.06	S
31	620588	H-1311/3/FRET2*2/SHAMA//KACHU/4/ HUW234+LR34/PRINIA*2//KIRITATI	SDSS13Y00019T-0B-0Y-0M-0Y-0B-16Y	8.00	3.29	1.34	S
40	620598	IG 122727/8/CNDO/R143//ENTE/MEXI_2/3/ AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/ PICUS/6/TROST/7/TACUPETO 2001/9/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KI RITATI	SDSS13Y00029T-0B-0Y-0M-0Y-0B-55Y	8.00	4.86	1.98	S
76	620630	H-1694/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00061T-0B-0Y-0M-0Y-0B-36Y	8.00	10.79	4.40	S
150	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)// COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-106Y	8.00	5.06	2.70	S
178	620657	CETA/AE.SQUARROSA (895)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/ PIFED	SDSS13Y00088T-0B-0Y-0M-0Y-0B-120Y	8.00	5.37	3.59	S
196	620678	H-1491/ROLF07//NAVJ07	SDSS13Y00109T-0B-0Y-0M-0Y-0B-54Y	8.00	4.60	1.88	S
27	620586	INDIA-101/3/FRET2*2/SHAMA//KACHU/4/ HUW234+LR34/PRINIA*2//KIRITATI	SDSS13Y00017T-0B-0Y-0M-0Y-0B-61Y	8.17	5.49	2.24	S
58	620616	IG 122146/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/R OLF07/5/NELOKI	SDSS13Y00047T-0B-0Y-0M-0Y-0B-71Y	8.17	4.71	3.03	S
108	620638	LOCAL RED/AE.SQUARROSA (223)// BORL14/3/COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-55Y	8.17	5.53	3.12	S

Supplementary Table6(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
200	620680	IG 41243/NAVJ07//KACHU	SDSS13Y00111T-0B-0Y-0M-0Y-0B-64Y	8.17	5.71	3.24	S
207	620685	ARLIN/AE.SQUARROSA (283)//KACHU/3/BAJ #1	SDSS13Y00116T-0B-0Y-0M-0Y-0B-83Y	8.17	5.64	2.30	S
209	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-111Y	8.17	5.04	3.07	S
240	620699	IG 41506/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00130T-0B-0Y-0M-0Y-0B-74Y	8.17	3.37	1.38	S
2	620575	DOY1/AE.SQUARROSA (488)//BAJ #1/3/SUP152	SDSS13Y00006T-0B-0Y-0M-0Y-0B-52Y	8.33	3.08	3.09	S
48	620604	IG 42152/6/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00035T-0B-0Y-0M-0Y-0B-60Y	8.33	4.89	1.99	S
102	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-67Y	8.33	5.65	2.65	S
118	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-42Y	8.33	4.68	1.91	S
16	620580	GARZA/BOY//AE.SQUARROSA (695)/3/BAJ #1/4/SUP152	SDSS13Y00011T-0B-0Y-0M-0Y-0B-44Y	8.50	5.32	2.17	S
32	620592	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (390)/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.71/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00023T-0B-0Y-0M-0Y-0B-60Y	8.50	5.09	2.08	S
53	620613	IG 41505/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00044T-0B-0Y-0M-0Y-0B-28Y	8.50	5.32	3.00	S
113	620640	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (628)/5/BORL14/6/COPIO	SDSS13Y00071T-0B-0Y-0M-0Y-0B-45Y	8.50	9.03	3.69	S
134	620642	D67.2/PARANA 66.270//AE.SQUARROSA (1085)/3/BORL14/4/COPIO	SDSS13Y00073T-0B-0Y-0M-0Y-0B-80Y	8.50	5.92	3.29	S
162	620652	PERSIA-7/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00083T-0B-0Y-0M-0Y-0B-73Y	8.50	4.55	2.46	S
167	620653	PERSIA-21/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00084T-0B-0Y-0M-0Y-0B-74Y	8.50	5.89	2.40	S
