EFFECTS OF MELODIYOGNE INCognita
ON COTTON AND COWPEAS IN ROTATION

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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 2%. Nematode reproduction on cowpea in plots with low initial population levels was 6% of that on cotton.

Population densities of Cystoscyclus exscolentus and Paratrichodorus variabilis 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) Chittwood 1949, has prompted pest management recommendations in the San Joaquin Valley of California for the use of cowpeas. C. 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) Chittwood 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 as it does in monoculture (2). Cowpea Variety reduces population levels of the cotton pathogen, M. incognita. A third nematode species, Paratrichodorus minor (Colman) Siddiqui is a frequent associate of M. javanica in 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 in the San Joaquin Valley. The objectives were: i) to determine the growth reduction caused by M. incognita and P. minor on cotton and cowpea varieties commonly grown in the San Joaquin Valley; ii) to validate a mathematical model for yield reduction by two nematode species (5) using field data; and iii) to quantify the influence of the 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 82J) and Pluma Valley (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 (P1) in each cotton plot were determined by sampling to a depth of 30 cm on plots in each of the two varieties by using 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-planting, on both the first and the third oldest leaves. Sample counts were adjusted to reflect a 20% extraction efficiency. Final population levels (Pf) 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 parasitic nema5es 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-scale belt thrasher. 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 P1 levels according to the model Y = y1 + y2P1 + y3P12 + y4P13 + y5P14 + y6P15 + y7P16 + y8P17 (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 P1 level which is specific for each host-nematode-environmental system. The model assumes that a maximum yield proportion (m) may exist, below which damage does not occur, regardless of nematode P1 levels. The remaining proportion (1-m) is subject to the effects of nematode parasitism described by the term y-P1. As population (P) levels increase, the proportion of undamaged, healthy cotton is weighted more heavily and reflects the declining influence per nematode at higher densities. Best-fit parameter estimates for given data sets of y and P1 result in sigmoid shaped curves with negative slopes 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 P1 levels before regressing average y values against average P1 values for each group of pooled data. Data were pooled by grouping plots with log2P1 values which occurred within the same unit values, i.e., 0-10, 1-10, 10-100. Data were fitted to yield data to determine if additional yield variation could be explained by P. minor P1 levels in the same model. The model was also fitted to cotton and cowpea yield data with those of the second nematode species, P. minor, 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-P1=y1+1-y1/T1) reflects competition between nematode species based on population levels and virulence. The tolerance capacity in the model (c=2y1+2y2+2y3)/2 is an average of the tolerance capacities of the two nematode 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 provide 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 where 1 unit value represented an approximate twofold density increase.

On July 8, September 1 and September 19-20 measurements were taken of the two 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 spaced 7 cm between the 120 cm of 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 three measurements in order for additional replications. Two, three and eight replications/plot were made on July 8, September 1 and September 19-20, respectively. Measurements were made twice to ensure the third youngest (fully expanded) leaf on plants randomly selected in each plot. Data within each block 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 Pf level according to the model described previously.
Results and Discussion

Regression of cotton weight against P. m. incognita (Fig. 1) showed significantly higher yields at 4.59 g
per plant in SJ2 cotton compared to 2.53 g per plant on SJJ cotton. The yield advantage was
significantly higher in SJ2 cotton and the difference was 2.06 g per plant (p<0.01). In previous studies,
Hollis (1) noted a highly significant correlation between severity of Fusarium-induced vascular
discoloration and root galling caused by P. m. incognita in a field sample. Such correlation between
nematode seed-spread and tomato wilt severity caused by P. oxysporum f. sp. lycopersici increased directly
with P. m. incognita population (Table 1). However, this picture was not universal. In tomato, wilt severity caused by P. oxysporum f. sp. lycopersici increased directly with tomato seed infection (Fig. 2).

