EVALUATION OF EDIBLE GINGER AND TURMERIC CULTIVARS FOR ROOT-KNOT NEMATODE RESISTANCE

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ABSTRACT

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Edible ginger and turmeric roots are important agricultural commodities for the State of Hawaii. Bacterial wilt, *Ralstonia solanacearum*, and root-knot nematodes, *Meloidogyne* spp., are major factors hindering optimum production. An evaluation of tolerance and resistance to *M. incognita* was undertaken with 22 commercially grown cultivars. *Curcuma longa* Red Hawaiian turmeric had the greatest susceptibility with the highest number of juveniles in the soil and the most eggs recovered from the roots. The population factor (Pf) of *M. incognita* was largest in *C. longa* Red Hawaiian turmeric and *Alpinia galangal* Blue finger. *Curcuma caesia* Black turmeric was the most intolerant cultivar with the lowest rhizome weights and greatest yield losses. The highest tolerance was seen in *Zingiber officinale* J and I, which demonstrated the greatest rhizome yields and lowest yield differences when inoculated. *Zingiber officinale* M had the lowest Pf value, suggesting partial resistance to *M. incognita*. Effective management strategies need to be investigated as significant yield reductions are occurring when cultivating ginger and turmeric in root-knot nematode infested fields.

Key words: *Alpinia*, *Curcuma*, Ginger, *Meloidogyne incognita*, root-knot nematode, turmeric, *Zingiber*

RESUMEN

Myers, R. Y., C. L. Mello, y L. M. Keith. 2017. Evaluacion de resistencia de cultivares cosmetibles de jengibre y curcuma a nematodos noduladores. Nematropica 47:99-105.

El jengibre comestible y las raíces de cúrcuma son importantes productos agrícolas para el Estado de Hawai. El marchitamiento bacteriano, causado por *Ralstonia solanacearum* y los nematodos noduladores, *Meloidogyne* spp., son los principales factores que limitan una producción óptima. Se realizó una evaluación de tolerancia y resistencia a 22 cultivares comerciales a *M. incognita*. *Curcuma longa* (Cúrcuma Hawaiana Roja) presentó la mayor susceptibilidad con el mayor número de juveniles en suelo y huevos recuperados de las raíces. El factor poblacional (Pf) de *M. incognita* fue mayor en *C. longa* (Cúrcuma Hawaiiana Roja) y en *Alpinia galangal* (Dedo azul). *Curcuma caesia* (Cúrcuma Negra) fue el cultivar más intolerante con el menor peso de rizomas y mayor pérdida de rendimiento. La mayor tolerancia se observó en *Zingiber officinale* J e I, que presentaron los mayores rendimientos de rizoma y menores diferencias de rendimiento cuando se inocularon. *Zingiber officinale* M tuvo el menor valor de Pf, sugiriendo resistencia parcial a *M. incognita*. Es necesario investigar estrategias de manejo efectivas para disminuir pérdidas significativas en rendimiento cuando se cultiva jengibre y cúrcuma en campos infestados con nematodos noduladores.

Palavras-Chave: Alpinia, Curcuma, Cúrcuma, *Jengibre, Meloidogyne incognita,* Nematodos Noduladores.

INTRODUCTION

Edible ginger, *Zingiber officinale*, and turmeric, *Curcuma* spp., roots are specialty crops grown for culinary and medicinal use. An important agricultural export for the State of Hawaii, ginger root is grown on 50 acres with yields of approximately 1.6 million pounds (USDA NASS, 2011). The record high for ginger root production was 360 acres yielding 18 million pounds in 2001. Production has steadily declined in part due to bacterial wilt, *Ralstonia solanacearum*, and root-knot nematodes, *Meloidogyne* spp. (USDA NASS, 2005). Fumigation with methyl bromide was the previous practice for suppressing these disease-causing organisms (Hepperly *et al*., 2004). With limited control options, growers now move to clean fields that have not been in ginger cultivation (Nelson, 2013). Since effective management of these diseases could increase yields by threefold (Trujillo, 1964), new methods for control must be identified.

Host-plant resistance has potential for increasing yields in root-knot nematode infested fields. Screening of ginger germplasm from the Indian Institute of Spices Research, Kerala, India, identified three lines resistant to *M. incognita* (Eapen *et al.*, 1999) including IISR Mahima which is currently being licensed by a grower in Telangana (Prasath *et al*., 2016). In addition, two cultivars "Rio de Janeiro" and "UG1" were found to be resistant to *Meloidogyne* spp. in a greenhouse screening of the genebank at the National Root Crops Research Institute in Nigeria (Okorocha *et al.*, 2014). The Indian Institute of Spices Research also reported eight turmeric cultivars with *M. incognita* resistance (Eapen *et al*., 1999).

