The Relationship of *Meloidogyne incognita acrita* to the Incidence of Cabbage Yellows

G. Fassuliotis and G. J. Rau[1]

Abstract: Three inoculum level combinations of *Meloidogyne incognita acrita* and *Fusarium oxysporum* f. *conglutinans* did not affect the incidence of cabbage yellows in the moderately-resistant 'Greenback' or the highly-resistant 'Marion Market' varieties. The susceptible 'Early Round Dutch' variety was more susceptible to low levels of fungus inoculum in the presence of the nematode.

The interrelation of nematodes and other pathogenic organisms in plant disease complexes have been reviewed (5). Only a few *Fusarium*-nematode interaction studies have involved diseases of vegetable crops. Young (11) reported wilt resistance in tomatoes (*Lycopersicon esculentum*) decreased in the presence of *Heterodera marioni* (= *Meloidogyne* sp.). Jenkins and Coursen (4) also found the wilt-resistant tomato 'Chesapeake' became diseased more quickly when either *M. incognita acrita* or *M. hapla* was present, and concluded the nematodes lowered natural resistance and provided an infection court. Similar results were obtained by Cohn and Minz (2). Winstead, Strider and Person (10) found 80% of wilt-resistant 'Charleston Gray' watermelon plants dead in fields infested with *Fusarium* and *M. incognita acrita.* Thomason (6) and Thomason, Erwin and Garber (7) reported fusarium wilt of cowpeas to be more severe in soils infested with *M. javanica.*

In other investigations the incidence of fusarium wilt was not affected by root-knot nematodes. Contrary to the findings by Jenkins and Coursen (4), Binder and Hutchinson (1) could not induce wilt in the resistant tomato 'Chesapeake' with the race of *M. incognita acrita* and inoculum level they used, and suggested the ability to break resistance in tomato depended upon nematode pathogenicity and the number of nematodes in the inoculum. According to Giamalva, Martin and Hernandez (3), *M. incognita, M. incognita acrita, M. hapla, M. arenaria,* and *M. javanica* do not increase fusarium wilt in sweetpotato.

Cabbage yellows, caused by the soil-borne fungus, *Fusarium oxysporum* f. *conglutinans*, is a serious disease wherever non-resistant cabbage (*Brassica oleracea* v. *capitata*) is grown in warm climates. Control by cultural methods is ineffective because the organism remains viable indefinitely in soil (8).

M. incognita acrita, common on vegetables throughout the Southeast, is the predominant root-knot species in coastal South Carolina. Winstead (9) reported root-knot nematodes in North Carolina to be of little importance in spring cabbage, but severely damaged the direct-seeded fall crop, planted in late summer when soil temperatures are favorable to nematodes.

The need for further studies of *Fusarium-Meloidogyne* interactions on vegetables, the economic importance of the fall cabbage crop and the occurrence of warm soil temperatures (favoring both organisms) in the Southeast led us to determine whether the root-knot nematode, *M. incognita acrita,* predisposed yellows-resistant cabbage varieties to infection by *F. oxysporum* f. *conglutinans.*

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[1] Nematologist and Agricultural Research Technician, respectively, Crops Research Division, Agricultural Research Service, United States Department of Agriculture, Charleston, South Carolina 29407.

TABLE 1. Root gall and yellows indices of three cabbage varieties inoculated with combinations of three levels of *Meloidogyne incognita acrita* larvae and *Fusarium oxysporum* f. *conglutinans.*

