EFFECTS OF MELOIDOGYNE INCOGNITA ON COTTON AND COWPEAS IN ROTATION

L. W. Duncan and H. Ferris
Graduate Research Assistant and Associate Nematologist
Department of Nematology
University of California
Riverside, CA 92521

Abstract

In small-plot field studies, cotton yield was inversely related to initial population levels of *Meloidogyne incognita*. A tolerance limit of 21 juveniles and eggs/1000 g soil is estimated and maximum yield reduction was 34%. Cowpea yields, in a similar study, indicated greater tolerance to *M. incognita*. Yield reduction did not occur at initial population levels below 249 juveniles and eggs/1000 g soil and maximum reduction at high nematode densities was 12%. Nematode reproduction on cowpea in plots with low initial population levels was 6% of that on cotton. Population densities of *Cyperus esculentus* and *Paratrichodorus minor* were in direct proportion to those of *M. incognita*. Covariation of these organisms and *Fusarium oxysporum* f. sp. *vasinfectum* with *M. incognita* may allow simplification of yield forecasting methods.

Introduction

Susceptibility of Acala cotton varieties (*Gossypium hirsutum*) to infection by only one root-knot nematode species, *Meloidogyne incognita* (Kofoid and White 1919) Chitwood 1949, has prompted pest management recommendations in the San Joaquin Valley of California for the use of cowpeas (*Vigna sinensis* L.) as a resistant rotation crop. The cowpea variety Blackeye 5 is well suited for this purpose because although it is susceptible to infection by *M. javanica* (Treub 1885) Chitwood 1949, it supports only limited reproduction by *M. incognita* (6,20). In greenhouse experiments, growth reduction caused by *M. incognita* was slight (6). Thus, in rotation, cotton does not allow reproduction of *M. javanica*, a serious pathogen on Blackeye 5, while the cowpea variety reduces population levels of the cotton pathogen, *M. incognita*. A third nematode species *Paratrichodorus minor* (Colbran) Siddiqi is a frequent associate of *M. incognita* in cotton fields with light-textured soils (16,21). While *P. minor* has been demonstrated to reduce growth of greenhouse-grown cotton plants (1), results are variable (12,13) and field observations of growth or yield reduction have not been reported.

The studies reported herein were conducted in cotton and cowpea fields naturally infested with *M. incognita* and *P. minor*. The objectives were: i) to determine growth effects by *M. incognita* and *P. minor* on cotton and cowpea varieties commonly grown in the San Joaquin Valley; ii) to validate a mathematical model of host damage by two nematode species (5) using field data; and iii) to quantify the influence of each host crop on nematode population development under field conditions.

Methods

Experimental plots 3 m long and four rows wide (96.5 cm centers) were established near Bakersfield (cotton cv. Acala SJ2) and Pixley (cowpea cv. Blackeye 5), California, which had suitably high populations of *M. incognita* and *P. minor*. Seventy-five and 60 plots were established in the cotton and cowpea fields, respectively. Soil texture in both fields was sandy loam.

Preplant nematode population densities (P_i) in each cotton plot were determined by sampling to a depth of 30 cm on March 31, seven days prior to planting. Two samples of 12 randomly collected soil cores (2.5 cm diam) were obtained from each plot. Cowpea plots were sampled in the same manner, two days post-plant, on May 16. Samples were extracted using a semi-automatic elutriator (3,4) and plant-parasitic nematodes counted and identified with the aid of a dissecting microscope. Sample counts were adjusted to reflect a 20% extraction efficiency. Final population levels (P_f) were determined in the same manner within one week following harvest. Species identification was based on microscopic examination of 10-15 females of each genus, or perineal patterns in the case of *M. incognita* which were collected from midseason host plants.

Both crops were grown to maturity. The cotton plots were hand picked on October 10, and cowpea plots were cut on August 1 and threshed on August 11 with a small-plot belt thresher. Dry lint and seed weight per plot were yield parameters in the cotton and cowpea studies, respectively.