Host-plant resistance would be a promising management option for growers in Hawaii if nematode resistant germplasm was locally available. We acquired edible ginger and turmeric cultivars from the USDA ARS DKI-PBARC National Clonal Germplasm Repository, University of Hawaiʻi at Mānoa College of Tropical Agriculture and Human Resources Komohana Research Extension Center, and local ginger growers to screen for resistance or tolerance to root-knot nematodes.

MATERIALS AND METHODS

Twenty-two edible ginger, *Zingiber officinale* and *Alpinia galangal*, and turmeric, *Curcuma longa* and *C. caesia*, cultivars were acquired and screened for resistance or tolerance to *Meloidogyne incognita*. Rhizomes were cut into 55 g pieces and dipped in a 0.6% NaOCl solution for 10 minutes (Trujillo, 1964; Hepperly *et al*., 2004). After 2 days of drying, rhizomes were planted in 66 L white grow bags in greenhouses in Hawaii in May according to established practices for producing bacterial wilt-free ginger (Hepperly *et al*., 2004). Average day temperatures ranged from 24 to 32°C and night temperatures ranged from 14 to 24°C. Sunshine® Mix #4 (Sun Gro Horticulture Canada Ltd. Agawam, MS) and Nutricote® 240-day slow release 13-13-13 fertilizer with micronutrients (Chisso-Asahi Fertilizer Co., Ltd. Tokyo, Japan) were used in the grow bags. The cultivars were placed in a randomized block design with the uninoculated controls grown on separate benches. Five repetitions of each cultivar were inoculated with nematodes and two repetitions remained uninoculated. Three months after planting, each grow bag was inoculated with 2,000 *M. incognita* eggs dispensed with a pipette in a 10 mL volume. The nematode eggs were extracted from a greenhouse culture (Barker, 1985) being raised on papaya, *Carica papaya* cv. Kapoho. After senescence, 6 months post inoculation, a 100 cm^3 soil sample was collected from the root zone of each plant. The soil was processed by the Baermann funnel method (Walker and Wilson, 1960) and juvenile nematodes (J2) collected and counted. During harvesting, roots were removed from the rhizomes, weighed, and shaken in sodium hypochlorite to extract nematode eggs (Barker, 1985). The eggs were counted with an inverted microscope. The ginger rhizomes were cleaned and dried according to grower practices then weighed. Data were analyzed by ANOVA and means separated by Duncan's Multiple Range test (SAS, 2008). Population factors (Pf) were determined by combining the final nematode densities in 100 cc soil with the density in the root systems and transforming the total by log10(x+1). The trial was conducted in 2013 and repeated in 2014. New grow bags and sterile media were used for the second trial with seed pieces harvested from year one.

RESULTS

The population density of *M. incognita* varied among the cultivars ($P < 0.0001$) (Table 1). *Curcuma longa* Red Hawaiian turmeric supported the highest nematode numbers in the soil (940 J2/100 cm^3) and root systems (14,285 eggs) ($P < 0.05$). *Alpinia galangal* Blue finger had the next highest population in the roots ($P < 0.05$) but did not differ ($P > 0.05$) from the remaining cultivars when comparing *M. incognita* soil densities, except for *Z. officinale* K and Q, which reported the lowest number of J2 recovered from the media. *Zingiber officinale* B and I had the least number of nematodes in their root systems although not statistically significant from the other cultivars. *Curcuma longa* Red Hawaiian turmeric and *A. galangal* Blue finger had the highest population factor (Pf) of 3.32 and 3.19, respectively ($P < 0.05$). *Zingiber officinale* M had the lowest Pf (1.72) and differed from all but six of the other cultivars evaluated ($P < 0.05$).

Curcuma caesia Black turmeric and *A. galangal* Blue finger had heavier root systems than the other cultivars tested ($P < 0.05$). *Alpina galangal* Bubba blue had the next largest roots and differed from *C. longa* Red Hawaiian turmeric, which had the least ($P < 0.05$). *Curcuma longa* Red Hawaiian turmeric had the most eggs per gram of fresh root ($P < 0.05$) whereas the least amount of eggs per gram of root was recovered from *Z. officinale* I and M.

Differences in rhizome yield were observed among cultivars in both trials ($P < 0.0001$) (Table 2). The uninoculated *Z. officinale* H had the largest mean

Table 1. Reproduction of *Meloidogyne incognita* on *Zingiber officinale*, *Alpinia galangal*, and *Curcuma* spp. Samples with the same letter are not different ($P > 0.05$) according to Duncan's multiple range test.