	Early Round Dutch (susceptible)		Greenback (mod-resistant)		Marion Market (highly-resistant)	
Treatments[a]	Gall[b] index	Yellows[c] index	Gall index	Yellows index	Gall index	Yellows index
N_0F_0[d]	1.0 a	2.7 abcde	1.0 a	1.0 a	1.0 a	1.0 a
N_1F_0	2.0 c	1.0 a	1.6 b	1.4 abc	2.0 b	1.0 a
N_2F_0	3.1 d	1.4 abc	2.9 d	1.0 a	2.8 c	1.0 a
N_3F_0	4.4 e	1.4 abc	4.0 e	1.0 a	3.7 d	1.0 a
W F_0	1.0 a	1.0 a	1.0 a	1.1 ab	1.0 a	1.0 a
N_0F_1	1.0 a	6.9 ij	1.0 a	3.1 cdefg	1.0 a	1.0 a
N_1F_1	1.7 b	7.7 jk	1.7 b	3.9 fgh	2.0 b	1.6 abcd
N_2F_1	2.0 c	7.6 jk	2.9 d	1.9 abcde	2.7 b	2.7 abcdefg
N_3F_1	2.9 d	8.9 kl	4.6 f	2.9 abcdefg	4.1 e	1.6 abcd
W F_1	1.0 a	8.3 jkl	1.1 a	1.0 a	1.0 a	1.0 a
N_0F_2	1.0 a	8.7 kl	1.0 a	3.3 cdefg	1.0 a	1.6 abcd
N_1F_2	1.3 ab	9.6 l	2.1 c	2.1 abcdefg	2.3 b	1.0 a
N_2F_2	2.0 c	9.0 kl	2.7 d	3.4 defg	2.9 c	1.0 a
N_3F_2	2.7 d	9.6 l	4.0 e	3.3 cdefg	3.7 d	1.9 abcde
W F_2	1.0 a	9.6 l	1.0 a	3.0 bcdefg	1.0 a	2.1 abcdefg
N_0F_3	1.0 a	9.3 kl	1.0 a	2.0 abcdef	1.0 a	2.0 abcdefg
N_1F_3	1.7 b	9.2 kl	1.7 b	3.4 defg	2.0 b	2.6 abcdefg
N_2F_3	1.3 ab	9.7 l	3.0 d	4.0 gh	2.6 c	2.7 abcdefg
N_3F_3	1.7 b	9.7 kl	3.1 d	3.7 efg	3.7 d	2.0 abcdefg
W F_3	1.0 a	8.7 kl	1.0 a	5.5 hi	1.0 a	2.0 abcdefg

[a] The capital letters and subscript numerals indicate the treatment combination and the level of inoculum: N = nematode; F = Fusarium; W = artificial wounding; O = no inoculum; 1 = low level of inoculum (1,000 larvae or 95% light transmittancy of Fusarium; 2 = medium level (5,000 larvae or 75% light transmittancy); 3 = high level (25,000 larvae or 35% light transmittancy).

[b] Root knot galls scored on basis of 1–5 scale: 1 = no galls; 2 = an occasional gall, difficult to find; 3 = few galls; 4 = moderate number of galls; 5 = many galls.

[c] Yellows scored on the basis of 1–10 scale: 1 = no yellows; 2 = light yellowing of lower leaves; 4 = moderate yellowing of several leaves; 6 = most of leaves yellow and falling off; 8 = some leaves turning brown; 10 = plant is dead.

[d] Values followed by the same lower-case letters are not significantly different according to Duncan's Multiple Range Test at the 5% level.

MATERIALS AND METHODS

Nematode inoculum was increased on 'Homestead' tomato plants for six months from a single egg mass of *M. incognita acrita* infecting snap beans on the U. S. Vegetable Breeding Laboratory farm near Charleston, South Carolina. Viable larvae were obtained from tomato root galls, containing numerous egg masses, by mist chamber extraction, programmed to deliver 10 seconds of fine warm water spray every 12 min for 24 hr.

F. oxysporum f. *conglutinans* was obtained from Dr. J. K. Armstrong of Clemson University. Cultures were grown on Wellman's medium in 250 ml flasks at room temperature for 5 days with constant agitation. The fungus mats were washed into a Buchner funnel, then blended for 30 seconds in a small quantity of water. Three fungus inoculum concentrations were prepared by water dilution and the titer measured as percent light transmittancy on a "Spectronic 20" colorimeter at a wave length of 550 mμ.

Three varieties of cabbage were tested: the highly yellows-susceptible 'Early Round Dutch,' the moderately-resistant 'Greenback' and the highly-resistant 'Marion Market.'

