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Influence of *Meloidogyne incognita* on Resistant and Susceptible Sweet Potato Cultivars[1]

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Abstract: Effects of several population densities of *Meloidogyne incognita* on the sweet potato cultivars Centennial (susceptible) and Jasper (moderately resistant) were studied. Field plots were infested with initial levels (Pi) of 0, 10, 100, 1,000, 5,000, and 10,000 eggs and juveniles/500 cm³ soil in 1980 and 0, 100, 1,000, 2,000, 3,000, 4,000, and 5,000 in 1981. *M. incognita* population development trends were similar on both cultivars; however, at high Pi, more eggs and juveniles were recovered from Centennial than from Jasper. The highest Pi did not result in the highest mid-season (Pm) counts. Pi was negatively correlated with the number of marketable roots and root weight but positively correlated with total cracked roots, percentage of cracked roots, and cracking severity. Jasper tolerated higher Pi with greater yields and better root quality than Centennial. Cracking of fleshy roots occurred with both cultivars at low Pi.

Key words: ecology, *Ipomoea batatas,* nematode reproduction, population densities, root cracking, southern root-knot nematode.

The southern root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood, is a major pest of sweet potatoes (*Ipomoea batatas* (L.) Lam.). Infection suppresses yield and quality of fleshy roots (12). *Meloidogyne incognita* causes cracking with accompanying necrosis and occasional protuberances on the fleshy roots (20).

Control practices for *M. incognita* include the use of resistant sweet potato cultivars in combination with nematicides. Differences in cultivar resistance have been known since 1925 (4). As of 1978, 14 resistant sweet potato cultivars were recorded (22).

The objectives of this study were to 1) assess the effect of resistance in sweet potato cultivars on population development of *M. incognita,* 2) estimate population densities that reduce yield and quality, and 3) estimate the degree of root-knot nematode control afforded by use of a resistant cultivar alone. An abstract of this research has been published (15).

MATERIALS AND METHODS

Experiments were conducted on an Olivier silt loam (5% sand, 80% silt, 15% clay, pH 4.5) at the Burden Research Plantation in Baton Rouge, Louisiana. Field plots were fumigated with 134 kg/ha of Terr-O-Gas 67 (67% methyl bromide, 31.8% chloropicrin) injected 20 cm deep using a single chisel applicator. Rows were then covered with 1.5-mil black polyethylene plastic. Plastic covers were removed 10 days before planting. Ethoprop (6 EC) was applied between rows at a rate of 7.0 kg a.i./ha in 1980.

A population of race 1 of *Meloidogyne incognita* (22) was increased in a greenhouse on tomatoes (*Lycopersicon esculentum* Mill. cv. Rutgers) inoculated with eggs extracted from galled tomatoes (9). Field plot inoculum was prepared by combining the soil from 50 inoculated tomatoes. The infected root systems were fragmented and mixed with the soil. Samples were processed to estimate the total number of eggs and juveniles in the soil. Soil from noninoculated tomatoes was used to dilute nematode-infested soil to insure that a uniform amount of soil was added to each field plot.

Field plots were infested on 5 June 1980 and 22 May 1981 by distributing the inoculum in a furrow to give initial populations (Pi) in the root zone (upper 30 cm of soil) of 0, 10, 100, 1,000, 5,000, or 10,000 eggs and juveniles in 1980 and 0, 100, 1,000, 2,000, 3,000, 4,000, or 5,000 eggs and juveniles in 1981. The beds were reformed and immediately planted with terminal vine cuttings of *Ipomoea batatas* (L.) Lam. cv. Centennial or cv. Jasper. Centennial was rated as susceptible and Jasper moderately resistant to this *M. incognita* population in previous greenhouse tests (8,17).

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The experimental design was a randomized complete block with five replications in 1980 and four replications in 1981. Plots were 191 cm long with five terminal vine cuttings planted 43 cm apart in 1980. In 1981 plots were 177 cm long with five terminal vine cuttings planted 31 cm apart. Each plot consisted of one row of sweet potatoes grown on ridges 30 cm high and 61 cm wide with 122-cm row spacings. Border rows and planted alleys were used between plots each year.