Effects of *M. incognita* on host growth were determined by regressing yield against nematode P_i levels according to Seinhorst's model $y=m+(1-m)z^{P-T}$ if $P \geq T$ and $y=1.0$ if $P<T$ (17). The model expresses yield (y) of a given plot as a proportion of the average yield in uninfested plots. It recognizes that plants appear to compensate for nematode damage so that growth reduction is not observed below a tolerance threshold (T), a P_i level which is specific for each host-nematode-environmental system. The model assumes that a minimum yield proportion (m) may exist, below which damage does not occur, regardless of nematode P_i levels. The remaining proportion (1-m) is subject to the effects of nematode parasitism described by the term z^{P-T}. As population (P) levels increase, the proportion of undamaged root tissue declines. The parameter z is defined as the proportion of root undamaged after parasitism by one nematode. Since $z<1.0$, the factor z decreases with increasing P_i above T. The rate of decrease also declines with increasing P_i, reflecting declining influence per nematode at higher densities. Best-fit parameter estimates for given data sets of y and P_i result in sigmoid shaped curves with negative slope and clearly defined T and m values (9). In the present study, variation in fit of the model to the data, due to sample error and plot heterogeneity, was reduced by pooling data from plots with closely similar P_i levels before regressing average y values against average P_i values for each group of pooled data. Data were pooled by grouping plots with $\log_2 P_i$ values which occurred within the same unit values, i.e., $0<\log_2 P_i \leq 1$, $1<\log_2 P_i \leq 2$, etc. (8).

A model of host damage by two nematode species (5) was also fitted to yield data to determine if additional yield variation could be explained by *P. minor* P_i levels. The model, $y=m'+(1-m')c'z_1^{P_1}z_2^{P_2}$ for $y \leq 1.0$, and $y=1.0$ for $y>1.0$, is a modification of Seinhorst's model which extends the original assumptions to include effects of a second species. The minimum yield term $(m'=m_1+(m_2-m_1)(1-y_2)/[(1-y_1)+(1-y_2)])$ reflects competition between nematode species based on population levels and virulence. The tolerance capacity in the model $(c'=(z_1^{-T_1}+z_2^{-T_2})/2)$ is an average of the tolerance capacity of the host to the individual species. Coefficients of determination obtained from the two-species model were compared with those of the Seinhorst model to determine whether model predictions based on two nematode species provided significant improvement over predictions based on *M. incognita* alone.

Yellow nutsedge (*Cyperus esculentus* L.) distributions became apparent shortly after cotton emergence and population densities occurred roughly in proportion to those of *M. incognita*. On May 20 a visual estimate of nutsedge densities was made using a 0-4 scale in which unit values represented an approximate twofold density increase.

On July 8, September 1 and September 19-20 measurement of stomatal conductance was made of plants in selected cotton plots using a Licor 1600 Steady-state Porometer. July measurements were made one day post-irrigation, and September measurements were begun one week following the final irrigation. Measurements were taken between 1200 and 1500 hr to minimize temperature and humidity changes during data collection. To further minimize effects of environmental variation, one reading per plot was taken sequentially in each of the plots and the process was repeated in identical order for additional replications. Two, three and eight replications/plot were made on July 8, September 1 and September 19-20, respectively. Measurements were taken from the lower portion of the blade of the third youngest (fully expanded) leaf on plants randomly selected in each plot. Data within each blocked set were expressed in relative terms as proportions of the highest reading per set, and the average proportion for each plot was regressed against *M. incognita* P_i level according to the model described previously.

Results and Discussion

Regression of cotton weight against P_i *M. incognita* (9) resulted in Seinhorst model parameter values of $T=27$, $m=0.66$ and $z=0.995$. The model accounted for 35% ($p=.01$) of the yield variation between individual plots, and 97% ($p=.01$) of the variation between yield data pooled for common P_i (Fig. 1). Regression of cowpea seed weight against P_i *M. incognita* accounted for 56% ($p=.01$) of the yield variation between plots and 99% ($p=.01$) of the variation between pooled yield data (Fig. 1). Seinhorst model parameter values for cowpea data were $T=249$, $m=0.88$ and $z=0.996$.

