

Article

Meloidogyne spp. Population Diversity and Inoculum Density Influence Parasitism of Kiwifruit Plants

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Abstract

Kiwifruit (*Actinidia* spp.) has become a globally important crop, with *A. chinensis* var. *deliciosa* cv. Hayward being the most widely cultivated cultivar. Root-knot nematodes (RKNs, *Meloidogyne* spp.) are highly damaging plant parasites that are widespread in Portugal. *Meloidogyne hapla* predominates in the major production areas and occasionally co-occurs with *M. arenaria* and *M. hispanica*; however, the effects of these RKNs on kiwifruit performance and yield remain largely unclear. This study evaluated the reaction of Hayward and Tomuri cultivars to different *Meloidogyne* spp. and inoculum levels, focusing on plant–nematode interactions with distinct *M. hapla* populations. Kiwifruit’s reaction to RKN parasitism varied according to both the *Meloidogyne* spp. and the intraspecific variability of *M. hapla*. *Meloidogyne arenaria* and *M. hispanica* caused different impacts in kiwifruit cultivars. Intraspecific variation in *M. hapla* influenced the host reaction, with certain populations showing high parasitic rates. Gall numbers increased with *M. hapla* inoculum density, indicating that higher nematode populations intensify pressure on the host. Although few differences were observed between cultivars, *M. arenaria* had a greater impact on cv. Hayward (female), while *M. hispanica* affected cv. Tomuri (male) more strongly, showing the importance of investigating cultivar- and sex-specific responses to RKNs for effective management in kiwifruit. These findings highlight that susceptibility and tolerance in kiwifruit depend on the RKN species identity, intraspecific variability, population density and cultivar-specific responses, emphasizing the complexity of host–nematode interactions.

Keywords: *Actinidia* spp.; cv. Hayward; cv. Tomuri; *Meloidogyne hapla*; Root-knot nematodes



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1. Introduction

Kiwifruit (*Actinidia* spp.) is a crop of global importance that originates from north–central China [1]. Among the approximately seventy species, the deciduous and perennial *A. deliciosa* and *A. chinensis* are the most commercially significant. *Actinidia chinensis* var. *deliciosa* cv. Hayward stands out as the dominant kiwifruit cultivar grown globally, due to its large fruits, organoleptic properties, and remarkable storage capability; the widespread cultivation of kiwifruit can be largely attributed to the success of this cultivar [2,3]. The main producers are China, New Zealand, Italy and Greece, whilst Portugal ranks eighth worldwide and fourth in Europe [4]. According to Instituto Nacional de Estatística (INE), Entre-Douro e Minho and Beira Litoral are the major regions of kiwifruit production in the

country, having increased in planted area by around 33% in recent years [5,6]. Despite their economic importance, kiwifruit plants are exposed to various biotic stress factors, notably fungal, bacterial, and nematode infections [7].

Root-knot nematodes (RKNs), *Meloidogyne* spp., are among the most devastating plant-parasitic nematodes, affecting a wide range of economically important crops worldwide. These obligate endoparasites have a broad geographic distribution and an extensive host range, which contributes to their agricultural significance [8]. Their impact is particularly strong, as beyond feeding on their host, they compromise plant health by disrupting root function, reducing water and nutrient uptake, and ultimately leading to decreased yields and fruit quality [9]. Among the species identified, *M. hapla* and *M. incognita* are the most frequently reported parasites of kiwifruit [10–13]. In Portugal, RKNs appear to be widespread in kiwifruit orchards, having been detected in 92.5% of orchards sampled in the main production regions [14]. *Meloidogyne hapla* is the dominant species, with the additional detection of a mixture of *M. hapla* with *M. arenaria* and *M. hispanica* [14,15]. The impact of these RKN species on fruit yield and quality is unknown. Furthermore, most growers are unaware of the presence of RKNs in their orchards, and even when infestations are detected, yield losses are only reported informally. Hence, losses due to RKNs in kiwifruit have not been documented or quantified, leaving a gap in our understanding of the actual impact of these nematodes on the crop.