224	620690	GAN/AE.SQUARROSA (206)//KACHU/3/BAJ #1	SDSS13Y00121T-0B-0Y-0M-0Y-0B-79Y	8.50	5.68	2.72	S
142	620646	IWA8611400/BORL14//COPIO	SDSS13Y00077T-0B-0Y-0M-0Y-0B-106Y	8.67	5.43	2.78	S
269	620768	H-1659/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00199T-0B-0Y-0M-0Y-0B-44Y	8.67	5.50	3.07	S
22	620583	H-1624/BAJ #1//SUP152	SDSS13Y00014T-0B-0Y-0M-0Y-0B-37Y	8.83	5.12	2.52	S
36	620594	INDIA-223/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/F3.71/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST/7/TACUPETO F2001	SDSS13Y00025T-0B-0Y-0M-0Y-0B-48Y	8.83	5.64	2.77	S
59	620616	IG 122146/4/PRL/2*PASTOR//PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00047T-0B-0Y-0M-0Y-0B-74Y	8.83	5.38	3.29	S
75	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-51Y	8.83	5.04	2.06	S
115	620640	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (628)/5/BORL14/6/COPIO	SDSS13Y00071T-0B-0Y-0M-0Y-0B-47Y	8.83	5.71	2.33	S
135	620645	IWA8612416/BORL14//COPIO	SDSS13Y00076T-0B-0Y-0M-0Y-0B-35Y	8.83	5.81	2.94	S
252	620736	IG 122627/6/KAUZ//ALTAR 84/AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI/7/SW89.5277/BORL95//SKAUZ/3/PRL/2*PASTOR/4/HEILO	SDSS13Y00167T-0B-0Y-0M-0Y-0B-34Y	8.83	5.85	2.99	S
17	620581	IG 42134/BAJ #1//SUP152	SDSS13Y00012T-0B-0Y-0M-0Y-0B-54Y	9.00	5.40	2.70	S
129	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-60Y	9.00	5.90	3.34	S
171	620654	CETA/AE.SQUARROSA (850)/3/KACHU #1/KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/PIFED	SDSS13Y00085T-0B-0Y-0M-0Y-0B-62Y	9.00	5.55	2.27	S
183	620662	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (477)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/KUKUNA*2//FRTL/PIFED	SDSS13Y00093T-0B-0Y-0M-0Y-0B-82Y	9.00	5.51	2.68	S

Supplementary Table7(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
276	620785	IWA8614378/NAVJ07//KACHU	SDSS13Y00216T-0B-0Y-0M-0Y-0B-125Y	9.00	5.93	2.42	S
43	620600	H-1357/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/TROST /7/TACUPETO F2001/9/KAUZ//ALTAR 84/AOS/3/ PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRITATI	SDSS13Y00031T-0B-0Y-0M-0Y-0B-44Y	9.17	4.62	1.89	S
153	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)//COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-112Y	9.17	5.71	3.00	S
177	620657	CETA/AE.SQUARROSA (895)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/ PIFED	SDSS13Y00088T-0B-0Y-0M-0Y-0B-115Y	9.17	4.96	2.02	S
266	620759	PERSIA-88/3/PBW343*2/KUKUNA*2//FRTL/PIFED /4/QUAIU #1	SDSS13Y00190T-0B-0Y-0M-0Y-0B-89Y	9.17	4.45	1.82	S
KUTLUK (S)		KRASNODARSKAYA//INIA-66/LILIFEN/3/ CALIBASAN		9.25	8.62	4.31	S
12	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-64Y	9.33	5.79	2.36	S
19	620583	H-1624/BAJ #1//SUP152	SDSS13Y00014T-0B-0Y-0M-0Y-0B-31Y	9.33	3.44	2.75	S
193	620670	LOCAL RED/AE.SQUARROSA (222)/3/PBW343*2/ KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00101T-0B-0Y-0M-0Y-0B-81Y	9.33	4.68	1.91	S
141	620646	IWA8611400/BORL14//COPIO	SDSS13Y00077T-0B-0Y-0M-0Y-0B-92Y	9.50	5.13	2.09	S
KUTLUK (S)		KRASNODARSKAYA//INIA-66/LILIFEN/3/CALIBASAN		9.50	4.73	2.36	S
