Resistance Reactions of Castor and Guar to Root-Knot Nematodes

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ABSTRACT

Cotton root-knot nematodes, *Meloidogyne incognita acrita*, in naturally infested cotton-field soil, invaded the roots of guar and castor, but development was slow, or females failed to mature and reproduce. Guar roots produced a hypersensitive reaction, and giant cells were poorly formed. Castor roots were readily invaded by root-knot larvae; however, the larvae either migrated out of the root or failed to develop.

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Additional key words: penetration, larval development.

Castor (*Ricinus communis* L.) an oilseed crop, and guar [*Cyamopsis tetragonoloba* (L.) Taub.] a legume crop used for industrial gum, are grown on the high plains and rolling plains of Texas. Both crops are grown in rotation with cotton on soil infested with cotton root-knot nematodes, *Meloidogyne incognita acrita* [(Kofoid and White, 1919) Chitwood, 1949]. Root-knot nematode damage to castor and guar has been observed in the field, but the extent of injury and the histopathology of roots damaged by nematodes is not well documented. Greenhouse and laboratory experiments were conducted to determine the extent of injury, the reaction of root cells to invasion, and the population dynamics of root-knot nematodes in the soil after castor and guar had been grown.

Invasion of a susceptible root by larvae of *Meloidogyne* spp. Goeldi, 1887 usually causes major changes in plant cells surrounding the nematode. Near the head of the parasite, normal vascular tissue is replaced by giant cells, and hypertrophy and hyperplasia occur (1, 7, 10).

In resistant roots, larvae may fail to enter, enter in reduced numbers with little or no development, or enter in large numbers with varying degrees of nematode development. Hypersensitivity is a common type of response of resistant plants to nematode invasion(11, 12). The larvae may enter roots of resistant plants in large numbers, but hypersensitive cells quickly die and wall off the pathogen, so that injury to the host by each larva is confined to a few cells (10, 11, 12).

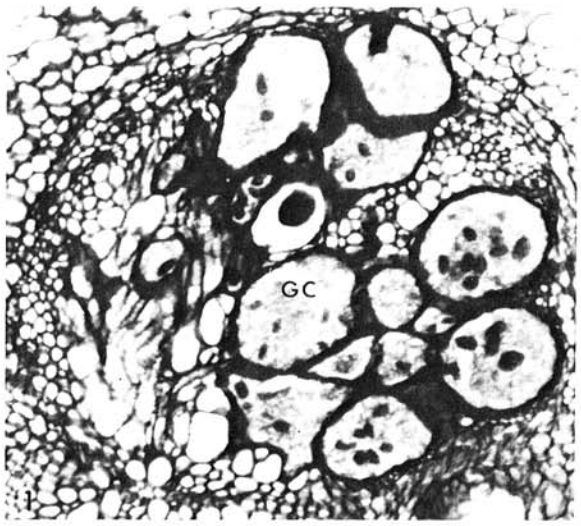
Castor was reported by Lear and Miyagawa (8) to be resistant to *M. thamesi* and *M. hapla;* however, the varieties tested were not resistant to *M. incognita* and *M. javanica*.

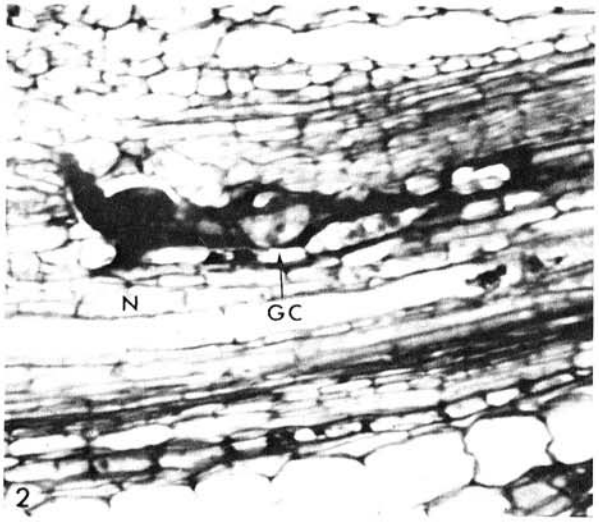
Huang and Maggenti (5) reported that nuclei in the giant cells were formed by repeated nuclear divisions. Earlier workers, Dropkin, et al. (3) and Christie (1), reported that part of the giant cell formation was caused by the incorporation of the cytoplasms and nuclei of adjacent cells by cell-wall breakdown.