Plant susceptibility to RKN parasitism is generally defined by the efficiency of the plant as a host, typically assessed through comparisons of nematode reproduction across different plant genotypes. However, susceptibility is a complex trait that depends on multiple factors, including the ability of infective juveniles (J2s) to invade the roots, induce the formation of giant cells that manifest as knots (galls) on the roots, and successfully reproduce [16]. The nematode female resides within these galls, continually feeding from the giant cells and producing eggs encased in a gelatinous matrix that usually protrudes from the root. The hatching J2s are then capable of infecting other roots of the same or neighboring plants [17]. Therefore, the reproductive success of nematodes, commonly referred to as fitness, is maximized under favorable host and environmental conditions [18] and can be measured indirectly through fecundity, defined as the number of eggs per egg mass, capturing the reproductive output of each female within the population.

Depending on the effects of RKN parasitism, plants may be classified as resistant when they are able to restrict nematode reproduction [19]. In resistant hosts, RKNs may be unable to penetrate the roots, die after penetration, fail to complete their development, or be prevented from reproducing [17,20]. This diversity in plant–nematode interaction outcomes is evidenced by the wealth of distinct races and virulent populations within the same species of RKN, capable of reproducing even on resistant plants [21].

The tolerance of plants to RKN parasitism is determined by the symptoms they exhibit and their growth and yield performance. In severe infections, yield losses may be substantial, potentially resulting in premature plant death. However, the impact of RKNs on plant performance and yield depends on multiple factors, including the nematode population density, environmental conditions, variations in host susceptibility, and level of genetic variability within RKN populations [22]. An adequate understanding of the RKN–kiwifruit plant interactions is lacking.

This study aims to investigate the susceptibility of the widely planted female *A. deliciosa* cv. Hayward and the commonly planted male cv. Tomuri to different *Meloidogyne* spp. previously detected in Portuguese kiwifruit orchards (*M. arenaria*, *M. hapla* and *M. hispanica*) across a range of inoculum densities representative of low to high field infestations. We further aim to investigate the plant–nematode interactions involving genetically

different populations of *M. hapla* [23] to gain insight into the nematode–host interactions potentially underlying symptoms and yield losses in the field in Portugal.

2. Materials and Methods

2.1. Obtaining *Meloidogyne* spp. Isolates

A total of five populations, one of *M. arenaria*, three of *M. hapla* and one of *M. hispanica*, originally isolated and identified from kiwifruit orchards in Portugal, were tested. The three isolates of *M. hapla* were selected due to the apparent high intraspecific diversity of this species in kiwifruit orchards in Portugal [23], as well as their different in-field population densities: *M. hapla* 1 had the highest density, followed by *M. hapla* 2 and *M. hapla* 3 with the lowest population density [14]. The RKN populations were increased on tomato plants, *Solanum lycopersicum*, cv. Tiny Tim. One-month-old tomato plants were transferred to pots filled with 300 mL of autoclaved soil and each inoculated with a single egg mass of a nematode population. The plants were kept in a controlled environment cabinet (23 °C, 75% humidity and 12 h photoperiod) and watered daily with tap water.

Sixty days after inoculation, eggs were collected from the tomato roots using 0.5% NaOCl extraction [24] and used as an inoculum.

2.2. Host Reaction Experiments

Considering the dioecious nature of kiwifruit plants, the experimental trials were conducted using cv. Hayward as the female and cv. Tomuri as the male, both cultivars being selected due to their prominence in commercial kiwifruit production in Portugal.

2.2.1. Effects of Inter- and Intraspecific Variability of RKNs

To establish and assess the interactions between kiwifruit plants and RKNs, pot trials were conducted with the RKN species detected in association with kiwifruit in Portuguese orchards in previous studies [14,23]. Considering that *M. hapla* represents the most prevalent species in those orchards, distinct populations of this nematode were then examined to determine whether host plant responses vary according to the intraspecific, genetic differences among populations that may influence plant susceptibility and tolerance. To investigate these interactions, for each RKN species or population, five kiwifruit plants of each cultivar were transplanted into pots containing 300 mL of autoclaved soil and inoculated with 5 eggs.mL^{−1} of soil. Uninoculated kiwifruit plants were used as controls, and all plants were maintained in a controlled environment cabinet (23 °C, 75% humidity, and 12 h photoperiod) and watered daily with tap water. Sixty days after inoculation, the shoot fresh weight and biomass were determined after drying in a ventilated oven. For the roots, the fresh weight was determined, and nematode-induced galls and all egg masses were counted in whole roots. All eggs were extracted for final nematode population quantification [24] to allow the calculation of the reproduction factor (RF) as $RF = \text{final population} / \text{initial population}$, indicating reproductive success [25]. Fecundity was calculated as the total number of eggs/number of egg masses to estimate the average number of eggs produced per female as a direct estimation of fitness [26].

