Table 2. Comparison of actual reducing sugar quantity in carrot roots as determined by high performance liquid chromatography to that estimated using a DNSA spot test.

DNSA score[z]	1	2	3	4
Reducing sugar percentage used to obtain DNSA score	0.1%	0.5	2.0	5.0%
Genotype predicted	*rs/rs*	*rs/rs*	*Rs/_*	*Rs/_*
Number of carrot roots with a given score	157	144	138	801
Number of genetically misclassified roots	0	0	2	0
Range of reducing sugar percentage in roots as determined by HPLC.	0–0.4%	0.3%–1.5%	1.5%–3.1%	2.6%–6.8%

[z]DNSA score is an arbitrary value based upon visual inspection and given to samples of sugar solutions spotted onto filter paper and detected with dinitrosalicylic acid.

and 419042, Peoples Republic of China) was included in the course of 3 years. DNSA scores of 1, 2, 3, or 4 were assigned to samples, based upon whether intensity of brown color of spots most closely matched spots on standard sheets with 0.1%, 0.5%, 2.0%, or 5.0% reducing sugar, respectively. To evaluate variation in DNSA scores within and between paper sheets, 2 separate drops of carrot juice were spotted on each of 2 sheets for each root sampled. DNSA scores were identical within and between sheets unless overheating occurred, as determined by overly dark 2% glucose standard spots (incidence of less than 5%). In some cases, spotted sheets were stored for over one year before DNSA color development and color score were unchanged. Developed sheets were stored for over 3 years with no change in color score.

The range of actual reducing sugar percentage in carrot roots as determined by HPLC compared well with that estimated by DNSA score (Table 2). Some roots with similar high reducing sugar percentage by HPLC had different DNSA scores. Thus, the 27 roots with 2.6% to 3.1% reducing sugar were given DNSA scores of either 3 or 4. These roots, however, were not misclassified genetically. Only *rs/rs* roots with a DNSA score of 3 and with 1.5% reducing sugar or more were misclassified as *Rs/_*. Two roots were misclassified genetically in this way.

The Chip Color Tester (6) did not suffer from interference by sucrose or other carrot constituents, and it had the advantage of being a one-step procedure. This test-tape was developed to estimate glucose levels in potatoes for chipping, and it has application for predicting the color of deep-fried carrot chips. It was difficult, however, to distinguish between 1% and 5% reducing sugar carrots. This difficulty allowed for classification of *rs/rs* roots with 1.0% to 1.5% reducing sugar as *Rs/_*. There were 47 *rs/rs* roots with 1.0% or more reducing sugar.

The correlation coefficient (r) between DNSA score and reducing sugar percentage was 0.88 over all populations, locations, and years. Between 71 populations (at 3 locations over 3 years), correlations ranged from 0.76 to 0.98 (population size varied from 10 to 66 roots). The probability that these correlations were the result of chance was 0.003 or less for every population and less than 0.0001 overall. These statistics suggest a general applicability of the DNSA spot method to a diverse range of the *D. carota* germplasm. Considering all phases of sample preparation and analysis, this method allows 12 to 30 samples to be analyzed per hr, whereas carrot sugar analysis by HPLC can be performed at a rate of 3 to 5 samples per hr. Soluble solids evaluation could be combined easily with this method.

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Influence of Root-knot Nematode on Onion

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Abstract. **The effects of the root-knot nematode [*Meloidogyne incognita* (Kofoid and White)] Chitwood 'Race 3', on 'Utah Yellow Sweet Spanish' onion were investigated in microplots containing a sandy loam. Inoculum levels of *M. incognita* ranged from 0 to 20,900 eggs and juveniles/500 cm^3 soil. Onion growth and yield were suppressed severely in all nematode infested plots. Bulb weight/plant in the nematode infested plots was 24% of that in the root-knot nematode free plots. Symptoms of plants infected with *M. incognita* included numerous small galls on the roots, retarded growth, light foliage color, and leaf tip burn. The data indicated that *M. incognita* densities greater than 250 eggs and juveniles/500 cm^3 soil can cause significant yield loss in onions in sandy loam.**

The southern root-knot nematode Chitwood infects onion *Allium cepa* L. (8), but is not usually considered an important onion pest. Taubenhaus (9) cautions about effects of root-knot nematode, but cites no data, and Jaworski et al. (5) report onion seedling response to fumigation which controlled *M. incognita* plus other nematode and fungus disorders. Onions in the southern United States commonly are planted in the fall or winter and mature from March through June. Much of the crop growth occurs when soils are relatively cool, when *M. incognita* would not be expected to cause serious problems. In areas like southern New Mexico, long-day onion cultivars are seeded in the spring for harvest in late summer. The latter stage of onion development occurs when soil temperatures are highest, which is favorable for growth, development, and reproduction of the root-knot nematode. A survey of onion fields in July (8), and an observational test in 1979 in microplots indicated that high populations of root-knot nematodes severely inhibited onion growth and bulb development. A study was initiated in 1980 to assess effects of various population levels of *M. incognita* on onion growth and yield in microplots.