To minimize root injury, seeds were sown directly into methyl bromide-fumigated sandy loam soil in 4-inch pots. Seedlings in the cotyledon stage were thinned to 5 plants per pot by clipping the unwanted plants at soil

TABLE 2. Effects of *Fusarium oxysporum* f. *conglutinans, Meloidogyne incognita acrita* and artificial wounding on the incidence of cabbage yellows in three cabbage varieties.

Treatments	Yellows Indices: Early Round Dutch (susceptible)	Greenback (moderately resistant)	Marion Market (resistant)	Mean
Fusarium				
F_0	0.32 a	0.11 a	0.00 a	0.14 a
F_1	6.86 f	1.54 cd	0.57 ab	2.99 b
F_2	8.29 g	2.03 de	0.51 ab	3.61 c
F_3	8.20 g	2.69 e	1.20 bc	4.03 d
Wounding (Nematode)				Wounding Mean
N_0	5.64 e	1.36 bcd	0.39 a	2.46 a
N_1	5.86 e	1.72 d	0.50 a	2.69 a
N_2	5.93 e	1.57 cd	0.82 abc	2.77 a
N_3	6.25 e	1.68 d	0.61 ab	2.85 a
Artificial Wounding	5.89 e	1.64 cd	0.54 a	Artificial Wounding Mean 2.69 a
Variety Means	5.91 c	1.59 b	0.57 a	

level. Seedlings in the two-leaf stage were inoculated by gently watering-in the prepared inoculum directly on the soil surface.

The experiment consisted of 20 treatments with 7 replications arranged in a randomized split-plot design. To test the effect of artificial wounding on the incidence of cabbage yellows, we stabbed the soil and roots around the stem of the plants five times with a knife. The inoculum levels and the method of yellows and root-knot symptom indexing are given in Table 1.

RESULTS AND DISCUSSION

Root gall and cabbage yellows indices for three cabbage varieties are presented in Table 1. In all three varieties root galling severity was directly correlated with initial inoculum levels of root-knot larvae. In many cases, 'Early Round Dutch' root-knot infection was difficult to estimate because the roots were in an advanced state of decay from severe *Fusarium* infection. This accounts for the relatively low root gall index in plants that received the N_0F_3 inoculum level.

Data in Table 2 show the effects of mechanical wounding treatments on the incidence of cabbage yellows. As expected, the severity of yellows between susceptible and resistant varieties was highly significant: 'Early Round Dutch' had the highest incidence of yellows with a rating of 5.9, 'Greenback' had 1.6, and 'Marion Market' had 0.6. We observed no interactions between the type of wounding (artificial or by nematodes) and variety. The only significant variable was the level of *Fusarium*.

Interaction between wounding × *Fusarium* × variety was significant, but this resulted from the high susceptibility of 'Early Round Dutch'. At the conclusion of the experiment, examination of cut stems showed typical tyloses in the vascular bundles of surviving plants and observable external symptoms.

These results do not agree with the general concept that attacks on *Fusarium*-resistant plants by root-knot nematodes predispose them to wilt. Failure of *M. incognita acrita* to break yellows resistance in 'Marion Market' or in 'Greenback,' may reflect the particular type of resistance involved. Two types of resistance occur; Type A and Type B which are qualitatively and quantitatively inherited, respectively. In susceptible varieties, the fungus readily enters the young root tissues and becomes established in the vascular system. A similar pathology is evident as a low grade infection in Type B resistance. In Type A-resistant plants, as in 'Marion Market' (8), the fungus penetrates only as far as the cortex and does not invade the vascular system. An apparent incompatibility of the fungus with the resistant host tissue was not altered by the root-knot larvae that had penetrated the root and provided the fungus with a port of entry to the vascular cylinder. The nematode did not decrease wilt resistance of 'Marion Market' or 'Greenback'; however, it did produce a significant increase in the incidence of the disease in the susceptible variety 'Early Round Dutch,' especially at low inoculum levels of *F. oxysporum* f. *conglutinans*.

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