Soil samples were collected from each plot every 30 days to study the population development of *M. incognita.* A soil core 2 × 20 cm deep was collected from five areas in each plot. Cores from each plot were thoroughly mixed and a 250-cm^3 subsample collected. Nematodes were extracted using a semi-automatic elutriator, and a 38-μm-pore sieve fraction was further processed by centrifugal flotation (sucrose sp. gr. 1.13) (10). Root fragments collected on a 425-μm-pore sieve were extracted with sodium hypochlorite and then further processed by centrifugal flotation for an estimation of egg production (1,10).

Plots were harvested on 10 October 1980 and 24 September 1981. Fresh weights of sweet potatoes were recorded for each grade category. Each marketable root was rated for cracking severity on a 0–4 scale (0 = no cracks, 1 = trace, 2 = slight cracking, 3 = moderate cracking, and 4 = severe cracking).

All tests were analyzed as two factor factorial experiments with six inoculation levels in 1980, seven inoculation levels in 1981, and two cultivars each year. Population analyses were performed at each sample date.

Results

1980 test: Meloidogyne incognita population development trends were similar on both Centennial and Jasper, but total nematode population (egg and juvenile counts) reached higher levels on Centennial than on Jasper (Fig. 1). After initial soil infestation in June, the populations recovered 30 days later were low for both cultivars. Only a few juveniles and no eggs were recovered. Populations were highest in the 62-day samples for all treatments with the exception of Pi 1,000 and 10,000 on Centennial. There were no significant differences among Pi levels in nematode counts from the 62-day samples on Jasper, but nematode counts for Centennial at Pi 5,000 and 10,000 were significantly greater than from Pi 0. Counts from Pi 5,000 on Centennial were significantly greater than counts obtained from any Pi levels on Jasper.

All population levels were lower at 88 days than at 62 days after planting with the exception of Pi 10,000 and Pi 1,000 on Centennial, which had increased. Populations recovered from Pi 5,000 on Jasper were significantly greater than from Pi 0. The 88-day counts from Pi 1,000, 5,000, and 10,000 on Centennial were significantly greater than from Pi 0. Populations from Pi 1,000, 5,000 and 10,000 were significantly greater on Centennial than from the same Pi densities on Jasper.

Population levels continued to decline as indicated by the 118-day counts. There were no significant differences among counts from Pi levels from either cultivar. By 153 days after planting, few eggs and juveniles were recovered from any Pi level and recovery remained low through 184 days when sampling was terminated.

Pi level was negatively correlated with the weight of the marketable fleshy root, all grades combined, where $r = -0.4391$ ($P = 0.01$) and $r = -0.1982$ for Centennial and Jasper, respectively. Initial nematode infestation levels of 10 and 100 appeared to affect the weight of marketable Centennial roots (Fig. 2). Significantly lower weights were recorded at Pi 1,000 and above than at Pi 0. Reduction in marketable root weights of Jasper were not recorded at infestation levels below Pi 1,000, and weight was not significantly reduced at the higher Pi levels. Weights of mar-

