POPULATION FLUCTUATIONS OF <u>XIPHINEMA</u> <u>AMERICANUM</u> IN A COFFEE GROVE IN GUATEMALA

by

Dwight L. Walker

A Thesis Submitted to the Faculty of the

DEPARTMENT OF PLANT PATHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 6 7

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Dwight L. Walker

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Edward L. Nigh Jr. — 27 December 1966

EDWARD L. NIGH, JR. — Date

Associate Professor of Plant Pathology

ACKNOWLEDGMENTS

It is the pleasure of the author to express his appreciation to the School of Agriculture of the University of San Carlos, Guatemala City, Guatemala, for making special arrangements and providing the necessary facilities for this thesis work. In particular the author would like to express his appreciation to Professor Mario Brunner, Professor of Soils, for his assistance with the soil moisture analysis; to Professor Mario Molina Llarden, Professor of Plant Pathology, for the use of the equipment of the Department of Plant Pathology; and to Professor Mario Martinez, of the Department of Research, for his active interest and assistance with the research involved in this thesis project.

In addition, the author would like to express his appreciation to Dr. James Walker, of the Agency of International Development, for his assistance with the soil texture analysis and advice concerning the soil moisture study.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

Two seasonal population peaks of *Xiphinema americanum* Cobb were observed in a coffee grove in Guatemala. The two peaks occurred on about April 1 and August 1 in 1965. In 1966, the first population peaks appeared on June 15. At the upper soil sampling level (0-6 inches) the correlation between moisture and nematode populations was found to be statistically significant. However, the correlation between temperature and the populations was not significant at the 0-6 inch depth. At the three lower sampling levels (6-12, 12-18, 18-24 inches), the correlation between soil population and soil temperature was statistically significant, while soil moisture and nematode population levels were not significantly correlated.

INTRODUCTION

Discussion of Nematodes on Coffee Plants in Guatemala

In Guatemala, as in many places of the world, *Xiphinema americanum* Cobb (the American dagger nematode) is rather widely distributed on one or more hosts. Thorne and Schieber (1962) reported *X. americanum* as occurring widely throughout the coffee growing areas of Guatemala. These authors reported this species in especially high numbers on one coffee plantation where 280 acres were being abandoned at the time the nematodes were collected. They also reported *Meloidogyne* sp. and *Pratylenchus* sp. present with the large *X. americanum* population. The symptoms resulting from the attack of the three nematode species were complex and the damage attributable to any one of the three genera would be difficult to determine. Preliminary observations made by the author before beginning this work indicated that *X. americanum* occurred in varying numbers in most of the random soil samples taken from coffee growing areas of Guatemala.

Economic Importance of *Xiphinema americanum*

Although *X. americanum* does not usually produce such distinctive symptoms as many other nematodes, its economic importance must not be overlooked. Christie (1953) suggested that ectoparasitic nematodes of plants may be responsible for crop losses equal to those caused by the more commonly observed root-knot and lesion producing nematodes. One of the reasons that the importance of ectoparasitic nematodes is often overlooked lies in the difficulty with which the symptoms are related to the causal nematode. Symptoms of these nematodes can often be mistaken for any one of a series of conditions that kill root tips or stop their growth. Westgate (1952) found that a toxic concentration of copper in the soil produced a condition similar to those produced by external feeding (ectoparasitic) nematodes.

The distribution and host range of *X. americanum* is demonstrated by the reports of various investigators in the United States. Griffin (1954) found *X. americanum* occurring in 49% of the soil samples collected from the major corn producing areas of Wisconsin. Mai, Dolliver, Kirkpatrick, and Parker (1957) reported that about one-third of the trees from 81 sour cherry orchards studied in New York State supported populations of this nematode. In addition, they reported its occurrence in orchards of apple and peach. Ward (1960) also indicated large numbers of *X. americanum* occurring in alfalfa, birdsfoot trefoil, and white clover in New York State. This worker indicated a definite association between high populations of the above nematode and poor growth of alfalfa. In this work, the possible critical relationship between soil moisture and population build-up of this species is indicated. Christie (1952) states that severe injury of the roots of oak trees, pecan trees, and azaleas may result from *X. americanum* infection.

Two species of dagger nematodes, *X. americanum* and *X. chambersi*, were studied by Perry (1958) in connection with reddish-brown lesions on strawberry roots. These lesions were reported to progress to an eventual blackening of the root system. The author suggested a relationship involving other organisms following the nematode puncture. Although little actual experimental work has been done on the relationship between *X. americanum* and decay organisms, it is generally considered that by providing a mode of entrance into the plant for a variety of such organism this nematode is doing the plant a rather serious disservice.

Griffin and Epstein (1964) have indicated the importance of *X. americanum* in weakening the ornamental spruce to such a degree that it became difficult for it to effectively overwinter in Wisconsin. Winterkill ranged from 25% to 100%, with the number of nematodes per pot varying from 500 to 2,500. Epstein and Griffin (1962), in work with Cytospora canker of the ornamental spruce, noted that the diseased trees were heavily infected with *X. americanum* and *Criconemoides xenoplax*. They suggested that the nematode infection predisposes the trees to the Cytospora canker disease.

Xiphinema americanum as a Virus Vector

The discovery that *X. americanum* is involved as a vector in the transmission of plant viruses has greatly increased the original estimation of its economic importance. Fulton (1962) discovered that the tobacco ringspot virus is transmitted to cucumber by *X. americanum*. In this work, it was determined that 27 C. or 34 C. were more favorable than lower temperature for the transmission. In this respect, the tropics present, at least temperature-wise, favorable transmission conditions. Soil temperatures under tropical conditions fall within this range for many months of the year. Under semitropical conditions, temperatures approach this range (Fig. 7). Griffin, Huguelet and Nelson (1963) demonstrated *X. americanum* as a vector of necrotic ringspot virus of blueberry. Breece and Hart (1959) indicated a possible relationship between nematodes and the peach yellow mosaic virus. This implication was later effectively demonstrated by Frazier and Maggenti (1962) when this virus was transmitted to healthy strawberry plants by populations of *X. americanum*.

Population Studies of *Xiphinema americanum*

It has been suggested for some time that rather marked population fluctuations occur throughout the year in populations of *X. americanum* (Thorne 1962). In a study of the relationship between soil moisture, soil temperature, and population levels of *X. americanum*, Norton (1963) found population levels in an Iowa alfalfa field to be directly proportional to soil temperature and inversely related to soil moisture content. Griffin and Darling (1964) found a somewhat similar pattern when *X. americanum* populations were studied in an ornamental spruce nursery. In addition, in this study it was noted that during the period of May to December two population peaks were noted with the population between the peaks dropping to a rather low level. In both of the two above named studies, soil moisture and soil temperature fluctuated rather drastically.

The work reported in this paper represents an attempt by the author to present data concerning population levels of *X. americanum* as noted under the semitropical conditions of the Guatemalan highlands. Soil temperature and soil moisture conditions in tropical or semitropical situations differ greatly from those of Iowa or Wisconsin, for example, where population studies of *X. americanum* have been done. Soil temperature under Guatemalan conditions remains relatively constant through the year (Fig. 7). Soil moisture, on the other hand, fluctuates rather drastically (Fig. 8), being directly related to the monsoon-like rainy conditions of this area.

