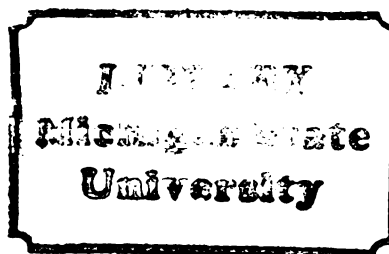


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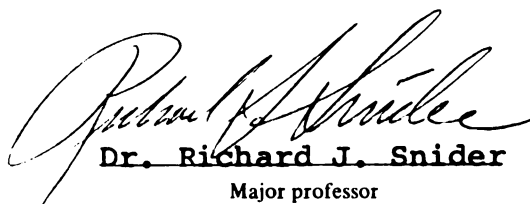
**THE EFFECTS OF ATRAZINE
ON NON-TARGET SOIL ARTHROPODS IN NO-TILL
CORN PRODUCTION**

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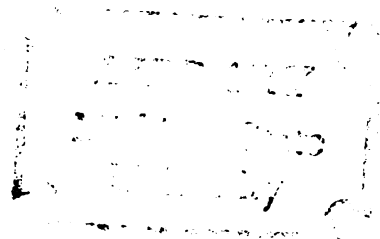
JOHN CHRISTOPHER MOORE

has been accepted towards fulfillment
of the requirements for

M. S. degree in Zoology


Dr. Richard J. Snider
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THE EFFECTS OF ATRAZINE
ON NON-TARGET SOIL ARTHROPODS IN NO-TILL
CORN PRODUCTION

By

John Christopher Moore

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE

Department of Zoology

1981

ABSTRACT

THE EFFECTS OF ATRAZINE

ON NON-TARGET SOIL ARTHROPODS IN NO-TILL

CORN PRODUCTION

By

John Christopher Moore

The effects of Atrazine on soil microarthropods was assessed for the first growing season of No-till corn at the new Crops and Soil Science farm of Michigan State University.

Epigeic Collembola were directly affected by tillage while edaphic Collembola were not. Atrazine had no negative effects on Collembola; however two species, Sminthurinus elegans (Fitch) and Tullbergia granulata (Mills), were found in greater numbers in Atrazine treated plots. Tillage and Atrazine decreased Prostigmata and Mesostigmata mite populations. Astigmatid and Cryptostigmatid mite populations increased as a result of tillage.

Changes in Collembola and Acarina populations occurred when the habitat changed. It was difficult to determine whether No-tillage and/or Atrazine directly affected individuals or if changes in the soil microenvironment and surface vegetation caused by these treatments affected them.

TO MINDY
+1

ACKNOWLEDGEMENTS

I would like to thank Dr. Ivan Mao of the Department of Dairy Science and Dr. Robert Boling and his staff for their assistance with the statistical analysis, and Dr. Lynn Robertson and Mr. Dallas Hyde of the Department of Crops and Soil Science for planning and managing the farm operations. Special thanks is given to my major Professor, Dr. Richard Snider, for his patience and guidance throughout this study.

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INTRODUCTION AND LITERATURE REVIEW

Agronomists recognize the need to minimize tillage in order to reduce runoff and erosion. Many forms of "conservation tillage" have been developed and are being practiced. The method employed depends on the crop and soil (Robertson et al, 1976; Vitosh & Warncke, 1976; Cook & Robertson, 1979). A form of conservation tillage used for row crop production on well-drained soil is "No-till" (Nelson et al, 1976). In this practice, a narrow slit is made in the soil with a fluted coulter. Seeds are dropped into the slit and covered. Pesticides and fertilizer may be added during planting. No further cultivation is needed. When compared to conventional tillage, No-till offers labor and energy savings, since fewer trips to the field are required (Phillips & Young, 1973; Foth, 1978). Because the soil is minimally disturbed and plant residues are allowed to accumulate, there is a decrease in erosion and runoff and an increase in moisture retention (Nelson et al, 1976; Robertson et al, 1976).

To ensure these benefits however, one must rely completely on herbicides to control weeds (Chase & Meggitt, 1976). Many herbicides persist in soil, bound to organic matter and clay, long after their application (Talbert & Fletchall, 1963; Bucholtz, 1965; Upchurch, 1966; Williams, 1970; Skipper & Volk, 1977). Laboratory and field investigations indicate that their annual use may adversely affect arthropod

populations responsible for soil formation and nutrient recycling (Edwards, 1970; Galston, 1979). The purpose of this study was to evaluate the effects of the herbicide Atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine) on soil arthropods in No-till corn production.

Laboratory Studies

Several laboratory studies have shown that herbicides induce mutations in non-target plants and animals (Fahmy & Fahmy, 1954, 1955; Herkowitz, 1956; Wu & Grant, 1966; Liang & Liang, 1972; Plewa & Gentile, 1976; Gentile et al, 1977; Murnik & Nash, 1977). Few investigations on direct effects of herbicides on soil arthropods have been reported. However, some of those recently published used Collembola as a test animal (Eijsackers, 1975; Dwidjasatmoko, 1978)

Eijsackers (1975) observed the reactions of Onychiurus quadriocellatus (Gisin) to varied concentrations of 2,4,5-T. Increased activity, leg tremors, and paralysis were observed at doses of 1.25, 2.50, and 5.00 cc/M². Mortality was related to the concentration of the 2,4,5-T; the higher the dose, the greater the mortality. Collembola presented with a choice between treated and untreated food demonstrated a preference for the latter.

