RESEARCH/ INVESTIGACIÓN

DAMAGE POTENTIAL OF *MELOIDOGYNE INCOGNITA* POPULATIONS ON SELECTED TOMATO GENOTYPES IN ETHIOPIA

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ABSTRACT

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Reliable data are required to relate the effect of initial population density (*Pi*) on plant growth, biomass, and yield for specific crop-nematode associations under local conditions. In Ethiopia, no information is available on the effect and relationship between *Pi* of *Meloidogyne incognita* and damage to tomato cultivars. Hence, the effect of a series of *Pi* of two populations of *M. incognita* on tomato cultivars Assila, Chochoro, Moneymaker, and Tisey and the breeding line CLN-2366B on growth, yield, and the relationship with final nematode population density (*Pf*) were studied. Each tomato cultivar was inoculated with a geometric series of *Pi* (0, 0.125, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, and 256 J2/100 g dry soil) and grown until senescence. The relationship between *Pi* and *Pf* was fitted to the Seinhorst population dynamics model ($Pf = (M * Pi) / (Pi + M/a)$ while the effect of *Pi* on different plant parameters was fitted to the Seinhorst yield model ($Y = Ymax*(m + (1 - m)* Z^{((Pi-T)/T)})$). Based on the damage model all the tested plant parameters were negatively affected by both populations of *M. incognita*. The Jittu *M. incognita* population had greater effect on the majority of tomato parameters compared to the Babile population. Based on reproduction factors (RF), all the tomato cultivars were good hosts for both populations of *M. incognita*. The highest RF was obtained at lower *Pi*s (0.125 J2/100 g dry soil) and was reduced with increasing *Pi* on all cultivars. Severity of root galling and number of egg masses per root system increased with increasing inoculum levels of both nematode populations. The seedlings of all tomato genotypes died at the higher *Pi* value (256 J2/100 g dry soil) except for Assila. The cultivar Tisey was highly susceptible to both the Babile and Jittu populations and all the seedlings died at $Pi \geq 16$ J2/100 g dry soil. Moneymaker seedlings died at $Pi \geq 64$ J2/100 g dry soil. For all the plant parameters studied, Tisey had the lowest damage threshold T whereas Assila (except for root weight) had greater T. A difference was observed among the tomato genotypes on minimum yield (m) for the different plant parameters against the Babile and Jittu populations. Determination of T and m of a given crop variety for the prevailing *Meloidogyne* species in fields to be planted (local setting) is vital.

Key words: Damage, extrapolation, initial population density, local setting, *Meloidogyne incognita*, minimum yield, tolerance limit

RESUMEN

Seid A., C. Fininsa, T. M. Mekete, W. Decraemer, and W. M. L. Wesemael. 2019. Daño potencial de las poblaciones de *Meloidogyne incognita* en genotipos de tomate seleccionados en Etiopía. Nematropica 49:124-133.

