# SEASONAL VARIATIONS IN POPULATION OF PLANT PARASITIC NEMATODES IN "PENNCROSS" BENTGRASS AT CERTAIN SOIL LEVELS AND CONTROL PRACTICES

By

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# CHAPTER I

## INTRODUCTION

Healthy bentgrass greens are essential to the operation of golf courses, and maintaining high quality turf is the concern of all golf course superintendents. Poor root systems are commonly found to be among the major limiting factors in maintaining a healthy stand of grass. Nematodes are among the many soil pests that attack turf. Nematodes feeding on the grass root system can cause severe enough damage to reduce their ability to absorb the nutrients needed for proper growth. Thus, symptoms resulting from nematode injury are similar to those associated with poor fertility. Nematodes feeding on the underground plant parts can provide an opening in the root through which fungi can enter thus causing a disease complex.

Many types of nematodes are found in turfgrass, however, there are relatively few species known to be parasitic. The majority of nematodes found in the soil are free living, saprophytic forms that live on organic matter and are, in part, beneficial. Several different parasitic nematode species can be feeding at different sites along the root, thereby increasing the severity of plant damage.

Bentgrass (*Agrostis* sp.) is commonly used on golf course putting greens in Oklahoma. Research in recent years has shown that nematicides, properly applied to established bentgrass greens, can result in improving the growth and quality of the grass when damaging nematode populations are present. Thus, information on any seasonal changes that may occur in population densities or nematode species in established turf is important in understanding the response of the grass and will aid in developing more effective control.

The objectives of this study were:

1. To study the populations of plant parasitic nematodes associated with established "Penncross" bentgrass (*Agrostis palustris* Huds.) at various soil depths over a 12-month period.
2. To monitor certain parasitic nematodes present in the study and to determine effects of soil depth and chemicals on specific nematode populations and plant root system.

# CHAPTER II

## LITERATURE REVIEW

Nematodes have been shown to play an important role in reduction of root growth and incidence of soil diseases (3, 5, 44, 45, 50, 54, 77). Nutter (50) reported that nematode damage to major turfgrasses was widespread since 1955. Numerous studies have been reported on the different plant parasitic nematode species occurring on grasses grown on golf greens in many states (8, 22, 43, 69, 70, 71).

### Nematodes Which Damage Turf

In 1953, Kelsheimer and Overman (31) found *Trichodorus* sp., *Criconemoides* sp., *Ditylenchus* sp., *Belonolaimus gracilis*, *Radopholus similis*, and *Hoplolaimus coronatus* associated with root injury of declining St. Augustine grass. Good et al. (19), in 1959, reported *Xiphinema* sp., *Criconemoides* sp., *Trichodorus* sp., *Tylenchorhynchus* sp., *Belonolaimus* sp., *Helicotylenchus nannux*, *Pratylenchus brachyurus*, and *Hoplolaimus tylenchiformis* occurring frequently around the roots of grasses grown in nurseries.

Rhoades (59, 60) reported *Belonolaimus longicaudatus* and *Trichodorus christiei*, and *T. proximus* caused severe chlorosis and damaged the root system of common St. Augustine grass.

Winchester (76) pointed out that sting nematode *Belonolaimus* sp. and root-knot nematode *Meloidogyne* sp. were the most important nematodes causing decline of turfgrass in South Florida.

Lucas et al. (43), in 1974, reported that *Trichodorus christiei*, *Hoplolaimus galeatus*, *Tylenchorhynchus claytoni*, and *Helicotylenchus dihystera* might be the most important nematodes on bentgrass in North Carolina. Three years later, in 1977, he concluded that *B. longicaudatus* had the potential to be a serious problem on "Penncross" bentgrass.

Tashiro (69) found that in Hawaii, *Trichorodus* and *Helicotylenchus* species were frequently associated with creeping bentgrass whereas *Criconemoides*, *Helicotylenchus*, *Meloidogyne*, and *Pratylenchus* species were recovered from bermudagrass. He concluded that there was no correlation between population density of nematode and the turf quality. The same result was obtained from Bruton (5) who pointed out that high nematode populations could not be correlated with turf density.

Creeping bentgrass on an Illinois golf green was found to be a good host for a member of *Meloidogyne incognita* group, *M. naasi*, and *Tylenchorhynchus agri* (22, 64).

In Stillwater, Oklahoma, Bruton (5) found *Criconemoides*, *Tylenchorhynchus*, *Pratylenchus*, *Paratylenchus*, *Trichodorus*, and *Xiphinema* species associated with "Penncross" creeping bentgrass.

Tylenchorhynchus spp.

This nematode had been reported to be the most commonly found in the turf in many areas. In 1954, Troll and Tarjan (71) found Tylenchorhynchus species to be the most widely distributed phytoparasitic nematodes associated with turf-grass in Rhode Island. They concluded that T. claytoni Steiner and T. dubius (Bütschli) Filipjev were likely to play major roles in devitalizing bentgrass turf.

Krupinsky et al. (33), in 1981, collected 3,099 soil samples from grasses in North and South Dakota and found 21% of Tylenchorhynchus species associated with grasses. Powell (57) reported T. maximus was a major contributing factor to the decline of lawn grasses in Georgia. A study from Illinois showed that Tylenchorhynchus spp. was the most abundant parasitic genus present in bentgrass putting greens (70).

In Wisconsin, Perry et al. (56) reported Helicotylenchus digonicus and T. maximus were the most numerous and most commonly recovered from Kentucky bluegrass turf.

Fushtey and McElroy found Tylenchorhynchus sp. with a high population of Criconemoides sp. associated with unhealthy turf in British Columbia.

Sumner (68) showed that Tylenchorhynchus dubius, T. claytoni, and Helicotylenchus dihystera were the predominant nematodes causing fading-out in Kentucky bluegrass lawns in Nebraska.

Sikora et al. (64) reported "Toronto" C-15 creeping bentgrass was an excellent host for Meloidogyne naasi and Tylenchorhynchus agri. However, when both nematodes occurred in combination, high populations of T. agri can reduce M. naasi infection (65). Similar types of interaction was reported by Johnson (25) among Criconemoides ornatus, Tylenchorhynchus martini, and Hoplolaimus longicaudatus on six bermudagrass cultivars: Tifdwarf, Common, U-3, Tufcote, Continental, and Tiffine.

Tylenchorhynchus capitatus, T. claytoni, T. dubius, T. maximus, T. striatus, and T. parvus were reported associated with turf in the northeastern U.S. (46).

In South Dakota, T. nudus was found in the greatest numbers, 46% of 81 soil samples, around Kentucky bluegrass roots (66).

In an assay of pathogenic capabilities, Troll and Rohde (72) found T. claytoni was pathogenic to creeping red fescue when inoculated with 5,000 specimens per pot. This nematode was considered to be weakly pathogenic to Kentucky bluegrass, creeping red fescue, and annual ryegrass.

Laughlin and Vargas (37) reported in 1972 that T. dubius fed primarily on root hairs and epidermal cells resulting in reduction of foliar and root weights of both "Toronto" bentgrass and "Merion" Kentucky bluegrass. They concluded that the amount of growth reduction of "Toronto" bentgrass was greater when soil temperatures were below 20 C.

In 1972, Vargas and Laughlin (74) indicated that T.

*dubius* in combination with *Fusarium roseum* increased severity of Fusarium blight symptoms on turfgrass than the fungus alone.

Krusberg (34) pointed out that *T. claytoni* may persist in soil several months at low temperatures (2-24 C) and the reproductive rate increased as the temperature increased above 18 C.

Although some species of *Tylenchorhynchus* caused a reduction in total roots or top weights of turf, in some instances, top weights of cereals and grasses were found to be greater in soil infested with populations of *T. claytoni* than in nematode-free soil (34, 73).

*Criconemoides spp.*

Chlorosis, decline in vigor, and dieback of grass blades are often reported as symptoms of ring nematode associated with turfgrass (8, 15, 31, 62, 71).

In 1964, Seshadri (63) reported *Criconemoides xenoplax* reproduced and moved best in sandy soil. Lucas et al. (43) indicated that *C. ornatus* was probably more important on bermudagrass than on bentgrass in North Carolina.

*Criconemoides lobatum* and *C. xenoplax* were found associated with turf in the northeastern U.S. (46).

Salford and Riedel (62) in 1976 found six species of *Criconemoide*: *C. xenoplax, C. ornatum, C. parvum, C. carvatum, C. rusticum,* and one unidentified species, were widespread in fairways and greens on Ohio golf courses.

Criconemoides xenoplax, occurring in 80% of the grass samples, were recovered populations of 8,000 per 500 ml of soil from the sample exhibiting chlorosis and dieback of grass blades.

Lownsberry (39, 40) concluded that C. xenoplax reached a higher population level at 26 C than lower temperatures, and a decrease in population occurred during summer months when the soil had higher temperatures with periodic dying. Also, Seshadri (63) reported that this nematode was very sensitive to low temperature conditions.

Johnson and Powell (28) studied pathogenic capabilities of C. lobatum on various turfgrass and found the nematode reproduced readily on "Tifgreen" bermuda, St. Augustine, centipede, and "Emerald" Zoysia. The reduction of fibrous roots was the obvious effect of this nematode on the grasses tested. Ratanaworabhan and Smart (58) indicated that inocula of 1,000 to 10,000 specimens of C. ornatus per 15 cm pot containing 1,500 ml of soil were pathogenic to centipede grass resulting in retarding growth but the 500 inoculum level was not.

## Other Genera Found Associated With Turf

The sting nematode (Belonolaimus spp.) was reported to cause a serious problem to several turfgrasses (4, 5, 19, 25, 31). Belonolaimus longicaudatus was parasitic on "Penncross" bentgrass in North Carolina (43), on St. Augustine grass in Florida (58), and on Ormon bermudagrass (75).

The spiral nematode (*Helicotylenchus* spp.) *Helicotylenchus pseudorobustus* was found associated with "Zoysiagrass decline" in Maryland (29). Summer dormancy of Kentucky bluegrass was reported to be caused by *H. digonicus* (56). Other workers have also indicated the spiral nematode causing injury to turf (17, 19, 31, 43, 69).

The lance nematode (*Hoplolaimus* spp.) was clearly shown to cause damage to turfgrasses (19, 34, 43, 46, 50, 52).

The root-knot nematode (*Meloidogyne* spp.) has been reported to be pathogenic to turfgrass (18, 22, 61, 64, 65), but its importance is limited to certain areas (21).

The pin nematode (*Paratylenchus* spp.) has not been proven to be a serious parasite on turf. In Stillwater, Oklahoma, Bruton (5) found high populations of the pin nematodes with a population peak in January associated with "Penncross" bentgrass. Other researchers reported the pin nematode is frequently found associated with turf (19, 43, 46, 70).

The lesion nematode (*Pratylenchus* spp.) had been recovered from several turf nurseries (17, 43, 67, 69). In a greenhouse study, *Pratylenchus penetrans* significantly reduced root growth of annual ryegrass but not of Kentucky bluegrass (72). *P. penetrans* was also reported to be highly pathogenic to "Toronto" C-15 creeping bentgrass when present in soil in combination with *Meloidogyne naasi* and *Tylenchorhynchus agri* (64).

The stubby root nematode (*Trichodorus* spp.) occurred frequently around grass roots (19, 31, 69). Trichodorus christiei Allen significantly reduced root weight of St. Augustine grass (59) and might be the most important nematode on bentgrass in North Carolina (43). In greenhouse studies, Rhoades (60) showed that Trichodorus proximus caused more damage to St. Augustine grass than that caused by T. christiei.

The dagger nematode (Xiphinema spp.) was frequently recovered from turfgrass (19, 43, 46), and might cause destruction to root in deeper rhizospere (5). Xiphinema americanum was found in heavy populations associated with Zoysia decline in Maryland (29), and the decline of Midland bermuda pasture in Oklahoma (30).

## Nematode Control in Turf

When nematodes become a problem in an established turf grass, nematicide treatments have been shown to be effective in reducing the plant parasitic nematode population resulting in more vigorous root systems (5, 15, 67, 77). In general, nematicides reduce the nematode populations but do not eliminate them from the soil. Grass in infested areas of high population will grow poorly during the summer. Nematicides are both fumigant and non-fumigant, but fumigant chemicals are not satisfactory on established turf because of their phytotoxic effects on grass (15, 21, 32). Laughlin (35) pointed out in 1972 that a split application of non-fumigant nematicides applied in the spring and fall are more effective in maintaining a lower nematode populations during the year than a single application in the spring.

DBCP (Nemagon) proved to be very effective in controlling nematodes in turf resulting in satisfactory growth of turfgrass (3, 4, 8, 52, 55). The number of Helicotylenchus sp. and Tylenchorhynchus sp. populations were reported to be reduced by 51% of total numbers, 22 weeks after application (52). Since DBCP use was cancelled by the U. S. Environmental Protection Agency (E.P.A.), the use of other available organophosphate and carbamate compounds has been studied on turfgrass.

Feldmesser and Golden (15, 16) showed that the application of ethoprop (Mocap) at the rate 224.5 kg/ha reduced nematode populations 85 to 90% resulting in increasing the growth of grass and reducing chlorosis. In contrast, Miller (49) in 1979 showed that ethoprop 15 G was not effective for control of Tylenchorhynchus dubius and Hoplolaimus galeatus in bentgrass.