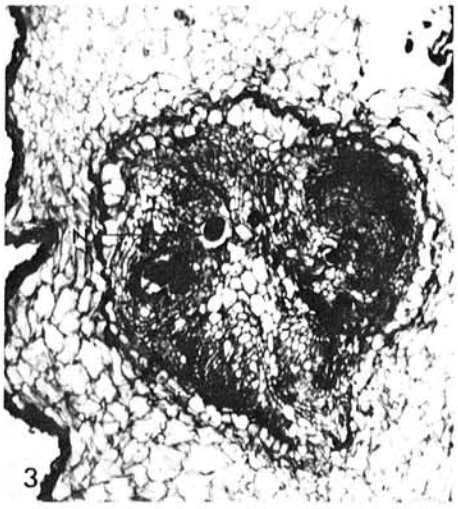
MATERIALS AND METHODS.—Three commonly grown cultivars of castor (Lynn, Baker 296, and Baker Hybrid 55) and three cultivars of guar (Mills, Brooks, and

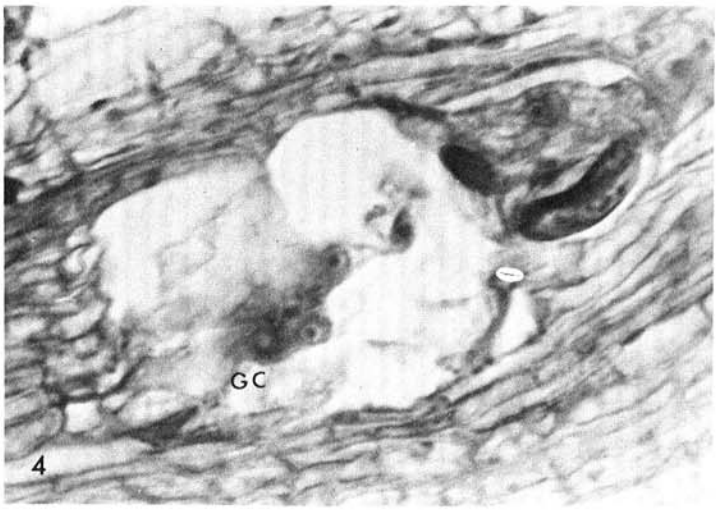
Hall) were included in the studies. Cultivars of castor and guar were planted in 10.2-cm clay pots filled with Brownfield loamy sand, naturally infested with cotton root-knot nematodes. Plants were grown in the laboratory under a 14-hour day at 27 C.

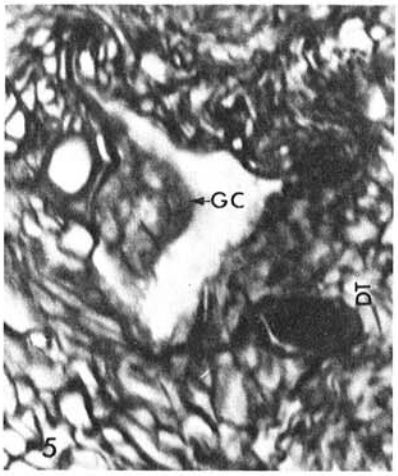
Plant tops were harvested and weighed after 22, 32, and