2.2.2. Effect of RKN Population Density

To assess whether the effect of RKNs on kiwifruit performance depends on the nematode population density, a pot trial was conducted with *M. hapla* at different inoculum levels. Five plants of each cultivar were inoculated with *M. hapla* population 1 at 0.5, 1, 5, and 15 eggs.mL^{−1} of soil, representing a gradient from low to high soil infestation densities [14]. *Meloidogyne hapla* 1 was chosen based on its comparatively high population density in kiwifruit orchards, which may reflect a greater degree of host-specific adaptation

to *A. deliciosa* [23]. This trial was performed under the same light, temperature and watering conditions as above, employing uninoculated kiwifruit plants as controls. The same plant and nematode parameters were estimated at sixty days after inoculation.

2.3. Statistical Analysis

For both trials, the numbers of galls and egg masses were analyzed using Generalized Linear Models (GLMs) with a Poisson distribution and log link function. Estimated marginal means (EMMs) were calculated from the models and compared pairwise with Tukey's adjustment to assess statistically significant differences among treatment factors (cultivars, RKN species, and inoculum levels). Fecundity data were log-transformed ($\log + 1$), and the reproduction factor (RF) was square-root-transformed; both variables, as well as root and shoot weights, were analyzed using GLMs with a Gaussian distribution and identity link function. The number of egg masses g^{-1} root for both trials was square-root-transformed and analyzed using GLMs with a Gaussian distribution and identity link function. All statistical analyses were conducted using R v. 4.2.2 freeware (R Core Team, 2018).

3. Results

3.1. Host Reaction to Different RKN Species and Populations

The fresh root and shoot weights of kiwifruit plants were not significantly influenced by the RKN species or population (Table 1). The impact of RKNs on kiwifruit plants was influenced by the *Meloidogyne* spp. parasitizing them and the kiwifruit cultivar (Figure 1). *Meloidogyne arenaria* and *M. hispanica* caused different impacts in kiwifruit cultivars. *Meloidogyne hispanica* induced a larger number of root galls in cv. Tomuri compared with cv. Hayward, whereas the opposite pattern was observed for *M. arenaria* (Figure 1C). A similar trend was verified for the number of egg masses produced by these species. However, when the number of egg masses g^{-1} root was analyzed, significant differences between the kiwifruit cultivars or *Meloidogyne* spp. were not detected (Figure S1). Additionally, neither the fecundity nor the reproduction factor resulted in significant differences across treatments. Despite this, *M. hispanica* showed a tendency toward higher fecundity in cv. Hayward than in cv. Tomuri, even though the number of egg masses was lower, suggesting that each female produced a higher number of eggs.

Table 1. Shoot and root weights of kiwifruit plants inoculated with *Meloidogyne* spp.

Kiwifruit Cultivar	RKN Species	Root Weight	Shoot Weight	
		Fresh (g)	Fresh (g)	Dry (g)
Tomuri	Control	5.09 ± 2.51	7.79 ± 4.46	1.72 ± 1.01
	<i>M. hapla</i> 1	5.38 ± 1.31	7.55 ± 1.26	1.78 ± 0.56
	<i>M. hapla</i> 2	3.29 ± 1.63	5.69 ± 2.89	1.10 ± 0.58
	<i>M. hapla</i> 3	3.43 ± 1.75	6.39 ± 3.47	1.20 ± 0.63
	<i>M. arenaria</i>	3.23 ± 1.49	5.16 ± 2.09	1.05 ± 0.41
	<i>M. hispanica</i>	3.26 ± 1.53	6.06 ± 4.37	1.29 ± 0.91
Hayward	Control	3.37 ± 1.87	6.68 ± 3.27	1.33 ± 0.71
	<i>M. hapla</i> 1	4.17 ± 1.91	5.63 ± 2.42	1.33 ± 0.63
	<i>M. hapla</i> 2	3.89 ± 0.89	6.56 ± 1.60	1.44 ± 0.44
	<i>M. hapla</i> 3	2.71 ± 1.71	3.96 ± 2.32	0.97 ± 0.42
	<i>M. arenaria</i>	3.24 ± 1.29	4.69 ± 2.23	1.06 ± 0.49
	<i>M. hispanica</i>	2.82 ± 1.11	5.77 ± 2.43	1.26 ± 0.4

Values are mean ± standard deviation of 5 replicates.