Troll and Rohde (73) in 1966 indicated that average clipping weights of a mixture of "Merion" Kentucky bluegrass and creeping red fescue were significantly increased by using O, O-diethyl-O-4 (methylsulfinyl) phenyl phosphorothioate (Bayer 25141 or Dasanit) at the manufacturers' suggested rate and at double the dosage. Bay 25141 was also reported to give excellent control of Belonolaimus longicaudatus on bermudagrass for seven months (4). Wolford and Sturgeon (77) and Sturgeon and Jackson (67) reported fensulfothion (Dasanit) gave the best results on controlling the nematode populations in common bermudagrass. However, fensulfothion at the rate 19.6 kg/ha was phytotoxic to Midland bermudagrass (30).

In 1970, Johnson (24) found that ethyl 4-(methylthio)-m-tolyl isopropyl-phosphoramidate (Bay 68138, Nemacur) when used as a chemical dip at 1,000 ppm for 30 minutes on "Tifdwarf" bermudagrass would control Hoplolaimus galeatus 100% without phytotoxic effect.

Juska (29) reported in 1972 that Bay 25141 (Dasanit) was more effective in suppression of nematode populations than DBCP.

Lucas (42) reported fensulfothion and fenamiphos improved the bermudagrass quality within four weeks after application. Fensulfothion reduced populations of Belonolaimus longicaudatus for only one month after treatment but Criconemella ornata population increased whereas fenamiphos significantly reduced numbers of these nematodes. He concluded that fenamiphos (Nemacur) was the most effective nematicide used on turf infested with B. longicaudatus.

Results obtained by Laughlin (37) showed that both Bay 68138 (Nemacur) and Bay 25141 (Dasanit) significantly suppressed Tylenchorhyncus dubius population in "Toronto" creeping bentgrass up to three months after application. Similar result was obtained by Nutter et al. in 1980 (53) showing that fenamiphos (Nemacur 15 G) provided excellent control of Tylenchorhynchus sp. in creeping bentgrass up to

90 days after treatment. Fenamiphos (Nemacur) was also effective for control of *Meloidogyne incognita, Pratylenchus penetrans, Criconemoides* spp. and *Xiphenema* spp. (28). However, Krauz (32) showed that this nematicide significantly reduced only the populations of *Belonolaimus longicaudatus* in bermudagrass, *Trichodorus christiei* and *Macroposthonia* sp. populations were not significantly decreased.

Perry and Dickerson (55) pointed out that fenamiphos (Nemacur) improved bermudagrass but did not control nematodes as well as DBCP.

Carbofuran (Furadan) is one of the non-fumigant nematicides that was clearly proven to be effective in increasing root growth (11), however, this nematicide was reported to be toxic at pH 6.5 and 7.5 (47). DiSanzo (13) studied the movement of carbofuran (Furadan) through the soil profile and found that it moved down to a depth of at least 45 cm when applied on the surface of sandy loam soil in the field.

Since systemic compounds can be translocated within the plant from the root to the above ground plant, research in the method of nematicide application has been done to determine the most effective method. Applying a nematicide through sprinkler irrigation or foliar application has been shown to effectively control nematode populations (12, 26, 27).

Johnson et al. (27) indicated that fenamiphos (Nemacur), ethoprop (Mocap), and carbofuran (Furadan) effectively controlled parasitic nematode populations on squash, southern pea, and corn when applied through an overhead sprinkler irrigation system. Although this method offered several advantages, there were no significant differences when this treatment was compared to a soil treatment.

DiSanzo (12) used microplot studies and showed that populations of Pratylenchus penetrans in corn roots and populations of Tylenchorhynchus claytoni, Xiphinema americanum, and Hoplolaimus sp. in soil can be reduced with foliar application of carbofuran (Furadan) and FMC 35001. Here again, there were no differences between foliar treatment and soil treatment.

## Extraction Procedures

Selecting the proper extraction procedure is essential for accurate estimation of nematode populations in the soil. There are several known extraction procedures, however, some methods are more effective than others for a particular type of nematode or for certain kinds of plants (14).

The centrifugal-flotation method has been successfully used for sandy soils and has been considered an effective method for recovering of Criconemoides spp. (71).

In 1971, Dunn (14) compared two centrifugal-flotation techniques (direct centrifugation and seiving-centrifugation) with Seinhorst elutrition and concluded that direct centrifugation was excellent in recovering many different kinds of nematodes from soil. However, Dickerson (9) showed in 1977 that direct centrifugal-flotation was not as effective as the seiving-centrifugal flotation and was not as consistent.

# CHAPTER III

## MATERIALS AND METHODS

This study was carried out on an established stand of "Penncross" creeping bentgrass (_Agrostis palustris_ Huds.), located at the O.S.U. Plant Pathology Farm, Stillwater, Oklahoma. This stand of "Penncross" bentgrass was approximately nine years old, growing on a premixed soil at pH 7. The study area was fertilized according to recommendations based on soil analysis. The bentgrass plots were irrigated each day, except during rainy periods when no water was necessary, and mowed three times a week. Core cultivation (aerification) was done on March 24, 1982, followed by topdressing with sand. The herbicide "Betsan" was applied on March 31, 1982 at the rate of 200.125 g ai./93 $m^2$. On April 8, the plots were fertilized with Country Club Fertilizer 18-4-6 at the rate of 454 g N/93 $m^2$. After April 8, Milorganite (6-2-0) was applied at 680 g N/93 $m^2$ on a 14-day schedule. Brown Patch and Dollar Spot was controlled with chlorothalonil (Daconil 2787 WP) at 113.5-170.25 g ai./93 $m^2$ as needed. Subdue 2E was applied once during the summer for control of Pythium blight.

Six treatments were established and replicated four times. The 24 plots were laid out in a randomized block design. Each plot area was 0.762 by 3.048 meters in size. Three granular nematicide formulations: (1) O, O-diethyl O-4-(methylsulfinyl) phenyl phosphorothioate (fensulfothion) at 680 gm/93 $m^2$, and at 1,360 gm/93 $m^2$; (2) 2, 3-dihydro-2, 2-dimethyl-7 benzofuranyl methyl carbamate (carbofuran) at 2,041 gm/93 $m^2$; and (3) Ethyl 3-methyl-4-(methylthio) phenyl (1-methyl-ethyl) phosphoramidate (fenamiphos) at 680 gm/93 $m^2$ and at 1,360 gm/93 $m^2$ were applied on September 16, 1981, and May 15, 1982. Nematicides were applied evenly over the plots with a Mason glass jar and drenched into the soil with approximately 1.27 cm to 2.54 cm of water. Soil samples were taken in a zigzag pattern to ensure equal distribution from the plots by using a soil sampler with dimensions of 2 cm by 50 cm. Sampling dates were as follows: pretreatment before nematicide application on September 16, 1981, and May 15, 1982, and the after treatment samples were taken at monthly intervals from October 1981 to August 1982. Seven soil cores from each plot were taken at the depth of 0-5 cm, 5-10 cm, 10-15 cm, and placed in plastic bags labeled according to soil depth. Soil cores from each depth sampled were mixed together and nematodes were extracted from a 100 ml aliquant of soil taken from each sample by a centrifugal technique (6, 22). Plant parasitic nematodes were counted and identified to genus.

Soil temperatures at the three depths were taken at each sampling date and recorded as the mean of two observations.

A comparison of the centrifugal technique with a modification of the Christie-Perry extraction method (7), for extraction procedure was made three times, in December 1981 and June and July 1982, to evaluate the effectiveness of the the two methods of recovering nematodes from turfgrass (8).

## Endoparasitic Nematode Assay

Root weight per 100 ml of soil at the three depths were measured each month from January through August 1982. The roots were washed free of soil in running tap water, weighed, placed in 250 ml flasks containing water, and aerated by bubbling air through them. Root samples were incubated for two weeks and the endoparasitic nematodes were then counted and identified at the end of each week.

CHAPTER IV

# RESULTS

Nematodes recovered from the bentgrass study were species of *Macroposthonia*, *Tylenchorhynchus*, *Helicotylenchus*, *Hoplolaimus*, *Paratylenchus*, *Pratylenchus*, *Psilenchus*, *Belonolaimus*, *Meloidogyne*, *Hemicycliophora*, *Trichodorus*, and *Tylenchus*. The nematode species most consistently recovered at all depths, 0-15 cm, were *Macroposthonia* sp. and *Tylenchorhynchus* sp. The other genera were recovered infrequently and in low population numbers (Table I).

In plots receiving no nematicide treatments, populations of *Macroposthonia* sp. and *Tylenchorhynchus* sp. fluctuated greatly from September 1981 through August 1982 (Figures 1 and 2). The greater densities of *Macroposthonia* sp. occurred at all three depths during July 1982. Populations of 402, 223, and 180 were recovered from 100 ml aliquant of soil taken at 0-5 cm, 5-10 cm, and 10-15 cm soil depths, respectively. The lowest Macroposthonia populations were recovered during January 1982 with an average population of 95 at 0-5 cm level, 43 at 5-10 cm level, and 50 at 10-15 cm level. The *Macroposthonia* sp. population recovered in late August 1982 did not differ from those recovered in early September 1981 (Figure 1). The number of

TABLE I

AVERAGE NUMBER OF VARIOUS GENERA OF NEMATODES RECOVERED FROM "PENNCROSS" BENTGRASS AND SOIL TEMPERATURE AT VARIOUS SOIL DEPTHS BETWEEN SEPTEMBER 1981 AND AUGUST 1982[1]

| Date | Ring | | | Stunt | | | Others[2] | | | Soil Temperature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | A | B | C |
| 9- 2 | 220 | 108 | 56 | 374 | 60 | 36 | 4 | 4 | 2 | 25.5 | 25.0 | 24.0 |
| 10- 6 | 144 | 68 | 50 | 305 | 33 | 23 | - | 2 | - | 11.0 | 10.0 | 10.0 |
| 11-16 | 122 | 72 | 46 | 260 | 44 | 11 | 4 | - | 13 | 5.0 | 4.8 | 4.8 |
| 12-20 | 151 | 68 | 60 | 523 | 32 | 33 | 3 | 2 | - | 1.0 | 0.5 | 0.5 |
| 1-29 | 95 | 43 | 50 | 340 | 57 | 19 | - | - | 2 | 4.4 | 4.4 | 3.9 |
| 2-22 | 167 | 89 | 70 | 704 | 70 | 12 | 3 | 4 | 1 | 10.0 | 10.0 | 9.0 |
| 3-27 | 242 | 94 | 50 | 474 | 59 | 16 | 4 | 6 | 2 | 12.0 | 11.0 | 10.0 |
| 4-26 | 171 | 81 | 41 | 412 | 69 | 20 | 4 | 1 | 2 | 17.7 | 19.0 | 21.0 |
| 5-30 | 239 | 94 | 72 | 161 | 52 | 16 | 5 | 8 | 12 | 19.0 | 18.8 | 18.3 |
| 6-30 | 246 | 191 | 74 | 283 | 84 | 33 | 1 | 5 | 6 | 24.0 | 23.8 | 23.0 |
| 7-30 | 402 | 223 | 180 | 529 | 76 | 32 | 5 | 54 | 46 | 25.6 | 24.4 | 23.3 |
| 8-28 | 257 | 186 | 98 | 801 | 86 | 26 | - | 3 | 1 | 25.6 | 25.6 | 25.0 |

[1]These numbers are an average of 4 replications from the untreated plots.

[2]Includes species of *Belonolaimus*, *Helicotylenchus*, *Hoplolaimus*, *Paratylenchus*, *Pratylenchus*, *Psilenchus*, *Meloidogyne*, *Hemicycliphora*, *Trichodorus*, and *Tylenchus*.

A = 0-5 cm soil depth
B = 5-10 cm soil depth
C = 10-15 cm soil depth
Ring = *Macroposthonia* sp.
Stunt = *Tylenchorhynchus* sp.