Cultivar	J2 per 100c soil	Eggs per plant	Root weight (g)	Eggs per g root	Population factor (Pf)
C. longa Red Hwn turmeric	940 a	14285 a	20 c	718 a	3.32 a
A. galangal Blue finger	511 b	9159 b	79 a	136 b	3.19 a
A. galangal Bubba blue	373 bc	909 c	46 b	23 b	2.43 b
Z. officinale Japan yellow	366 bc	516 c	26 bc	25 b	2.29 b
Z. officinale H	322 bc	1030 c	28 bc	38 b	2.43 b
A. galangal Giant Thai	260 bc	1034 c	34 bc	48 b	2.52 b
Z. officinale Varada	260 bc	779 c	39 ab	20 b	2.49 b
Z. officinale Giant yellow	259 bc	557 c	47 b	15 b	2.34 b
Z. officinale R	244 bc	565 c	28 bc	24 b	2.14 bc
Z. officinale HP RUHI 1	240 bc	1275 c	43 bc	35 b	2.50 b
Z. officinale HP RUHI 2	229 bc	1068 c	30 bc	60 b	2.41 b
Z. officinale I	215 bc	499 c	37 bc	13 b	2.11 bc
Z. officinale GE	212 bc	1371 c	38 bc	40 b	2.41 b
C. caesia Black turmeric	202 bc	2351 c	86 a	73 b	2.47 b
Z. officinale J	164 bc	1138 c	42 bc	41 b	2.32 b
Z. officinale True white	162 bc	1364 c	32 bc	59 b	2.29 b
Z. officinale D1	153 bc	719 c	33 bc	36 b	2.08 bc
Z. officinale B	145 bc	457 c	29 bc	17 b	2.29 b
Z. officinale M	116 bc	599 c	38 bc	14 b	1.72 c
Z. officinale Yellow GP	109 bc	961 c	38 bc	26 b	2.12 bc
Z. officinale Q	91 c	643 c	27 bc	24 b	2.00 bc
Z. officinale K	65 c	1694 c	27 bc	79 b	2.16 bc

Table 2. Yield and percent yield reduction of *Zingiber officinale*, *Alpinia galangal*, and *Curcuma* spp. cultivars inoculated with and without *Meloidogyne incognita*.

	Year one			Year two		
Cultivar	Yield (g) Inoculated	Yield (g) Uninoculated	Decrease in Production	Yield (g) Inoculated	Yield (g) Uninoculated	Decrease in Production
Z. officinale I	586	714	18	1034	1162	11
Z. officinale Q	512	986	48	1004	1146	12
Z. officinale K	509	780	35	974	1214	20
Z. officinale H	496	860	42	828	1330	38
Z. officinale M	440	624	29	893	1169	24
Z. officinale GE	435	921	53	668	993	33
Z. officinale D1	377	591	36	819	1170	30
Z. officinale HP RUHI 2	360	903	60	975	1099	11
Z. officinale B	359	709	49	565	943	40
Z. officinale HP RUHI 1	346	554	38	1121	1250	10
Z. officinale J	304	497	39	1251	1330	6
Z. officinale R	301	969	69	801	1125	29
Z. officinale Yellow GP	275	442	38	457	532	14
Z. officinale Japan yellow	252	666	62	572	814	30
A. galangal Blue finger	218	513	58	426	746	43
Z. officinale Giant yellow	217	380	43	544	722	25
C. longa Red Hwn turmeric	195	616	68	806	900	10
A. galangal Bubba blue	183	447	59	658	847	22
Z. officinale Varada	164	325	50	412	702	41
A. galangal Giant Thai	161	268	40	497	691	28
Z. officinale True white	122	657	81	795	976	19
C. caesia Black turmeric	60	307	80	243	422	42

Fig. 1. Yield of *Meloidogyne incognita* inoculated (left) and uninoculated (right) *Zingiber officinale*, *Alpinia galangal*, and *Curcuma caesia* rhizomes. 1. *Z. officinale* D1, 2. *C. caesia* Black turmeric, 3. *Z. officinale* True white, 4. *A. galangal* Blue finger, 5. *Z. officinale* R, 6. *Z. officinale* Japan yellow.

yields over year 1 and 2 at 1,095 g and differed from 50% of the uninoculated and inoculated cultivars combined ($P < 0.05$). The uninoculated *Z. officinale* Q, R, HP RUHI2, and K had the next heaviest weights. Among inoculated cultivars, *Z. officinale* I and J produced the best yields in the combined two-year average at 810 g and 778 g, respectively. Inoculated *C. caesia* Black turmeric had the lowest weight (152 g) and differed from all but 12 inoculated cultivars and 5 uninoculated cultivars including itself ($P < 0.05$). *Zingiber officinale* Varada, *A. galangal* Giant Thai, and *A. galangal* Blue finger had the next lowest weights at 288 g, 329 g, and 322 g, respectively.

Overall yields were 45% higher in year two; 59% among inoculated plants, and 35% among uninoculated controls. The yield difference between nematode-infested plants and controls was 50% in year one and 21% in year two.