MATERIALS AND METHODS

Location and Time of Study

This study was begun on April 1, 1965 at the School of Agriculture Experimental Farm of the University of San Carlos, located in Guatemala City, Guatemala. The study was carried out over a period of fourteen months. Five trees known to be infected with *Xiphinema americanum* were selected from a small demonstration planting of *Coffee arabica*. With the exception of rare appearances of *Pratylenchus coffea*, no parasitic nematodes other than *Xiphinema americanum* were observed during the study period. The area under study was level and exhibited a uniform soil profile. The trees chosen represented different population levels of *X. americanum*.

Soil Sampling Technique

Soil samples were taken at 0-6, 6-12, 12-18, and 18-24 inch depths. On each sampling date soil cores were taken on opposite sides of each tree and within a range of 12-18 inches from the base of the trunk. Preliminary sampling indicated extensive root growth throughout this range. From the two cores, composite samples were formed. Nematode population analysis was made biweekly; soil moisture data were taken approximately monthly. Soil temperature data were taken at 7 to 12 day intervals. A 2.5 inch soil auger was used for sampling when the soil was moist, but during the dry season it became necessary to use a heavy-duty 1.5 inch soil sampling tube. Upon removal of the soil core, the resultant hole was carefully filled and marked with a wooden peg to prevent resampling at the same point. Soil samples used for nematode population studies were placed in Baermann funnels within thirty minutes after collection; thus, it was not necessary to take any special precautions such as refrigeration in preserving the samples. Samples used for the soil moisture determinations were collected in polyethylene bags and tightly sealed with a piece of string.

Laboratory Processing of Nematodes

The composite samples, representing about 1,000 grams of soil from each sampling level, were thoroughly mixed in the laboratory. From this material, 250 grams of soil were processed by the Baermann funnel method. The 250 gram portions of soil from each soil sampling level were distributed between five Baermann funnels, each receiving 50 grams. The recovery of *X. americanum* individuals by the small soil sample (50 grams/funnel) technique was found to be 67% (Table 1). The samples were left in the funnels for a period of 48 hours at which time the nematodes were drawn off for study to determine the number of juvenile and adult individuals.

No attempt was made to differentiate between gravid and non-gravid adults. Norton (1965) feels that it is probably important to process samples as soon after collecting as possible so as to study the adult females before they have an opportunity to lay an egg. In the work reported in this thesis it was necessary many times to store samples as long as ten days, thereby making it difficult to secure valid data concerning the ratio of gravid and non-gravid adults.

Soil Texture Analysis

The apparent soil texture was determined for the different sampling levels as indicated in Table 2.

TABLE 1

DETERMINATION OF THE PERCENTAGE RECOVERY OF *X. AMERICANUM* IN A SMALL SOIL SAMPLE (50 GRAMS) BY THE BAERMANN FUNNEL TECHNIQUE

Original Number of *X. Americanum*	Number Recovered
30	19
30	22
30	24
30	17
30	19
Percentage Recovery	67.0

TABLE 2

APPARENT SOIL TEXTURE ANALYSIS

Sampling Depth (inches)	Soil Texture
0-6	Silt loam
6-12	Silt loam
12-18	Sandy clay loam
18-24	Sandy clay loam

Soil Organic Matter Analysis

The soil organic matter was found to be quite high. Simons (1959) has indicated that in this region of Guatemala the soil organic matter is about 4%. It is expected that the soil from under the coffee trees would contain more than the reported 4% organic matter. This assumption is indicated by a persistent surface layer of decomposing leaves and twigs.

Soil Moisture Analysis

Soil moisture was determined by weighing the samples before and after heating overnight at 200 C. Soil moisture at field capacity was determined as described by Walker (1966), by taking soil samples from a column of soil formed by digging a doughnut-shaped hole to a depth of 24 inches. The hole was filled with water, allowed to drain, refilled with water, and allowed to drain a second time; after waiting three hours, it was assumed the soil was at field capacity and the soil samples for analysis were collected. The purpose of this method of determining soil moisture at field capacity stems from the need to avoid disrupting the characteristic soil structure, and at the same time being reasonably sure of approaching a soil moisture condition of field capacity. Table 3 indicates the results of this work.

<u>Soil Temperature</u>

Soil temperatures were taken at 3, 9, 15, and 21 inch depths with a 23 inch laboratory thermometer. To facilitate placing the thermometer at the proper depth each time the soil temperature was taken, small galvanized tubes were permanently placed at the depths indicated above and each was capped with aluminum foil. Temperature data were taken at about 10:00 A.M. and at about weekly intervals. To determine the difference in soil temperatures that occur throughout a given day, soil temperatures were taken hourly on April 17, 1966. The resulting maximum and minimum temperatures are reported in Table 4. It was noted that the soil temperature remains reasonably constant. This was to be expected as nighttime air temperatures in Guatemala drop very little in comparison with those in temperate climates.

TABLE 3

SOIL MOISTURE CONTENT AT FIELD CAPACITY

Sampling Depth (inches)	Soil Moisture (Percent at Field Capacity)
0-6	23.2
6-12	23.2
12-18	24.2
18-24	27.8

TABLE 4

MAXIMUM AND MINIMUM SOIL TEMPERATURE

Date: April 17, 1966

Depth	Max. Temp.	Min. Temp.
3 inches	20.0 C.	18.0 C.
9 inches	20.2	18.4
15 inches	21.5	20.5
21 inches	20.5	19.8

RESULTS

Population Levels

During about nine months of the sampling period, rather low population levels of *X. americanum* were found on the roots of the five coffee trees studied. The smallest number of nematodes was found at the upper sampling level between the surface and a depth of six inches. The largest number of nematodes was found at the six to twelve inch level. An approximate equal number of nematodes was found at the two lower sampling levels. No attempt was made to determine the quantity of roots at any of these levels or the number of nematodes per gram of foot material.

At the three lower levels, two population peaks were observed during the fourteen-month observation period (Figs. 3, 4, and 5). In the upper level, only one peak was observed (Fig. 2). In 1965, the peaks occurred on or before March 1,and approximately July 1, in 1966 the first peak appeared slightly later. The population peaks were slightly more pronounced at the two intermediate levels in comparison to the upper or lower levels. From about August 15, 1965 to about April 1, 1966, nematode populations were continually at a low level.

The maximum number of juveniles found during the second population increase of 1965 appears at the same time as the maximum number of adults. In 1966 during the first population increase, the maximum number of juveniles appeared earlier than the maximum number of adults. During the period of low nematode population levels, the number of juveniles continually was lower than the number of adults. No attempt was made to determine any difference in the adult and juvenile ratio at the different soil sampling levels.