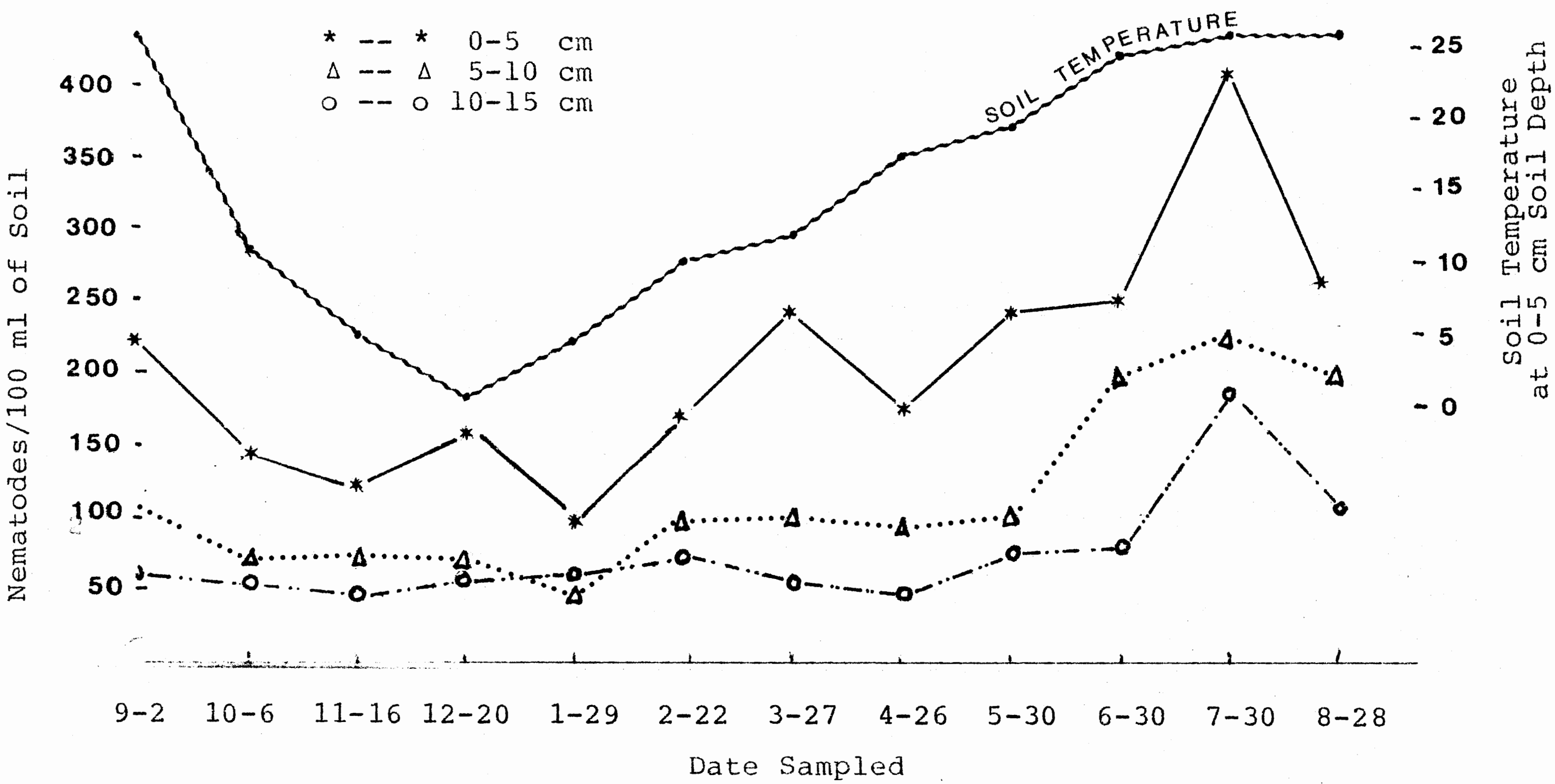


Figure 1. Seasonal Population Changes of Macroposthonia sp. in "Penncross" Bentgrass at Various Depths During September 1981 - August 1982 from Untreated Plots

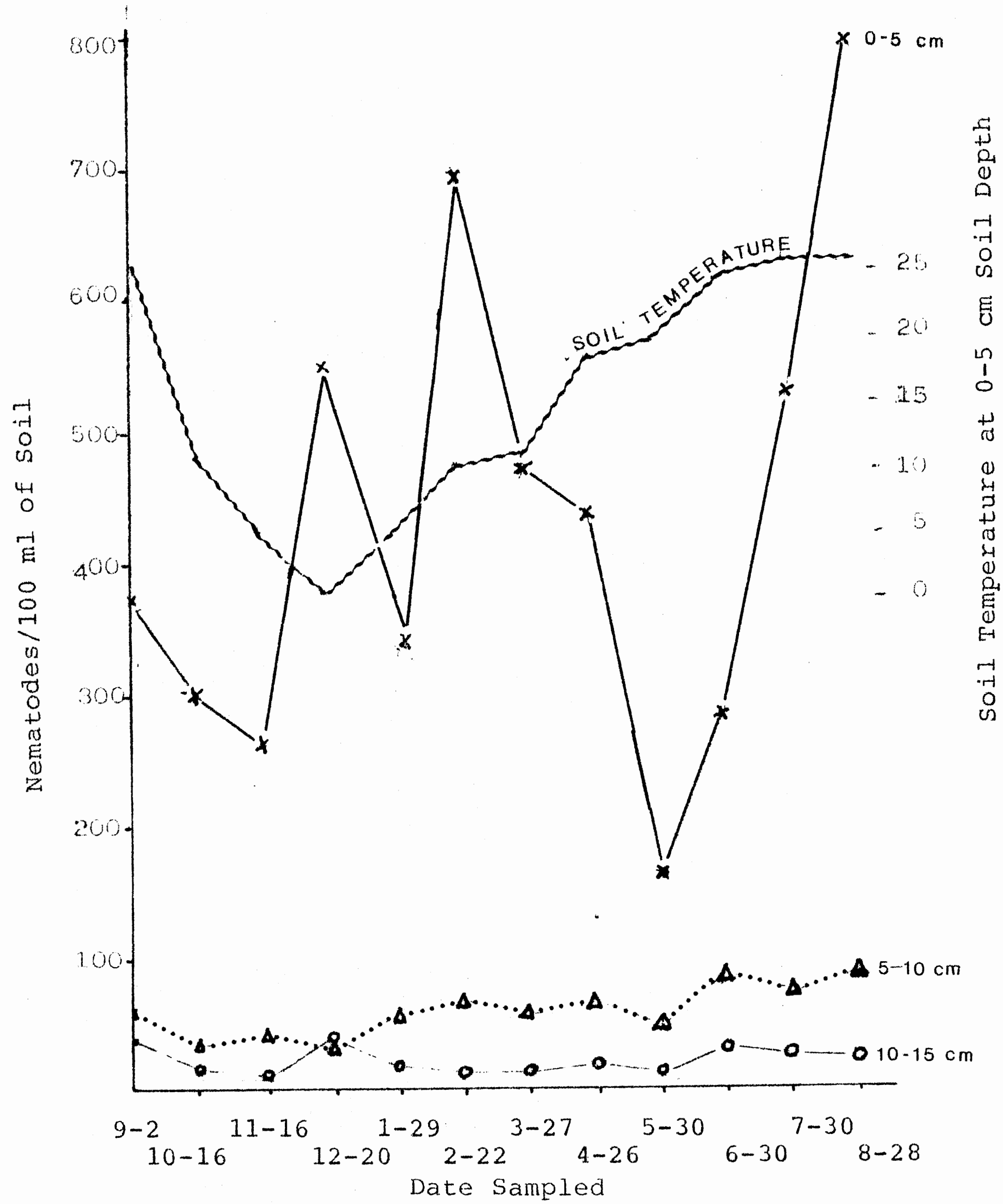


Figure 2. Seasonal Population Changes of <u>Tylenchorhynchus</u> sp. in "Penncross" Bentgrass at Various Depths During September 1981 - August 1982 From Untreated Plots

Tylenchorhynchus sp. recovered from plots receiving no nematicide treatments peaked two times, February and August, during the 12-month monitoring period (Figure 2). The lowest population of this nematode specie occurred at the 0-5 cm level in May which was 60.9% lower than the population recovered in April. In contrast, populations recovered from 5-10 cm and 10-15 cm levels recovered in May were not different from those recovered in April.

Trichodorus sp. occurred less frequently in the study area than other nematode species, however, moderate populations can produce significant injury.

As shown in Table I, temperature at the various depths seemed to be a significant factor for increasing or suppressing nematode populations in the soil. The greater population number of Macroposthonia sp. and Tylenchorhynchus sp. were recovered during the period when soil temperatures were 23-25 C. However, despite the frozen condition of the soil in December 1981 and January 1982, the population of Tylenchorhynchus sp. was still high whereas the Macroposthonia sp. population decreased under the low 4 C temperature.

Densities of Pratylenchus sp. increased in June and July in the soil and roots at all levels with a decline in August (Tables I, II).

## Effect of Nematicides on Nematode Populations

Pretreatment samples from the established bentgrass on

TABLE II

PLANT PARASITIC NEMATODES/GRAM OF ROOT WEIGHT/100ML OF SOIL RECOVERED AT VARIOUS SOIL DEPTH[a]

| Date | Treatment | Rate gm/ 93m² | Root weight (gm) | | | *Pratylenchus* sp. in root | | | *Pratylenchus* sp. in soil | | | Total nematodes in soil[b] | | | Soil temperature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A* | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 1-29 | Untreated plots | | 3.71 | 1.12 | 0.08 | | | | | | | 435 | 100 | 72 | 4.4 | 4.4 | 3.9 |
| | Fensulfothion | 680 | 5.18 | 1.09 | 0.23 | - | 1 | 1 | - | - | - | 979 | 121 | 56 | | | |
| | Fensulfothion | 1360 | 4.45 | 1.30 | 0.23 | 2 | - | 1 | - | - | - | 549 | 148 | 56 | | | |
| | Carbofuran | 2041 | 3.54 | 0.99 | 0.23 | | - | - | - | - | - | 408 | 124 | 125 | | | |
| | Fenamiphos | 680 | 2.52 | 1.18 | - | 3 | 1 | 1 | - | - | - | 363 | 95 | 50 | | | |
| | Fenamiphos | 1360 | 3.25 | 1.20 | 0.10 | 2 | - | 1 | - | - | - | 265 | 88 | 52 | | | |
| 2-22 | Untreated plots | | 4.16 | 0.69 | 0.07 | 29 | 16 | 27 | - | - | - | 874 | 163 | 83 | 10.0 | 10.0 | 9.0 |
| | Fensulfothion | 680 | 3.15 | 0.51 | 0.16 | 1 | 12 | 6 | - | - | - | 602 | 99 | 103 | | | |
| | Fensulfothion | 1360 | 4.02 | 0.63 | 0.04 | 2 | 4 | 4 | - | 2 | - | 521 | 58 | 40 | | | |
| | Carbofuran | 2041 | 2.25 | 0.53 | 0.05 | | - | 6 | - | - | - | 218 | 90 | 103 | | | |
| | Fenamiphos | 680 | 2.90 | 0.89 | 0.12 | 1 | 1 | - | - | - | - | 324 | 105 | 44 | | | |
| | Fenamiphos | 1360 | 3.53 | 0.69 | 0.08 | 1 | - | - | - | - | - | 97 | 86 | 48 | | | |
| 3-27 | Untreated plots | | 5.73 | 1.77 | 0.18 | 25 | 41 | 2 | - | - | - | 745 | 200 | 70 | 12.0 | 11.0 | 9.0 |
| | Fensulfothion | 680 | 4.89 | 1.58 | 0.35 | | - | - | - | - | - | 484 | 103 | 64 | | | |
| | Fensulfothion | 1360 | 6.08 | 1.36 | 0.11 | - | - | - | - | - | - | 500 | 166 | 109 | | | |
| | Carbofuran | 2041 | 5.03 | 1.55 | 0.11 | - | - | - | - | - | - | 331 | 106 | 80 | | | |
| | Fenamiphos | 680 | 5.33 | 1.51 | 0.16 | - | 3 | - | - | - | - | 132 | 32 | 32 | | | |
| | Fenamiphos | 1360 | 6.08 | 2.16 | 0.18 | - | - | - | 1 | 6 | 2 | 354 | 72 | 41 | | | |

TABLE II (CONTINUED)

| Date | Treatment | Rate gm/ 93m$^2$ | Root weight (gm) | | | *Pratylenchus* sp. in root | | | *Pratylenchus* sp. in soil | | | Total nematodes in soil[b] | | | Soil temperature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A* | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 4-26 | Untreated plots | | 6.53 | 1.88 | 0.70 | 8 | 19 | 27 | - | - | - | 595 | 170 | 90 | 17.7 | 19.0 | 21.0 |
| | Fensulfothion | 680 | 6.54 | 2.05 | 0.58 | 1 | 12 | 6 | 6 | - | - | 714 | 330 | 128 | | | |
| | Fensulfothion | 1360 | 6.25 | 2.68 | 0.29 | 2 | 4 | 1 | - | - | - | 637 | 93 | 106 | | | |
| | Carbofuran | 2041 | 6.32 | 1.46 | 0.42 | 1 | - | 6 | - | - | - | 353 | 124 | 58 | | | |
| | Fenamiphos | 680 | 5.19 | 2.01 | 0.51 | 1 | 2 | - | 2 | - | - | 191 | 66 | 35 | | | |
| | Fenamiphos | 1360 | 5.65 | 2.77 | 0.32 | 1 | - | - | 1 | - | - | 151 | 90 | 49 | | | |
| 5-30 | [c]Untreated plots | | 5.60 | 1.11 | 0.35 | 14 | 4 | 35 | 4 | 4 | 8 | 419 | 158 | 135 | 19.0 | 18.8 | 18.3 |
| | Fensulfothion | 680 | 3.80 | 0.91 | 0.42 | 14 | 52 | 16 | - | 1 | - | 355 | 286 | 65 | | | |
| | Fensulfothion | 1360 | 3.27 | 1.00 | 0.57 | 8 | 27 | 26 | 5 | - | 2 | 465 | 244 | 168 | | | |
| | Carbofuran | 2041 | 4.00 | 1.32 | 0.26 | - | - | - | - | - | - | 249 | 128 | 71 | | | |
| | Fenamiphos | 680 | 3.72 | 1.35 | 0.43 | - | - | - | - | - | - | 79 | 46 | 10 | | | |
| | Fenamiphos | 1360 | 3.05 | 1.22 | 0.29 | 1 | - | - | - | - | - | 89 | 77 | 45 | | | |
| 6-30 | Untreated plots | | 3.86 | 1.09 | 0.32 | 50 | 3 | 2 | | | | 580 | 283 | 115 | 24.0 | 23.8 | 23.0 |
| | Fensulfothion | 680 | 3.13 | 0.66 | 0.35 | 3 | 10 | 1 | 3 | 7 | 4 | 540 | 247 | 180 | | | |
| | Fensulfothion | 1360 | 2.87 | 0.58 | 0.19 | 1 | - | - | 3 | 25 | 28 | 449 | 257 | 211 | | | |
| | Carbofuran | 2041 | 2.34 | 0.48 | 0.21 | 4 | 2 | 9 | - | - | - | 539 | 240 | 250 | | | |
| | Fenamiphos | 680 | 3.15 | 0.80 | 0.18 | - | - | - | 1 | 1 | 1 | 141 | 63 | 37 | | | |
| | Fenamiphos | 1360 | 3.03 | 0.80 | 0.29 | - | - | - | - | - | - | 174 | 56 | 53 | | | |