In year one, *Z. officinale* I had the highest production among inoculated cultivars and lowest yield reduction of 18% under infested conditions. It performed well in year two with the third largest yield and a yield reduction of only 11% compared with yields of uninoculated plants. The cultivar with the highest rhizome weight under infested conditions and greatest tolerance (6% yield reduction) in year two was *Z. officinale* J. Edible ginger cultivars HP RUHI 1, Yellow GP, M, and K showed the next highest levels of tolerance to *M. incognita* in the combined trials.

In year one and two, *C. caesia* Black turmeric had the greatest yield losses due to root-knot nematodes, 80% in year one and 42% in year two. It also performed poorly in non-infested conditions with the lowest yields among the cultivars in year two. *Alpinia galangal* Blue finger was highly intolerant in both years with 58% and 43% yield losses. True white had an 80% yield reduction in year one but produced well in year two with only 19% difference in inoculated plants. *Zingiber officinale* I and J were the most tolerant to *M. incognita* with the lowest yield losses overall.

Variation was observed in the two *Curcuma* species evaluated. In year one, Red Hawaiian turmeric had significantly higher production than Black turmeric among inoculated and uninoculated plants ($P < 0.05$). Red Hawaiian turmeric also showed a much higher tolerance to *M. incognita* in year two with a 10% yield loss compared to 42% in Black turmeric.

DISCUSSION

Zingiber officinale I, J, M, Q, and K demonstrated the highest yields and most tolerance to root-knot nematode infestation. These edible ginger cultivars produced some of the heaviest rhizomes in the presence and absence of *M. incognita*. Over two growing seasons, cultivars J and I had the largest rhizomes and lowest yield differences under root-knot nematode infestation. M had the lowest Pf and low numbers of nematodes recovered in soil and roots, suggesting partial resistance. K was highly susceptible and had the most nematodes in the roots and most eggs per gram of root of the *Z. officinale* cultivars. *Zingiber officinale* H had the highest yield among uninoculated plants but was a good host for *M. incognita* and more intolerant of infestation. Specialty *Alpinia* ginger and turmeric on average had lower yields than *Z. officinale* cultivars especially when grown in the presence of root-knot nematodes. These niche products likely have a higher value in the marketplace, which could make up for their harvestable volume.

Yield reduction was the greatest consequence of root-knot nematode infestation. Reductions in rhizome weights as high as 80% were observed in *C. caesia* Black turmeric and *Z. officinale* True white. During the first trial, there was an average yield loss of 50% due to *M. incognita* infestation, which demonstrates just how damaging this pest can be. Other studies have reported yield losses as great as 74% in similar potted plant bioassays (Sudha and Sundararaju, 1986).

Although total crop yield is the most significant outcome of *M. incognita* infestation, the saleable product can also be negatively affected. Typically, galls are not visible on the outside of *Z. officinale* rhizomes, but once cut open, corkiness and cracking of the cortex can be seen (Trujillo, 1964). In addition, wounds caused by feeding nematodes can provide entryways for bacterial and fungal pathogens that could damage the crop in the planting or postharvest stages. It has been reported that the severity of rhizome rot caused by *Pythium aphanidermatum* is greatly enhanced when the crop is infested with *M. incognita* or *Pratylenchus coffeae* (Dohroo *et al*., 1987). In this study, no symptoms of root-knot nematode infestation were visible on the rhizomes likely due to the low levels of inoculum (2,000 J2/plant). Other studies for screening resistance had inoculum levels as high as 10,000 J2/plant (Sudha and Sundararaju, 1986).

Okorocha *et al*. (2014) set the economic threshold for *Z. officinale* at 1,000 *M. javanica* eggs per plant where significant damage and yield reductions could occur. Haider *et al*. (1998) reported that inoculation with as few as 100 root-knot nematode juveniles could negatively affect the growth of turmeric in a potted plant bioassay.

The larger rhizome production in year two suggests an increased tolerance of the cultivars to nematode infestation likely due to an improvement in overall plant heath during that growing season. The mean yield losses observed with inoculated plants were 22% as compared to 50% in year one. Shoot weights were not evaluated in this test but may have confirmed that the overall health of the plants were better, although *M. incognita* infestation had little observable effect on the growth of the upper vegetative portions in this study. Okorocha *et al.* (2014) also reported that the growth of the foliage remained vigorous even with high amounts of galling on the roots caused by *M. javanica*.

The significant yield reductions resulting from *M. incognita* infestation highlight the immediate need to find effective management techniques for this pest. Employing host-plant resistance has potential for improving production in root-knot nematode infested fields. Some promising cultivars of *Z. officinale* were discovered in this study and field testing is necessary to further evaluate their tolerance under natural conditions and stronger pest pressure.

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