Se requieren datos confiables para relacionar el efecto de la densidad poblacional inicial (*Pi*) sobre el crecimiento de las plantas, la biomasa y el rendimiento para asociaciones específicas de cultivos y nematodos en condiciones locales. En Etiopía, no se dispone de información sobre el efecto y la relación entre *Pi* de *Meloidogyne incognita* y el daño a los cultivares de tomate. Por lo tanto, se estudió el efecto de una serie de *Pi* de dos poblaciones de *M. incognita* en los cultivares de tomate Assila, Chochoro, Moneymaker y Tisey y la línea de reproducción CLN-2366B sobre el crecimiento, el rendimiento y la relación con la densidad de población final (*Pf*). Cada cultivar de tomate se inoculó con una serie geométrica de *Pi* (0, 0.125, 0.5, 1, 2, 4, 8, 16, 32, 64, 128 y 256 J2 / 100 g de suelo seco) y se cultivó hasta la senescencia. La relación entre *Pi* y *Pf* se ajustó al modelo de dinámica de población de Seinhorst (*Pf* = (M * *Pi*) / (*Pi* + M / a), mientras que el efecto de *Pi* en diferentes parámetros de la planta se ajustó al modelo de rendimiento de Seinhorst (Y = Ymax * (m + (1 - m) * Z ^ ((*Pi*-T) / T). Según el modelo de daño, todos los parámetros de la planta probados se vieron afectados negativamente por ambas poblaciones de *M. incognita*. La población de Jittu *M. incognita* tuvo mayor efecto en la mayoría de los parámetros de tomate en comparación con la población de Babile. Sobre la base de los factores de reproducción altos (RF), todos los cultivares de tomate fueron buenos hospedadores para ambas poblaciones de *M. incognita*. La RF más alta se obtuvo con un *Pi*s más bajo (0.125 J2 / 100 g de suelo seco) y se redujo con el aumento de *Pi* en todos los cultivares. La severidad del desgaste de las raíces y el número de masas de huevos por sistema de raíces aumentaron con el aumento de los niveles de inóculo de ambas poblaciones de *M. incognita.* el valor *Pi* más alto (256 J2 / 100 g de suelo seco) a excepción de Assila. tivar Tisey fue altamente susceptible a las poblaciones de Babile y Jittu y todas las plántulas murieron en *Pi* ≥ 16 J2 / 100 g de suelo seco. Las plántulas de Moneymaker murieron en *Pi* ≥ 64 J2 / 100 g de suelo seco. Para todos los parámetros de plantas estudiados, Tisey tuvo el umbral de daño más bajo T mientras que Assila (excepto el peso de la raíz) tuvo una mayor T. Se observó una diferencia entre los genotipos de tomate en el rendimiento mínimo (m) para los diferentes parámetros de plantas contra Babile y Jittu poblaciones La determinación de la T y m de una variedad de cultivo dada para la especie *Meloidogyne* prevaleciente en los campos que se plantarán (entorno local) es vital.

Palabras clave: Ajuste local, daño, densidad de población inicial, extrapolación, límite de tolerancia, *Meloidogyne incognita*, rendimiento mínimo

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INTRODUCTION

In Ethiopia, tomato (*Solanum lycopersicum*) is widely cultivated during the wet and dry seasons on a range of farms (Mekete *et al*., 2003). Tomato is among the most profitable vegetable crops for small-scale farmers (Lemma *et al*., 1992). Nonetheless, root-knot nematodes (*Meloidogyne incognita*, *M. javanica* and *M. ethiopica*) are associated with tomato and often dramatically reduce yield (Mandefro and Mekete, 2002; Abebe *et al*., 2015). However, the relationship between initial population densities (*Pi*) of *M. javanica* and damage to tomato has only been determined in small pots (Mekete *et al*., 2003). Information on tomato-nematode relationship is vital for farmers to decide on economically feasible management strategies within their production systems (Kamran *et al*., 2013). Hence, reliable data are required to relate the effects of a range of *Pi* to plant growth, biomass, and yield for tomato-nematode associations under local conditions. The objectives of this study were to: i) determine the damage thresholds of *M. incognita* populations originating from Babile and Jittu Ethiopia on four tomato cultivars and one breeding line, and ii) quantitatively study the *Pi* and final population density (*Pf*) relationship of *M. incognita* populations on four tomato cultivars and one breeding line.

MATERIALS AND METHODS

Tomato genotypes and soil solarization

Tomato genotypes Assila, CLN-2366B, Chochoro, and Tisey were chosen based on their resistance potential (Seid *et al*., 2017) and preference by small-scale farmers of Ethiopia. The tomato cultivar Moneymaker was used as a susceptible control. Tomato seedlings were raised in a seedling tray filled with steam-sterilized soil. Four-leaf-stage tomato seedlings were transplanted into 6,000 cm^3 pots filled with solarized sandy soil (74% sand, 20% silt, 6% clay). Two seedlings were transplanted into each pot and later thinned to 1 plant per pot 8 days after transplanting. Plants were watered as required. The pots were maintained in an open field at Tony Farm (9.6°N 41.8°E). The average maximum temperature recorded during the experimental period was 36.4°C.

For this experiment, a sandy field soil was collected, covered with polyethylene film, and solarized for 10 wk at Dire Dawa (Tony farm), Ethiopia. Tony farm is located at the eastern escarpment of the Rift Valley 9.6°N 41.8°E and with an altitude of 1,196 m.a.s.l. The soil pile was 8 cm tall and 10 m long. The soil was inverted and homogenized every 2 wk and recovered with the polyethylene film. The average daily soil temperature inside the polyethylene was 38°C. After solarization, the presence or absence of any plant-parasitic nematodes (PPN) was determined by collecting nematodes from 10 100-cm^3 subsamples using a modified Baermann funnel technique (Hooper *et al*., 2005). The absence of live PPN in the soil was confirmed before commencing the experiment.