TABLE II (CONTINUED)

| Date | Treatment | Rate gm/ 93m[2] | Root weight (gm) | | | *Pratylenchus* sp. in root | | | *Pratylenchus* sp. in soil | | | Total nematodes in soil[b] | | | Soil temperature | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A* | B | C | A | B | C | A | B | C | A | B | C | A | B | C |
| 7-30 | Untreated plots | | 3.44 | 0.30 | 0.15 | 5 | - | - | - | 3 | 7 | 941 | 353 | 258 | 25.6 | 24.4 | 23.0 |
| | Fensulfothion | 680 | 3.21 | 0.34 | 0.02 | 9 | 1 | 1 | 11 | 22 | 19 | 755 | 295 | 220 | | | |
| | Fensulfothion | 1360 | 2.93 | 0.57 | 0.23 | 6 | 3 | 1 | 15 | 14 | 23 | 564 | 368 | 243 | | | |
| | Carbofuran | 2041 | 2.76 | 0.62 | 0.09 | 4 | 2 | - | - | - | | 584 | 337 | 145 | | | |
| | Fenamiphos | 680 | 3.50 | 0.43 | 0.14 | 2 | - | - | - | 3 | 7 | 209 | 55 | 25 | | | |
| | Fenamiphos | 1360 | 2.93 | 0.57 | 0.23 | - | - | - | - | 3 | 7 | 177 | 44 | 19 | | | |
| 8-28 | Untreated plots | | 2.87 | 0.32 | 0.12 | - | - | - | - | 3 | - | 1058 | 275 | 125 | 25.6 | 25.6 | 25.0 |
| | Fensulfothion | 680 | 3.62 | 0.06 | 0.01 | - | - | - | - | 8 | 12 | 1194 | 319 | 304 | | | |
| | Fensulfothion | 1360 | 3.37 | 0.10 | - | - | - | - | - | 7 | 4 | 737 | 347 | 249 | | | |
| | Carbofuran | 2041 | 2.73 | 0.08 | - | - | - | - | - | - | - | 658 | 237 | 249 | | | |
| | Fenamiphos | 680 | 2.36 | 0.28 | 0.01 | - | | - | - | - | - | 294 | 73 | 39 | | | |
| | Fenamiphos | 1360 | 1.36 | 0.28 | 0.01 | - | - | - | - | - | - | 183 | 62 | 34 | | | |

[a]Fensulfothion = Dasanit 15G, carbofuran = Furadan 10G, fenamiphos = Nemacur 15G.

[b]Included *Criconemoides* sp., *Tylenchorhynchus* sp., *Pratylenchus* sp. in root and soil, and other genera.

[c]Nematicide application made on May 15, 1982.

*A = 0-5 cm soil depth, B = 5-10 cm soil depth, C= 10-15 cm soil depth.

September 2, 1981, showed no significant difference in populations of Macroposthonia sp. (Table III) or Tylenchorhynchus sp. (Table IV) in any of the treatments before the first nematicide application was made in late September 1981.

Twenty days after the first nematicide application, on October 6, 1981, none of the nematicides had significantly reduced the Macroposthonia sp. population at the three sampling depths (Table III). However, on November 16, 61 days after the late September application, the population in plots receiving fenamiphos (Nemacur) applied at 680 gm/93 $m^2$ (low rate) and 1360 gm/93 $m^2$ (high rate) was lower than plots receiving fensulfothion (Dasanit) and carbofuran (Furadan) and was 50% and 20% lower than plots receiving no chemical treatments at the depth of 0-5 cm. Populations in plots receiving fensulfothion at low rate in late September increased notably during January and April, four and seven months after nematicide application, respectively.

Soil samples taken on May 30, 1982, 15 days following the second nematicide application showed that fenamiphos at low and high rates were the only nematicide treatments significantly reducing Macroposthonia sp. populations at the 0-5 cm depth. The Macroposthonia populations recovered from the 5-10 cm and 10-15 cm depths in plots receiving high and low rates of fenamiphos were significantly lower than untreated plots and plots receiving carbofuran and fensulfothion at the low and high rates in July 1982. The Macroposthonia sp.

TABLE III

NUMBER OF *MACROPOSTHONIA* SP. PER 100 ML OF SOIL BEFORE AND FOLLOWING TREATMENT[a]

| Treatment | Rate gm/ 93 $m^2$ | Date Sampled 9-2 | 10-6 | 11-16 | 12-20 | 1-29 | 2-22 | 3-27 | 4-26 | 5-30 | 6-30 | 7-30 | 8-28 | Depth (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Untreated plots | | 220[b] | 144 | 122 | 151 | 95 | 167 | 242 | 171 | [c]239 | 246 | 402 | 257 | 0-5 |
| Fensulfothion | 680 | 269 | 229 | 176 | 182 | 429 | 216 | 270 | 415 | 264 | 397 | 413 | 385 | |
| Fensulfothion | 1360 | 285 | 259 | 201 | 371 | 192 | 220 | 300 | 383 | 304 | 394 | 324 | 227 | |
| Carbofuran | 2041 | 298 | 257 | 262 | 161 | 111 | 116 | 200 | 167 | 173 | 447 | 331 | 299 | |
| Fenamiphos | 680 | 231 | 218 | 72 | 117 | 145 | 125 | 111 | 144 | 70* | 123 | 180* | 238 | |
| Fenamiphos | 1360 | 233 | 205 | 98 | 141 | 176 | 62 | 220 | 108 | 78* | 128 | 120* | 97* | |
| L.S.D. 0.05% | | ns | ns | ns | ns | ns | ns | ns | ns | 132 | ns | 152 | 203 | |
| Untreated plots | | 108 | 68 | 72 | 68 | 43 | 89 | 94 | 81 | 94 | 191 | 223 | 186 | 5-10 |
| Fensulfothion | 680 | 101 | 69 | 105 | 157 | 95 | 73 | 63 | 239 | 189 | 165 | 195 | 236 | |
| Fensulfothion | 1360 | 146 | 119 | 114 | 104 | 73 | 50 | 144 | 212 | 167 | 179 | 261 | 281 | |
| Carbofuran | 2041 | 146 | 136 | 105 | 180 | 96 | 75 | 91 | 84 | 102 | 206 | 256 | 157 | |
| Fenamiphos | 680 | 91 | 74 | 60 | 51 | 36 | 58 | 29 | 30 | 44 | 60 | 50* | 70 | |
| Fenamiphos | 1360 | 135 | 111 | 86 | 68 | 76 | 79 | 67 | 81 | 67 | 53 | 43* | 59 | |
| L.S.D. 0.05% | | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | 113 | ns | |
| Untreated plots | | 56 | 50 | 46 | 60 | 50 | 70 | 50 | 41 | 72 | 74 | 180 | 98 | 10-15 |
| Fensulfothion | 680 | 75 | 65 | 79 | 141 | 48 | 82 | 53 | 88 | 38 | 141 | 152 | 242 | |
| Fensulfothion | 1360 | 77 | 62 | 39 | 89 | 43 | 35 | 104 | 76 | 121 | 131 | 183 | 224 | |
| Carbofuran | 2041 | 80 | 99 | 70 | 103 | 80 | 90 | 76 | 37 | 67 | 225 | 114 | 186 | |
| Fenamiphos | 680 | 71 | 51 | 19 | 58 | 36 | 38 | 31 | 26 | 10 | 34 | 19* | 37 | |
| Fenamiphos | 1360 | 65 | 68 | 30 | 95 | 44 | 45 | 41 | 46 | 45 | 53 | 19* | 32 | |
| L.S.D. 0.05% | | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | 89 | ns | |

[a]Fensulfothion = Dasanit 15G, carbofuran = Furadan 10G, fenamiphos = Nemacur 15G.
[b]First nematicide application on September 16, 1981.
[c]Second nematicide application on May 15, 1982.

# TABLE IV

## NUMBER OF TYLENCHORHYNCHUS SP. PER 100 ML OF SOIL BEFORE AND FOLLOWING TREATMENT[a]

| Treatment | Rate gm/ 93 $m^2$ | Date Sampled 9-2 | 10-6 | 11-16 | 12-20 | 1-29 | 2-22 | 3-27 | 4-26 | 5-30 | 6-30 | 7-30 | 8-28 | Depth (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Untreated plots | | 374[b] | 305 | 260 | 523 | 340 | 704 | 474 | 412 | [c]161 | 283 | 529 | 801 | 0-5 |
| Fensulfothion | 680 | 400 | 202 | 104 | 200 | 544 | 412 | 207 | 264 | 74 | 131* | 307 | 792 | |
| Fensulfothion | 1360 | 396 | 187 | 93 | 182 | 349 | 207 | 197 | 239 | 112 | 47* | 213 | 488 | |
| Carbofuran | 2041 | 360 | 280 | 136 | 114 | 262 | 124* | 131 | 181* | 76 | 87* | 227 | 347 | |
| Fenamiphos | 680 | 259 | 137 | 38* | 42 | 89 | 107* | 21* | 43* | 9* | 18* | 21* | 25* | |
| Fenamiphos | 1360 | 262 | 159 | 47* | 23 | 64 | 37* | 134* | 40* | 6* | 16* | 6* | 6* | |
| L.S.D. 0.05% | | ns | ns | 193 | ns | ns | 536 | 340 | 131 | 131 | 132 | 331 | 592 | |
| Untreated plots | | 60 | 33 | 44 | 32 | 57 | 70 | 59 | 69 | 52 | 84 | 76 | 86 | 5-10 |
| Fensulfothion | 680 | 55 | 35 | 28 | 18 | 24 | 13 | 39 | 59 | 35 | 59 | 62 | 62 | |
| Fensulfothion | 1360 | 52 | 32 | 14* | 6 | 68 | 5 | 22 | 63 | 6 | 17* | 62 | 54 | |
| Carbofuran | 2041 | 66 | 36 | 25 | 16 | 26 | 15 | 15 | 40 | 6 | 22* | 65 | 62 | |
| Fenamiphos | 680 | 28 | 10 | 9* | 5* | 55 | 45 | 3* | 33 | 2* | 2* | 5* | 3* | |
| Fenamiphos | 1360 | 48 | 29 | 5 | 4* | 12 | 7* | 5* | 8 | 2* | 3* | 1* | 3* | |
| L.S.D. 0.05% | | ns | ns | 25 | 22 | ns | 67 | 40 | ns | 39 | 61 | 40 | 52 | |
| Untreated plots | | 36 | 23 | 11 | 33 | 19 | 12 | 16 | 20 | 16 | 33 | 32 | 26 | 10-15 |
| Fensulfothion | 680 | 29 | 21 | 15 | 4 | 16 | 20 | 9 | 27 | 8 | 27 | 30 | 42 | |
| Fensulfothion | 1360 | 34 | 32 | 6 | 31 | 13 | 5 | 2 | 21 | 7 | 23 | 23 | 17 | |
| Carbofuran | 2041 | 19 | 14 | 2 | 11 | 45 | 12 | 4 | 13 | 4* | 15 | 20 | 45 | |
| Fenamiphos | 680 | 24 | 20 | 5 | 3 | 12 | 6 | 1* | 9 | 0* | 2* | 3* | 2* | |
| Fenamiphos | 1360 | 25 | 11 | 27 | 7 | 7 | 3 | 0 | 3 | 0* | 0* | 0* | 2* | |
| L.S.D. 0.05% | | ns | ns | ns | ns | ns | ns | 9 | ns | 8 | 32 | 22 | 28 | |

[a]Fensulfothion = Dasanit 15G, carbofuran = Furadan 10G, fenamiphos = Nemacur 15G.
[b]First nematicide application on September 16, 1981.
[c]Second nematicide application on May 15, 1982.

populations, 15 days after second application of carbofuran were 28% lower than those recovered from plots receiving no treatment at the 0-5 cm depth, however, there was no difference in population between the two treatments at the lower (5-15 cm) depths.

Fensulfothion at low and high rates did not seemingly suppress Macroposthonia sp. populations following nematicide application at the various depths when compared to plots receiving no treatment (Figures 3, 4, 5).