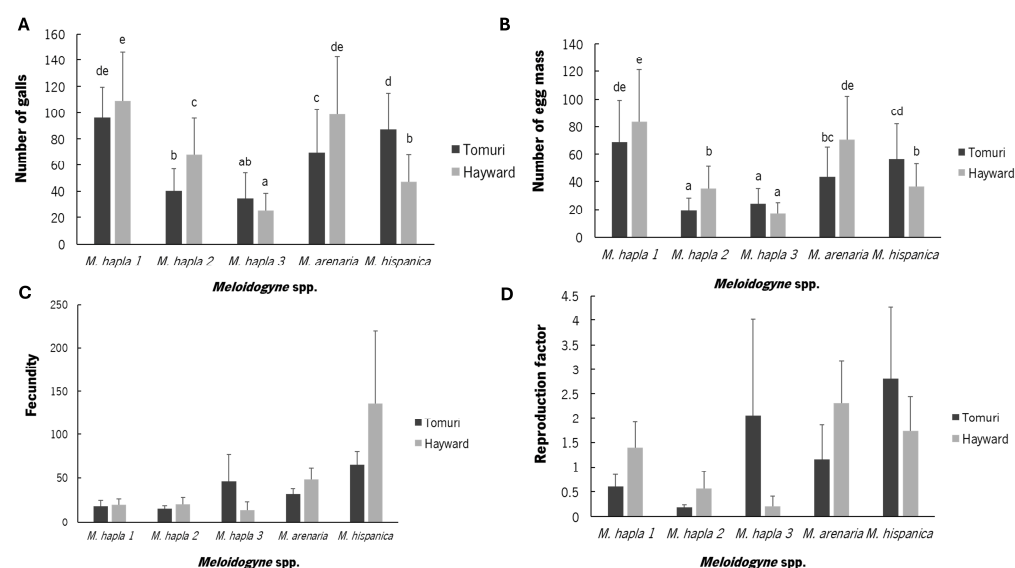


Figure 1. Numbers of galls (A) and egg masses (B), fecundity (C) and reproduction factor (D) of five *Meloidogyne* spp. on roots of kiwifruit cultivars Hayward and Tomuri. Values are mean and standard error of 5 replicates. Different letters indicate significant statistical differences ($p < 0.05$) according to GLM with Tukey's adjustment.

Kiwifruit plants exhibited different levels of susceptibility to *M. hapla* parasitism depending on the nematode population. Significantly larger numbers of root galls and egg masses were observed in plants inoculated with *M. hapla 1* compared with those inoculated with *M. hapla 2* or 3 (Figure 1A,B). Nevertheless, the number of eggs per egg mass was similar among the *M. hapla* populations (Figure 1C).

Although no significant differences were detected in the RF among the kiwifruit cultivars or *Meloidogyne* spp. and populations, *M. hispanica* showed an increase in population density ($RF > 2$), whereas *M. hapla* population 2 exhibited an $RF < 1$, indicating a decline in population by the end of the experiment (Figure 1D).

3.2. Host Reaction to Population Density of *M. hapla*

The inoculum levels of *M. hapla 1* did not cause significant variation in the root and shoot weights of kiwifruit plants. Although not statistically significant, the shoot and root fresh weights were largest in Hayward plants inoculated with RKNs at the highest inoculum level; this effect was not observed for kiwifruit of cv. Tomuri (Table 2).

Table 2. Shoot and root weights of kiwifruit cultivars Hayward and Tomuri sixty days after inoculation with different inoculum levels of *Meloidogyne hapla 1*.