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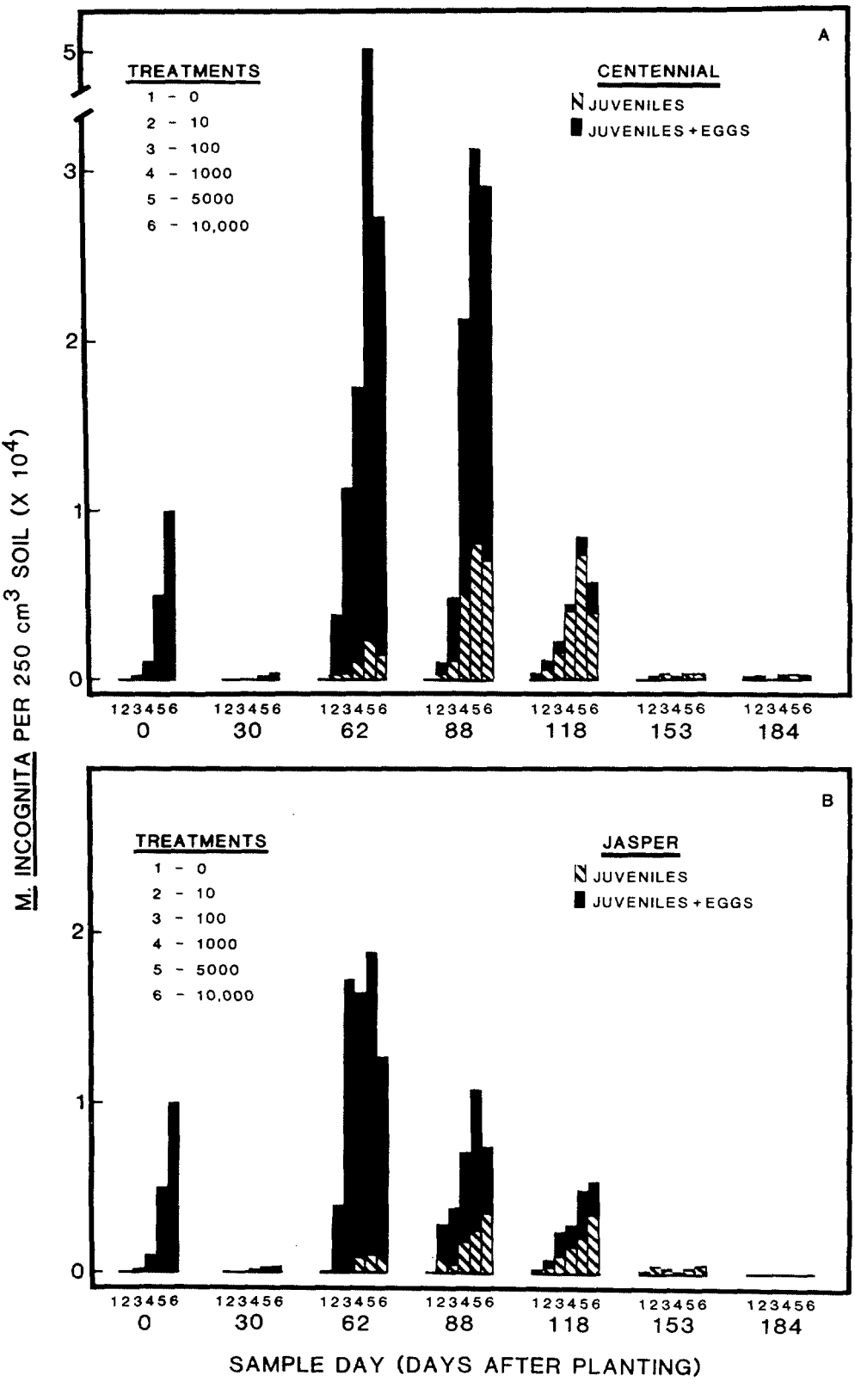
Fig. 1. Population development of six *Meloidogyne incognita* (Mi) initial population densities (Pi) on Centennial and Jasper sweet potatoes in 1980. Populations represent eggs and juveniles on (A) Centennial, Mi susceptible, and (B) Jasper, Mi moderately resistant. Each point on the graph represents the mean of five replications for each Pi.


A
TREATMENTS
1 - 0
2 - 10
3 - 100
4 - 1000
5 - 5000
6 - 10,000
CENTENNIAL
JUVENILES
JUVENILES + EGGS
5
3
2
1
0
123456 123456 123456 123456 123456 123456 123456
0 30 62 88 118 153 184
B
TREATMENTS
1 - 0
2 - 10
3 - 100
4 - 1000
5 - 5000
6 - 10,000
JASPER
JUVENILES
JUVENILES + EGGS
2
1
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123456 123456 123456 123456 123456 123456 123456
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M. INCOGNITA PER 250 cm3 SOIL (X 10^4)
SAMPLE DAY (DAYS AFTER PLANTING)