Culturing and inoculation of Meloidogyne incognita

The Jittu and Babile populations of *M. incognita* were identified using a combination of DNA and isozyme-based techniques (Seid *et al*., 2017) and used to examine damage potential and *Pi*-*Pf* relationship on the tomato genotypes. A stock culture of these *M. incognita* were reproduced on Moneymaker in 8,000 cm^3 pots containing steam sterilized soil and maintained in a greenhouse (23 ± 3°C) for 10 wk. Inoculum was prepared from heavily galled tomato roots by chopping roots into 2-cm-long pieces and placing the sections on a Baermann pan (Hooper *et al*., 2005). Every 24 hr, freshly hatched second-stage juveniles (J2) were collected, and the water in the pan replenished with fresh tap water. J2 were collected from the roots for 6 consecutive days and stored at 10°C until use.

Ten days after transplanting, the tomatoes were inoculated using a geometric series of 12 nematode densities (*Pi*) of *M. incognita* Jittu and Babile populations: 0, 0.125, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, to 256 J2/100 g dry soil (Norshie *et al*., 2011). Three holes were bored around each tomato plant and 15 ml of the nematode suspension per plant was directly injected into the three holes using a pipette. Control plants received 15 ml fresh tap water. The pots were arranged in a completely randomized design with four replicates per treatment.

Nematode data parameters

The final *Pf* was estimated from roots and soil for each pot. The soil adhered into the whole root system was gently removed with a running tap water, and it was blotted dry to remove excess water before it was weighed. The mean number of J2 and eggs in the roots was estimated from the whole root system after extracting nematodes from a 5-g subsample according to Hussey and Barker (1973). The mean number of J2 and eggs from the 6,000 cm^3 soil was estimated after proper homogenization of the soil using a 100-cm^3 subsample per pot. Nematodes from soil samples were extracted using a modified Baermann funnel technique (Hooper *et al*., 2005). The recovered nematode suspension was expressed as J2+eggs/100 cm^3 soil. A Reproduction Factor (RF) was calculated by dividing *Pf* by *Pi* for each pot. The total number of galls present per plant root system per pot was estimated after counting the number of galls in a 5-g subsample. The number of galls present per 5-g root was counted using a stereomicroscope (Seid *et al*., 2017). The total number of egg masses present per plant root system per pot was estimated based on number of egg masses present in a 5-g subsample. Root gall index (RGI) and egg mass index (EMI) were determined at harvest for each plant using a 5-g subsample based on the Taylor and Sasser (1978) scoring system of 0 to 5; where 0= no galls or egg masses;

1 = 1-2 galls or egg masses; 2 = 3-10 galls or egg masses; 3 = 11-30 galls or egg masses; 4 = 31-100 galls or egg masses and 5 ≥100 galls or egg masses.

Plant parameters

Plant height (PH) was measured from the soil level to the main apex of the plant 8 wk after transplanting and mean values calculated per treatment. The total number of flowers (NFPP) was counted weekly per plant per pot starting from 3 wk after transplanting until 8 wk after transplanting. The total weight of roots per plant (RW) and root length (RL) was recorded after the final fruit harvest by removing the adhering soil. The adhering soil was gently washed away using tap water and excess water removed by blotting with tissue paper. RL was measured from the soil level to the tip of 75% of roots end. The total number of fruits (including marketable and unmarketable fruits) per plant per pot (TFr) was counted from the first harvest (8 wk after transplanting) through the last harvest (10 wk after transplanting). The number of healthy fruits that were free from any visible damage symptom starting from the first harvest to the final harvest per plant per pot was recorded mean was computed. In each harvest three ripe tomato fruits per plant were randomly selected, weighed and the mean per plant calculated as single fruit weight (SFW). Also in each harvest, the fruits selected for SFW were used to determine the number of seeds per fruit (NSPF).

