ASPECTS OF NEMATODE CONTROL ON SNAP BEAN WITH EMPHASIS ON THE RELATIONSHIP BETWEEN NEMATODE DENSITY AND PLANT DAMAGE[1]

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Abstract. **Relationships between nematode density and yield of snap bean (**Phaseolus vulgaris **L.) were examined in several field studies conducted near Homestead, Florida, in 1979. Regression equations were developed describing the inverse relationship between final density of** Meloidogyne incognita **(Kofoid & White) Chitwood and yield of snap bean cv. 'Sprite'. An inverse relationship between nematode numbers and yield was also found in 18 plots of snap bean which were naturally infested with** Rotylenchulus reniformis **Linford & Oliveira. Control of** R. reniformis **in these plots was attempted with a soil drench of 2.24 kg ai oxamyl/ha followed by weekly foliar sprays of 0.56 kg ai oxamyl/ha. Control of** R. reniformis **resulted in yield increases at high nematode population levels, but no consistent yield increase was obtained by treating plots having low population levels, even though nematode populations were reduced by treatment. Such results indicate that there may be an opportunity to make future treatment decisions based on population levels. Control of the root-knot nematode,** M. incognita, **was attempted using nematode-tolerant cultivars. In a field test, four** M. incognita**-tolerant snap bean cultivars showed significantly less galling than the commercial cultivar 'Harvester'.**

Snap Bean (*Phaseolus vulgaris* L.) is an important winter vegetable crop in Florida which is attacked by a wide variety of plant-parasitic nematodes. Damage to snap beans by root-knot nematodes, especially *Meloidogyne incognita* (Kofoid & White) Chitwood, has been reported in a number of cases (2, 4, 5, 7, 10). On sandy soils in Florida, the sting nematode, *Belonolaimus longicaudatus* Rau, can cause severe damage to beans, but Rhoades (13) has demonstrated effective control of this nematode by granular nonfumigant nematicides. Other nematodes reported from snap beans on sandy soils include *Paratrichodorus christei* (Allen) Siddiqi, *Dolichodorus heterocephalus* Cobb, and *Hoplolaimus* spp. (12, 13). On Rockdale soils in southern Florida, damage to snap bean has been reported by *M. incognita* (7), and by the reniform nematode, *Rotylenchulus reniformis* Linford & Oliveira (8). Other common nematodes on Rockdale soils are *Helicotylenchus dihystera* (Cobb) Sher and *Quinisulcius acutus* (Allen) Siddiqi, but these have not been shown to be injurious to beans (8, 16).

The present work examines the relationship between yield of snap bean and numbers of *M. incognita* and *R. reniformis,* the two most damaging nematode parasites of beans grown on Rockdale soils. In addition, new control strategies for these nematodes are discussed in an integrated pest management (IPM) context.

Materials and Methods

M. incognita and bean yields. The snap bean cv. 'Sprite' was planted by a commercial grower on December 15, 1978, in a site near Homestead, Florida. The soil type was a Rockdale series and contained an uneven infestation of *M. incognita*. The grower followed routine schedules for fertilization, cultivation, and spray applications, but no nematicides were used in the production of the crop. Plants were grown in rows 0.76 m apart and the average spacing between plants was 2.95 cm. Plants were harvested on February 21, 1979. At harvest, 10 plants were collected at each of 10 locations in the field, beginning in an area of high infestation and proceeding along the rows at 5.0 m intervals into an area of low infestation. At each location, the 10 plants were collected using a pattern of two plants each from 5 adjacent rows. Plants were collected by digging out the root system with a hand trowel. Galling was rated on a 0-5 scale, where 0 = 0 galls per root system; 1 = 1-2 galls; 2 = 3-10 galls; 3 = 11-30 galls; 4 = 31-100 galls; 5 = more than 100 galls (15). The total number of galls on each root system was counted, and the fresh weight of each root system was also obtained. In addition, the number of marketable beans on each plant was counted and weighed. Average readings of root galling and marketable bean weight were obtained for each of the 10 locations.