Soil Temperature Results

Soil temperatures remained quite constant throughout the year. The maximum fluctuation occurred at the three inch measuring depth. At this level a maximum temperature of 23.5 C. occurred during April and May; the minimum temperature occurred November 1, and was found to be 16.5 C. At lower depths less fluctuation occurred.

Soil Moisture Results

In contrast to soil temperature, the percent soil moisture fluctuated very greatly. In 1965, percent soil moisture at the zero to six inch level reached a low of 5.25 (Fig. 8). At lower sampling levels, such a low percentage was not reached. During 1966, the percent soil moisture failed to reach the low levels of the previous year. In 1965, the soil moisture climbed rapidly during the first few days of June with the beginning of the rainy season. The following year, this sudden increase occurred about a month earlier. During the months of June, July, August, and September soil moisture remained at or close to field moisture capacity. Following September and corresponding to the reduction in rainfall, soil moisture gradually decreased.

DISCUSSION

The population level is affected by both soil moisture and soil temperature. At the 0-6 inch soil sampling level, the statistical correlation coefficient for the number of nematodes as correlated to soil moisture was found to be significant at the 1% level (Appendix). At this soil sampling level, the correlation coefficient for the population as related to soil temperature was not significant. At the three lower sampling levels, it was found that the correlation coefficients for the correlations between population and soil temperature were significant. At the 6-12 inch level, the level of significance was 1%; at the 12-18 inch level, 2%; and at the 18-24 inch level, 1%. At the three lower soil sampling levels, the correlation coefficients for the correlation between population and soil moisture were not significant.

Lownsbery and Maggenti (1963) reported a soil temperature of 21 C. to be more optimum for the culture of X. americanum than either 16 C. or 27 C. The most direct correlation between soil temperature and the number of nematodes found in this study occurs during

October and November when the soil temperatures reach a low of between 16 C. and 18 C.; at this time the number of nematodes is approaching its lowest level. Yet, the period of optimum soil temperatures as reported by Lownsbery and Maggenti (1963) does not correspond to the period of the greatest number of nematodes found during the study reported in this thesis.

No nematodes were found in soil in which the soil moisture had dropped to less than 10%. Lownsbery and Maggenti (1963) reported 18% to be more optimum for X. americanum than either 13% or 24%. A soil moisture percentage approaching 25% may be the reason for the decline in the level of the nematode population that occurred during the month of August. A soil moisture percentage of 25 approaches or exceeds the field moisture capacity for this soil (Table 3).

In January, a gradual increase in the number of nematodes begins. This may be the result of soil moisture and temperature conditions approaching the above indicated optimums of 18% and 21 C.

It is interesting to note that the two population peaks which occurred approximately four months apart in this study corresponded to those population peaks of X. *americanum* in a Wisconsin blue spruce nursery reported by Griffin and Darling (1964).

The increase in the number of juveniles that began on March 1, 1966 and was followed by an increase in the number of adults represented the expected situation of an earlier rise in the number of juveniles as compared to adults. Between June 1, 1965 and June 15, 1965 the numbers of adults and juveniles increased rather sharply. It would be expected that the number of juveniles would increase before the number of adults. Possibly the fact that this population increase followed immediately another population increase and decrease would account for the total number of adults being larger during the time of increase as compared to the number of juveniles. It is possible that the adults remaining from the first population increase obscured the relationship of adults and juveniles in the second population increase.