Data analysis and model fitting

Non-linear regression analysis was conducted to estimate yield, damage, and *Pi*-*Pf* relationship using a script written in Tinn-R version 4.0.2.1 and run in R version 3.2.2. The relationship between ranges of *Pi* and the plant growth damage of the two (Babile and Jittu) aggressive populations of *M. incognita* was described using the Seinhorst yield loss model (Seinhorst, 1986; Schomaker and Been, 2013). The model (Eq.1) was fitted to the data using least square methods to estimate the parameters of plant damage.

Equation 1

$$Y = Ymax*(m + (1 - m)* Z\^{} ((Pi\text{-}T)/T))$$
when $Pi \geq T$, and $Y = Ymax$ ($Pi \leq T$)

Where 'Y' is the relative average value of plant weight; 'm' the relative minimum value of Y at a very large *Pi*, 'T' the tolerance limit, and 'Z' a constant < 1 indicating nematode damage in which Z-T = 0.95. The coefficient of determination (R^2) adjusted for degrees of freedom (df) was used to indicate the goodness-of-fit of the model. The population dynamics models for migratory nematodes with multiple generation developed by Seinhorst (1970) and as described by Schomaker and Been (2013) was used to fit the model (Eq. 2) to the data of the *Pf* and estimate population dynamics parameters; the maximum multiplication rate (a) and maximum population density (M) using the least square methods. The population dynamics model used was:

Equation 2

$$Pf = (M * Pi) / (Pi + M/a)$$

A one-way ANOVA was performed between the tomato genotypes and each growth, biomass, yield, yield component, and nematode data parameter to measure the damage of the tomato genotypes and population dynamics of *M. incognita* populations at 5% level of significance using SPSS 22 statistical software package. A factorial ANOVA was also performed among tomato genotypes, populations of *M. incognita*, and *Pi* at 5% level of significance. Data were log transformed when they failed to satisfy the assumption of ANOVA.

RESULTS

Nematode parameters

The tomato genotype, population of *M. incognita*, and *Pi* effected *Pf* ($P < 0.001$, $P < 0.001$, and $P < 0.001$, respectively), RF ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively), Galls/RS ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively) and EM/RS ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively). The interaction effect was significantly lower compared to the main effects. The greatest RF for both nematode populations was obtained on all the tested cultivars at lower *Pi* (0.125 J2/100 g dry soil) and reduced with increasing *Pi*. The RF of the Babile population ranged from 1.80 to 62.87 on Assila tomato, from 5.80 to 103.30 on CLN-2366B, 2.00 to 145.50 on Chochoro, from 33.30 to 990.30 on Moneymaker, and from 63.00 to 793.00 on the cultivar Tisey. Similarly, the RF of the Jittu population ranged from 3.00 to 148.50 on Assila, from 6.00 to 280.30 on CLN-2366B, from 10.00 to 256.00 on Chochoro, from 37.00 to 1358.30 on Moneymaker, and from 122.00 to 1229.50 on the cultivar Tisey. The greatest values for *Pf*, Galls/RS, EM/RS, RGI, and EMI were associated with higher *Pi* while the least values was recorded at the lower *Pi*. The severity of Galls/RS and EM/RS increased with increasing inoculum levels of both populations of *M. incognita*. The RGI and EMI were greatest in Tisey and Moneymaker. The RGI and EMI were high on Assila and CLN-2366B at $Pi \geq 128$ J2/100 g dry soil for both populations of *M. incognita*. The values of a and M are presented in (Table 1). Based on the population dynamics model's curve, all the tomato cultivars tested are a host for the populations studied.

Tolerance limit and minimum yield

The tomato genotypes, populations of *M. incognita*, and *Pi* had a significant effect on PH ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively), NFPP ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively), RW ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively), RL (P < 0.001, P = 0.586, P < 0.001, respectively), TFr ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively), MFr ($P < 0.001$, $P < 0.001$, $P < 0.001$, respectively), SFW ($P < 0.001$, $P < 0.05$, $P < 0.001$, respectively), and NSPF ($P < 0.001$, P = 0.691, $P < 0.01$, respectively). The interaction effect of these factors was not significant for some of the plant parameters, however, when differences were found, they were lower compared to the main effects. Based on the damage model fitted to the data, all the tested plant parameters were negatively affected by both populations of *M. incognita*. The Jittu population had a greater effect on the majority of plant parameters compared to the Babile population.