Plots receiving fenamiphos at low and high rates showed a significantly reduced Tylenchorhynchus sp. population on November 16, 1982, 61 days after the nematicide application, at the depths of 0-5 cm and 5-10 cm, when compared to plots receiving no chemical (Table IV). Significant reduction in numbers of this nematode were detected up to seven months in the 0-5 cm and 5-10 cm depths from plots receiving the high and low rates of fenamiphos. Plots receiving carbofuran showed significantly reduced Tylenchorhynchus sp. populations five to seven months, February through April, after chemical application in the 0-5 cm depth when compared to no treatment. Tylenchorhynchus sp. populations at the 0-10 cm depths were significantly lower two months following the May 15 nematicide application in all nematicide treated plots, except those receiving fensulfothion at the low rate.
Plots receiving low and high rates of funsulfothion showed an increase of this nematode population three and four months following application at all depths (Figures 6, 7, 8).

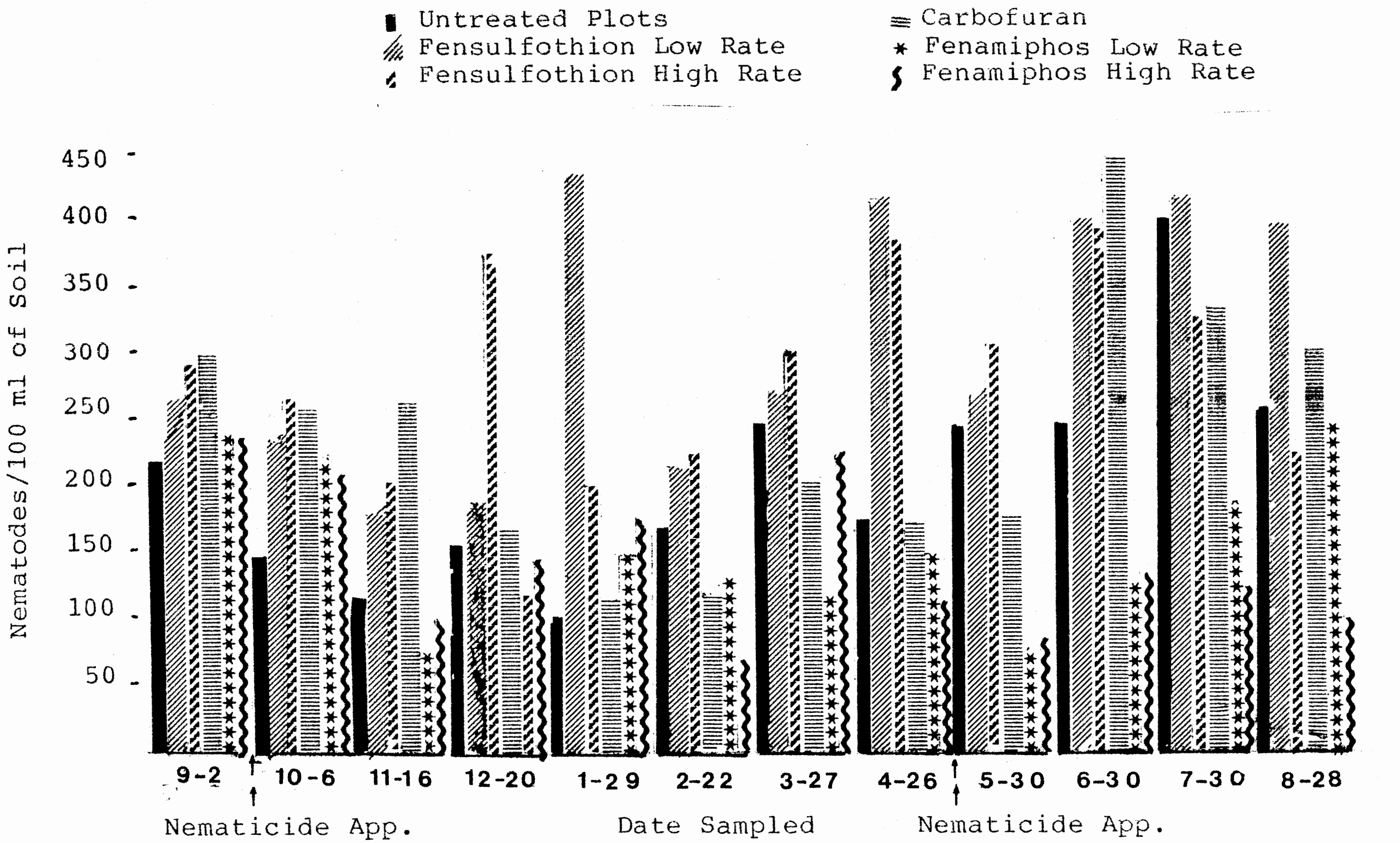


Figure 3. Response of Macroposthonia sp. Population to Chemical Treatments at 0-5 cm Depth in Established "Penncross" Bentgrass During September 1981 - August 1982

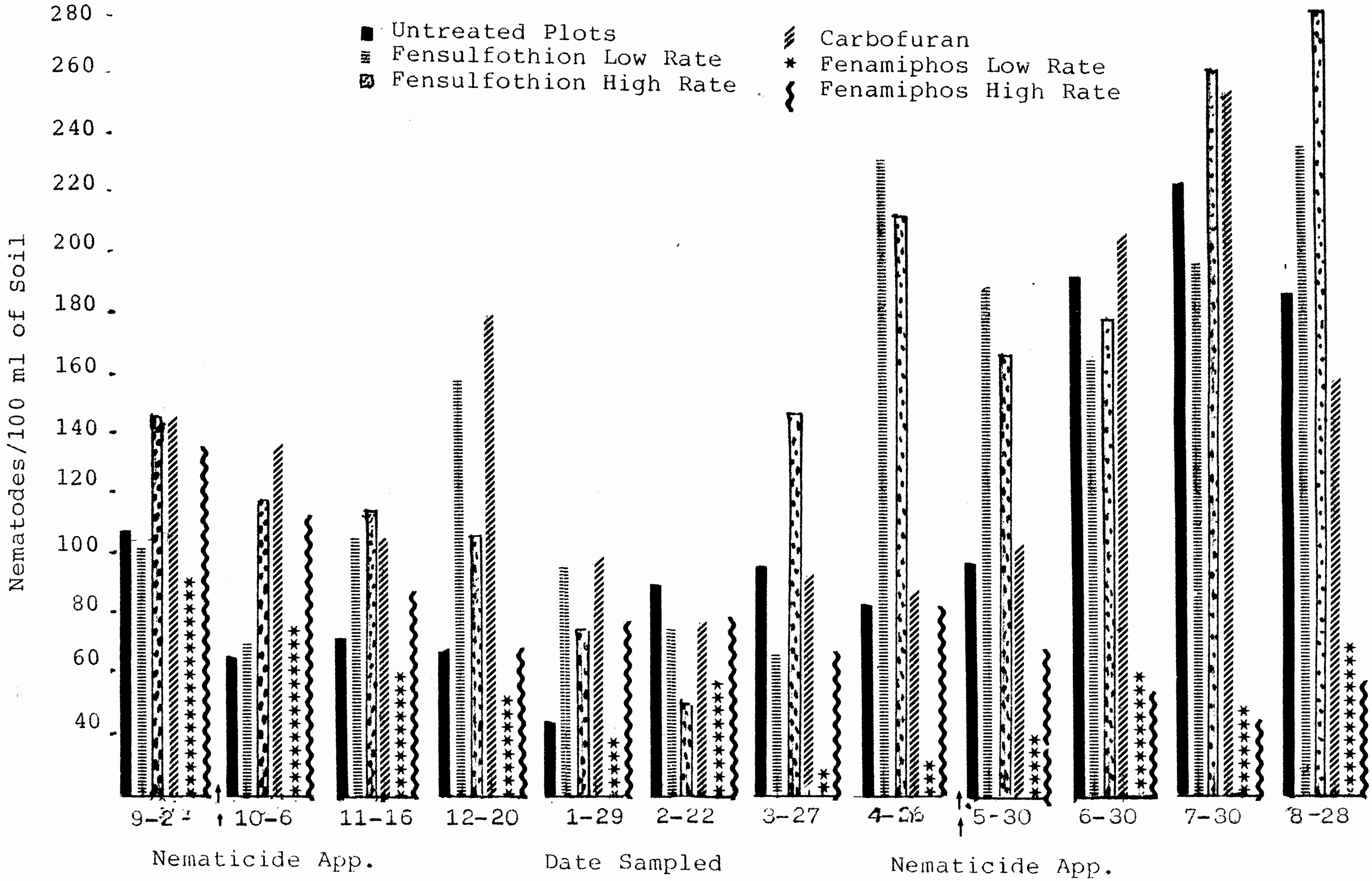


Figure 4. Response of Macroposthonia sp. Population to Chemical Treatments at 5-10 cm Depth in Established "Penncross" Bentgrass During September 1981 - August 1982

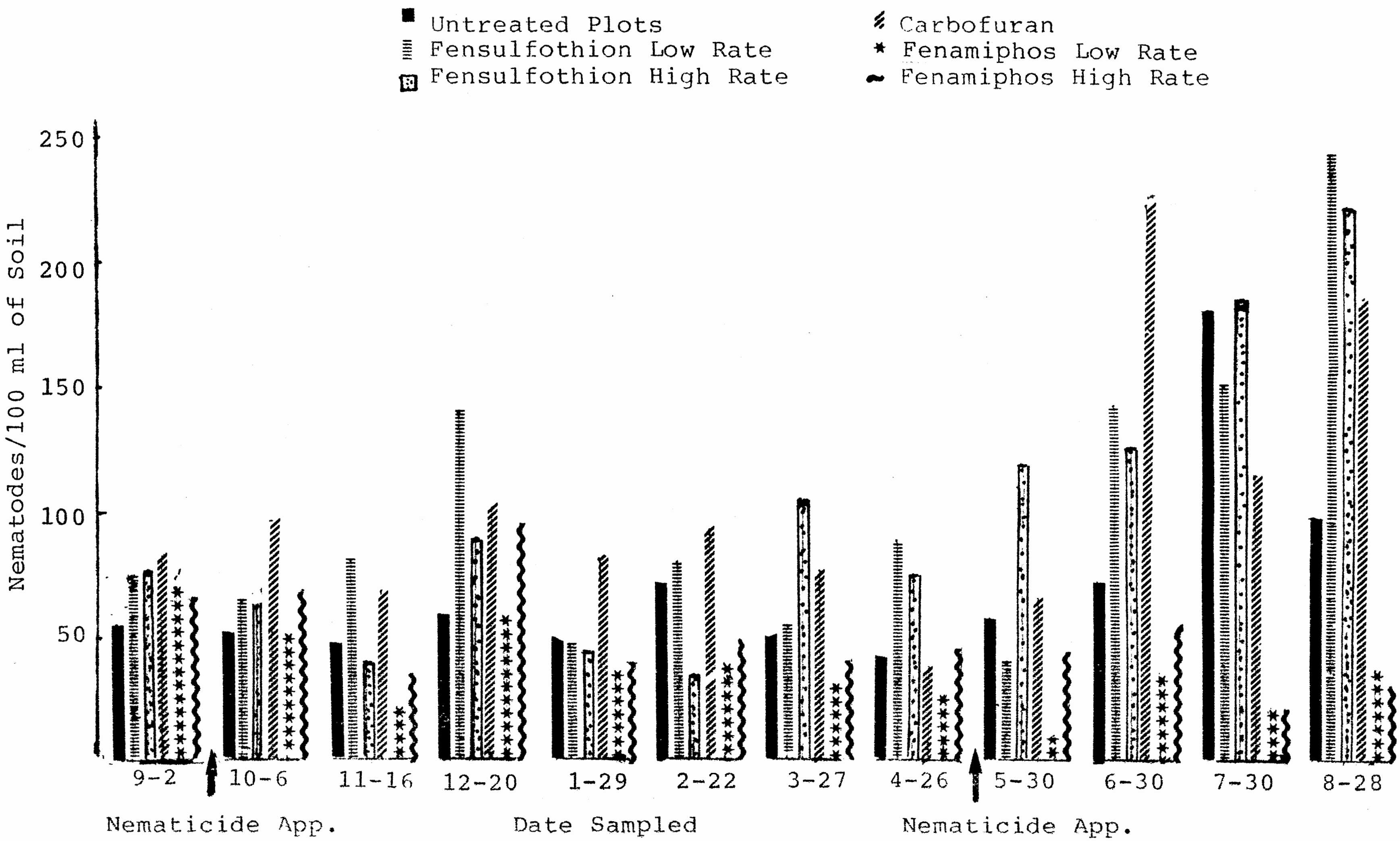


Figure 5. Response of Macroposthonia sp. Population to Chemical Treatments at 10-15 cm Depth in Established "Penncross" Bentgrass During September 1981 - August 1981