Final population levels of *M. incognita* were higher in the cotton than in the cowpea plots (Fig. 2). In plots with low P_i levels, harvest populations (P_f) of *M. incognita* on Blackeye 5 cowpea were approximately 6% of those on SJ2 cotton. High P_i level plots, which have lower rates of reproduction due to resource competition, barely maintained original population levels in Blackeye 5 (ca 3000 juveniles and eggs/1000 g soil) while increasing significantly in SJ2 (ca 30,000 juveniles and eggs/1000 g soil).

Host-parasite relationships confirm that use of cotton and Blackeye 5 cowpea in rotation may be a practical method to manage populations of *M. incognita*. The tolerance limit in SJ2 was only 10% of T for Blackeye 5, and yields of SJ2 plots were suppressed up to one third compared to 12% in Blackeye 5. Further, overwinter mortality rates of 97% (an estimate derived by dividing average P_i by average P_f levels in cotton) would result in average P_i levels in cowpea plots which are 7% those in cotton plots. Thus, P_i levels in cowpea plots would, on average, be 53 juveniles and eggs/1000 g soil following the overwinter period. For cotton following cowpea, this P_i level corresponds to 0.96 relative yield (Fig. 1). In contrast, projected average P_i values in cotton plots following the overwinter period are 722 juveniles and eggs/1000 g soil, representing 0.67 relative cotton yield. The utility of such projections in a nematode management program depends on specific conditions, including nematode P_i levels. Yield forecasts must be evaluated in terms of projected costs and values of the two crops and costs of pest management alternatives such as soil fumigation.

The cotton tolerance threshold noted in this study is similar to T values noted in previous studies in the San Joaquin and Coachella Valleys of California (Howard Ferris, Philip Roberts, personal communication). The present damage curve is steeper than those noted previously, however, and may be due to covariance of *M. incognita* with other diseases and pests in this field. Particularly noteworthy were the presence of yellow nutsedge and the wilt fungus *Fusarium oxysporum* f. sp. *vasinfectum*. Despite the presence of these two organisms, which can seriously limit cotton development, the Seinhorst model based on *M. incognita* P_i levels adequately accounted for nearly all of the variation in pooled yield data. Distribution patterns of pathogen/pest populations may partly explain this observation.

Results of the nutsedge population survey (Fig. 3) suggest that weed densities tend to reflect historical patterns of nematode demography. Highest nutsedge densities occurred in plots with moderate to high nematode populations. Such plots may represent areas in which cotton plants were most heavily infected during the previous season, allowing maximum nutsedge development in response to less vigorous competition by cotton for light and nutrients. Decline of nematode populations due to intraspecific competition for host resources (and exacerbated by nutsedge competition) or an increase of density-dependent biotic control agents, could result in moderate nematode P_i levels during the current season. Plots with highest nematode P_i levels, by such reasoning, could be expected to contain moderate nutsedge populations resulting from nematode pressure on cotton during the previous season as nematode populations increased. These plots would be expected to contain the highest nutsedge populations at the beginning of the succeeding season. In such a system of covarying pests and pathogens, nematode effects on host growth could appear more virulent than in systems with adequate weed control.

Fusarium wilt, detected in some plots late in the season, may represent a further example of the results of co-specific parasitism interpreted in relation to just one pathogen. Although no quantitative estimate of *Fusarium* levels per plot was obtained, previous studies have shown that wilt incidence varies in proportion to root-knot nematode densities (10,14,22). Hollis (11) noted a highly significant correlation between severity of *Fusarium*-induced vascular discoloration and root galling caused by *M. incognita* during field surveys which included seven cotton varieties. In tomato, wilt severity caused by *F. oxysporum* f. sp. *lycopersici* increased directly with *M. incognita* population levels to a maximum level (18). Bergeson et al., (2) measured increased propagules of this fungus in tomato rhizospheres when root-knot nematodes were present. Such findings suggest that, providing host crops remain suitable for development of both species, significant information about *Fusarium* levels may be acquired through knowledge of nematode levels.

It is unclear whether nematode damage functions can be accurately defined in relation to background biotic agents (presence or absence of nutsedge or *Fusarium* wilt) in the same way that they may be defined in terms of specific edaphic and climatic conditions (7). The degree to which measurement of just one species is adequate to forecast host damage by additional, covarying species depends on the nature and strength of interactions between concomitant pathogen or pest populations. If both species compete directly for host resources, measurement of each population may be more important than when one species directly enhances the development of a second. For example, by enhancing weed and wilt development, root-knot nematode population levels are likely to more accurately reflect populations of *F. oxysporum* f. sp. *vasinfectum* or various weed competitors of cotton than to reflect population levels of a second nematode species with which it competes for host nutrients.