147	620647	T.DICOCCON PI94624/AE.SQUARROSA (454)// COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00078T-0B-0Y-0M-0Y-0B-86Y	9.67	6.71	2.74	S
190	620667	DOY1/AE.SQUARROSA (415)/3/PBW343*2/ KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00098T-0B-0Y-0M-0Y-0B-69Y	9.67	5.24	2.14	S
233	620695	INDIA-107/KACHU//BAJ #1	SDSS13Y00126T-0B-0Y-0M-0Y-0B-103Y	9.67	6.65	2.72	S
13	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-65Y	9.83	6.52	3.50	S
25	620586	INDIA-101/3/FRET2*2/SHAMA//KACHU/4/ HUW234+LR34/PRINIA*2//KIRITATI	SDSS13Y00017T-0B-0Y-0M-0Y-0B-43Y	9.83	6.62	3.11	S
46	620600	H-1357/8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/ TROST/7/TACUPETO F2001/9/KAUZ//ALTAR 84/ AOS/3/PASTOR/4/MILAN/CUPE//SW89.3064/5/KIRIT ATI	SDSS13Y00031T-0B-0Y-0M-0Y-0B-51Y	9.83	5.49	2.24	S
186	620662	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (477)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/ KUKUNA*2//FRTL/PIFED	SDSS13Y00093T-0B-0Y-0M-0Y-0B-97Y	9.83	6.62	2.70	S
198	620678	H-1491/ROLF07//NAVJ07	SDSS13Y00109T-0B-0Y-0M-0Y-0B-74Y	9.83	4.54	1.85	S
235	620696	IG 41242/3/PBW343*2/KUKUNA*2//FRTL/ PIFED/4/QUAIU #1	SDSS13Y00127T-0B-0Y-0M-0Y-0B-75Y	9.83	6.08	2.48	S
5	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-47Y	10.00	5.18	3.04	S
72	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-44Y	10.00	6.07	3.31	S
105	620638	LOCAL RED/AE. SQUARROSA (223)//BORL14/3/ COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-39Y	10.00	10.18	4.16	S
230	620694	INDIA-59/KACHU//BAJ #1	SDSS13Y00125T-0B-0Y-0M-0Y-0B-91Y	10.00	6.72	3.59	S
BEZOST AJA (S)		LUT17/SRS2		10.00	4.24	2.12	S
14	620579	D67.2/PARANA 66.270//AE.SQUARROSA (677)/3/BAJ #1/4/SUP152	SDSS13Y00010T-0B-0Y-0M-0Y-0B-35Y	10.17	5.95	3.44	HS
79	620630	H-1694/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00061T-0B-0Y-0M-0Y-0B-49Y	10.17	3.97	1.62	HS
103	620637	TXL92.8.1/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00068T-0B-0Y-0M-0Y-0B-65Y	10.17	5.64	2.91	HS
258	620746	IG 122738/3/PBW343*2/KUKUNA*2// FRTL/PIFED/4/QUAIU #1	SDSS13Y00177T-0B-0Y-0M-0Y-0B-59Y	10.17	6.68	3.09	HS
92	620634	INDIA-38/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00065T-0B-0Y-0M-0Y-0B-54Y	10.33	6.53	3.02	HS
172	620654	CETA/AE.SQUARROSA (850)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/ PIFED	SDSS13Y00085T-0B-0Y-0M-0Y-0B-64Y	10.33	4.23	1.73	HS
188	620665	GARZA/BOY//AE.SQUARROSA (281)/3/PBW343*2/ KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00096T-0B-0Y-0M-0Y-0B-58Y	10.33	5.54	2.26	HS

Supplementary Table8(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
192	620669	LOCAL RED/AE.SQUARROSA (220)/3/PBW343*2/ KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00100T-0B-0Y-0M-0Y-0B-87Y	10.33	6.44	3.36	HS
21	620583	H-1624/BAJ #1//SUP152	SDSS13Y00014T-0B-0Y-0M-0Y-0B-34Y	10.50	5.89	2.40	HS
120	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-45Y	10.50	3.15	1.28	HS
122	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-48Y	10.50	5.24	3.25	HS
3	620575	DOY1/AE.SQUARROSA (488)//BAJ #1/3/SUP152	SDSS13Y00006T-0B-0Y-0M-0Y-0B-56Y	10.67	6.74	2.75	HS