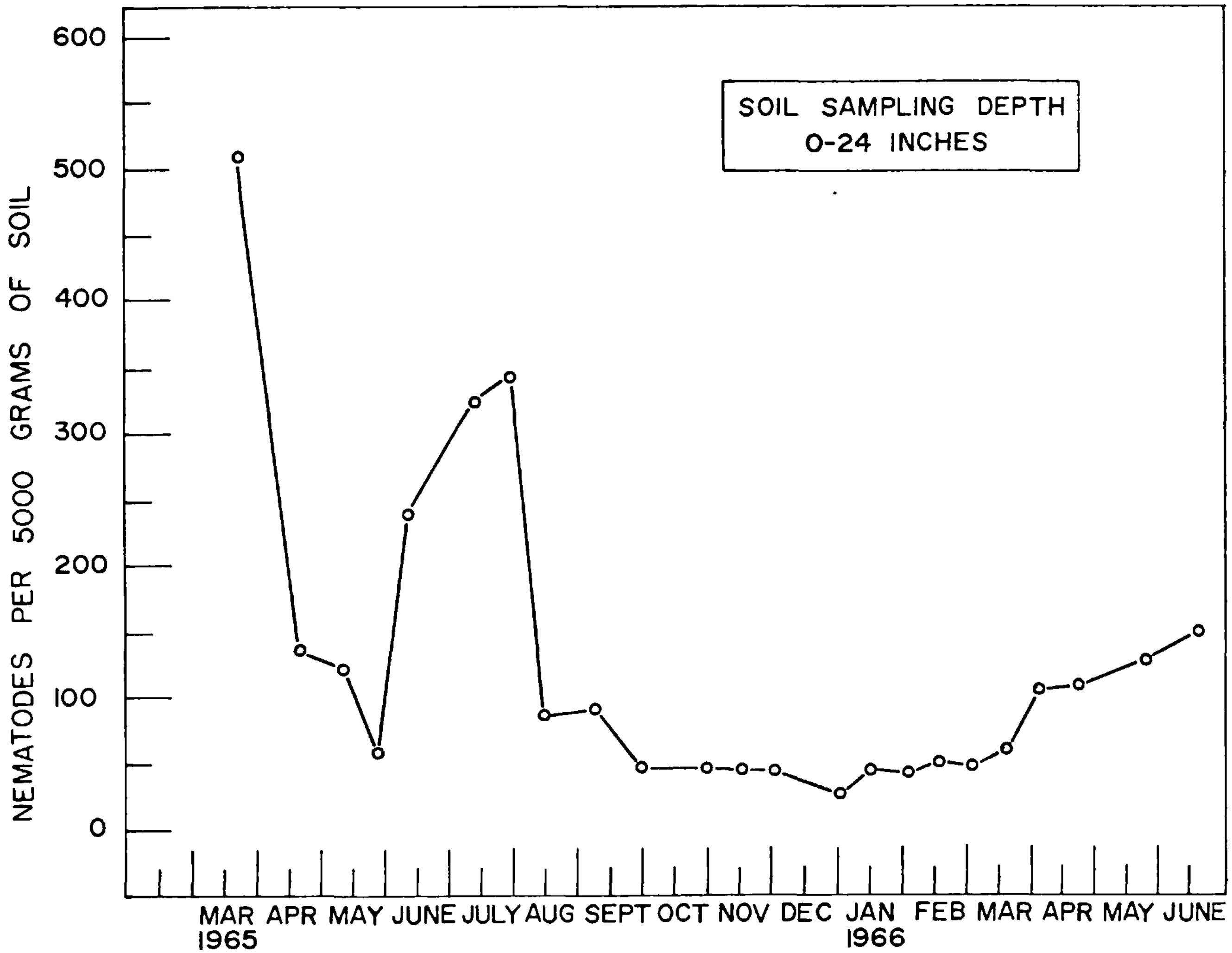

FIG. I. SEASONAL POPULATIONS OF XIPHINEMA AMERICANUM IN LOAM SOIL FROM COFFEE TREES IN GUATEMALA

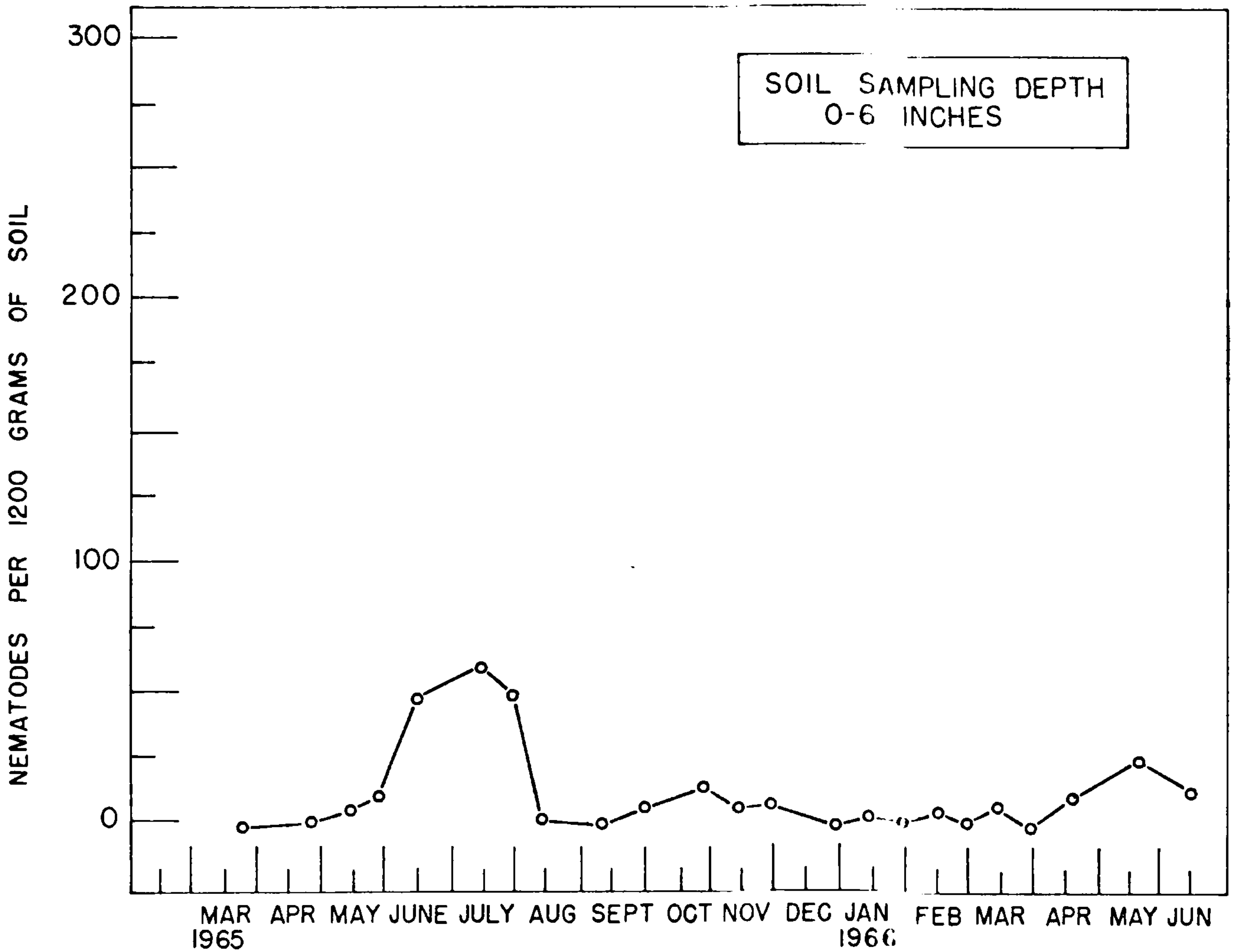

FIG. 2. SEASONAL POPULATIONS OF XIPHINEMA AMERICANUM IN LOAM SOIL FROM COFFEE TREES IN GUATEMALA

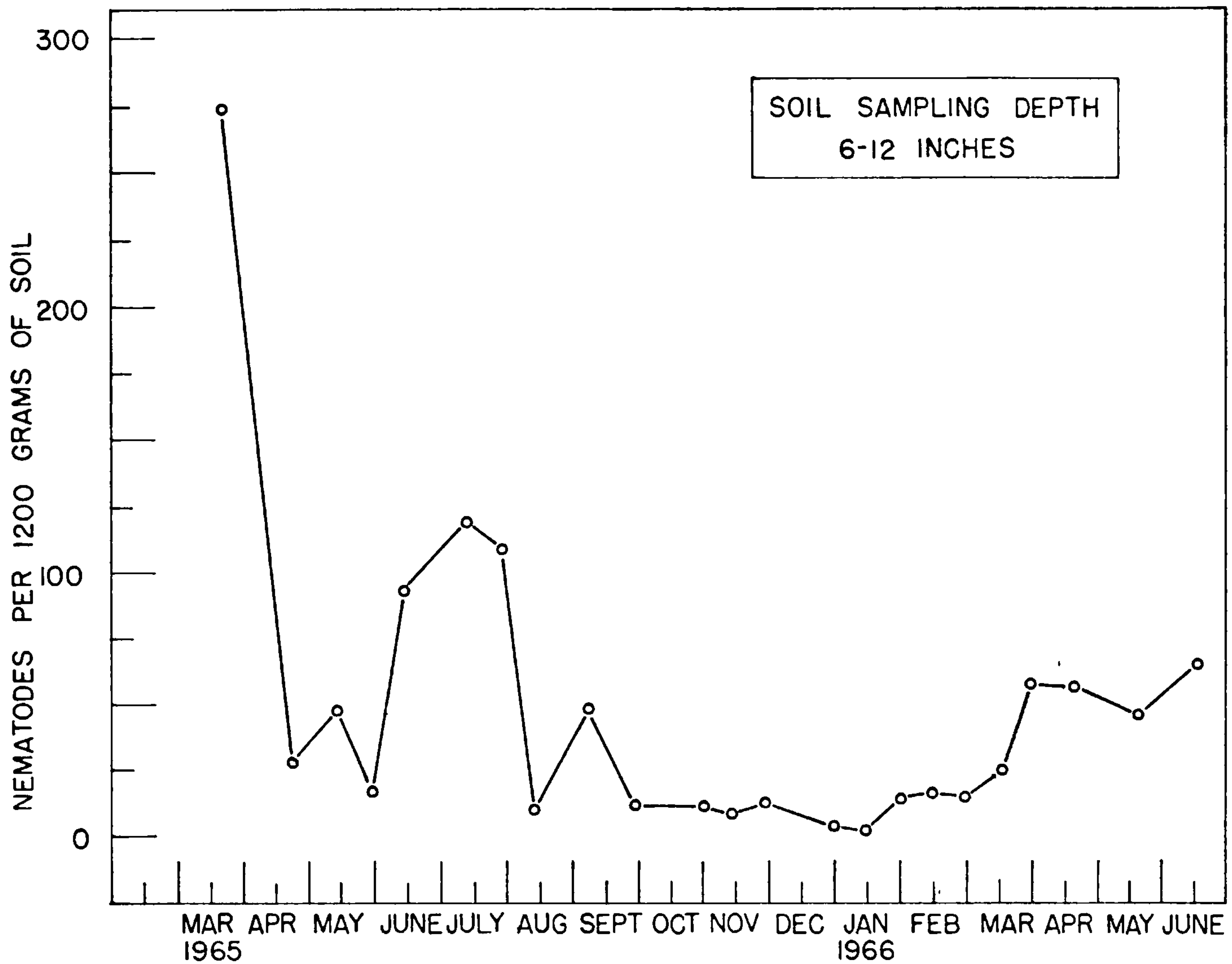