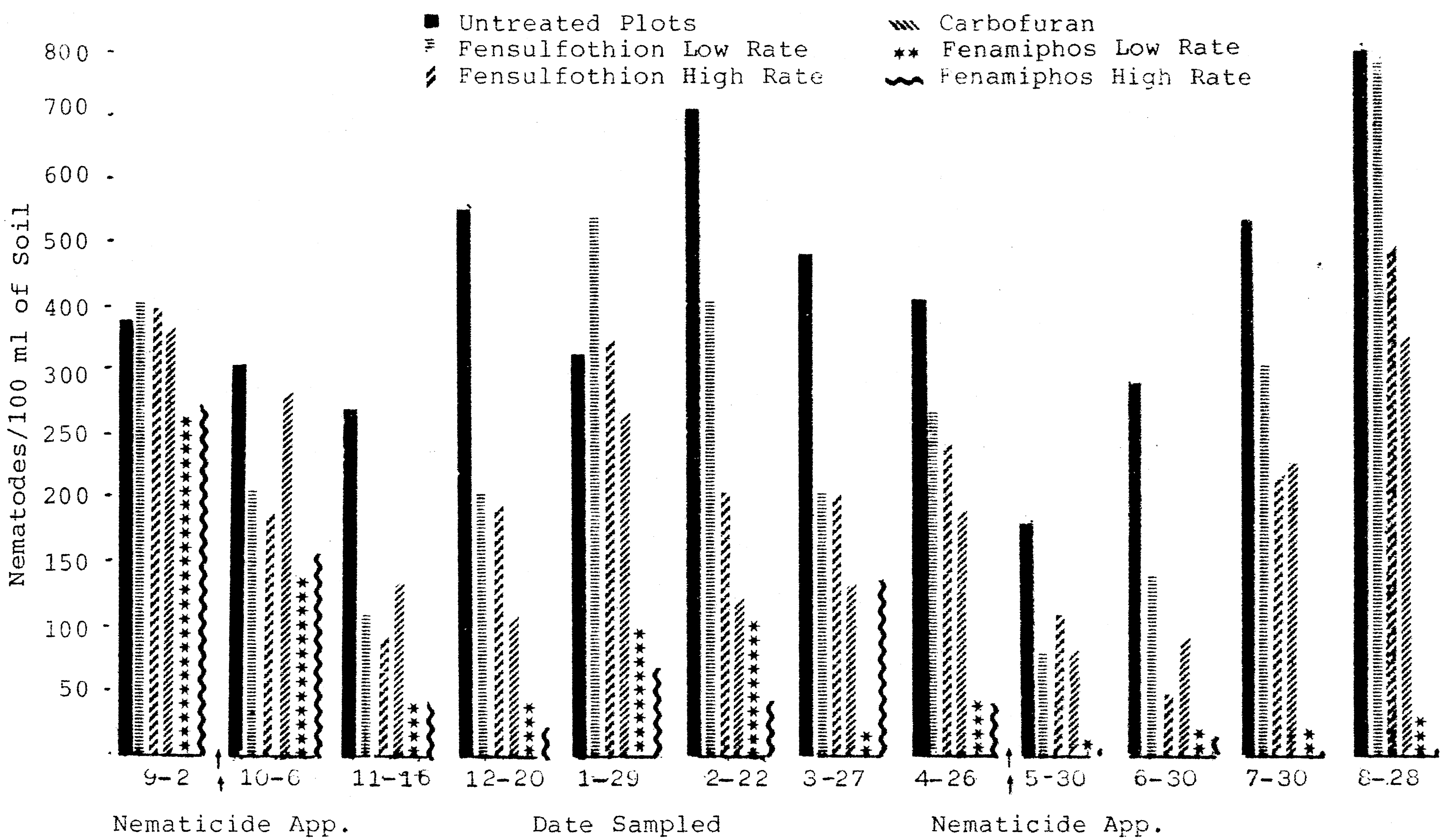


Figure 6. Response of Tylenchorhynchus sp. Population to Chemical Treatments at 0-5 cm Depth in Established "Penncross" Bentgrass During September 1981 - August 1982

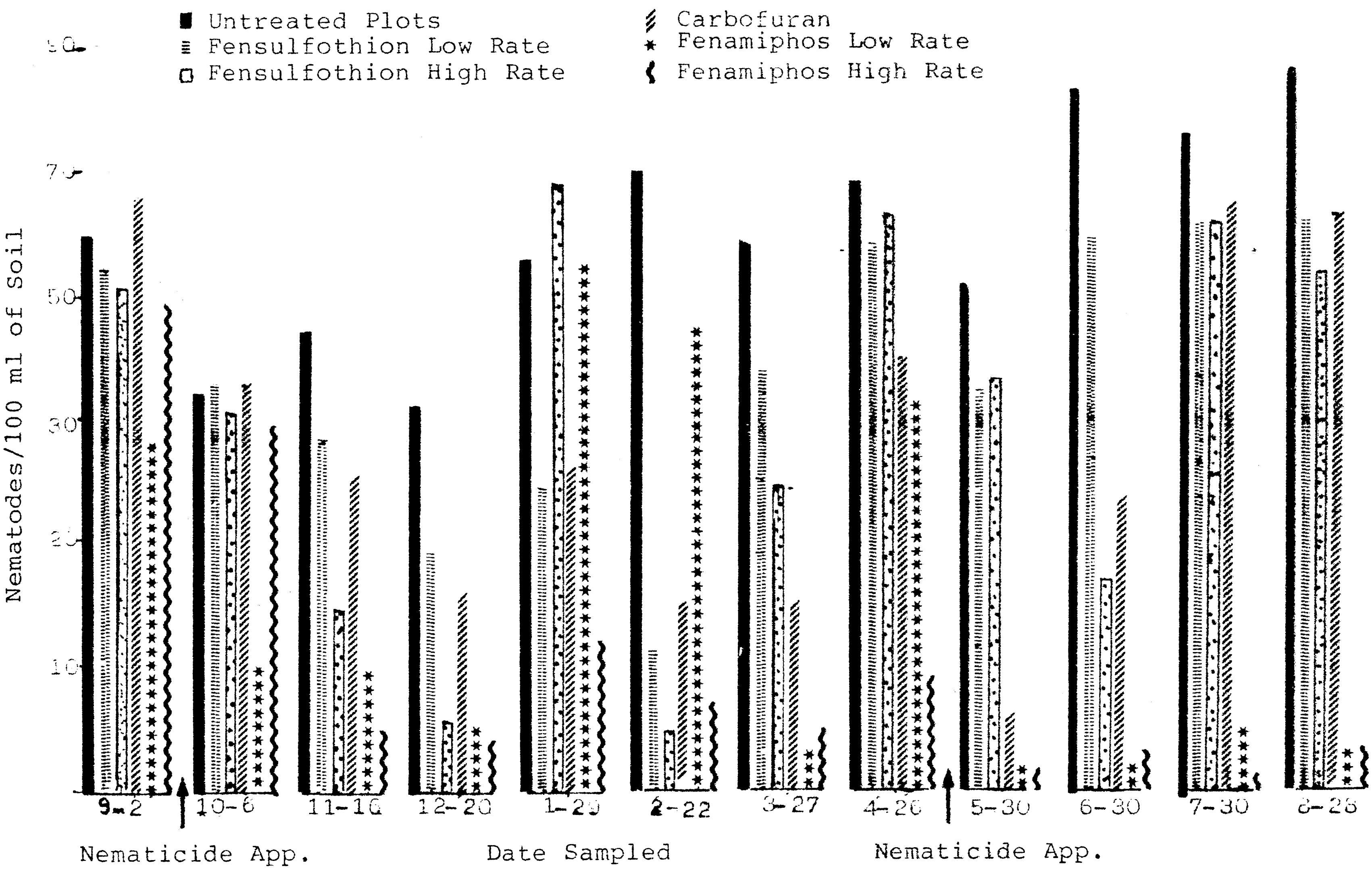


Figure 7. Response of <u>Tylenchorhynchus</u> sp. Population to Chemical Treatments at 5-10 cm Depth in Established "Penncross" Bentgrass During September 1981 - August 1982

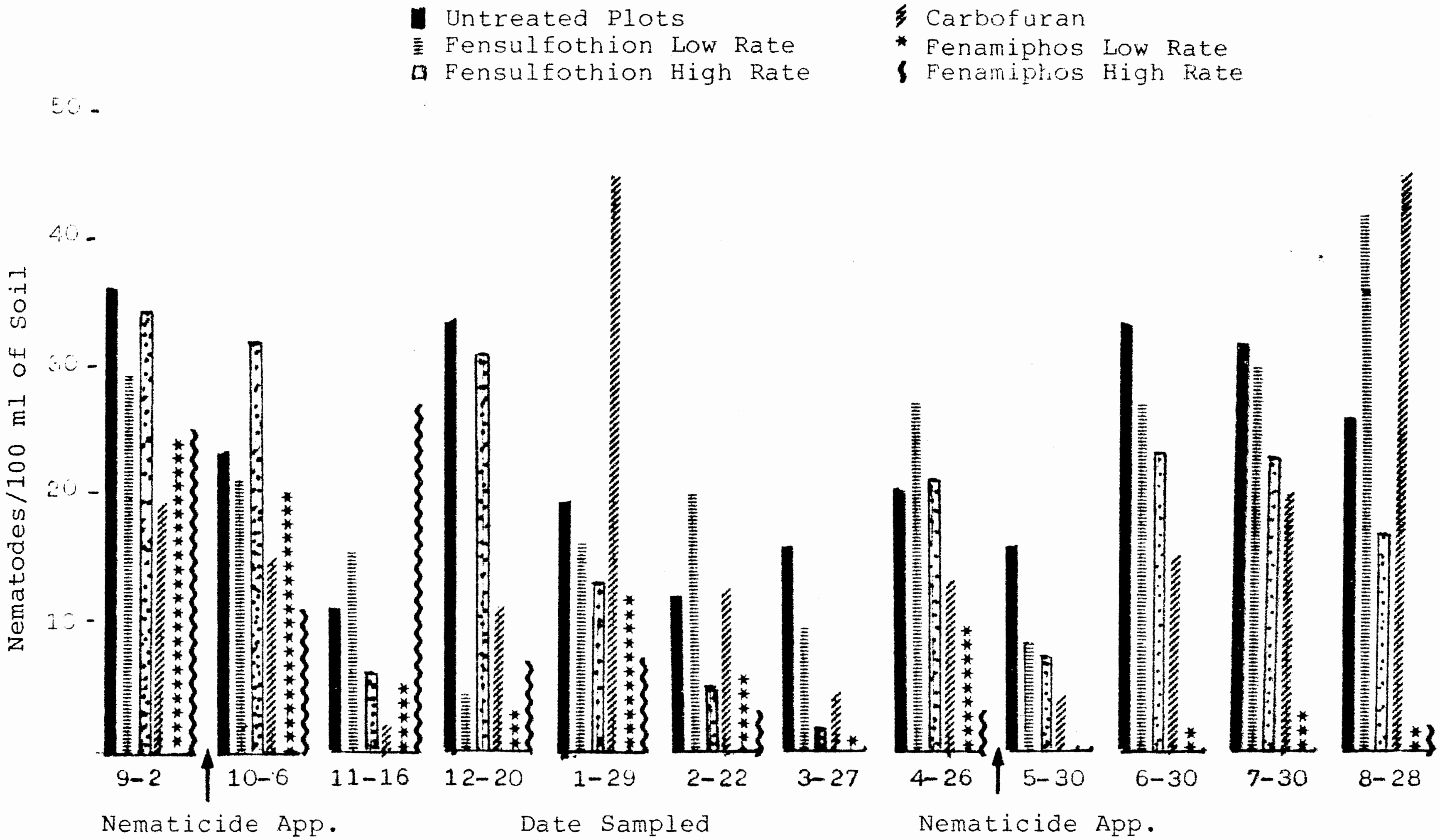


Figure 8. Response of Tylenchorhynchus sp. Population to Chemical Treatments at 10-15 cm Depth in Established "Penncross" Bentgrass During September 1981 - August 1982

*Pratylenchus* sp. was the primary nematode recovered from the roots, with greater numbers recovered at the 0-10 cm soil depth (Table II). The numbers of *Meloidogyne* spp. and *Tylenchorhynchus* larva were so low and inconsistent they were not reported.

Greater numbers of *Pratylenchus* spp. were recovered from roots and soil in June, and were found in roots from 0-5 cm depth, however, the higher numbers were recovered at 5-15 cm in the soil. The number of *Pratylenchus* spp. recovered from roots collected on May 30, 1982, increased in plots receiving fensulfothion applied on May 15, 1982, and decreased in roots and increased in soil from the June 30 sampling (Table II).