Soil samples were also collected at each site to assess soil populations of plant-parasitic nematodes. Subsamples were collected with a hand trowel to a depth of 10-12 cm from the sites where the 10 plants were removed at each location and combined to form a single sample per location. Each sample was passed through a 4 mm sieve to remove rock, and a 100 cm^3 subsample was then suspended in water and processed by decanting and sieving followed by suspension of the residues in modified Baermann funnels (1, 3). Correlation coefficients were then calculated between bean yields and population levels of the various nematodes found at these locations.

R. reniformis and bean yields. This test was performed in 18 small plots having various cropping histories (8). Similar methods of crop management were used for all of these plots. All plots were located near Homestead, Florida, on Rockdale series soils with pH ranging from 7.6 to 7.8. Prior to planting, all sites were treated with 840 g ai of trifluralin/ha and 448 kg/ha of fertilizer (7-14-14). Plots were planted on October 3, 1979, with the snap bean cultivar 'Harvester'. Permethrin at 112 g ai/ha and mancozeb at 1.8 kg ai/ha were applied weekly for insect and disease control. Overhead irrigation was applied to all plots as needed, and 224 kg/ha of supplementary fertilizer (7-14-14) was added to all sites and incorporated by cultivation on October 26, 1979. Each of the 18 plots consisted of paired rows, each 3.66 m long and 0.9 m apart. One row of each pair was treated with an oxamyl (Vydate® L) soil drench at planting followed by 6 weekly foliar sprays of oxamyl beginning on October 11, 1979. The other row of each plot was an untreated control. The soil drench was applied at 2.24 kg ai/ha in 935 l of water/ha in a 25-cm band over the row immediately after planting. Each foliar spray consisted

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of 0.56 kg ai of oxamyl/ha in 935 l of water/ha. On November 19, soil samples were collected from each of the two rows in all 18 plots, and processed for nematodes by the methods described previously. On the next day, a 1.83 m portion of each row was harvested from each plot.

Meloidogyne-tolerant cultivars. Seed of 4 root-knot tolerant snap bean cultivars, G698, G699, G700, and G701, were obtained from Dr. J. E. Wyatt of the U. S. Vegetable Laboratory in Charleston, South Carolina. The test cultivar G699 has since been released as breeding line B4175 (17). These seeds, plus seed of the susceptible cultivar 'Harvester' were hand-planted in a Rockdale series soil on October 12, 1979. Each plot consisted of 8 plants of each cultivar, 3.8 cm apart, arranged in a randomized complete block design with 6 replications. The site had a low infestation of *M. incognita*, and methods of crop management were identical to those used in the tests involving *R. reniformis*. On December 6, 1979, plants were collected by digging out the root systems with a hand trowel, and rating them for galling on the 0-5 scale described previously. Root systems were then stained with Phloxine® B (6) and rated for *Meloidogyne* egg masses using the 0-5 scale. Average galling and egg mass indices were computed for the eight plants of a given cultivar in each replication. Differences between cultivars were further analyzed by analysis of variance followed by Duncan's New Multiple Range Test.

Results and Discussion

M. incognita and bean yield. Plants in this experiment exhibited yellowing of the foliage and stunting, especially in those locations having high populations of *M. incognita*. Root systems contained various levels of galling by *M. incognita*, and all root systems showed symptoms of *Rhizoctonia*, although the severity of this disease did not appear to increase in areas of high *M. incognita* infestation. Over all 10 sampling locations, only 3% of the beans harvested were culled for unmarketable characteristics, mostly stink bug damage. The percentage of culls did not vary significantly from site to site.