FIG. 3. SEASONAL POPULATIONS OF XIPHINEMA AMERICANUM IN LOAM SOIL FROM COFFEE TREES IN GUATEMALA

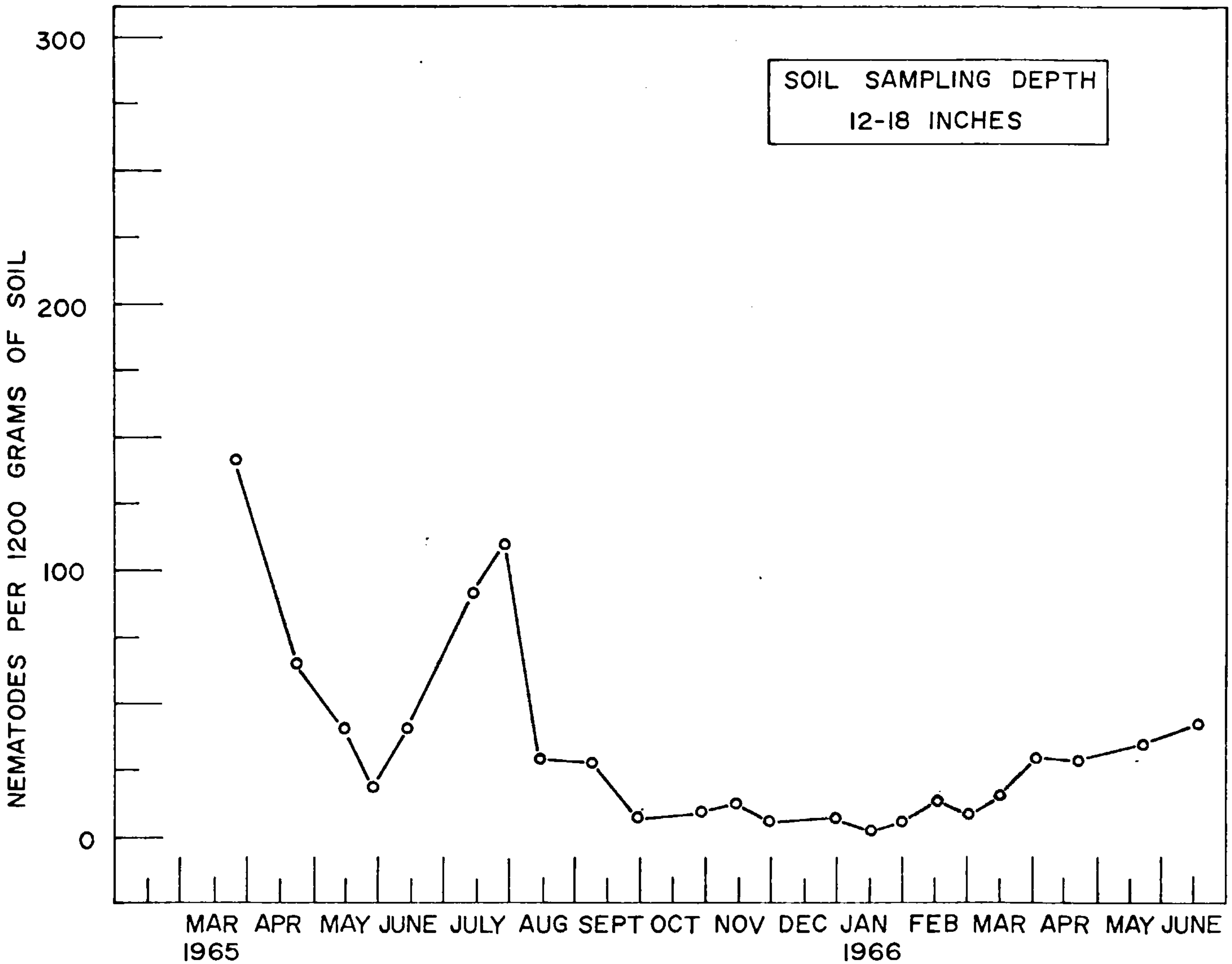

FIG. 4. SEASONAL POPULATIONS OF XIPHINEMA AMERICANUM IN LOAM SOIL FROM COFFEE TREES IN GUATEMALA

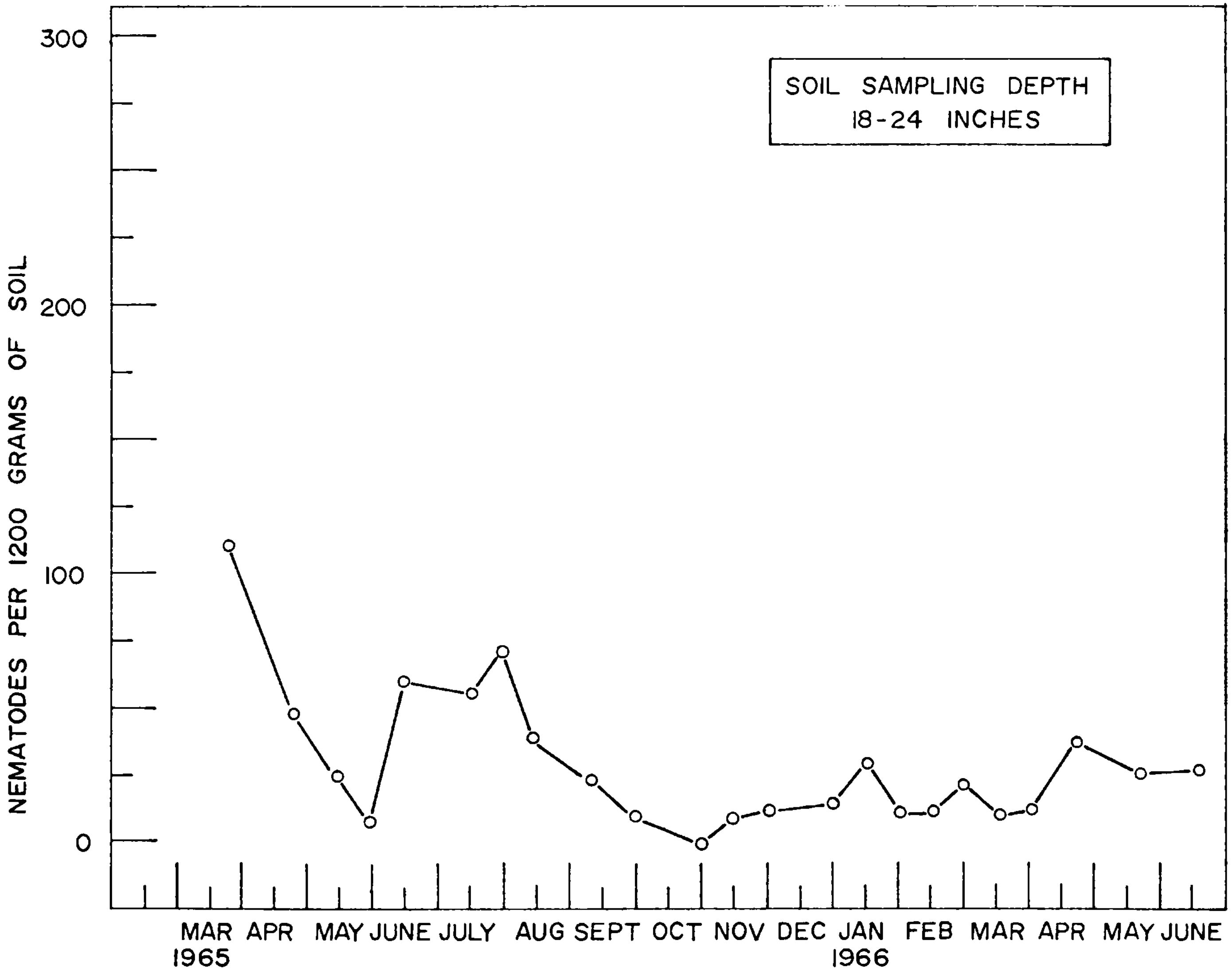

FIG. 5. SEASONAL POPULATIONS OF XIPHINEMA AMERICANUM IN LOAM SOIL FROM COFFEE TREES IN GUATEMALA