Mechanisms other than pest/pathogen interactions may result in population covariation of direct competitors for plant resources, however. Soil type is a primary factor influencing nematode population development and nematode-host interactions. *Meloidogyne* spp. and *Paratrichodorus* spp. are recognized pathogens primarily in lighter sandy soils (16,21). As niche requirements of species become more closely related, populations might be expected to covary to a greater degree, even as they compete for the same food source. Conditions which favor development of covarying species cannot remain static; eventually reduced food sources and/or the buildup of generalized predatory and parasitic natural control agents should sharply reduce population levels of both species. Conversely, reduced nematode levels may enhance nematode niche conditions if host growth increases and populations of natural control agents decline. In the present study, *P. minor* P_i levels in both fields were directly related to those of *M. incognita* (Fig. 4). Use of *P. minor* P_i levels to predict cotton and cowpea yield in the two-species model accounted for more yield variation than *M. incognita* P_i levels alone, however, results were not significant. Despite limited evidence of pathogenicity by *P. minor*, under experimental conditions, covariation of this parasitic species with those of *M. incognita* further supports the possibility of defining nematode damage functions in relation to key biotic as well as abiotic factors.

Predictably, nematode effects on stomatal conductance became more pronounced as soil water potential declined (Fig. 5). Soil moisture at depths of 30, 60 and 90 cm, respectively, was 17%, 12.5% and 10% on July 8, 14%, 11.5% and 9.5% on September 1 and 8.5%, 9.5% and 10% on September 19-20. Regression of stomatal conductance against P_i *M. incognita* resulted in the following Seinhorst model parameter values: July 8, $T=54$, $m=0.87$, $z=0.997$; September 1, $T=41$, $m=0.78$, $z=0.998$; September 19-20, $T=21$, $m=0.76$, $z=0.998$. Amount of explained variation between average conductance values/plot in ungrouped and pooled data, respectively was 17% ($P=.05$) and 36% ($p=.01$) on July 8, 10% ($p=.01$) and 85% ($p=.01$) on September 1 and 13% ($p=.01$) and 81% ($p=.01$) on September 19-20. Soil moisture is reflected by the position of each curve in Fig. 5. As moisture levels declined, tolerance levels to nematode infection were reduced and effects of P_i levels above T were enhanced. Reduced translocation by infected roots may be due to a combination of reduced feeder root volume, vascular disruption and tissue necrosis (15). These results support previous findings (15) that reduced transpiration of root-knot-infected cotton plants compared to control plants is enhanced when soil moisture levels fall below field capacity.

Unexplained variation of stomatal conductance was consistently and significantly greater than that of yield data. Use of P. minor P_i levels in the two-nematode species model accounted for a greater amount of variation at all three measurement dates than did use of M. incognita P_i levels alone. As with yield effects, no significant improvement of predictions using two species could be demonstrated, however. The utility of stomatal conductance measurements as a quantitative method depends on the precision with which experimental effects can be detected. In the present experiment, leaf damage by insects, disease agents and possibly senescence in plants with unthrifty growth made it difficult to standardize the experimental leaf tissue on randomly-chosen plants. Early-season data collection may help overcome this problem and reduce error variation. Preliminary experiments to optimize sample size and to determine tissues on plants of various developmental stages which provide the most accurate response to experimental effects will also increase the precision of these measurements.

References

1. Alhassan, S. A. and J. P. Hollis. 1966. Parasitism of Trichodorus christei on cotton seedlings. Phytopathology 56:573-574.

2. Bergeson, G. B., S. D. Van Gundy, and I. J. Thomason. 1970. Effect of Meloidogyne javanica on rhizosphere microflora and Fusarium wilt of tomato. Phytopathology 60:1245-1249.

3. Byrd, D. W., Jr., H. Ferris, and C. J. Nusbaum. 1972. A method for estimating numbers of eggs of Meloidogyne spp. in soil. J. Nematol. 4:266-269.