Tomato genotypes differed on their tolerance limit (T) and minimum yield (m) across the plant parameters and between nematode populations (Table 2). For plant height, the highest T was attained by Assila at 10 and 8 J2/100 g dry soil for the Babile and Jittu populations respectively. For many of the plant parameters, T was ≤ 1 on all cultivars for both nematode populations including NFPP, RW, RL, TFrNPP, MFrNPP, SFW, NSPF. For NFPP, T was 2 J2/100 g dry soil for the Babile

Table 1. Parameter estimations of the population dynamics model for *Meloidogyne incognita* populations form Ethiopia on five tomato genotypes given by the equation $Pf = (M * Pi)/(Pi + M/a)$, where N is the number of observations; '*a*' is the maximum multiplication rate of the nematode (*Pf/Pi*); '*M'* is the maximum population density in J2/100 g dry soil; R^2 = coefficient of determination '*Pf*' is the final population density, and df is the degree of freedom.

Tomato Cultivar	*M. incognita* populations	N	*Pf/Pi*	J2/100 g dry soil	SE^x	SE^y	R^2	df
Assila	Babile	11	12.59	357	1.83	81.63	0.96	9
	Jittu	11	36.94	372	5.39	59.00	0.96	9
CLN-2366B	Babile	10	23.26	556	3.62	154.38	0.96	8
	Jittu	10	89.24	373	11.00	41.28	0.97	8
Chochoro	Babile	9	56.16	279	6.87	37.64	0.97	7
	Jittu	9	68.96	312	9.75	46.72	0.96	7
Moneymaker	Babile	8	235.04	274	84.08	64.98	0.75	6
	Jittu	8	276.82	274	106.32	64.49	0.72	6
Tisey	Babile	7	151.89	396	31.24	95.84	0.92	5
	Jittu	6	294.23	348	91.04	100.88	0.84	4

^{x}SE = standard error for *Pf/Pi*
^{y}SE = standard error for J2/100 g dry soil

Table 2. Tolerance limit (T = J2/100gram of dry soil) and minimum relative yield (m) of the Seinhorst equation (Y = Ymax*(m + (1 - m)* Z^((Pi-T)/T)), where Ymax is the maximum yield at $Pi \leq T$, Y is yield in terms of a parameter, and Z a constant <1 for the relationship between plant parameters and initial population densities of two aggressive populations of *Meloidogyne incognita* originating from Ethiopia on five tomato genotypes. Data were collect at Pi levels of 0, 0.125, 0.5, 1, 2, 4, 8, 16, 32, 64, 128, and 256 J2/100 g dry soil.