Final population levels of A.ifestyles were higher in the cotton than in the cowpea plots (Fig. 2). In plots with
nematode levels, nematode densities significantly lower (p<0.01) of P. m. incognita on Blackeye 5 compared to those on SJJ cotton. High Pj level plots, which have lower rates of reproduction due to resource competition, rarely maintained original population levels in Blackeye 5 (ca 3000 juveniles and eggs/1000 g soil) while increasing significantly in SJJ (ca 30,000 juveniles and eggs/1000 g soil). Population levels of A. lifestyles were higher in the cotton than in the cowpea plots (Fig. 2). In plots with nematode levels, nematode densities significantly lower (p<0.01) of P. m. incognita on Blackeye 5 compared to those on SJJ cotton. High Pj level plots, which have lower rates of reproduction due to resource competition, rarely maintained original population levels in Blackeye 5 (ca 3000 juveniles and eggs/1000 g soil) while increasing significantly in SJJ (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 P. m. incognita. The tolerance limit in SJJ was only 10% of T for Blackeye 5, and yields of SJJ plots were suppressed up to one third compared to Blackeye 5. In SJ2 plots, overwintering mortality rates of 97% (an estimate derived by dividing average Pj by average Pj levels in cotton) would result in average Pj levels in cowpea plots almost the same as in P. m. incognita plots. In SJ2 plots, cowpea plots could, on average, be 53 juveniles and eggs/1000 g soil following the overwinter period. For cotton following cowpea, this would result in 97% of Pj levels alone; however, results 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 virulence of P. m. incognita with other diseases and pests in this field. Particularly noteworthy were the presence of yellow rust and 1-Cosmos sulfur (Fig. 3). Despite the presence of these two organisms, which can seriously limit cotton development, the nematode population model based on P. m. incognita Pj levels adequately accounted for the nematode levels in pooled yield data. Distribution patterns of pathogen/host 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 infested during the previous season, allowing maximum nutsedge development in response to less vigorous competition by cotton for root resources. 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 Pj levels during the current season. Plots with highest nematode Pj levels, by such reasoning, could be expected to contain moderate nutsedge populations resulting from nematode pressure on cotton during the previous season. The nutsedge population levels in these plots would be expected to contain the highest nutsedge populations at the beginning of the succeeding season. In such a system of coexisting pests and pathogens, nematode levels on hosts would be 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-gall density (4). Blackeye 5 developed root-knot disease under well-watered conditions. Hight levels of F. oxysporum f. sp. lycopersici increased directly with P. m. incognita population, while increasing significantly in SJ2 cotton, but significantly reduced due to competition by cotton for light and development space (17). Growth of SJ2 cotton was significantly reduced due to competition by cotton for light and development space (17). Growth of SJ2 cotton was significantly reduced due to competition by cotton for light and development space (17). Growth of SJ2 cotton was significantly reduced due to competition by cotton for light and development space (17).

It is unclear whether nematode damage functions can be accurately defined in relation to background biotic agents (presence or absence of surface water 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 pathogen hazards. 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 the other. For crops with a second root-knot nematode, root-knot nematode population levels are likely to more accurately reflect population of competing species or various competitors of cotton than to reflect population levels of a second nematode species with which it competes for host nutrients.

Mechanisms other than pathogen/pathogen interactions may result in population covariation of direct competitors for host resources. Hypothetical models linking specific functional responses in relation to key biotic agents (7) 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 interactions if host growth increases and populations of natural control agents decline. In the present study, P. minor Pj levels were significantly lower in both fine sandy loam plots than in plots with moderate to high nematode levels alone, however, results were not significant. Despite limited evidence of pathogenecity by P. minor, under conditions for experimental manipulation of this parasitic species with those of P. m. incognita further supports the possibility of defining nematode damage functions in relation to key biotic as well as abiotic factors.
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; 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; 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 unthriftv 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

Figure 2. Relationship of final to initial population levels of *Meloidogyne incognita* on cotton (Acala 552) (●) and cowpea (Blackeye 5) (○).

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 (○) fields previously planted with cotton (Acala 552).

Figure 5. Relationship between initial population level of *Meloidogyne incognita* and relative stomatal conductance of *Daucus carota* (solid line) and *Lycopersicon esculentum* (dashed line).