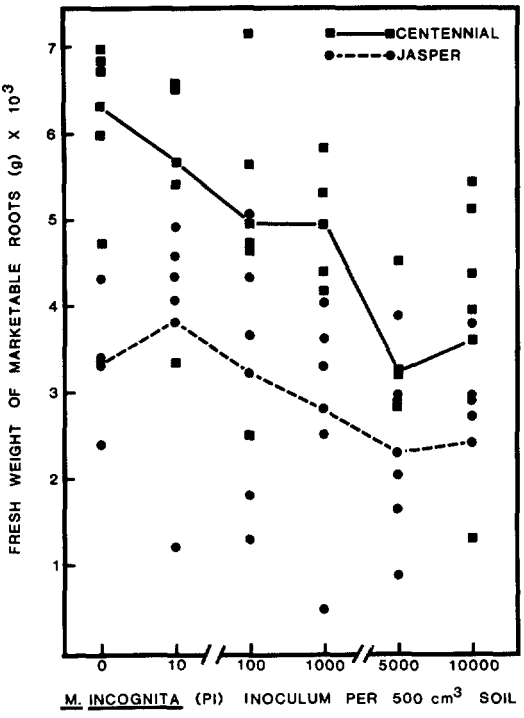

FIG. 2. Effect of initial *Meloidogyne incognita* soil infestation levels on the fresh weight of marketable roots produced from Centennial and Jasper sweet potatoes in 1980. Each point represents root weight of a replication; points on the lines represent the mean of five replications for each cultivar.

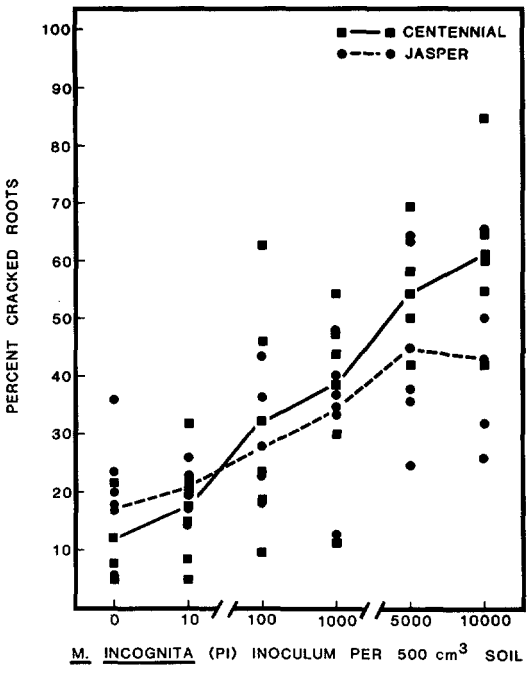

FIG. 3. Relationship between initial *Meloidogyne incognita* soil infestation levels and the percentage of fleshy roots with cracks from Centennial and Jasper sweet potatoes in 1980. Each point represents the percentage of cracked roots produced in a replication; points on the lines are the means for five replications for Centennial and Jasper.

ketable roots was greater at Pi 10,000 than at Pi 5,000 for both Centennial and Jasper.

Trends were similar for the number of marketable roots produced by both Centennial and Jasper. An increase over Pi 0 was observed at Pi 10 and 100. Fewer sweet potatoes were recovered at Pi 1,000 and 5,000. Centennial produced significantly fewer roots at Pi 1,000 than at Pi 0; however, there were no significant differences among Pi levels for the number of roots produced by Jasper. More roots were produced by both Centennial and Jasper at Pi 10,000 than at 5,000. There were no significant differences in the number of marketable roots produced by Centennial and Jasper at the same Pi. The number of roots produced was negatively correlated with Pi levels where $r = -0.4854$ ($P = 0.01$) and $r = -0.1246$ for Centennial and Jasper, respectively.

Pi was positively correlated with the number of cracked roots ($r = 0.4972$, $P = 0.01$ and 0.5416, $P = 0.01$), the percentage of cracked roots ($r = 0.6938$, $P = 0.01$ and 0.5340, $P = 0.01$), and cracking severity ($r = 0.652$, $P = 0.01$ and 0.5613, $P = 0.01$) for Centennial and Jasper, respectively. Although the number of cracked roots increased at Pi 10 for both cultivars, differences in the number of cracked roots of Centennial and Jasper at the same Pi were not significant. There were significantly more cracked roots in Centennial at Pi 10,000 than at 0. The percentage of roots with cracks increased at Pi 10 for both cultivars (Fig. 3). A significantly higher percentage of cracked roots was recorded at Pi 100 and higher, compared to Pi 0, for Centennial and Jasper, respectively. Significantly more cracked roots were recorded at Pi 10,000 from Centennial than from Jasper. Severity ratings of the cracked roots were significantly greater at Pi 1,000 for Centennial and Pi 5,000 for Jasper than at Pi 0.