Tomato genotype	*M. incognita* population	Plant height (cm)							
		m	T	Ymax	SE_m	SE_T	SEY_{max}	R^2	df
Assila	Babile	1	10	66.71	0.18	5.79	1.21	0.89	10
	Jittu	1	8	67.94	0.10	3.03	0.98	0.94	10
CLN-2366B	Babile	1	1	70.15	0.03	0.23	1.66	0.93	9
	Jittu	1	1	62.38	0.06	0.79	1.72	0.89	9
Chochoro	Babile	1	5	65.67	0.18	1.54	0.47	0.98	8
	Jittu	1	2	67.21	0.12	1.01	0.93	0.95	8
Moneymaker	Babile	1	1	78.62	0.02	0.10	0.86	0.98	7
	Jittu	1	1	78.32	0.05	0.18	2.05	0.93	7
Tisey	Babile	1	1	76.78	0.03	0.04	2.06	0.97	6
	Jittu	1	1	69.93	0.06	0.04	4.15	0.85	5
		Number of flowers per plant							
Assila	Babile	1	2	68.05	0.09	1.35	3.38	0.86	10
	Jittu	1	1	63.70	0.06	0.59	3.03	0.88	10
CLN2366B	Babile	1	1	103.49	0.06	0.47	5.47	0.82	9
	Jittu	1	2	88.94	0.11	1.07	3.48	0.89	9
Chochoro	Babile	1	1	57.46	0.05	0.29	1.12	0.95	8
	Jittu	1	1	58.86	0.06	0.35	1.38	0.93	8
Moneymaker	Babile	1	1	64.82	0.12	0.33	2.83	0.88	7
	Jittu	1	1	69.65	0.12	0.26	3.09	0.91	7
Tisey	Babile	1	1	60.29	0.06	0.08	2.00	0.94	6
	Jittu	1	1	54.30	0.50	0.43	2.47	0.86	5
		Root weight (g)							
Assila	Babile	0.56	1	21.73	0.05	0.13	1.56	0.86	10
	Jittu	0.50	1	21.59	0.05	0.17	1.24	0.90	10
CLN2366B	Babile	0.44	1	15.31	0.06	0.35	0.60	0.93	9
	Jittu	0.41	1	17.76	0.06	0.27	0.74	0.93	9
Chochoro	Babile	0.54	1	20.78	0.05	0.15	0.81	0.93	8
	Jittu	0.50	1	22.52	0.05	0.13	0.92	0.93	8
Moneymaker	Babile	0.37	1	17.16	0.11	0.22	0.84	0.92	7
	Jittu	0.47	1	17.50	0.09	0.17	1.16	0.89	7
Tisey	Babile	0.39	1	17.41	0.04	0.03	0.59	0.97	6
	Jittu	0.25	1	17.49	0.12	0.07	0.52	0.98	5
		Root length (cm)							
Assila	Babile	0.40	1	27.87	0.07	0.29	2.28	0.86	10
	Jittu	0.34	1	29.15	0.08	0.49	1.80	0.90	10
CLN2366B	Babile	0.36	1	28.68	0.07	0.17	2.28	0.89	9
	Jittu	0.28	1	29.88	0.05	0.10	1.32	0.96	9
Chochoro	Babile	0.47	1	29.07	0.05	0.05	2.04	0.90	8
	Jittu	0.40	1	24.78	0.09	0.17	2.32	0.84	8
Moneymaker	Babile	0.30	1	27.31	0.05	0.04	1.30	0.96	7
	Jittu	0.38	1	29.22	0.06	0.06	1.75	0.93	7
Tisey	Babile	0.31	1	26.77	0.07	0.04	1.76	0.94	6
	Jittu	0.35	1	26.22	0.13	0.06	2.36	0.88	5

Table 2. Continued

Tomato genotype	*M. incognita* population	Plant height (cm)							
		m	*T*	Ymax	SE_m[x]	SE_T[y]	SEY_{max}[z]	R^2	df
		Total fruit number per plant							
Assila	Babile	1	1	21.59	0.06	0.37	1.57	0.82	10
	Jittu	1	1	20.64	0.06	0.24	1.16	0.90	10
CLN2366B	Babile	1	1	31.43	0.07	0.19	2.13	0.91	9
	Jittu	1	1	27.02	0.04	0.12	1.14	0.95	9
Chochoro	Babile	1	1	22.83	0.05	0.11	1.00	0.93	8
	Jittu	1	1	21.34	0.10	0.30	1.18	0.89	8
Moneymaker	Babile	1	1	26.25	0.08	0.08	2.08	0.90	7
	Jittu	1	1	25.41	0.09	0.13	2.15	0.87	7
Tisey	Babile	1	1	20.75	0.10	0.09	0.98	0.94	6
	Jittu	1	1	19.92	0.04	0.02	0.53	0.98	5
		Marketable fruit number per plant							
Assila	Babile	1	1	19.23	0.06	0.38	1.00	0.86	10
	Jittu	1	1	17.70	0.09	0.54	1.31	0.83	10
CLN2366B	Babile	1	1	31.35	0.07	0.21	2.17	0.91	9
	Jittu	1	1	27.02	0.04	0.12	1.14	0.95	9
Chochoro	Babile	1	1	22.02	0.04	0.08	0.87	0.94	8
	Jittu	1	1	20.04	0.09	0.29	1.01	0.91	8
Moneymaker	Babile	1	1	22.57	0.08	0.12	1.28	0.94	7
	Jittu	1	1	25.07	0.09	0.11	1.94	0.90	7
Tisey	Babile	1	1	20.36	0.12	0.10	1.74	0.84	6
	Jittu	1	1	17.85	0.04	0.03	0.45	0.98	5
		Single Fruit Weight (g)							
Assila	Babile	0.71	1	86.11	0.03	0.28	2.06	0.92	10
	Jittu	0.67	2	78.99	0.12	2.64	4.64	0.53	10
CLN2366B	Babile	0.52	2	60.99	0.07	0.77	1.61	0.93	9
	Jittu	0.66	1	64.22	0.05	0.53	1.48	0.92	9
Chochoro	Babile	0.57	1	109.34	0.05	0.15	5.11	0.91	8
	Jittu	0.55	1	110.62	0.05	0.14	4.90	0.92	8
Moneymaker	Babile	0.51	1	96.74	0.05	0.12	2.49	0.96	7
	Jittu	0.44	1	92.14	0.09	0.22	3.57	0.93	7
Tisey	Babile	0.58	1	123.08	0.07	0.09	5.70	0.91	6
	Jittu	0.52	1	125.33	0.07	0.05	4.06	0.95	5
		Number of seed per fruit							
Assila	Babile	1	1	175.39	0.04	0.55	4.32	0.70	10
	Jittu	1	1	193.17	0.06	NaN	7.40	-0.41	10
CLN2366B	Babile	1	1	151.46	0.04	NaN	3.04	-0.03	9
	Jittu	1	1	149.10	0.02	0.35	2.15	0.75	9
Chochoro	Babile	1	1	189.77	0.05	0.10	9.21	0.72	8
	Jittu	1	1	201.54	0.04	0.19	9.15	0.83	8
Moneymaker	Babile	1	1	174.24	0.05	0.39	3.98	0.73	7
	Jittu	1	1	184.91	0.03	0.09	3.78	0.87	7
Tisey	Babile	NA	NA	176.45	NA	NA	2.15	0.01	6
	Jittu	NA	NA	344.74	NA	NA	1239.26	0.51	5