Kiwifruit Cultivar	Inoculum (J2s.mL ⁻¹ soil)	Root Weight Fresh (g)	Shoot Weight Fresh (g)	Shoot Weight Dry (g)
Tomuri	0	5.09 ± 2.51	7.79 ± 4.46	1.72 ± 1.01
	0.5	4.7 ± 1.42	7.72 ± 3	1.69 ± 0.72
	1	3.24 ± 1.62	5.91 ± 3.45	1.19 ± 0.82
	5	5.38 ± 1.31	7.55 ± 1.26	1.78 ± 0.56
	15	3.86 ± 1.89	5.39 ± 1.95	1.09 ± 0.48
Hayward	0	3.37 ± 1.87	6.68 ± 3.27	1.33 ± 0.71
	0.5	4.90 ± 3.88	5.27 ± 4.28	1.09 ± 0.83
	1	3.33 ± 1.08	6.55 ± 2.19	1.46 ± 0.42
	5	4.17 ± 1.91	5.63 ± 2.42	1.33 ± 0.63
	15	6.11 ± 1.98	6.82 ± 2.52	1.7 ± 0.63

Values are mean ± standard deviation of 5 replicates.

For both cultivars, the numbers of galls and of egg masses were larger in plants receiving the higher RKN inoculum levels (5 or 15 eggs.mL⁻¹ of soil) than in those inoculated with 0.5 or 1 eggs.mL⁻¹ of soil (Figure 2A,B). In addition, cv. Tomuri showed a significant increase in the numbers of root galls and egg masses at higher inoculum levels, whereas cv. Hayward exhibited only a slight and non-significant increase. However, when the number of egg masses per gram of root was analyzed, only an effect of inoculum level was observed, with higher values in plants inoculated with the highest inoculum level (Figure S2). Fecundity was not significantly affected by the inoculum level or kiwifruit cultivar (Figure 2C). Nevertheless, the greatest fecundity occurred in cv. Hayward at the highest inoculum level, whereas the lowest was observed in Tomuri at an inoculum of 1 egg.mL⁻¹, with cv. Tomuri reaching its second highest fecundity at 0.5 eggs.mL⁻¹.

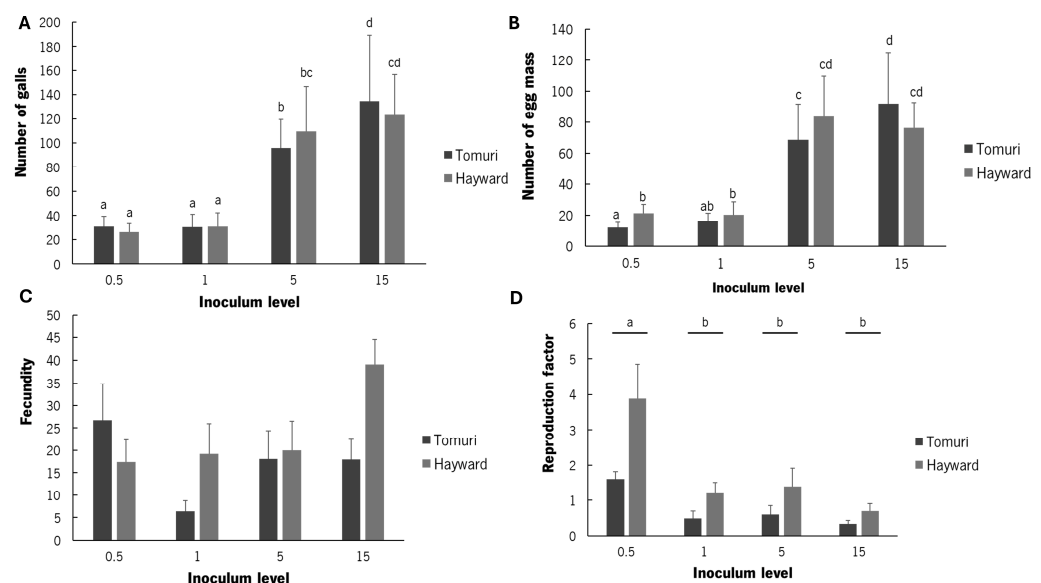


Figure 2. Numbers of galls (A) and egg masses (B), fecundity (C) and reproduction factor (D) produced by *M. hapla* 1 on roots of kiwifruit cultivars Hayward and Tomuri with different inoculum levels (0, 0.5, 1, 5 and 15 J2s.mL⁻¹ of soil). Results are mean and standard error of 5 replicates. Different letters indicate significant statistical differences ($p < 0.05$) according to GLM with Tukey's adjustment.

