Multiyear Population Dynamics of *Ditylenchus dipsaci* Associated with *Phlox subulata*[1]

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Abstract: Field population densities of *Ditylenchus dipsaci* associated with shoot tissue of *Phlox subulata* were monitored during two consecutive growing seasons and intervening periods of overwintering and plant storage. The population density increased significantly through four peaks during the first growing season, and decreased significantly during storage at 5–7 C or overwintering in the field. During the second growing season, there was only a single increase to a moderate population density, followed by a severe population decline associated with the poor physiological condition of the host. A simple model is proposed to explain the population dynamics of *D. dipsaci* during the first growing season. *Key Words:* ground phlox, moss pink, Michigan.

Biological races of the bulb and stem nematode *Ditylenchus dipsaci* (Kuhn, 1857) Filipjev, 1937, parasitize a wide range of plant species (6). Infestations associated with phlox were reported in 1898 (5). High population densities of *D. dipsaci* were found associated with commercial plantings of *Phlox subulata* (ground phlox or moss-pink) in southwestern Michigan in 1975. This study follows multiyear population dynamics of *D. dipsaci* associated with *P. subulata* and considers the impact of population changes on control procedures.

Received for publication 30 October 1979.

[1]Michigan State University Agricultural Experiment Station Journal Article No. 9213. Research conducted as part of a M.S. thesis by the senior author. Sincere appreciation is expressed to the phlox growers of southwestern Michigan for support of this project.

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MATERIALS AND METHODS

The experimental area was planted to ground phlox in 1973 and 1974 and fallowed in 1975. Commercial nursery divisions of stock plants of *P. subulata* (cv Emerald Pink) were planted 12 April 1976 in sandy loam soil (pH 6.4) in six 9.1-m rows with a two-row mechanical planter. The plants were spaced 15 cm in the row with the rows 0.6 m apart in soil prepared to seed-bed condition. The divisions had about 15–20 cm of shoot tissue and 5–8 cm of root tissue. The plants were not irrigated, fertilized, or treated with pesticides during the 2-yr test period. The plot was hand weeded when necessary. Air temperature was monitored, and nematode population dynamics are reported in relation to degree-days calculated by the Baskerville-Emin (1) method for a base of 10 C (DD_{10}).

Shoot tissue samples were collected at random from each plot biweekly during the growing season in 1976 and monthly in 1977. Using the shaker technique, nematodes were extracted from 1.0 g shoot tissue for 48 hours at 125 rpm and collected on a sieve with 38-μm openings (2). Collected nematodes were stored in water in test tubes at 5–7 C and counted within 2 weeks.

In October 1976, 10 plants from each replicate were removed from the field and stored in closed plastic bags at 5–7 C from October to May 1977. Entire plants and associated soil were included. While following the commercial practices of refrigerating stock plants for the winter, bimonthly samples of the shoot tissue were taken and nematodes were extracted as described above. In May 1977, propagation of these stored plants in the field failed because of the poor physiological condition of the plants and a very hot and dry spring.

RESULTS

First growing season: The initial nematode population density in the transplanted ground phlox was 23 *D. dipsaci*/g shoot tissue (Fig. 1). After 100 DD_{10} (2 weeks) the population increased to 133/g shoot tissue. During the next 4 weeks there was a gradual decline in population density to 49 *D. dipsaci*/g shoot tissue. The second population peak (388 *D. dipsaci*/g) occurred at 600 DD_{10} (10th week), and the third population peak (895 *D. dipsaci*/g) at 800 DD_{10} (14th week). During the next 2 weeks the population density declined. This was followed by a fourth population density peak (995 *D. dipsaci*/g) at 1,200 DD_{10} (September). Population behavior was not monitored further in 1976. Regression analysis showed a positive linear relationship (P = 0.05) between *D. dipsaci* population density and time (Y = 0.7701X – 145.7; r^2 = 0.8069). In the presence of *D. dipsaci*, growth of *P. subulata* was severely stunted compared with similar plants treated with aldicarb. The infected plants had conspicuous patches of necrotic tissue and an abnormally high mortality rate.