Root mass obtained at 0-5 cm depth from untreated plots increased consistently with increased plant parasitic nematode populations during January through April (Figure 9). Nematode populations recovered from the 0-5 cm depth on the February 22, March 27, and April 26 sampling were over 595 nematodes per 100 ml of soil (Table II). During this period, the greatest number of 874 parasitic nematodes were recovered on February 22 with the population decreasing to 595 in April. The root mass collected from the 0-5 cm depth declined while the nematode population and soil temperature increased during the month of May through August. The largest root mass of over 6.00 gm/100 ml of soil at 0-5 cm depth was collected in April and smallest root mass of 2.8 gm/100 ml of soil in August. This compares to the lower

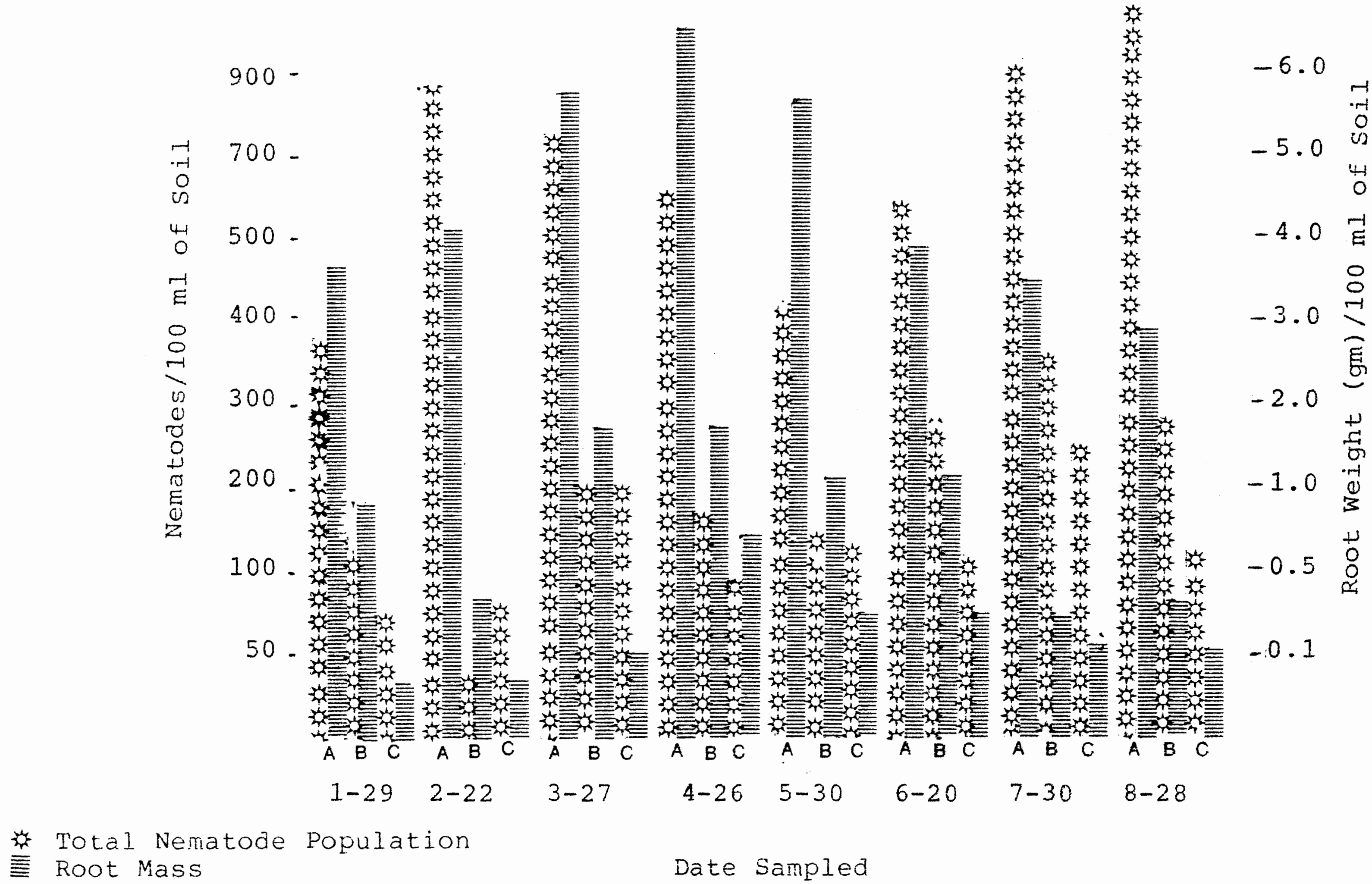


Figure 9. Root Mass and Total Nematode Population From Untreated Plots at the Depths 0-5 cm (A), 5-10 cm (B), and 10-15 cm (C)

nematode population of 435 and 419 nematodes per 100 ml of soil recovered in January and May, respectively, and highest numbers of 874 or greater reovered in February, July, and August. The highest soil temperatures of over 25 C were recorded for the 0-5 cm depth in July, and 0-15 cm depth in August (Table II). The nematode populations and root mass at 5-10 cm and 10-15 cm depth seemed to correlate with the trend found in 0-5 cm depth.

The total nematode populations per gram of root weight were much greater in roots taken from 0-5 cm depth than from those taken at 5-10 cm and 10-15 cm depth. The higher nematode populations from roots taken in the 0-5 cm zone were recovered during February, March, July, and August.

Root mass and nematode populations increased as soil tempertures increased from 10 C in February to 19 C in April. This trend occurred in all plots treated with a nematicide and those receiving no treatment (Table II). Following the application of nematicides on May 16, the root mass began to decrease in treated and untreated plots and continued to decrease through August. During the period May through August, total nematode populations increased in all treatments, with higher populations found in plots receiving fensulfothion and no nematicide. The lower populations were found in plots receiving fenamiphos from the May 30, 1982, sampling 15 days following nematicide application. This lower nematode population in the fenamiphos treated plots was found at all the three depths, 0-15 cm. The total nematode population at the 5-10 cm and 10-15 cm depth remained at a low level during June, July, and August in plots receiving fenamiphos as compared to same depths of plots receiving fensulfothion and carbofuran. The total nematode populations recovered from 0-5 cm depth, in plots receiving fenamiphos remained much lower through June, July, and August than plots receiving fensulfothion or carbofuran; however, a similar rate of increase was found to occur at this depth in all nematicide treated plots. Although a lower nematode population was recovered from plots receiving fenamiphos this is not shown in greater root mass (Table II and Figure 10).

Results obtained from the comparison of the two extraction procedures (the centrifugal technique and the modification of Christie-Perry extraction) showed the centrifugal technique recovered greater numbers of *Macroposthonia* sp. while the latter recovered very low numbers of this nematode (Figure 11). *Tylenchorhynchus* spp. populations recovered by both methods were only slightly different, however, the centrifugal technique tended to give better results (Figure 12).

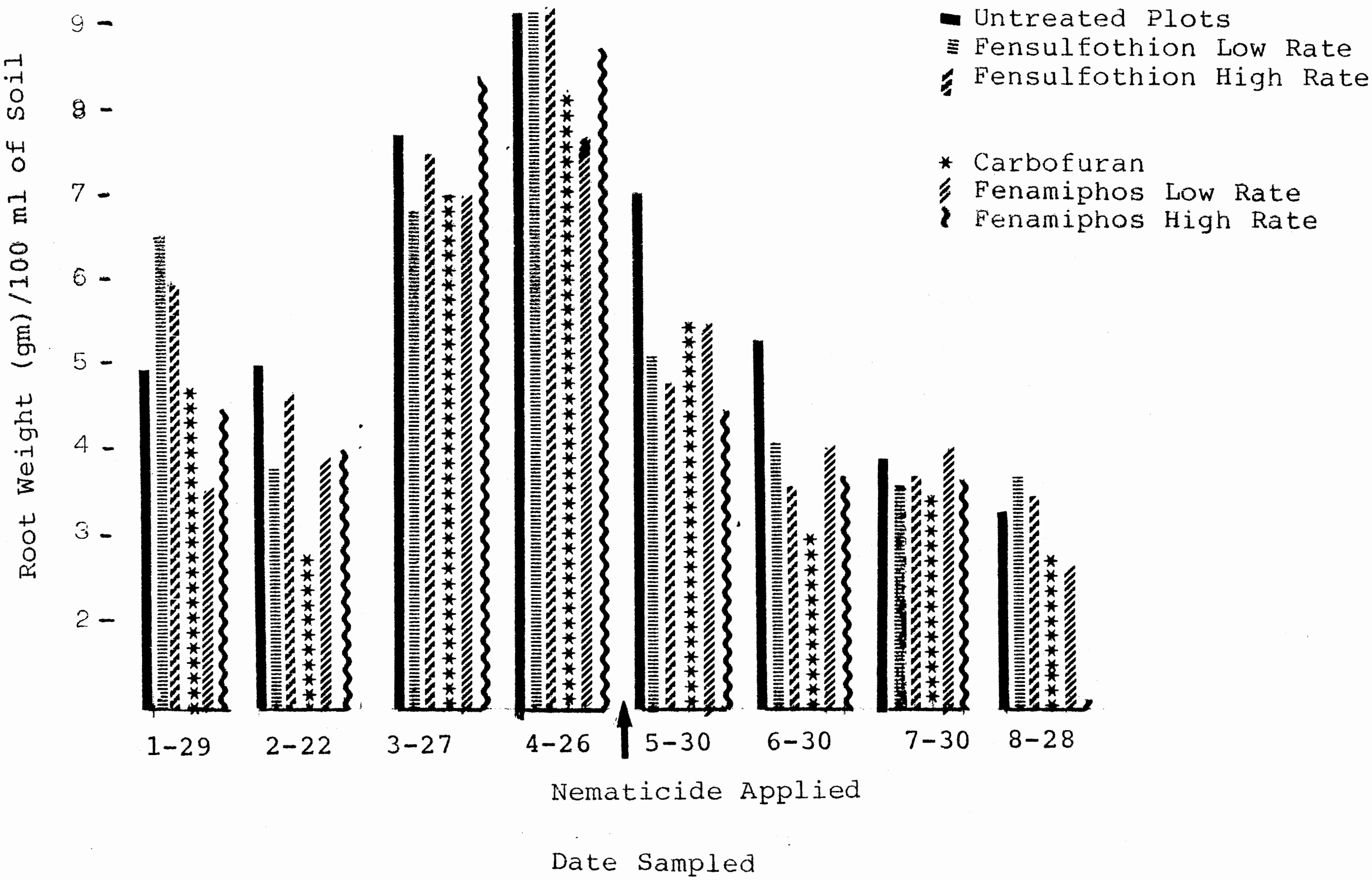


Figure 10. Root Mass Weights From Plots Receiving Nematicide Treatments During January - August 1982; Nematicide Application Made on May 15

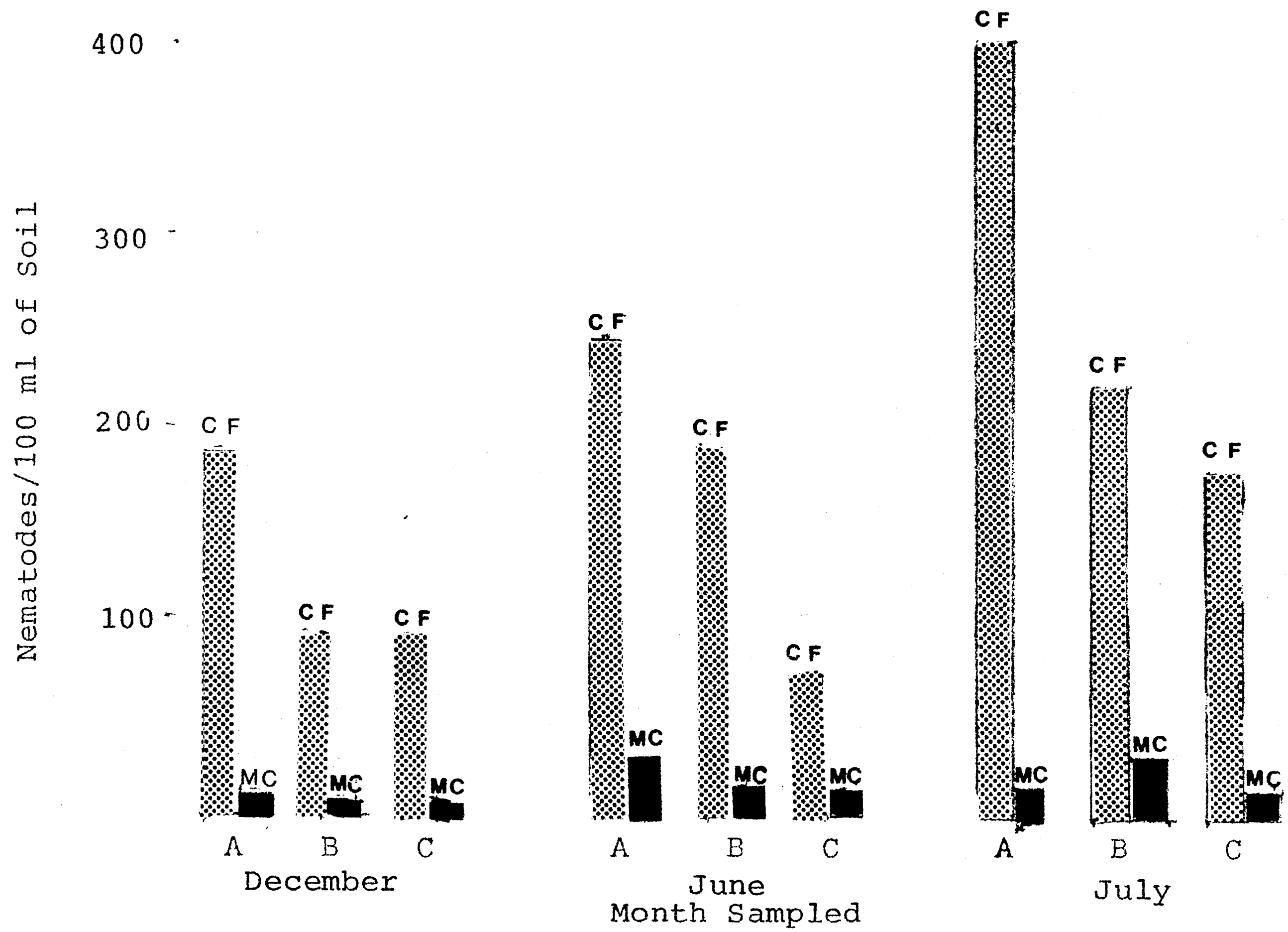


Figure 11. Comparison of Two Extraction Procedures; a Centrifugal Technique (CF) and a Modification of Christie-Perry (MC), for separation of <u>Macroposthonia</u> sp. From Untreated Plots at Various Soil Depths