Each microplot was contained in a fiberglass cylinder (80 cm in diameter × 60 cm high) which was inserted 50 cm deep in a sandy loam (64% sand, 22% silt, and 14%

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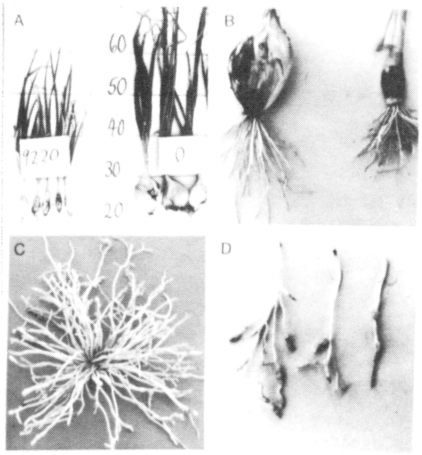

Fig. 1. **A**. Stunting caused by root-knot nematode (*M. incognita*) populations of 9220 eggs and juveniles per 500 cm^3 of soil. **B**. Root system of healthy (left) and nematode infested plant (right). **C**. and **D**. Galls on onion roots caused by root-knot nematode.

clay) with a pH of 8.0 and an organic matter content of 0.5%. Construction of these cylinders was described by Barker et al. (1). The microplots originally were fumigated with methyl bromide (150 g/m^2) in 1978 and inoculated with chopped infected tomato roots to provide different inoculum densitites of *M. incognita* 'Race 3' (7). In 1978 and 1979, chile (*Capsicum annum* L.) plants were grown in the microplots, and the *M. incognita* population densities used in the present study had developed on these 2 previous chile crops. Initial preplant *M. incognita* densities for this study were determined by collecting 10 soil cores/microplot on 3 Mar. 1980 and extracting eggs and juveniles by procedures described by Byrd et al. (3, 4) and Jenkins (6). Densities of *M. incognita* varied between microplots from 0 to 20,960 eggs and juveniles/500 cm^3 soil.

Four rows 12 cm apart were seeded (1 seed/cm) with 'Utah Yellow Sweet Spanish' onion in each microplot on 6 Mar. 1980. Plots were drip irrigated as needed. Before planting, plots were fertilized with N (40 kg/ha) and P (20 kg/ha). Nitrogen also was applied twice during the growing season (30 kg/ha each time).

Onions were harvested 10 Aug. when tops had fallen in the most advanced plots. The tops and roots were clipped and bulbs were weighed. Soil samples were collected from each microplot at harvest and assayed for *M. incognita*.

Table 1. Onion average bulb weight as affected by *Meloidogyne incognita*.

Preplant nematode densities Eggs plus juveniles/500 cm^3 soil		No. microplots	Bulb wt (g)
Range	Mean		
0	0	0	58.4**[z]
256–20,960	3879	27	14.3

[z]**Significant difference at 1% level, by *t* test for comparison of group means.

Table 2. Relationship of initial population densities (P_i) to final population densities (P_f) of *M. incognita* on 'Utah Yellow Sweet Spanish' onion.

Number of eggs and juveniles/500 cm^3 soil			
P_i		P_f	
Range	Mean	Range	Mean
0	0	0	0
250–460	370	1720–5410	3230
580–720	765	690–3340	2145
1180–20,960	5800	300–5280	1700

Symptoms on root-knot nematode infected plants included retarded growth and reduced bulb development (Fig. 1a and 1b), numerous small galls on roots (Fig. 1c and 1d), light colored foliage, and leaf tip burn.

The bulb weight of onions in the *M. incognita* infested microplots was 76% less than in the root-knot nematode free plots (Table 1). The bulb weight response seemed to follow a 2nd order regression, with minimal response to increasing populations above 1000 eggs and juveniles/500 cm^3 soil. Relatively few data points were obtained for populations below 500, and none for populations between 0 and 250 eggs and juveniles/500 cm^3 soil. The slope of a regression for population densities between 250 and 20,900 eggs and larvae/500 cm^3 soil was near 0 and not significant. It seems that the threshold of *M. incognita* population densities for bulb weight suppression is less than 250 nematodes/500 cm^3 soil. Additional data are needed to establish the threshold precisely.

Numbers of *M. incognita* 'Race 3' increased on onion in microplots containing initial populations of less than 1000 eggs and larvae/500 cm^3 soil (Table 2). The populations declined in microplots with initial levels above 1000 eggs and juveniles/500 cm^3 soil. The decline in nematode numbers on severely damaged plants is commonly observed (2). The extent of *M. incognita* reproduction on onion should be considered when the crop is followed by a crop susceptible to *M. incognita*.

The severity of the growth response of onion *M. incognita* is surprising in that the nematode generally has not been considered a serious onion pest. However, symptoms comparable to these have been observed in commercial fields (8). These data suggest that when onions are grown in sandy soils infected with *M. incognita* under high temperature environments, control measures should be considered. Additional research is needed to assess further the effect of root-knot nematode on spring planted onions in New Mexico.

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