[x]SE_m = standard error for *m*
[y]SE_T = standard error for *T*
[z]SEY_{max} = standard error for Ymax

population on Assila. For SFW, T was also 2 J2/100 g dry soil with the Jittu population on Assila and with the Babile population on CLN-2366B. In general, Tisey had the lowest Ts while Assila had higher Ts. Minimum yield (m) varied among growth parameters and among cultivars. The highest m for PH was obtained on CLN-2366B (0.72) while the lowest m was from Chochoro (0.31) with the Babile population. For NFPP, the highest m was obtained on Chochoro and CLN-2366B (0.63) with the Babile population while the lowest m was from Tisey (0.26) with the Jittu population. For RW, the highest m (0.56) was from Assila with the Babile population while the lowest m was on Tisey (0.25) infected with the Jittu population. For RL, the highest m was found on Chochoro (0.47) while the lowest m was from Moneymaker (0.30) with the Babile population. The highest m for TFrNPP was from Assila (0.57) while the lowest m was on Tisey (0.32) with the Babile population. For MFrNPP, the highest m was on Assila (0.58) while the lowest m was from Moneymaker (0.27) with the Babile population. The highest m for SFW was from Assila (0.71) with the Babile population while the lowest m was from Moneymaker (0.44) for Jittu *M. incognita* population. The highest m for NSPF was from CLN-2366B (0.89) for both Babile and Jittu populations while the lowest m was from Chochoro (0.76) with the Jittu population.

The seedlings of all the tomatoes died at the highest *Pi*, except Assila, where all seedlings survived under both nematode populations. The seedlings of the local tomato cultivar Chochoro were tolerant to $Pi \leq 64$ J2/100 g dry soil for the Jittu population but to $Pi \leq 128$ J2//100 g dry soil for the Babile population. At $Pi = 256$ J2/100 g dry soil, seedlings of CLN-2366B died with both populations of *M. incognita*. Among all the cultivar, Tisey was highly susceptible to both the Babile and Jittu populations with all seedlings dead at $Pi \geq 16$ J2/100 g dry soil. Susceptible control Moneymaker seedlings died at $Pi \geq 64$ J2/100 g dry soil.