4. Byrd, D. W., Jr., K. R. Barker, H. Ferris, C. J. Nusbaum, W. E. Griffin, R. H. Small, and G. A. Stone. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. J. Nematol. 8:206-212.

5. Duncan, L. W. and H. Ferris. 1982. Interactions between phytophagous nematodes. Pp 29-51 in: D. W. Freckman (ed.) Nematodes in Soil Ecosystems. Univ. of Texas Press.

6. Duncan, L. W. and H. Ferris. 1983. Validation of a model for prediction of host damage by two nematode species. J. Nematol. (in press).

7. Ferris, H. 1982. Approaches to the assessment of crop losses due to nematodes. Proc. Beltwide Cotton Prod. Res. Conf. Pp. 16-19.

8. Ferris, H. Nematode Damage Functions: the problem of experimental and sampling error. (In preparation).

9. Ferris, H., W. D. Turner, and L. W. Duncan. 1981. An algorithm for fitting Seinhorst curves to the relationship between plant growth and preplant nematode densities. J. Nematol. 13:300-304.

10. Garber, R. H., E. C. Jorgenson, S. Smith, and A. H. Hyer. 1979. Interaction of population levels of Fusarium oxysporum f. sp. vasinfectum and Meloidogyne incognita on cotton. J. Nematol. 11:133-137.

11. Hollis, J. P. 1958. Relations between root knot and Fusarium vascular discoloration in cotton varieties. Phytopathology 48:661-665.

12. Hollis, J. P. and W. J. Martin. 1960. Greenhouse pathogenicity trials with nematode-infested soil. Phytopathology 50:639-640. (Abstr.).

13. Martin, W. J., L. D. Newsom, and J. E. Jones. 1956. Relationship of nematodes to the development of Fusarium wilt in cotton. Phytopathology 46:285-289.

14. McGuire, J. M., H. J. Walters, and D. A. Slack. 1958. The relationship of root-knot nematodes to the development of Fusarium wilt in alfalfa. Phytopathology 48:344 (Abstr.).

15. O'Bannon, J. H. and H. W. Reynolds. 1965. Water consumption and growth of root-knot nematode infected and uninfected cotton plants. Soil Sci. 99:251-255.

16. O'Bannon, J. H. and H. W. Reynolds. 1961. Root-knot nematode damage and cotton yields in relation to certain soil properties. Soil Sci. 92:384-386.

17. Seinhorst, J. W. 1965. The relationship between nematode density and damage to plants. Nematologica 11:137-154.

18. Sidhu, G. S. and J. M. Webster. 1981. Influence of population levels of root-knot nematode on Fusarium wilt severity of tomato. Phytoprotection 62:61-66.

19. Thomason, I. J., D. C. Erwin, and M. J. Garber. 1959. The relationship of the root-knot nematode, Meloidogyne javanica, to Fusarium wilt of cowpea. Phytopathology 49:602-606.

20. Thomason, I. J. and H. E. McKinney. 1960. Reaction of cowpeas, Vigna sinensis, to root-knot nematodes, Meloidogyne spp. Pl. Dis. Reptr. 44:51-53.

21. Winfield, A. L. and D. A. Cooke. 1975. The ecology of Trichodorus. Pp 309-342 in: F. Lamberti, C. E. Taylor, and J. W. Seinhorst (eds.). Nematode Vectors of Plant Viruses. Plenum Press, London and New York.

22. Yang, H. K., N. T. Powell, and K. R. Barker. 1976. Interactions of concomitant species of root-knot nematodes and Fusarium oxysporum f. sp. vasinfectum on cotton. J. Nematol. 8:74-80.