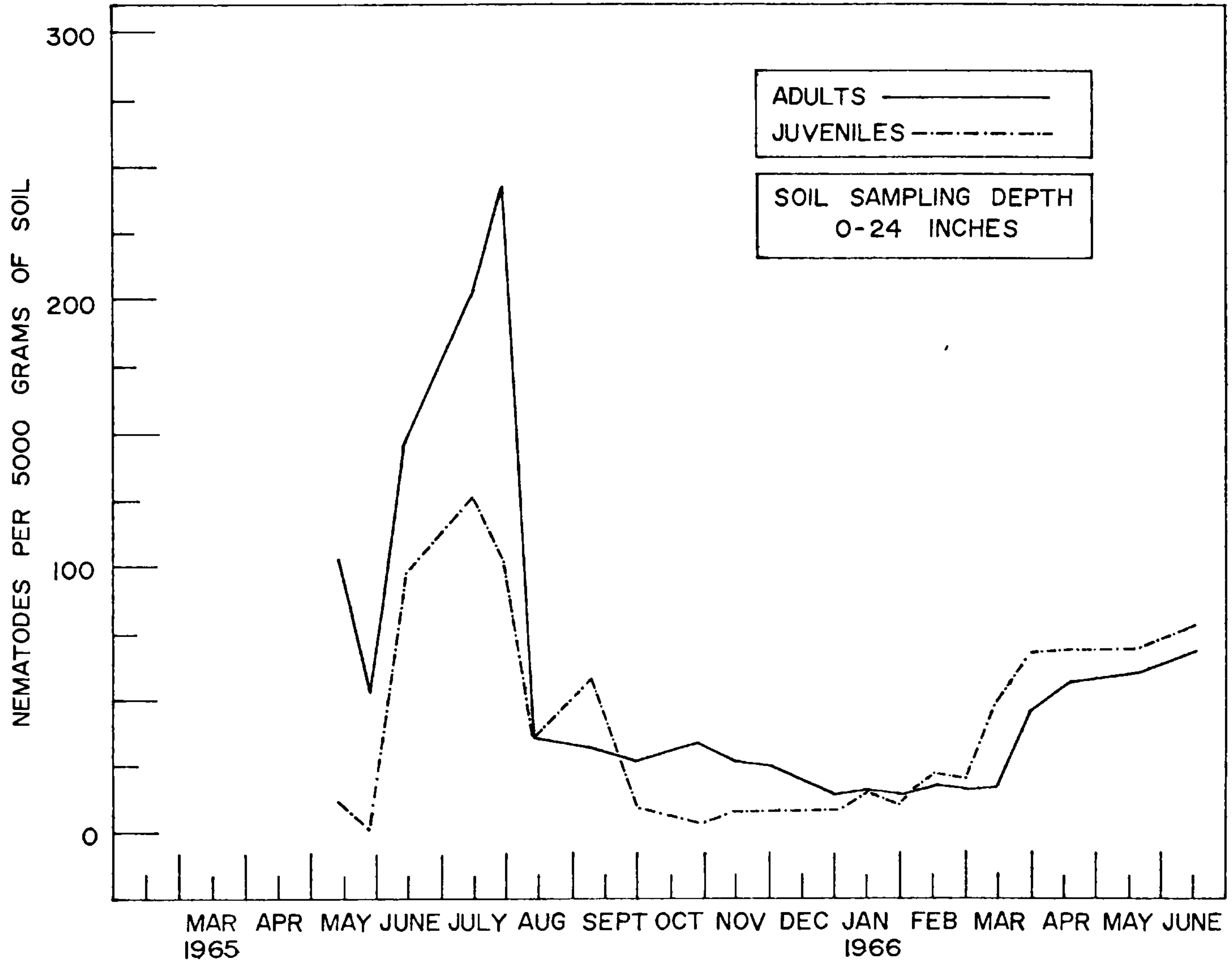

FIG. 6. SEASONAL POPULATIONS OF JUVENILES AND ADULTS IN LOAM SOIL FROM COFFEE TREES IN GUATEMALA

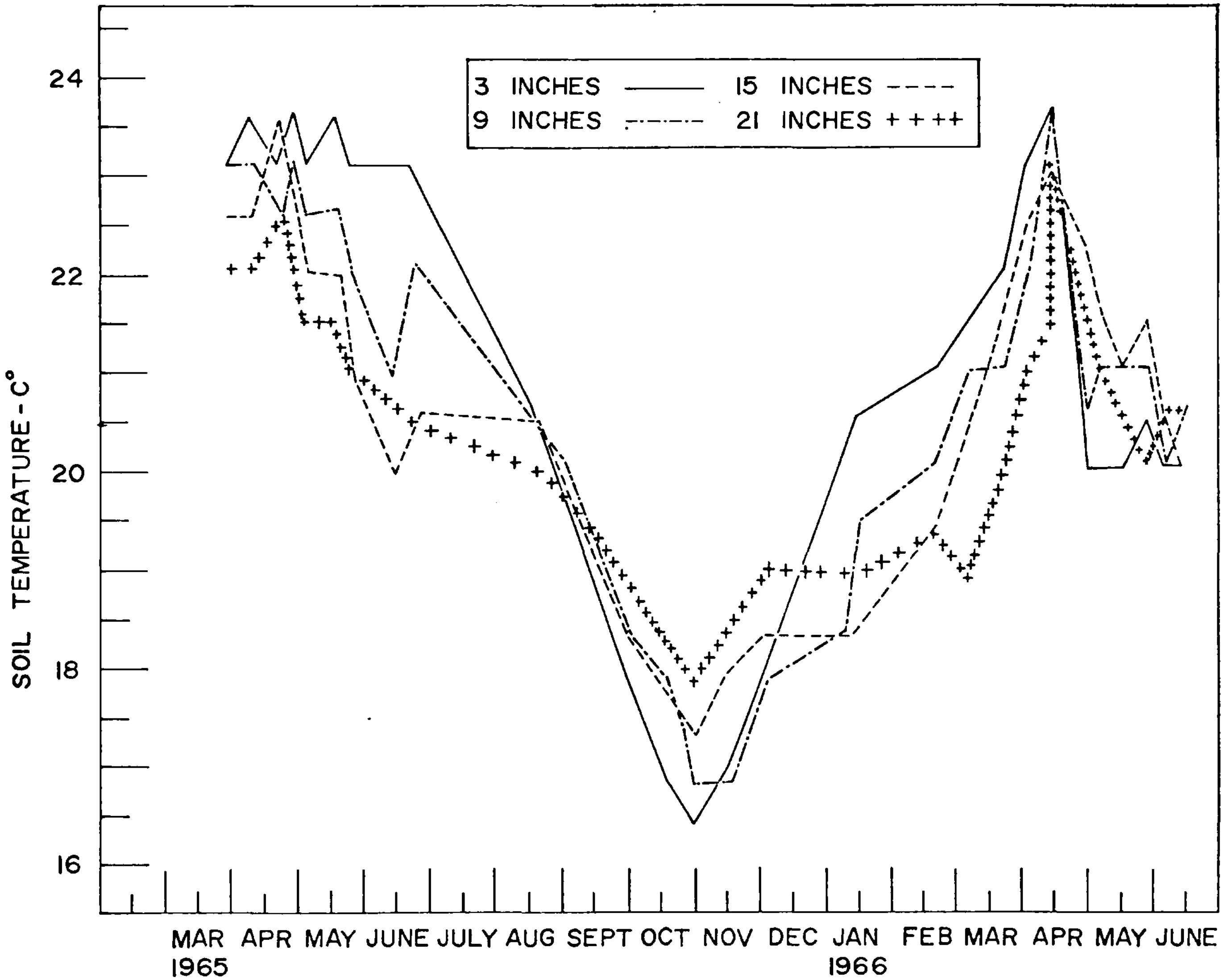

FIG. 7. SOIL TEMPERATURES OF SANDY LOAM SOIL FROM A COFFEE TREE PLANTING IN GUATEMALA. TEMPERATURES TAKEN AT 10:00 A.M.