Significantly higher RF values were obtained at an inoculum level of 0.5 eggs.mL⁻¹ of soil, with higher inoculum levels resulting in lower RF values for both cultivars (Figure 2D). The RF values were ca. two-fold higher in cv. Hayward than in cv. Tomuri, across all inoculum levels tested (Figure 2D), although this difference was not statistically significant.

4. Discussion

The impact of RKN parasitism on kiwifruit plants varied according to the RKN species and population. All RKN species induced root gall formation, highlighting their likely detrimental effects on plant growth and productivity. Plant susceptibility to RKN parasitism allows J2s to penetrate the roots, induce gall formation, and successfully reproduce [16], whereas resistant plants can restrict nematode development and reproduction [19]. In this study, the kiwifruit cultivars evaluated exhibited different levels of susceptibility to *M. arenaria* and *M. hapla*, as both nematode species were able to complete their life cycle; however, no significant differences were observed in the number of egg masses g⁻¹ of root or reproduction factor, suggesting a counterbalancing effect of the root system development itself. Different inoculum levels were not tested, which would be important to determine whether kiwifruit plants might exhibit partial resistance—where nematode penetration occurs but reproduction is limited—or, conversely, if they are highly susceptible, requiring

further assessment of the potential impact on plant growth and yield [17,20]. Future research should therefore focus on evaluating a broader range of inoculum levels and comparing cultivar responses to better characterize the degree and nature of resistance or susceptibility within kiwifruit. Notably, the virulence of *M. hispanica* on kiwifruit remains uncharacterized, and its identification as a parasite of this crop is a recent observation [15].

In kiwifruit, host reactions to RKNs largely depend on the characteristics of the specific nematode population, emphasizing the importance of intraspecific variation. *Meloidogyne hapla* populations showed variable responses in kiwifruit, with some displaying higher parasitism. *Meloidogyne hapla* 1 caused the most severe damage, reflected in an increased number of root galls, although the fecundity and reproduction factor remained similar across all *M. hapla* populations. Given that *M. hapla* 1 originated from a kiwifruit orchard with the highest RKN density, this population may be particularly well adapted to colonizing the host. This aligns with our findings on intraspecific genetic variability, where novel haplotypes in kiwifruit orchards suggest a degree of host specificity [23]. As *M. hapla* is the predominant species in kiwifruit orchards [14], understanding its behavior and adaptations is crucial for implementing targeted management strategies, such as mulches, cover crops, or other measures to reduce reproduction, since damage levels may vary among populations.

An increase in *M. hapla* inoculum levels led to a larger number of root galls, suggesting that increased nematode densities intensify the pressure on kiwifruit plants. This result agrees with observations on the reaction of susceptible plants [27] and suggests that high infestation levels will likely intensify damage to kiwifruit roots, potentially leading to reduced plant vigor and compromised commercial value of the fruit. Large numbers of galls have previously been reported to significantly increase the fresh weight of roots; this has been attributed not to larger root development but rather to the damage caused by galling itself [28]. Indeed, RKNs feeding on roots have seldom been shown to change a plant's performance, reflecting both increased shoot and root weight [29,30]. Although our results on cv. Hayward agree with those findings for a 15 J2s.mL⁻¹ inoculum, this was not a consistent effect across inoculum levels. Importantly, this effect was not observed for cv. Tomuri, suggesting different physiological investments between cultivars, and may be related to plant sex, as previously reported in dioecious plants [31]. However, these results have to be interpreted with caution, given that these differences were not statistically significant and are here attributed to natural variation. Further studies should elucidate differential plant performance and potential defense mechanisms among kiwifruit cultivars. However, several reports indicate that increasing nematode inoculum levels can negatively affect plant development and yield. For instance, initial population densities of *Meloidogyne incognita* of 8 and 32 eggs and second-stage juveniles (J2s) per mL of soil reduced kiwifruit plant growth by 40% and 55%, respectively [32]. Similarly, a significant reduction in vegetative development was reported in plants inoculated with *M. hapla* at densities exceeding 20 and 100 J2s per mL of soil [33], which are well above the inoculum levels evaluated in this study. In the conditions of the study, the damage threshold for *M. hapla* in kiwifruit would be 20 J2s per mL of soil, above which significant yield reduction may be expected. This is not in agreement with kiwifruit producers describing yield declines at lower infestation levels [14], which may relate to the RKNs' intraspecific variation in interacting with their host, as detailed above. Additionally, it is important to note that these trials were conducted exclusively under controlled conditions, without considering additional abiotic or biotic factors that may interact with nematode populations. In natural orchard environments, even lower population densities could have a compounded impact on kiwifruit plants, potentially influencing growth, yield, symptom expression, and reproductive success. In general, observations in kiwifruit orchards infested with different