An inverse relationship existed between mean weight of marketable beans per plant and mean number of root-knot galls per gram of fresh root weight for the 10 sampling locations in this experiment (Fig. 1). This inverse relationship was highly significant ($P = 0.01$), with $r = -0.916$, and the corresponding regression equation was $Y = -0.281X + 27.26$, where Y = grams of beans per plant and X = root-knot galls per gram of root weight. Inverse linear relationships were also obtained between grams of marketable beans per plant (Y) and: 1) mean number of galls per plant (X), with $Y = -0.487X + 26.10$; 2) mean index of root galling on a 0-5 scale (X), with $Y = -7.682X + 37.64$; and 3) the $\log_{10}$ – transformed values of root-knot galls per gram of root weight (X), with $Y = -17.84X + 43.22$. All of these relationships were also highly significant ($P = 0.01$), with r values of –0.886, –0.901, and –0.893, respectively. Although the results obtained using these other X-variables are very similar to the relationship illustrated in Fig. 1, some of the other variables, such as root galling index or galls per plant are much easier to assess than galls per gram of fresh root weight, and therefore may be of more practical value in estimating losses in field situations.

When yields of marketable beans per plant were compared to nematode counts from soil samples, only one significant relationship was found. Numbers of *Meloidogyne* larvae, averaging 17/100 cm^3 of soil over the 10 locations, showed a significant ($P = 0.05$) negative correlation with bean weight per plant, with $r = -0.678$. This was anticipated, in view of the significant correlations between galling and bean weight described previously. Other plant parasites were present at low numbers, with average counts of 5/100 cm^3 of soil for *Helicotylenchus* spp. and 12/100 cm^3 *Rotylenchulus* sp. Correlations between their counts and bean weight per plant were not significant, with $r = 0.035$ and $r = -0.070$, respectively.

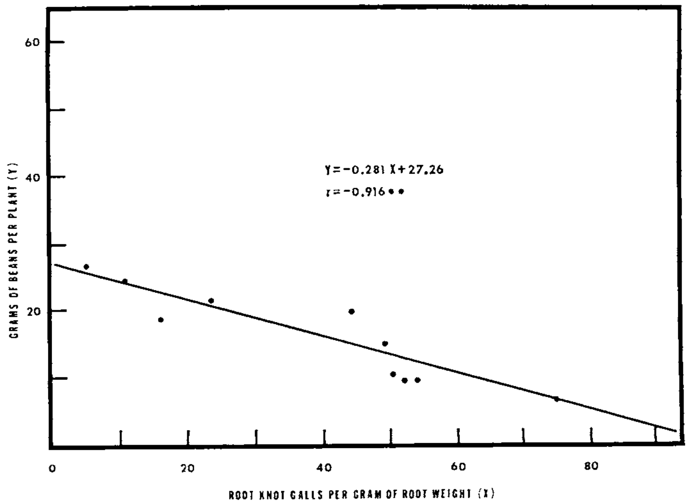

Fig. 1. Relationship between root galling from *Meloidogyne incognita* and bean yield per plant.

The relationship between final nematode numbers and yield (Fig. 1) has a shape similar to the general relationship proposed by Oostenbrink (11), with the exception that the x-axis here is linear instead of logarithmic (logarithmic transformation gave similar results here). The existence of such a relationship in the field indicates that it may be possible in the future to make treatment decisions for *M. incognita* on snap beans based on population levels in an IPM context. However, predictive relationships between preplant populations, initial populations, and final populations of *Meloidogyne* spp. must first be developed, a procedure which has been hampered by the lack of methodology to reliably detect *Meloidogyne* populations in fallow soil (9). Development of relationships parallel to Fig. 1 covering a variety of experimental conditions, such as different soil types, cultivars, etc., is also necessary.