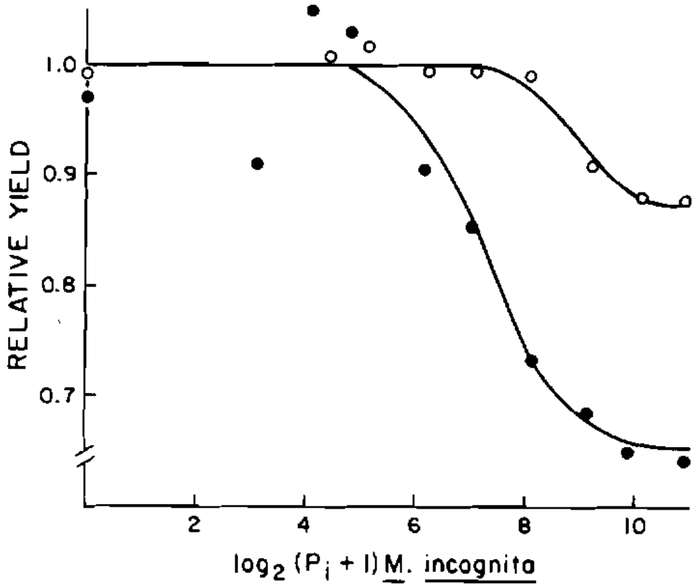

Figure 1. Relationships between initial population density of Meloidogyne incognita and relative yield of Gossypium hirsutum (Acala SJ2) (●) and Vigna sinensis (Blackeye 5) (○).

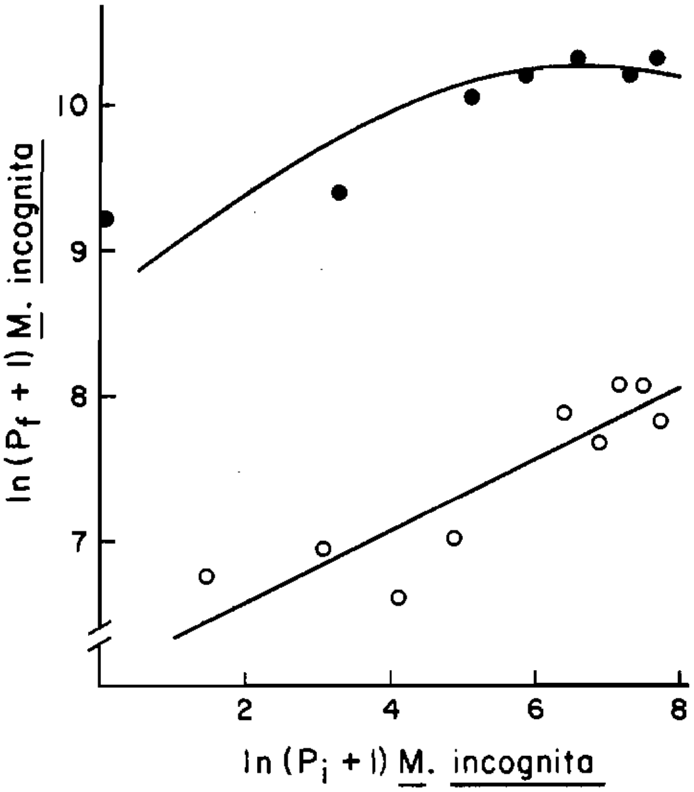

Figure 2. Relationship of final to initial population levels of *Meloidogyne incognita* on cotton (Acala SJ2) (●) and cowpea (Blackeye 5) (o).