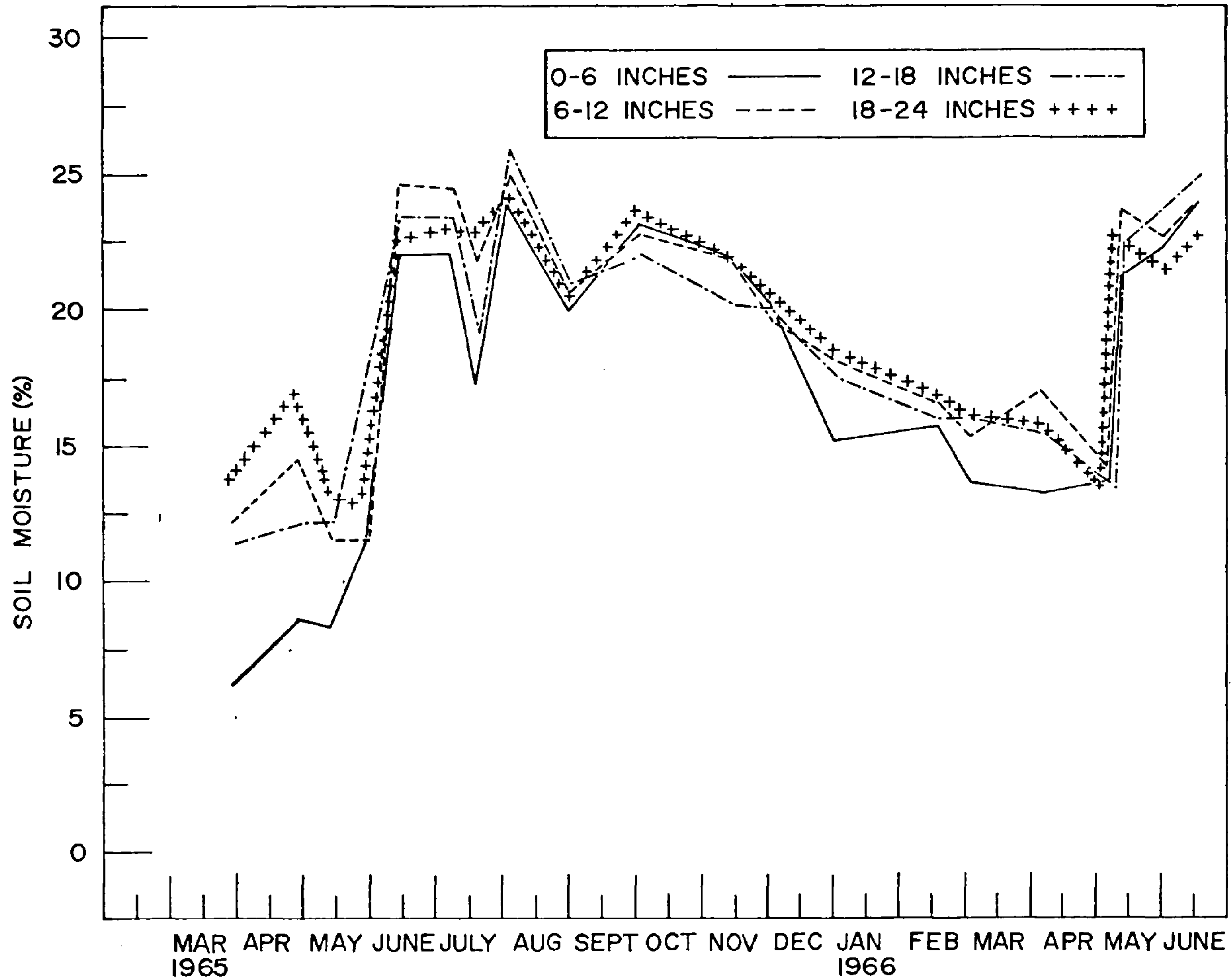

FIG. 8. MOISTURE CONTENT OF LOAM SOIL FROM COFFEE TREE PLANTING IN GUATEMALA

APPENDIX

IBM 1620 Data Processing

Linear Regression Analysis of All Combinations of Variables

```
VAR NO 0 = Dependant Variable: Nematode
                      Population
VAR NO 1 = Soil Moisture
VAR NO 2 = Soil Temperature
```