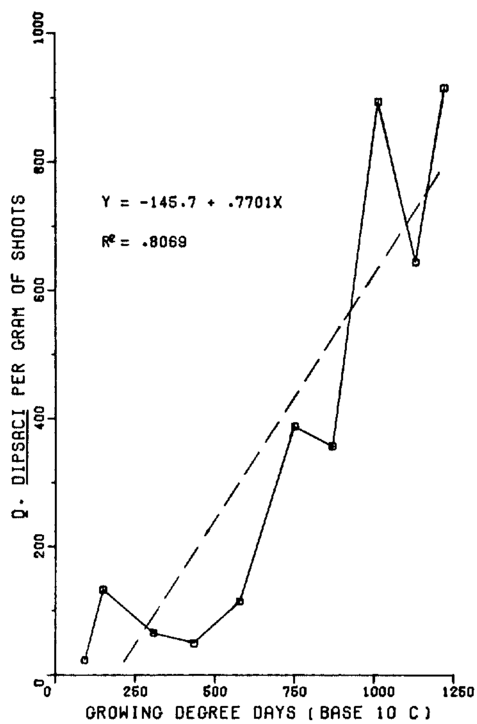

FIG. 1. Population dynamics of *Ditylenchus dipsaci* in shoot tissue of *Phlox subulata* (cv Emerald Pink) during the first growing season.

Storage: By January 1977, *D. dipsaci*-infected plants stored at 5–7 C began to deteriorate and nematode population densities declined to 306 *D. dipsaci*/g shoot tissue (Fig. 2). In March the population density was 19 *D. dipsaci*/g, followed in April by an increase to 80/g of shoot tissue.

Second growing season: P. subulata overwintering in the field had an initial 1977 population density of 4 *D. dipsaci*/g shoot tissue (Fig. 3). As the growing season progressed, the population density reached the 1977 maximum of 247 *D. dipsaci*/g shoot tissue at 550 DD_{10} (June). In the following months there was an oscillating decline in population density to 5 *D. dipsaci*/g shoot tissue at 1550 DD_{10} (October).

DISCUSSION

Multiseason population dynamics: The population dynamics of *D. dipsaci* associated with *P. subulata* appear to depend on the physiological condition of the host and can vary widely from one growing season to

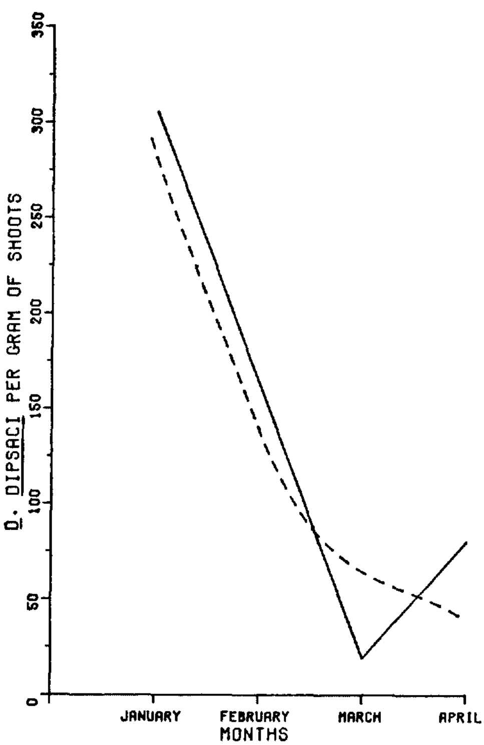

FIG. 2. Population dynamics of *Ditylenchus dipsaci* in shoot tissue of *Phlox subulata* (cv Emerald Pink) during winter storage at 5–7 C.