65	620625	IG 122795/4/PRL/2*PASTOR// PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00056T-0B-0Y-0M-0Y-0B-96Y	10.67	6.31	2.58	HS
95	620634	INDIA-38/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00065T-0B-0Y-0M-0Y-0B-60Y	10.67	6.65	2.72	HS
125	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/ AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-52Y	10.67	6.98	2.85	HS
175	620655	CETA/AE.SQUARROSA (872)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/ PIFED	SDSS13Y00086T-0B-0Y-0M-0Y-0B-64Y	10.67	6.77	3.13	HS
35	620594	INDIA-223/7/SHA7/VEE#5/5/VEE#8//JUP/BJY/3/ F3.71/TRM/4/2*WEAVER/6/SKAUZ/PARUS//PARUS/ 8/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/PICUS/6/ TROST/7/TACUPETO F2001	SDSS13Y00025T-0B-0Y-0M-0Y-0B-36Y	10.83	2.04	0.83	HS
50	620611	CETA/AE.SQUARROSA (391)/4/PRL/2*PASTOR// PBW343*2/KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00042T-0B-0Y-0M-0Y-0B-6Y	10.83	6.15	3.89	HS
63	620621	IG 122196/4/PRL/2*PASTOR//PBW343*2/ KUKUNA/3/ROLF07/5/NELOKI	SDSS13Y00052T-0B-0Y-0M-0Y-0B-80Y	10.83	6.62	2.70	HS
180	620661	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (460)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/ KUKUNA*2//FRTL/PIFED	SDSS13Y00092T-0B-0Y-0M-0Y-0B-97Y	10.83	6.62	2.70	HS
191	620669	LOCAL RED/AE.SQUARROSA (220)/3/PBW343*2/ KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00100T-0B-0Y-0M-0Y-0B-79Y	11.00	7.40	3.74	HS
111	620638	LOCAL RED/AE.SQUARROSA (223)//BORL14/3/ COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-65Y	11.17	6.40	3.29	HS
176	620657	CETA/AE.SQUARROSA (895)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/ PIFED	SDSS13Y00088T-0B-0Y-0M-0Y-0B-110Y	11.17	7.00	2.86	HS
71	620629	H-1546/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00060T-0B-0Y-0M-0Y-0B-33Y	11.33	7.09	3.38	HS
138	620645	IWA8612416/BORL14//COPIO	SDSS13Y00076T-0B-0Y-0M-0Y-0B-48Y	11.33	6.56	2.68	HS
173	620654	CETA/AE.SQUARROSA (850)/3/KACHU #1/ KIRITATI//KACHU/4/PBW343*2/KUKUNA*2//FRTL/ PIFED	SDSS13Y00085T-0B-0Y-0M-0Y-0B-69Y	11.33	7.39	3.90	HS
232	620695	INDIA-107/KACHU//BAJ #1	SDSS13Y00126T-0B-0Y-0M-0Y-0B-101Y	11.33	7.39	3.02	HS
94	620634	INDIA-38/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00065T-0B-0Y-0M-0Y-0B-58Y	11.50	7.87	4.01	HS
107	620638	LOCAL RED/AE.SQUARROSA (223)//BORL14/3/ COPIO	SDSS13Y00069T-0B-0Y-0M-0Y-0B-52Y	11.50	7.29	2.97	HS
117	620640	68.111/RGB-U//WARD RESEL/3/STIL/4/ AE.SQUARROSA (628)/5/BORL14/6/COPIO	SDSS13Y00071T-0B-0Y-0M-0Y-0B-53Y	11.50	5.92	3.50	HS
96	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-59Y	11.67	7.31	3.38	HS
140	620645	IWA8612416/BORL14//COPIO	SDSS13Y00076T-0B-0Y-0M-0Y-0B-50Y	11.67	8.02	3.27	HS
6	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-51Y	11.83	8.04	3.28	HS
26	620586	INDIA-101/3/FRET2*2/SHAMA//KACHU/4/HUW234+LR34/P RINIA*2//KIRITATI	SDSS13Y00017T-0B-0Y-0M-0Y-0B-54Y	11.83	6.37	2.60	HS
66	620627	68.111/RGB-U//WARD/3/FGO/4/RABI/5/ AE.SQUARROSA (890)/6/NELOKI/7/ATTILA*2/ PBW65//MURGA	SDSS13Y00058T-0B-0Y-0M-0Y-0B-43Y	11.83	6.62	3.48	HS