1981 test: Population trends for *M. incognita* in 1981 were similar to those for 1980 for both Centennial and Jasper and therefore are not presented. The highest total nematode counts on Centennial and Jasper were recorded from the Pi 4,000 and 3,000 treatments, respectively. More eggs were recorded at corresponding sampling periods in 1981 than in 1980.

Correlations between Pi and yield of the sweet potatoes in 1981 were also similar to those in 1980. When compared to Pi 0, Pi of 100 and 1,000 suppressed the number and total weight of Centennial sweet potatoes, but total weight of Jasper was not suppressed with Pi less than 2,000. Correlation coefficients for Pi versus total root weights were −0.3126 and −0.5120 (P = 0.01) for Centennial and Jasper, respectively. The number of roots produced by Jasper was not significantly affected by any Pi. Correlation coefficients for Pi versus number of roots produced were −0.4718 (P = 0.01) and −0.4012 (P = 0.05) for Centennial and Jasper, respectively.

The number of cracked roots and cracking severity ratings were not recorded in 1981 because of low incidence of cracking. However, when 2-mm slices of these roots were examined, numerous mature females (females and egg masses) were found embedded below the epidermis. These mature females were surrounded by necrotic cells. The number of females recovered increased with Pi more for Centennial than for Jasper (Fig. 4).

When comparing the common Pi from the 1980 and 1981 tests, a two-way interaction between Pi and year and between Pi and cultivar was significant (P = 0.05). This interaction indicated that growing season affected the total number of nematodes that developed on each cultivar and could be directly related to the amount of root growth exhibited by Centennial and Jasper during the two growing seasons. Root growth, as reflected in yield, was highly significant (P = 0.01) for the year × cultivar interaction.

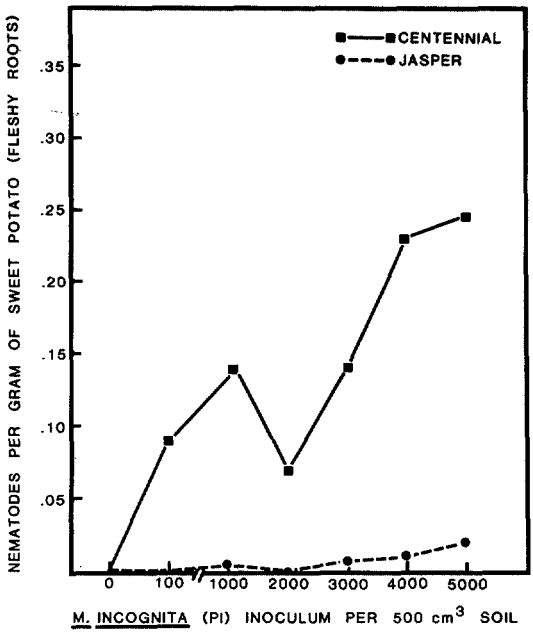

FIG. 4. Effect of initial *Meloidogyne incognita* soil infestation levels on the number of females embedded in fleshy roots after harvest in 1981. Each point on the lines represents the mean of four replications of the number of females per gram of root for Centennial and Jasper.

DISCUSSION

Although the rate of growth and development of *M. incognita* populations was similar on both cultivars, more juveniles matured on Centennial than on Jasper. Fewer eggs and juveniles were recorded from Jasper than Centennial. Approximately the same number of nematodes developed at the lower Pi on both cultivars, but as Pi increased, a greater proportion of the juveniles matured on Centennial, which had higher mid-season (Pm) nematode population densities. Above a certain Pi, or saturation point, juveniles did not increase to high Pm on Jasper.

Moderately resistant Jasper tolerated higher Pi of *M. incognita* with better yields and root quality than Centennial. Yields of both cultivars, however, were suppressed at high Pi. Quality of the sweet potatoes of both cultivars was decreased because of cracking at low Pi, although Jasper roots sustained fewer cracks than roots from Centennial.

Temporal variations in nematode population densities may be related not only to the nematode life cycle but also to the stage of sweet potato root development. Population densities in soil during the first month after planting were relatively low, indicating that many juveniles had entered the newly developing sweet potato fibrous roots but had not yet matured (14,16,27). The highest population densities were re-

covered approximately 2 months after planting, which is the time required by *M. incognita* to complete one or two life cycles on either cultivar (16). The initial growth phase of sweet potatoes has been described on the Porto Rico cultivar as consisting of a rapid growth of the fibrous root system and lasting about 67 days (4). Maximum nematode reproduction thus coincided with the time associated with maximum sweet potato root growth.