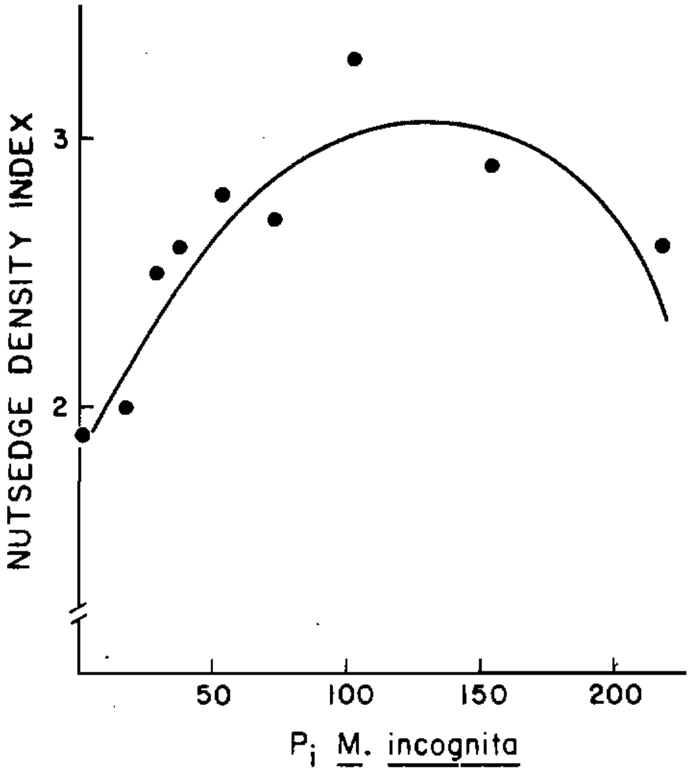

Figure 3. Relationship between initial population density of *Meloidogyne incognita* and plant density of *Cyperus esculentus* in seven-week-old cotton.

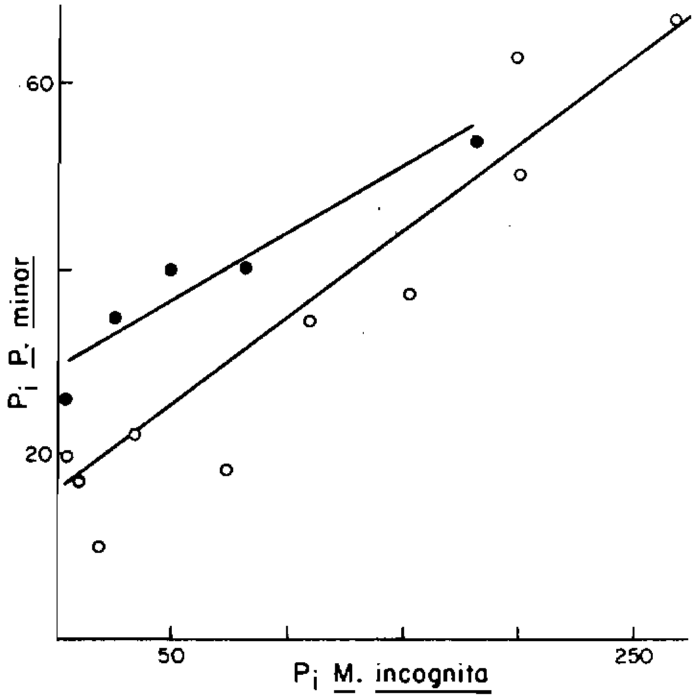

Figure 4. Covariation of *Meloidogyne incognita* and *Paratrichodorus minor* initial population levels in cotton (●) and cowpea (o) fields previously planted with cotton (Acala SJ2).

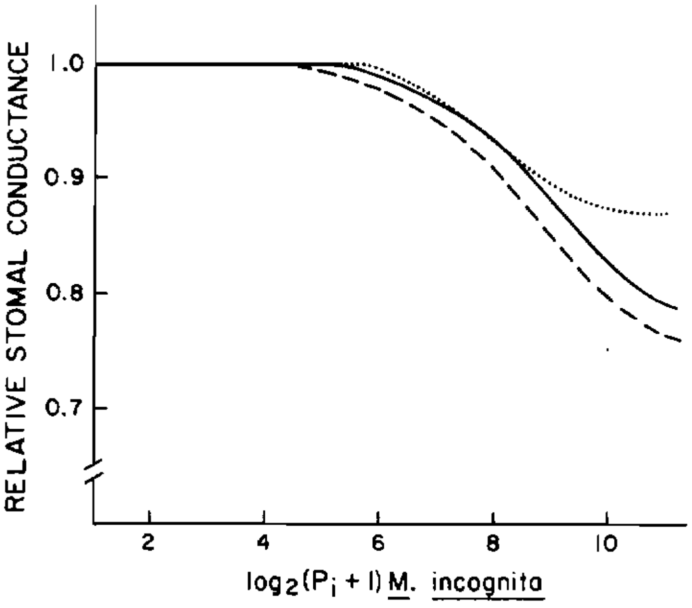

Figure 5. Relationship between initial population level of *Meloidogyne incognita* and relative stomatal conductance of *Gossypium hirsutum* (Acala SJ2) on July 8 (dotted line), Sept 1 (solid line) and Sept 19-20 (dashed line).