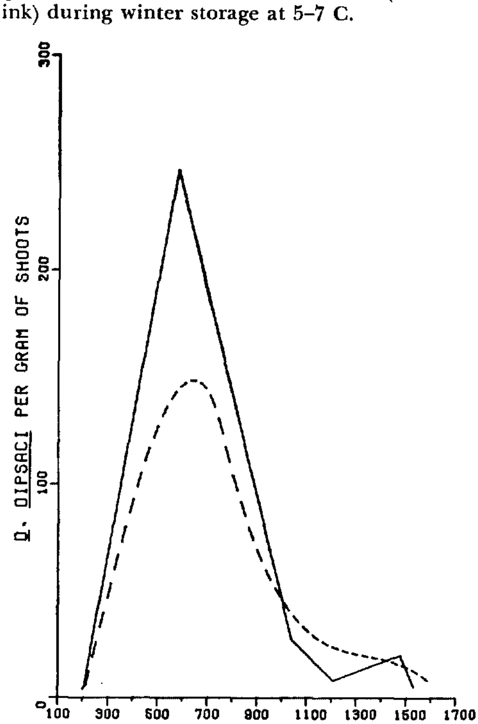

FIG. 3. Population dynamics of *Ditylenchus dipsaci* in shoot tissue of *Phlox subulata* (cv Emerald Pink) during the second growing season.

another. Nematode population growth in 1976 was an example of the potential of *D. dipsaci* to increase on actively growing shoot tissue of *P. subulata*. The nematode damaged the host physiologically, and, after overwintering in the field, the host-parasite relationship was not suitable for a second season of continual population density increase by *D. dipsaci*. The final density of *D. dipsaci* after the 1977 population decrease was only 22% of the initial population density in 1976 and about the same as the initial population density in 1977.

Information about multiyear population dynamics of plant-parasitic nematodes is essential for proper interpretation of population densities and host-parasite relations. In both 1976 and 1977, population densities were 200 *D. dipsaci*/g shoot tissue at 500 DD_{10}. In 1976, *D. dipsaci* increased significantly after 500 DD_{10} and depressed the growth and development of the plant, and there was a distinct need for a procedure to manage the nematode population. In 1977, however, the slight increase after 500 DD_{10} was followed by a distinct population decline, so no management tactic could be justified at that time. This indicates that it is necessary to consider both the host physiology and the current state of the multiyear population dynamics of *D. dipsaci* associated with *P. subulata* during implementation of nematode control measures.

First growing season: The data for the first growing season show a significant coefficient of linear correlation between *D. dipsaci* population growth and time. Closer examination, however, shows negative deviations from the regression line from the 5th through the 13th weeks as compared with an oscillatory population behavior as the season progressed beyond the 13th week (Fig. 1). A more correct interpretation of the 1976 data may be that *D. dipsaci* reproduces continuously, giving rise to a nonlinear relation between population and time. If the assumption is made, as with linear regression analysis, that the rate of change of population density depends only on conditions at some specific time, not on the past history of the population, erroneous conclusions may be reached. Prediction of changes in population density requires a knowledge of the age structure of the population as well as a knowledge of the total numbers present. If, at that time, the bulk of the population is adult females, an increase in food supply will be reflected quickly in an increase in nematodes caused by egg laying. If, on the other hand, the bulk of the population is in the form of eggs, there will be a delay in population increase while the nematodes mature. This study did not record age structure, but certain inferences can be derived mathematically about the way the population should vary naturally under the effects of age structure (4).

A complete analysis of the behavior of a population with overlapping generations would allow for variation in fertility and mortality rates as they interact with age. A simplified case would be one in which adults and juvenile stages are assumed not to compete with one another for food or resources. Since *D. dipsaci* spends 65% of its juvenile stage in the egg (7), such an assumption may be valid for our study. The further assumption is made that the population is regulated by factors limiting adults, with food and resources for the young nematodes being present in excess. The rate of decrease or increase over time and the equilibrium density of the population can be hypothesized when assumptions and data have been supplied as to (i) the probability of adult individuals dying in a given time interval, (ii) the number of eggs laid by each adult (i.e., half the number laid by each female if there is a 1:1 sex ratio) in the interval, (iii) the probability that the egg survives to the adult stage, and (iv) the time taken from egg to adult (4). This corresponds to the population graph for 1976 (Fig. 4).