80	620630	H-1694/NELOKI/3/ATTILA*2/PBW65//MURGA	SDSS13Y00061T-0B-0Y-0M-0Y-0B-55Y	11.83	6.65	2.71	HS
121	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/ AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-47Y	12.00	8.02	3.28	HS

Supplementary Table9(Continue): List of Drought and Heat Tolerant Spring Wheat lines and their Resistant Response to the CCN Heterodera filipjevi. (SD) Standard Deviation, (SE) Standard Error, (CID) Cross ID

ENTRY NUMBER	*CID*	*PEDIGREE (CROSS)*	*SELECTION HISTORY*	*(MEAN) CYSTS AND FEMALES*	*SD*	*SE*	*RESISTANT RESPONSE*
132	620642	D67.2/PARANA 66.270//AE.SQUARROSA (1085)/3/BORL14/4/COPIO	SDSS13Y00073T-0B-0Y-0M-0Y-0B-77Y	12.00	7.51	3.07	HS
185	620662	YAV79//DACK/RABI/3/SNIPE/4/AE.SQUARROSA (477)/5/KACHU #1/KIRITATI//KACHU/6/PBW343*2/KUKUNA*2//FRTL/PIFED	SDSS13Y00093T-0B-0Y-0M-0Y-0B-91Y	12.00	4.82	1.97	HS
156	620650	IG 41620/COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00081T-0B-0Y-0M-0Y-0B-78Y	12.17	5.12	2.09	HS
260	620747	IG 122740/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00178T-0B-0Y-0M-0Y-0B-47Y	12.33	8.12	3.87	HS
152	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)//COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-108Y	12.50	6.12	3.59	HS
116	620640	68.111/RGB-U//WARD RESEL/3/STIL /4/AE.SQUARROSA (628)/5/BORL14/6/COPIO	SDSS13Y00071T-0B-0Y-0M-0Y-0B-51Y	12.67	7.81	4.82	HS
133	620642	D67.2/PARANA 66.270//AE.SQUARROSA (1085)/3/BORL14/4/COPIO	SDSS13Y00073T-0B-0Y-0M-0Y-0B-79Y	12.67	7.26	2.96	HS
161	61665	EMPTY PLOT		12.67	8.04	3.28	HS
213	620687	CROC_1/AE.SQUARROSA (436)//KACHU/3/BAJ #1	SDSS13Y00118T-0B-0Y-0M-0Y-0B-129Y	12.67	7.84	3.20	HS
85	620633	IG 131672/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00064T-0B-0Y-0M-0Y-0B-50Y	13.17	6.37	3.79	HS
104	620637	TXL92.8.1/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00068T-0B-0Y-0M-0Y-0B-67Y	13.17	5.64	2.30	HS
151	620648	T.DICOCCON PI94625/AE.SQUARROSA (372)//COPIO/3/KACHU #1/KIRITATI//KACHU	SDSS13Y00079T-0B-0Y-0M-0Y-0B-107Y	13.17	7.76	3.99	HS
194	620674	JAL95.4.3/VORB//ROLF07	SDSS13Y00105T-0B-0Y-0M-0Y-0B-29Y	13.33	9.14	4.91	HS
15	620579	D67.2/PARANA 66.270//AE.SQUARROSA (677)/3/BAJ #1/4/SUP152	SDSS13Y00010T-0B-0Y-0M-0Y-0B-47Y	13.50	8.31	3.39	HS
89	620634	INDIA-38/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00065T-0B-0Y-0M-0Y-0B-46Y	13.50	9.31	4.88	HS
187	620663	GARZA/BOY//AE.SQUARROSA (278)/3/PBW343*2/KUKUNA*2//FRTL/PIFED/4/QUAIU #1	SDSS13Y00094T-0B-0Y-0M-0Y-0B-47Y	13.50	7.69	4.06	HS
126	620641	68.111/RGB-U//WARD RESEL/3/STIL/4/AE.SQUARROSA (630)/5/BORL14/6/COPIO	SDSS13Y00072T-0B-0Y-0M-0Y-0B-56Y	13.67	8.26	3.37	HS
101	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-66Y	14.00	8.37	3.42	HS
100	620635	INDIA-50/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00066T-0B-0Y-0M-0Y-0B-63Y	15.00	8.49	3.46	HS
7	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-53Y	15.50	8.34	3.40	HS
91	620634	INDIA-38/3/ATTILA*2/PBW65//MURGA/4/BORL14	SDSS13Y00065T-0B-0Y-0M-0Y-0B-53Y	15.67	10.75	6.02	HS
8	620577	DVERD_2/AE.SQUARROSA (333)//BAJ #1/3/SUP152	SDSS13Y00008T-0B-0Y-0M-0Y-0B-54Y	17.50	10.01	5.15	HS