Soil Sampling Depth 0-6 inches

```
LOAD DATA
CORRELATION          3.000       0

RES SUM SQUARES    =     .6139E 04, MULT CORR = .0000
    VAR NO 0 COEF =     .1363E 02

RES SUM SQUARES     =   .6077E 04, MULT CORR = .1000
    VAR NO 0 COEF   =   .2890E 02
    VAR NO 2 COEF   =   .7356E 00

RES SUM SQUARES     =   .4362E 04, MULT CORR = .5379
    VAR NO 0 COEF   =   .1440E 02
    VAR NO 1 COEF   =   .1626E 01

RES SUM SQUARES     =   .3708E 04  MULT CORR = .6292
    VAR NO 0 COEF   =   .9415E 02
    VAR NO 1 COEF   =   .2468E 01
    VAR NO 2 COEF   =   .3143E 01
```

Soil Sampling Depth 6-12 inches

```
LOAD DATA
CORRELATION          3.000       0

RES SUM SQUARES     =   .7525E 05,  MULT CORR =.0000
    VAR NO 0 COEF   =   .4621E 02
```

```
RES SUM SQUARES  =  .7459E 05, MULT CORR = .0932
   VAR NO 0 COEF =  .6904E 02
   VAR NO 1 COEF =  .1254E 01

RES SUM SQUARES  =  .5433E 05, MULT CORR = .5271
   VAR NO 0 COEF =  .2981E 03
   VAR NO 2 COEF =  .1677E 02

RES SUM SQUARES  =  .5151E 05, MULT CORR = .5616
   VAR NO 0 COEF =  .4249E 03
   VAR NO 1 COEF =  .2990E 01
   VAR NO 2 COEF =  .2029E 02
```

Soil Sampling Depth 12-18 inches

```
   LOAD DATA
   CORRELATION      3.000      0

RES SUM SQUARES  =  .2774E 05, MULT CORR = .0000
   VAR NO 0 COEF =  .3613E 02

RES SUM SQUARES  =  .2761E 05, MULT CORR = .0678
   VAR NO 0 COEF =  .4781E 02
   VAR NO 1 COEF =  .6101E 00

RES SUM SQUARES  =  .2112E 05, MULT CORR = .4885
   VAR NO 0 COEF =  .1790E 03
   VAR NO 2 COEF =  .1063E 02

RES SUM SQUARES  =  .1997E 05, MULT CORR = .5292
   VAR NO 0 COEF =  .2709E 03
   VAR NO 1 COEF =  .2095E 01
   VAR NO 2 COEF =  .1319E 02
```

Soil Sampling Depth 18-24 inches

```
   LOAD DATA
   CORRELATION      3.000      0

RES SUM SQUARES  =  .1300E 05, MULT CORR = .0000
   VAR NO 0 COEF =  .2739E 02
```

```
RES SUM SQUARES   =   .1298E 05 MULT CORR = .0316
   VAR NO 0 COEF =   .2314E 02
   VAR NO 1 COEF =   .2194E 00

RES SUM SQUARES   =   .8147E 04, MULT CORR = .6110
   VAR NO 0 COEF =   .2139E 03
   VAR NO 2 COEF =   .1206E 02

RES SUM SQUARES   =   .5604E 04 MULT CORR =  .7542
   VAR NO 0 COEF =   .3968E 03
   VAR NO 1 COEF =   .3511E 01
   VAR NO 2 COEF =   .1781E 02
```

REFERENCES

Breece, James R., and Hart, W. H. 1959. A possible association of nematodes with the spread of peach yellow bud mosaic virus. Plant Dis. Reptr. 43:989-990.

Christie, J. R. 1952. Ectoparasitic nematodes of plants. Phytopathology 42:483-484.

________. 1953. Ectoparasitic nematodes of plants. Phytopathology 43:295-297.

Epstein, A. H., and Griffin, G. D. 1962. The occurrence of Cytospora canker on spruce in the presence of *Xiphinema americanum* and *Criconemoides xenoplax*. Plant Dis. Reptr. 46:17.

Frazier, N. W., and Maggenti, A. R. 1962. Nematode transmission of yellow bud mosaic virus to strawberry. Plant Dis. Reptr. 46:303-304.

Fulton, J. R. 1962. Factors related to soil transmission of tobacco ringspot virus. (Abst.) Phytopathology 52:10.

Griffin, G. D., Huguelet, J. E., and Nelson, N. W. 1963. *Xiphinema americanum* as a vector of necrotic ringspot virus of blueberry. Plant Dis. Reptr. 47:703.

Griffin, G. D. 1964. Association of nematodes with corn in Wisconsin. Plant Dis. Reptr. 48:458-459.

Griffin, G. D., and Darling, H. M. 1964. An ecological study of *Xiphinema americanum* Cobb in an ornamental spruce nursery. Nematologica 10: 471-479.

Griffin, G. D., and Epstein, A. H. 1964. Association of dagger nematode, *Xiphinema americanum*, with stunting and winterkill of ornamental spruce. Phytopathology 54:177-180.

Lownsbery, B. F., and Maggenti, A. R. 1963. Some effects of soil temperature and soil moisture on population levels of *Xiphinema americanum*. *Phytopathology* 53:667-668.

Mai, W. F., Dolliver, James, Kirkpatrick, J. D., and Parker, K. G. 1957. Nematode genera found in New York State orchards. *Plant Dis. Reptr.* 41: 402-404.

Norton, Don C. 1963. Population fluctuations of *Xiphinema americanum* in Iowa. *Phytopathology 53*:66-68.

________. 1965. Personal communication.

Perry, Vernon G. 1958. Parasitism of two species of dagger nematodes-- (*Xiphinema americanum* and *X. chambersi*)--to strawberry. *Phytopathology* 48: 420-423.

Simons, C. S., Tarano, J. M., and Pinto, J. H. 1959. *Classificación de reconocimiento de los suelos de la República de Guatemala.* Instituto Agropecuario Nacional, Guatemala, C. A., 1000 pp.

Thorne, G. 1961. *Principles of Nematology.* McGraw-Hill Book Company, New York, 553 pp.

Thorne, G., and Schieber, E. 1962. American dagger nematode (*Xiphinema americanum*) on coffee in Guatemala, with suggestions for nematode control in nurseries. *Plant Dis. Reptr.* 46:857.

Walker, James. 1966. Personal communication.

Ward, C. H. 1960. Dagger nematodes associated with forage crops in New York. (Abst.) *Phytopathology* 50:658.

Westgate, P. J. 1952. Preliminary report on copper toxicity and iron chlorosis in oil vegetable fields. *Proc. Fla. State Hort. Soc.* 443-446.