RKN species have indicated significant yield losses. In two kiwifruit orchards infested with RKNs, with soil population densities ca. 526 and 333 J2s per 100 mL of soil, kiwifruit yields declined by 36% and 49%, respectively, as compared to non-infested orchards [34]. Although the effects of RKN parasitism on kiwifruit plants remain incompletely documented, this example showed that these nematodes have the potential to cause substantial yield losses. A lack of producer awareness regarding their presence may result in attributing declines to other factors, thereby underestimating their true impact. Without long-term monitoring of nematode populations alongside yield measurements, the full extent of their influence in orchards may remain unknown.

Our work suggests that although kiwifruit plants allow nematode infection and gall formation, they may also activate defense mechanisms that limit or suppress nematode reproduction, as demonstrated by moderate fecundity and reproduction factors. However, we cannot exclude the effect of the host carrying capacity limiting reproduction due to high infection levels [35]. Regarding *M. hapla*, kiwifruit plants generally exhibited lower susceptibility to certain populations, suggesting that differences among *M. hapla* populations may influence both tolerance and resistance in kiwifruit. Although resistance, as measured by RFs, was similar across populations, one population produced a markedly higher number of egg masses, suggesting that the host may be particularly susceptible to this population and highlighting the potential for population-specific effects on nematode proliferation. However, it is important to note that inoculation was performed using eggs rather than second-stage juveniles (J2s). Hatching rates and viability vary among nematode species and populations, which may have affected the effective infection pressure and masked statistical differences in the results. This limitation should be considered in future studies, both to improve experimental accuracy and to better assess the potential impact of these nematodes on kiwifruit.

Cultivar-specific responses are well documented in both annual and perennial crops [36–42]. Although differences were observed between kiwifruit cultivars inoculated with *M. arenaria* and *M. hispanica* ($p > 0.05$), no significantly different host reaction could be attributed to the RKN species, consistent with previous findings in dioecious host species [31]. Differences were, however, detected at the species or cultivar level when considering the egg masses g^{-1} root, reproduction factor or fecundity. Since only one female and one male kiwifruit cultivar were tested, it is not possible to determine whether the observed differences were due to cultivar identity or plant sex. Nevertheless, even from a preliminary study, our results suggest that plants may respond differently depending on their sex, highlighting the potential importance of considering plant sex in future research. The relatively small number of replicates and the limited number of cultivars may have constrained both the statistical power and the generalizability of the findings. Additionally, the experiments were not repeated, which could have strengthened the reliability of the results. Future studies should include a broader range of cultivars, account for plant sex, increase replication, and repeat experiments to provide more robust and generalizable insights, ultimately guiding the selection of suitable cultivars for orchard establishment in relation to nematode species and population densities in the field.

Overall, our observations revealed that susceptibility and tolerance in kiwifruit depend on the RKN species identity, intraspecific variability, infection pressure and cultivar response. This study emphasizes the complexity of host responses to different RKN species and populations, exposing the dynamics of host–parasite interactions in this widely cultivated plant and underscoring the importance of developing effective and sustainable nematode management strategies. The variation in plant response depending on the nematode species and populations reinforces the importance of accurately characterizing field

populations. Adapting control measures to the specific nematode communities in each orchard could greatly improve their effectiveness and sustainability.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/agronomy16040426/s1>, Figure S1: Number of *Meloidogyne* spp. egg masses per gram of root fresh weight of kiwifruit cultivars Hayward and Tomuri; Figure S2: Number of egg masses per gram of root fresh weight of kiwifruit cultivars Hayward and Tomuri in different inoculum levels of *Meloidogyne hapla*.

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Data Availability Statement: The original contributions presented in this study are included in the article/Supplementary Materials. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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