The apparent decline in the number of eggs recovered between 2 and 3 months after planting coincided with the second growth phase of sweet potato, lasting about 44 days and consisting of a decline in the rate of fibrous root development, an increase in vine growth, and the initial development of fleshy roots (4). Slow fibrous root growth probably resulted in the reduction of available penetration sites at this time, and thus many juveniles and few eggs were recovered at 118 days after planting. A similar decline in the number of nematodes recovered was observed in sweet potato fields in Japan (13).

The third and final stage of sweet potato growth, consisting of rapid development of the fleshy roots, begins approximately 111 days after planting (4). During the present study, nematode population densities continued to decline on both cultivars through this period, possibly also reflecting the limited availability of penetration sites in fibrous roots. Lateral roots arising from the fleshy roots, however, probably supplied the juveniles with additional points for infection. The majority of nematodes found in enlarging roots in another study were associated with lateral roots (12). Samples taken after harvest recovered only overwintering juveniles remaining in the soil because roots and egg masses were decomposed and nonrecoverable by our extraction procedure.

The highest Pi, 10,000 in 1980 and 5,000 in 1981, resulted in lower nematode population densities, more roots, and higher yields than the next lower Pi. These effects may be due to the self-limiting effect exhibited by many *Meloidogyne* spp. as the result of intraspecific competition for available feeding sites and food supply (3,24,25). Additionally, some of the juveniles from the initial population developed into males inside roots (16). Subsequent generations thus produced fewer offspring, and the plants were therefore exposed to less nematode stress than at intermediate Pi. Other workers have observed that males are more abundant under adverse conditions for nematode development and suggested that intraspecific competition and food supply are important causal factors in this phenomenon (2,3,23,24,26).

More roots were recovered at Pi 10 than Pi 0 in 1980. Stimulation of root growth has been observed with low nematode densities (28). Root proliferation is a common feature of many nematode infections and may indicate that the plant is responding to root destruction by the production of new roots (29). Root proliferation is also indicated in the 1980 test in that both Centennial and Jasper produced more U.S. Grade "canner" roots at low Pi. In 1981 low Pi did not seem to stimulate production of roots as in 1980.

Cracking in the sweet potato fleshy root has been associated with many environmental factors, especially soil moisture fluctuations (19). Such "growth cracking" occurs in all sweet potato cultivars, but some are more susceptible to cracking than others (5). As the sweet potato fleshy root develops, it is thought that pressure exerted by the enlarging vascular cylinder on inactive cortical tissue causes cortical cracking. Nematodes were first associated with sweet potato cracking in 1918 (6), as confirmed subsequently (11,12,18). Sporadic rainfall in 1980 resulted in periods in which fleshy roots developed very rapidly (19) which, in conjunction with disruption of tissue by the nematode, may have been responsible for the large number of cracked roots. Rainfall during the 1981 growing season was more uniform, and the sweet potatoes probably grew at a more uniform rate. Although nematodes were present inside fleshy roots, the sweet potatoes did not crack in 1981, suggesting that *M. incognita* may be a predisposing rather than a causal factor in cracking of sweet potatoes.

Nematode population density damage thresholds for various sweet potato cultivars would help in selecting nematode management practices. A Pi of about 10 *M. incognita* per 500 cm^3 is the damage threshold for cracking of Centennial and Jasper sweet potatoes. The economic threshold for *M. incognita* on sweet potato

was demonstrated to be 30 second-stage juveniles per 1,000 g loam soil and 5 per 1,000 g sand (7). If a single crack reduces the quality of the marketable root, then other management practices, such as nematicide application or crop rotation, should be employed to reduce the Pi of *M. incognita.* Others have shown that certain resistant cultivars, under different growing conditions, produce marketable roots without cracking in the presence of low soil population densities of root-knot nematodes (21).

Planting a resistant cultivar in a field infested with *M. incognita* could produce higher yields with less root cracking than planting a susceptible cultivar. However, other practices may be necessary to reduce Pi below the density that would significantly suppress yields and increase cracking in a moderately resistant sweet potato cultivar such as Jasper.

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