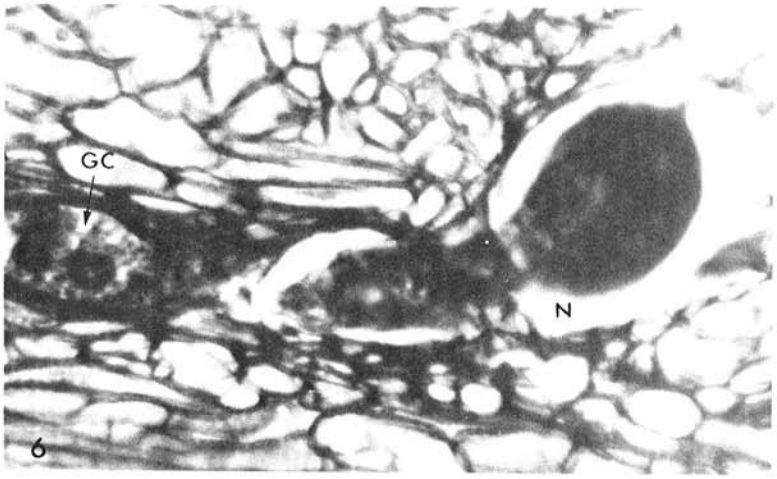












40 days. Plant weight, percent of roots infected, and number of root-knot larvae per gram of roots were recorded. To determine the percent of the roots infected, sections of roots were washed and stained with acid-fuchsin-lactophenol so nematode counts could be made (9). Other sections of infected root were washed, fixed in FAA, and embedded in paraffin in the typical manner after Johansen (6). After embedded roots were sectioned at 12 μm and mounted, the sections were stained in safranin and fast green to study giant-cell development (13).

In a greenhouse study, castor, guar, tomato, and cotton (cultivars Lynn, Mills, Rutgers, and Gregg, respectively) were grown in a ground bed. Plots were 60 cm square and 60 cm deep and lined with polyethylene to prevent contamination among plots. The soil in the bed was a Brownfield loamy sand, naturally infested with cotton root-knot nematodes. Plants were harvested after 90 days, and the weights of the oven-dried tops were recorded. Soil samples were then taken from each plot, and the number of root-knot nematode larvae in 250 g of soil was recorded. Three infested plots and one sterile plot were provided for each of the four crops, which were grown 16 consecutive times.

RESULTS.—Growth and development of guar was less in nematode-infested soil than in noninfested soil. In the greenhouse ground-bed test, the weight of top growth was 21% less in infested soil than for the control plants after 16 consecutive plantings (Table 1). Root-knot nematode larvae penetrated the roots of guar seedlings, often in large numbers. In later stages of growth, many roots were dead or deteriorated and contained secondary fungi.

The guar cultivar Mills contained more root-knot nematode infestations in roots than did Brooks or Hall (Table 2). In Mills plants, 90% of the plant roots contained root-knot nematodes in some stage of development, but the roots of only about 30% of cultivars Brooks and Hall were infested (Table 2). The development of root-knot larvae in guar roots (Fig. 4) was slow when compared to that in tomato (Fig. 1). After 22 days, most nematodes found were larvae, saccate females were found after 32 days, and a few females with eggs were observed after 40 days. Galls observed on roots were small and few in number. The population of root-knot larvae in the ground-bed study declined after 16 crops and was 76.5% of the initial infestation, while the nematode population under tomato and cotton increased to 756 and 284%, respectively (Table 1).

Guar appears to be a rather poor host to root-knot nematodes, although invasion of roots occurs, and some reproduction was observed. The resistance in guar appeared to be from hypersensitivity of plant cells, which prevented maturation (Fig. 6). Giant-cell formation was restricted in guar in comparison to that in tomato (Fig. 1, 4).

In the greenhouse ground-bed study, dry weight of castor grown in infested soil was 9% less than that of plants grown in the absence of root-knot nematodes (Table 1). Examination of castor roots after 90 days, showed either small scattered galls or a clean root appearance, in spite of the fact that roots examined after a few days growth had been heavily infested with root-knot nematode larvae. After 16 crops of castor, 42 root-knot nematode larvae/250 g soil were found, which was 65.6% of the number at the start of the experiment (Table 1).

Fresh weight of castor plants grown in the laboratory study was only half as much in infested soil as that of plants grown in sterile soil (Table 2). The roots of infected castor showed little evidence of gall formation, but 90% of roots stained with acid-fuchsin-lactophenol contained root-knot nematodes (Table 2). The cultivar Baker Hybrid 55 contained 40 nematodes/g of root and was the most heavily infected of the castor cultivars tested.

After 40 days, most of the root-knot nematodes found were females, with some exhibiting swelling. Few females with egg masses were observed, and there was a tendency toward maleness which has been associated with environmental stress: induces larvae to develop as males rather than females (4).

Several sections through castor root galls showed only slight swelling, and no necrosis or hypersensitive reaction was observed. Giant cells were formed only in the vascular cylinder, and were relatively small and few in number (Fig. 2). In regions of the root which contained small giant cells, the nematodes were immature, and the cellular stimulation was limited to a few cells around the nematode head (Fig. 3).