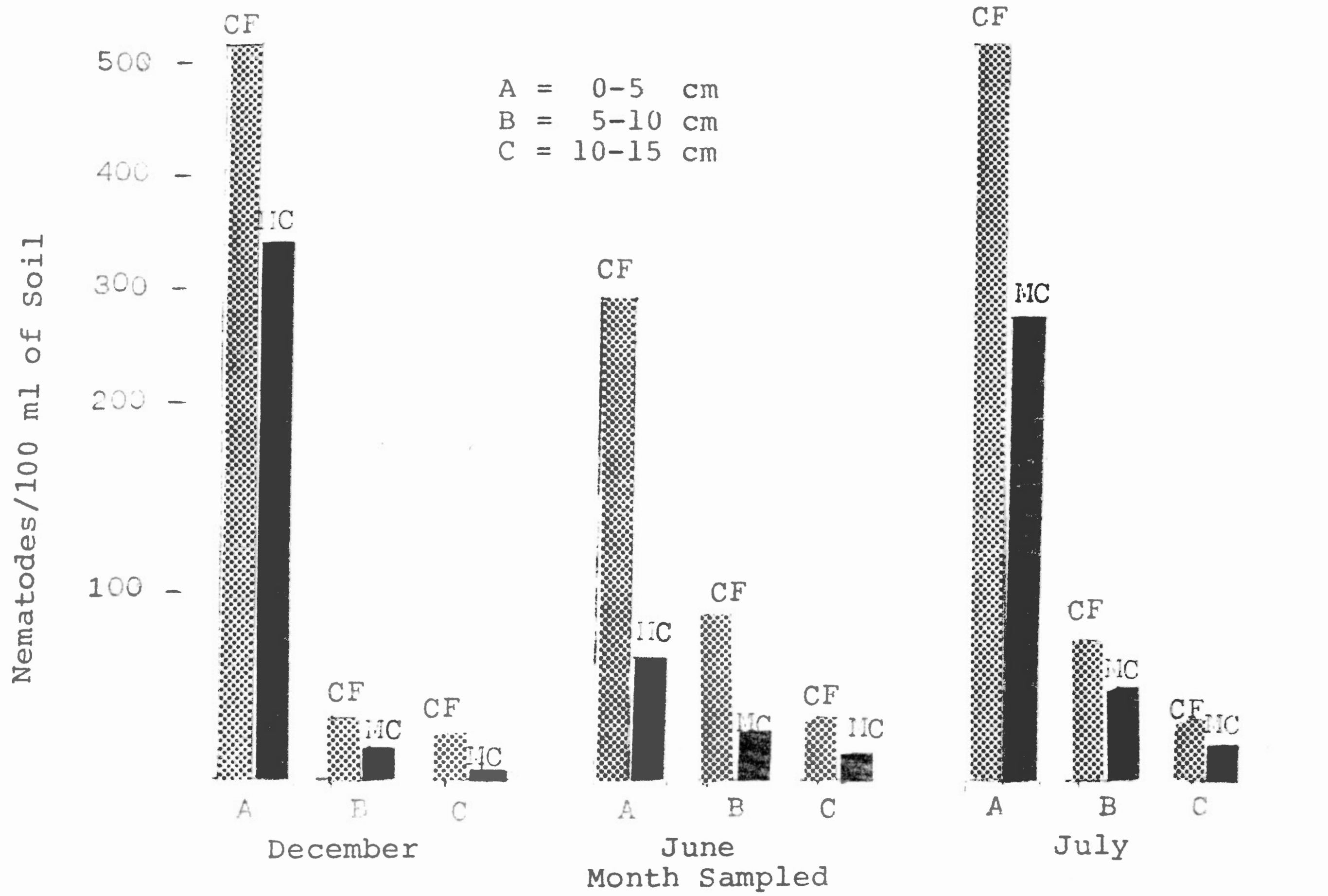


Figure 12. Comparison of Two Extraction Procedures; a Centrifugal Technique (CF) and a Modification of Christie-Perry (MC), for Separation of *Tylenchorhynchus* sp. From Untreated Plots at Various Soil Depths

# CHAPTER V

## DISCUSSION

A healthy root system is an important factor in maintaining a vigorous growing stand of bentgrass that can withstand the many stress factors. Nematode damage to the root system is commonly reflected in the aboveground plants being stunted, lacking vigor or exhibiting symptoms of poor fertility. It has been shown the response of grass plants will depend on kind and number of nematodes and amount of stress to which the plants are subjected. The number of nematodes it takes to cause a problem will depend on the species and amount of plant stress. It takes fewer sting nematodes, *Belonolaimus longicaudatus*, than stunt nematodes, *Tylenchorhynchus* sp., to damage a grass plant, and in many cases the above ground symptoms can be reduced or prevented with increased water and nutrients. When the more damaging nematode infestations are heavy, growth will be very slow, root systems will deteriorate, and bentgrass density will be reduced especially during the stress periods of summer.

The populations of ring, *Macroposthonia* sp., and stunt, *Tylenchorhynchus* sp., nematodes in the study area were found to be more consistent and at greater numbers than other nematode species. Other species such as *Helicotylenchus* sp., Belonolaimus sp. Hoplolaimus sp., Pratylenchus sp., Paratylenchus sp., and Tricodorus sp. were recovered in very low numbers and thought to occur too infrequently to provide quality data for this study. Although greater populations of ring and stunt nematode were recovered throughout the year, little effect could be noted on the collected root mass. We can assume the populations were not heavy enough to cause sufficient injury to reduce the root mass or maintenance practices were of the quality preventing stress of the plants, thus reducing plant damage. Although no significant difference among root mass could be detected, a lower turf density during August was apparent in the plots receiving no nematicide treatments (Table II). This decrease in turf density could be seen but not effectively measured. The decrease in turf density may have been encouraged by the greater populations of ring, Macroposthonia sp., and stunt Tylenchorhynchus sp., nematodes recovered in July and August or the increased populations of other genera; Trichodorus sp., Pratylenchus sp. at 0-15 cm soil depth, and/or effect of summer stress.

Although, greater numbers and population fluctuation of stunt than ring nematodes were found in the 0-5 cm soil depth, both species maintained a low but more uniform population level at 5-10 cm and 10-15 cm soil depths.

Throughout the year, greater populations of ring and stunt nematodes were found in the 0-10 cm soil depth. High densities of Macroposthonia sp. (more than 400 nematodes per

100 ml of soil) were recovered during January and April from plots receiving the low rate of fensulfothion, as compared to the higher numbers recovered from plots receiving carbofuran in June and untreated plots during July (Table III). Stunt nematodes were abundant at 0-5 cm soil depth with a population peak in August in untreated plots and plots receiving fensulfothion at the low rate (Table IV). This data agrees with that reported from North Carolina which showed highest densities of *Tylenchorhynchus claytoni* recovered from bentgrass occurred during August through September (44). The rapid increase in population of *Tylenchorhynchus* sp. at the 0-5 cm soil depth, and the fluctuation of *Macroposthonia* sp. at all soil depths in the untreated plots during the summer may have the potential to damage and reduce growth during high summer temperatures. The lower populations of *Tylenchorhynchus* sp. recovered in May from the untreated plots may have resulted from chemical movement from the treated plots because of heavy rainfall after nematicides were applied. The data would indicate the cold soil temperatures of January had more suppressing effect of the *Macroposthonia* sp. than *Tylenchorhynchus* sp. at 0-5 cm soil depth. The fluctuation of soil temperatures did not greatly effect the population densities at 5-10 cm and 10-15 cm soil depths. The increased populations of both species at 0-5 cm soil depth during June, July, and August can be correlated with increased soil temperature, hence, temperature at the various depths seems to have a

significant influence on the level of nematode population.

The application of nematicides did not have as dramatic effect on the nematode populations as expected. The lack of any significant decrease in certain nematode populations at various soil depths may have been due to excess water caused by frequent rains, ability of certain chemical formulations to move in the soil or chemical formulation effect on specific species. Fenamiphos (Nemacur) had a greater effect on Macroposthonia sp. than fensulfothion (Dasanit) or carbofuran (Furadan), however, significant reductions in population at the lower 5-15 cm soil depths did not occur until two months following the application of fenamiphos. Fenamiphos and carbofuran had a more significant effect on population of Tylenchorhynchus sp. than fensulfothion. Fenamiphos seemingly was more effective at lower 5-15 cm soil depths. Fenamiphos suppressed the Tylenchorhynchus sp. population during the seven months following application at all soil depths, whereas Macroposthonia sp. populations were significantly reduced during only three months following the May 16 application.

Fensulfothion at the low and high rates did not show significant suppression of Macroposthonia sp. populations at the various depths when compared to no treatment, however, it was observed that a higher quality turf was maintained in plots receiving fensulfothion compared to those receiving no treatment. Yet, when the population level before and after treatment was compared, fensulfothion at both rates suppressed the Macroposthonia sp. population for only one month following treatment. The population of Macroposthonia sp. and Tylenchorhynchus sp. increased at all soil depths the following month. Similar results were reported by Lucas (42) showing the numbers of ring nematodes, Criconemella ornata, and sting nematodes, Belonolaimus longicaudatus, increased following the treatment of fensulfothion.

Application of carbofuran suppressed populations of both Tylenchorhynchus sp. and Macroposthonia sp. at various soil levels, although not significantly.

Fenamiphos seemingly had a more suppressing effect at all soil depths on the various nematode populations monitored, however, no difference in quality of turf could be determined between those receiving applications of the other nematicides.

It is difficult to determine the true effectiveness of the nematicides at the deeper soil depths. The mass of stolons and roots which form the thatch in the upper soil level, together with soil moisture and soil temperature, may have reduced the penetration of the nematicides. Furthermore, application of some chemicals may increase the available plant nutrients resulting in increased plant root vigor.

Root masses recovered in this study seemed to correlate with nematode populations. Hence, increase in root masses resulted in increase in nematode populations in soil and root during the period bentgrass made its greatest growth.

Heavier root masses obtained in March and April probably resulted from the increased growth of bentgrass at this time of the year (Figure 9). It is possible that soil moisture from January and February snow fall was suitable for growth of roots at all soil depths when the temperature increased. Decline of root mass in the untreated plots may have resulted from increased populations of nematodes in soil. However, decline of root mass seems more closely related to temperature increase than by nematode popluations. The decline of root growth during periods of high temperature could be a temperature effect of reducing growth of a cool season grass. The occurrence of the disease Dollar Spot caused by Sclerotinia homoecarpa in June and Pythium Blight in July and August could have had some effect on retarding the root growth. The data obtained in this study indicated reduction of plant parasitic nematode populations by nematicides could not be correlated with increase in root mass. The data shows a given chemical may suppress the population of one nematode species successfully, but fail to suppress another. Therefore, the effectiveness of a nematicide on controlling the various plant parasitic nematodes present at various depths can be influenced by many factors.

Fenamiphos at low and high rates provided the more significant suppression of Macroposthonia sp. and Tylenchorhynchus sp. for longer periods but failed to increase the root mass. This nematicide also demonstrated a greater influence on suppression of the nematode populations at all the lower

5-15 cm soil depths. Although reducing nematode populations could not be shown to increase root mass among plots receiving the nematicides, a more dense stand of grass was common among these plots.

## CHAPTER VI

## SUMMARY

1. In an established "Penncross" bentgrass in Stillwater, Oklahoma, *Macroposthonia* sp. and *Tylenchorhynchus* sp. were found in greater numbers than other parasitic nematodes and were found more consistently at the 0-15 cm soil depth.

2. Densities of *Macroposthonia* sp., ring nematodes, peaked in July whereas *Tylenchorhynchus* sp., stunt nematodes, population peaked during the two months of February and August in untreated plots during a 12-month period.

3. *Pratylenchus* sp., root lesion nematodes, and *Paratylenchus* sp., pin nematodes, were recovered from the deeper soil profile, depths of 5-10 cm, with *Pratylenchus* sp. recovered mainly from roots collected at 0-10 cm root depth.

4. Heavier root masses were collected during March and April, with higher numbers of nematodes recovered at this same time, thus, the densities of the roots seemed to correlate with the densities of nematodes in the soil.

5. Fenamiphos (Nemacur) at low and high rates (680 and 1360 gm/93 $m^2$) provided more significant suppression of

*Macroposthonia* sp. and *Tylenchorhynchus* sp. population than carbofuran (Furadan) and fensulfothian (Dasanit).

6. At the lower depths (5-15 cm), fenamiphos (Nemacur) was seemingly more effective on suppression of the nematode populations than formulations of carbofuran (Furadan) or fensulfothion (Dasanit).

7. Fensulfothion (Dansanit) at low and high rates did not show significant suppression of ring, *Macroposthonia* sp., nematode populations.

8. Results obtained from this study would suggest nematode populations were not high enough to cause damage to the established bentgrass or the maintenance program was of the quality to overcome nematode damage.

9. Future studies should include treatments under low maintenance compared to treatments under high maintenance, with periods of drought stress included. Grass clippings should be taken in an attempt to measure turf quality and compare with root mass.

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