DISCUSSION

The Seinhorst model fit to all the plant parameter data considered in this study, supporting the negative effect of *Pi* on plant growth. The population dynamics models showed that the tomato cultivars are a host for these populations of *M. incognita*. As the RFs for the tomatoes were high, the cultivars are good hosts for both populations of *M. incognita*. Based on the T values generated from this study, Tisey is not a preferred tomato cultivar in areas infested with RKN. The T of Tisey was consistently lower for all plant parameters compared to the other genotypes including the susceptible control Moneymaker. Assila, CLN-2366B, and Chochoro showed a higher tolerance indicating that these genotypes could be used in nematode infested areas if integrated with other cultural management options such as crop rotation with cereals. The regression analysis showed that root galling, *Pf*, Galls/RS, EM/RS, RGI, and EMI were positively correlated to an increase in *Pi*. Root galling severity and number of egg masses per root system increased with increased inoculum of both populations. This is in agreement with several other studies (Zahid *et al*., 2001; Mekete *et al*., 2003; Charegani *et al*., 2012; Kankam and Adomako, 2014; Dammini Premachandra and Gowen, 2015).

All the four tomato genotypes (Assila, CLN-2366B, Chochoro and Tisey) had some degree of resistance to the Jittu population. Response to the Babile population differed among the tomato genotypes. Assila and CLN-2366B were susceptible whereas Chochoro and Tisey were slightly resistant (Seid *et al*., 2017). However, in this current study the *Pi*-*Pf* relation demonstrated that all these genotypes are good hosts for both nematode populations with the Jittu population reproducing more than the Babile population. This difference might have been due to the range of inoculum levels used in the current study as compared to the screening performed in the growth chamber using only one inoculum level (Seid *et al*., 2017). This result suggests that it is very crucial to consider a geometric series of inoculum levels rather than just using one inoculum level while screening for nematode resistance.

The severity of tomato crop damage caused by *Meloidogyne* species may depend on species and the level of nematode population densities present in the soil at the time of planting, populations of RKN, the occurrence of species mixture, and the tomato genotypes used (Sasanelli, 1994). The *Pi* of Babile and Jittu populations negatively affected the plant growth, biomass, and yield parameters of the tested cultivars (Seid *et al*., 2017). SFW was found negatively affected by increasing *Pi*. This parameter is especially important when the crop is destined for tomato processing (De Vito *et al*., 1991). If tomato growers want to guarantee better tomato production, they need reliable information on the initial nematode densities in the soil before establishing their crop (Dammini Premachandra and Gowen, 2015).

The tomato genotypes showed varying degrees of resistance against the two populations of *M. incognita*. The Jittu population was more aggressive compared to the Babile population. The majority of the nematode and plant parameters measured differed between the two nematode populations. There should also be an effort to study the genetic background of the tomato genotypes. The variations in resistance of the tomato genotypes against the two different populations of nematode emphasizes the importance of population-based nematode management strategies. Hence, searching for possible resistance in tomato genotypes or breeding lines should be against populations rather than at the species level.

It is not recommended to extrapolate T and m determined elsewhere. The field where the damage experiment is conducted is one of the main factors that determine the value of T and m. For example, the T and m determined in drought prevailing areas should not be extrapolated to areas with ideal growing conditions. Drought favors nematode damage to crops, and it may reduce the minimum yield and the tolerance limit compared to damage studies under ideal growing conditions (Wallace, 1973). In ideal conditions, nematodes may cause only moderate damage whereas under periods of drought or other related stress factors, nematodes may cause considerable damage reducing the value of T and m. Moreover, in the face of climate change and tropical agriculture, damage threshold determination studies should be locally studied and extrapolation should be handled with care (if needed). Additionally, the value of T and m is not equal when they are determined in fields with a history of nematode management and in fields where nematodes have not been managed. In the former case, the T and m values may be higher so that to extrapolate and use this value for advisory or predication purpose for fields that did not have any management history will be truly misleading. Therefore, determination of T and m of a given crop cultivar to the prevailing *Meloidogyne* species in the field (local setting) is vital.

Determining the T and m using naturally infested fields with different nematode population levels is more ideal than determining in artificially inoculated pot studies. Furthermore, employing naturally infested fields has several advantages. Firstly, growers could easily observe the difference as the experiment is conducted in their local settings that serves as a demonstration plot. Secondly, the determination will represent the ideal climatic (aerial temperature, relative humidity, temperature, wind) and edaphic (soil texture, soil moisture, soil temperature) conditions for both the crop and the nematode. Thirdly, the parameter estimates of the yield loss (T and m) are more close to the true estimate and can be reliably used for any advisory purpose or to predict the population dynamics for the future crop to be planted. Fourthly, roots assessed for damage under field conditions can grow freely and not be constrained as in a pot study.

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