DISCUSSION.—Larvae of *Meloidogyne* enter the host plant near the root cap. They migrate into the intracellular region of the differentiating vascular cylinder (1). In tomato and cotton, larvae caused the formation of typical giant cells from parenchymatous elements. These cells near the nematode head hypertrophied and became multinucleate giant cells (Fig. 1).

Giant cells in tomato had up to 17 nuclei. Castor and guar did not have such well-defined giant cells. Giant cells in castor were less pronounced and commonly had two-to-four nuclei, with two being the typical number. Typical giant cells in guar contained four nuclei (Fig. 6). In tomato, the nucleus appeared to be slightly fluted toward

Fig. 1-6. Comparative cellular morphology of root-knot, *Meloidogyne incognita acrita*, infection of a susceptible tomato root and roots of resistant guar and castor. **1)** Tomato cultivar Rutgers root with cotton root-knot nematode (N) surrounded by 15 giant cells (GC), which contain 6-10 nuclei each. Cortex remains normal in all respects (× 63). **2)** Castor cultivar Baker 296. Two small, poorly developed giant cells lie to the right of the developing nematode (× 160). **3)** Castor cultivar Baker 296. Four developing larvae are seen in cross-section. The root tissue is irregular and distorted. The vascular cylinder developed into irregular-formed vessels (× 63). **4)** Guar cultivar Hall. Giant cells (GC) are diffuse in character. Above the giant cell with eight nuclei, a portion of the degrading cell wall remains. Two nematodes and a developing giant cell with one nucleus are present at upper right (× 160). **5)** Guar cultivar Brooks. Giant cells are small and irregularly shaped, with one or two nuclei present, which is a typical number. Cortex is distorted, and the developing tissue (DT) remained abnormal throughout all sections studied (× 400). **6)** Guar cultivar Brooks. After 40 days a developing female lies in the feeding position. The giant cell is small and contains four nuclei. Part of a broken cell wall lies across the nematode (× 400).

TABLE 1. Plant weight, root-knot nematode larvae in 250 g soil, and the percent change from the original infestation after sixteen 90-day growth periods of the same crop in the same plot

	Oven-dry plant weight				
	Oven-dry (g/plant)				
	Infected	Check	Reduction (%)	Larvae/ 250 g soil	Fraction of original infestation after (%) 16 crops
Original infestation				64	100.0
Guar	0.95	1.2	21	49	76.5
Castor	25.4	27.6	9	42	65.6
Cotton	11.3	13.9	19	182	284.4
Tomato	54.2	70.4	23	484	756.25

TABLE 2. Infestation levels of root-knot nematodes and their effect on cultivars of guar and castor

Plant and cultivar	Fresh weight (g/plant)		Plants infected (%)	Nematodes per gram of root
	Infected	Check		
Guar				
Mills	0.87	3.7[a]	90.9	23
Brooks	0.93	4.1	30.8	4
Hall	0.85	2.2	31.2	13
Castor				
Lynn	13.6	37.5	90	19
Baker 296	15.4	23.8	90	12
Baker Hyb 55	13.1	28.4	87	40

[a]Weight of infected plants was significantly different from weight of the check $P = 0.01$.

the nematode head, while in guar and castor it was not.

Preparations of tomato root showed reproducing females with large egg masses. In guar and castor, there were a few females, but no egg masses were found (Fig. 2, 4, 6). Crittenden (2) showed that *M. incognita acrita* did not reproduce in asparagus. There was no noticeable change in tomato anatomical structure, but in castor cultivar Baker (Fig. 3), six nematodes caused the abnormal development of that root, which had eight developing lobes of vessels. In more mature sections of this root, the tissue had become a solid cylinder of vessels. The endodermis remained a distorted band of cells, but the cortex remained normal. In guar cultivar Brooks (Fig. 5), the developing nematode was observed with the giant cell in a thin cytoplasmic mass. The giant cells had one or two nuclei. The cells surrounding the giant cell and nematode were highly distorted and irregular in nature. Tomato tissue showed no distortion (Fig. 1).

Giant cells were small in guar and castor, which suggested that guar and castor were more resistant than tomato. Observations of these crops in the field and greenhouse indicate some stunting in guar, but only slight stunting in castor. The histological studies presented support for the conclusions of Lear and Miyagawa (8), who stated that castor was a useful rotation crop to suppress populations of root-knot nematodes.

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