The oscillatory behavior of the population can be divided into seven periods. The oscillations in population density represent a delay of about two intervals (28 days), the time necessary for eggs to develop into adults. During period 1 (weeks 1–3) the increase in population is probably caused by maturation of eggs that have overwintered in the refrigerated phlox plants. In period 2 (weeks 3–7) the death rate exceeds the rate of population restoration. In period 3 (weeks 7–11) the population increases as eggs laid during period 2 hatch. During period 4 (weeks 11–13) there is a slight de-

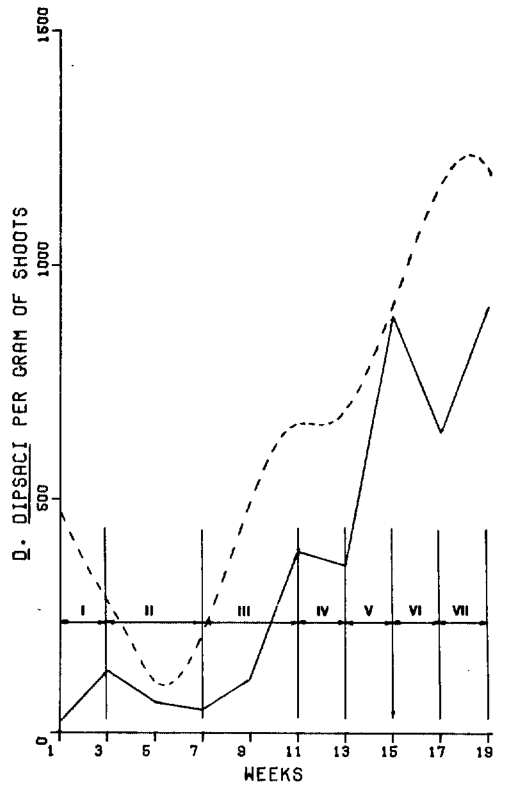

FIG. 4. Predicted (------) and actual (———) population dynamics of *Ditylenchus dipsaci* per gram shoot tissue of *Phlox subulata* (cv Emerald Pink) in 1976.

crease, possibly because the adult population for weeks 5–7 was very small and therefor few eggs were laid that would hatch during this period. In period 5 (weeks 13–15) there is a renewed increase in adult population density. In period 6 (weeks 15–17) there is a slight decrease, possibly from the small adult population during period 4. During period 7 (weeks 17–19) there is a renewed increase in the population density of adults. In subsequent unmonitored time intervals, the population density declined and few eggs were deposited.

This uncomplicated model of population behavior provides an approximate picture of the effects of various factors on the behavior of the population. Even though age classes were not recorded in our experiment, the changes we found in the natural populations of *D. dipsaci* follow the model rather well. The data from this experiment do fit the model when age structure is taken into account. In general, both fertility and mortality (not fertility alone, as assumed in the model) are likely to be a function of age, population density at that time, and many other factors (3). To predict the behavior of such a population, the effects of age, density, and other relevant factors on fertility and mortality must be known. This requires that data be taken for numbers of live nematodes in different age classes at given times.

Second growing season: Field survival of phlox plants infected with *D. dipsaci* was low. In some instances, only 10–12 plants remained alive in a 9.1-m row. These surviving plants showed little growth the second season and were about one-third the size of plants treated with aldicarb. Survival declined further in the summer months, when no supplemental irrigation was given. The data from 1977 fluctuate widely over the course of the growing season. The population density of *D. dipsaci* increased early in the second season as nematodes matured from eggs overwintered in field plants. This large population was not sustained because the phlox plants were in such poor physiological condition.

LITERATURE CITED

1. Baskerville, G. L., and P. Emin. 1969. Rapid estimation of heat accumulation from maximum and minimum temperatures. Ecology 50:514-17.

2. Bird, G. W. 1971. Influence of incubation solution on the rate of recovery of Pratylenchus brachyrus from cotton roots. J. Nematol. 3:378-385.

3. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Reptr. 48:692-694.

4. Smith, J. M. 1974. Mathematical ideas in biology. Cambridge University Press, London.

5. Steiner, G., and F. B. Dodge. 1929. The bulb and stem nematode, Tylenchus dipsaci Kuhn, as a pest of phlox. J. New York Bot. Gar. 30:177-184.

6. Webster, J. M. 1967. The significance of biological races of Ditylenchus dipsaci and their hybrids. Ann. Appl. Biol. 59:77-83.

7. Yuksel, H. S. 1960. Observations on the life cycle of Ditylenchus dipsaci on onion seedlings. Nematologica 5:289-296.