R. reniformis and bean yield. An inverse relationship between bean yield and nematode numbers parallel to Fig. 1 has also been established for *R. reniformis* (8). In addition, efficacy of the oxamyl drench and foliar spray in controlling *R. reniformis* has been demonstrated (8). However, the 18 paired treated and untreated plots in this experiment provided the opportunity to compare yield increases resulting from treating plots having a wide range in population levels. Each of the 18 pairs of rows consist of a high population (P_{max}) and a low population (P_{min}) of *R. reniformis*. In general, P_{min} also represented the population in the treated row of the pair, with the exception of one case in which the population in the treated row was higher than that in the untreated row of the pair. Yield differences (YD) between the rows of each pair can be calculated, such that $YD = Y_1 - Y_2$, where Y_1 = Yield at P_{min} and Y_2 = yield at P_{max}. These yield differences, expressed as a percent of Y_1 (% YD), are significantly ($P = 0.05$) correlated with P_{max} ($r = 0.482$), and are related by the regression equation $\%\ YD = 0.0283\ P_{max} - 4.319$ (Fig. 2). Although too general for predictive purposes, some interesting observations can be made from this relationship. The yield differences essentially represent crop loss at a given population level or yield increases anticipated when oxamyl was used in plots having that population level (Fig. 2). Positive yield differences are most readily apparent at *R. reniformis* populations of more than 400/100 cm^3 of soil. With lower populations of *R. reniformis*, use of the nematicide may or may not be accompanied by a positive yield response. When low populations were treated and further reduced, the treated rows yield less than the untreated rows almost as often as the reverse is true. The implication is that these populations are below levels sufficient to cause significant plant damage, and hence nematicide treatment is unwarranted. Thus it is possible that oxamyl could be applied on an as-needed IPM basis in the future.

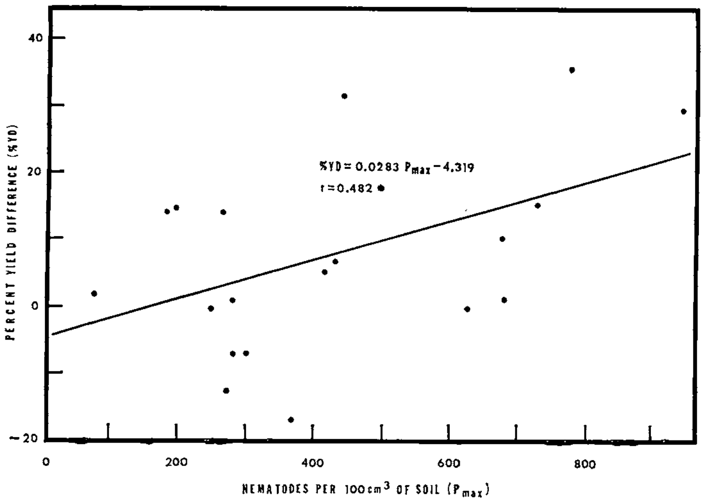

Fig. 2. Percent yield differences in 18 paired plots compared to maximum *Rotylenchulus reniformis* populations in each pair.

Meloidogyne-tolerant cultivars. Cultivars resistant or tolerant to *Meloidogyne* spp. may be an alternative or an addition to chemical control, and a number of these are currently available (14). The 4 tolerant cultivars tested here showed significantly less galling from *M. incognita* than did the susceptible 'Harvester' (Table 1). However, nematode reproduction was similar on all cultivars, as shown by the egg mass indices. While these cultivars may reduce galling, populations of *M. incognita* would not necessarily be reduced by their use, and precautions may have to be taken when growing susceptible crops on the site in the future. Yields of the tolerant cultivars were comparable to or surpassed 'Harvester' in this small test (Table 1), although more extensive agronomic testing of this aspect would be desirable.

In summary, promising control measures exist for two of the most damaging nematodes on snap beans in south Florida. Combination of a soil drench and foliar spray of oxamyl is effective for *R. reniformis* and tolerant cultivars may minimize damage from *M. incognita*. However, the damage caused by each of these nematodes is related to their population levels, with damage being anticipated only at high populations. For this reason, it may be possible in the future to make treatment decisions about these nematodes in an IPM context.

Table 1. Comparison of yields, galling and egg mass indices of *Meloidogyne incognita* on roots of five snap bean cultivars.

Cultivar	Galling index[z]	Egg mass index[z]	Number of beans per 8 plants[z]	Weight of beans (g) per 8 plants
Harvester	1.56b	1.81a	43.2b	238.0a
G698	0.25a	1.42a	41.8ab	296.8b
G699	0.21a	1.52a	35.5a	258.3ab
G700	0.02a	1.04a	35.2a	216.8a
G701	0.29a	1.69a	36.0a	247.8a

[z]Mean of six replications. Means in columns followed by the same letter were not significantly (P = 0.05) different, according to Duncan's New Multiple Range Test.

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