Atrazine and Paraquat, herbicides commonly used in corn production, may affect the reproductive system of Collembola (Dwidjasatmoko, 1978). Folsomia candida (Willem) and Tullbergia granulata (Mills) showed delayed instar durations and reduced fecundity when fed 600 ppm, 1000 ppm, and 5000 ppm. When reared on soils treated with 5000 ppm Atrazine,

Collembola showed increased mortality levels.

Field Studies-Herbicide Effects

Since herbicides were introduced to control weeds, many field investigations on possible non-target effects have been undertaken. Studies in grasslands and cereal crops have shown MCPA does not effect the soil fauna (Rapoport & Cangiolli, 1963; Davis, 1965). The same conclusions were drawn from investigations of 2,4-D and DNOC treated grassland (Johnson et al, 1955; Rapoport & Cangiolli, 1963; Fox, 1964). A later study by Edwards (1970) found lower Collembola population levels in DNOC treated plots. These populations quickly recovered after levels of the compound in the soil had decreased.

Results of field studies on the effects of Paraquat and Dalapon are conflicting. When compared with untreated fields, Fox (1964) found no significant difference within the total fauna in fields treated with either herbicide. Closer analysis indicated Collembola populations had increased. Similarly, Edwards et al (1971) showed an increase in arthropod populations exposed to Paraquat in slit-seeded (No-till) wheat fields. Groups demonstrating more pronounced increases were rhodacarid mites, entomobryid and sminthurid Collembola, Symphyla, Thysanoptera, and Coleoptera. Curry (1970), on the other hand, found decreased soil arthropod populations in fields treated with Dalapon and Paraquat. These changes were attributed to habitat changes cause by the herbicide rather than toxicity.

Herbicides that have demonstrated adverse effects are

Monorun and the s-triazines. Fox (1964) found a significant decrease in wireworms, Collembola, and Acarina in grasslands treated with Monorun. The same study showed Atrazine reduced Collembola populations in grass plots. Popovici et al (1977) treated corn fields with Atrazine at 5 kg/ha and 8 Kg/ha and found a 68% and 75% reduction in Acarina. Collembola were reduced 91% and 95% for these concentrations. Four months following application, Collembola were still reduced 59% and 80%. Edwards (1970) and Edwards et al (1971) reported similar results for Collembola populations responding to Simazine, in that 70% of the Collembola were eliminated. After 5 months, however, very little difference was observed between population levels in Simazine treated fields and untreated controls. The same study reported reduced numbers of mesostigmatid and oribatid mites, and isotomid Collembola in plots treated with 2 and 4 Kg/ha of "Bladex."

Field Studies-Tillage Effects

A problem investigators have when studying the influence of herbicides on the soil fauna of agricultural soils is separating tillage effects. The extent of tillage effects depends on tillage type. Edwards and Lofty (1975) compared the effects of conventional tillage and slit-seeding (No-till). Significantly fewer arthropods were found in conventionally plowed plots. The more intensively tilled plots showed greater reductions. Arthropods most effected were cryptostigmatid mites and surface dwelling and hemi-edaphic Collembola. The effects of slit-seeding differed between different arthropod groups. Most showed no changes; however,

predatory mites, euedaphic Collembola, and larval Diptera populations were significantly reduced. Loring (1979) compared the effects of No-till, moldboard plow, and chisel plow tillage systems on soil arthropod populations. Unlike Edwards and Lofty (1975), Loring (1979) found conventional tillage systems stimulated microarthropod populations. However, the authors do agree that surface dwelling and hemiedaphic arthropods decreased. Loring (1979) found No-till population levels to be the same as those of "old fields."

MATERIALS AND METHODS

The study area was located off Jolly and College Roads, on the north end of section "C" of the new Crops and Soil Science farm at Michigan State University. The field was maintained as grassland for seven years prior to the present investigation. The soil was classed as a Celina loam (soil management group 2.5 a, Aquic Hapudalf, fine, mixed, mesic). In May, 1979, twelve 6.1m x 15.2m plots were established. The plots were divided equally among three treatments. The treatments were untilled grass without Atrazine (control), tillage without Atrazine (No-till control), and tillage with Atrazine (No-till Atrazine).

On May 12, 1979, corn was planted and fertilized with 150kg/ha of 6-24-24. May 18 and June 12, 0.47 and 0.94 cc/m² of Atrazine was broadcasted. Sprinkler irrigation was installed over the entire study area June 28, with 12.7mm supplied June 28, 38.1mm on July 10 and 18, and 25.4 on July 27. The irrigation system was removed August 16 and the

corn was harvested October 28.

Soil samples were taken from April 17 through November 8, 1979, at two to three week intervals. Prior to planting, samples were taken to establish base population levels. On May 15 and 31 three plots per treatment were sampled. On those dates 10 samples per plot were taken. On June 14, all treatment replicates were sampled and five samples per plot were taken. On subsequent sampling dates seven samples per plot were taken. A catalog of all field preparations and sampling dates is provided in Table 1.

At each sampling date, soil (15cm depth) and air temperature (1m height) were recorded using a Yellow Springs Telethermometer (YSI 42SC) (Table 2). Daily maximum and minimum temperature and precipitation were obtained from the Michigan State Weather Service (Horticultural Garden Station) located three miles from the study site (Figures 1 and 2).

Samples were placed in plastic bags. To avoid overheating in the field and during transportation, samples were stored in a styrofoam cooler. Samples were placed in Tullgren funnels and extracted for a minimum of three days. A 25 watt light bulb was used as the heat source. Extracted animals were preserved in 95% ethanol - 1% glycerol.

Arthropods were identified to species (Collembola), family (Acarina), and order (Coleoptera, Diptera, Puaropoda, and Symphyla). Collembola were identified according to Snider (1967) and Christiansen and Bellinger (1981). Acarina were identified according to Krantz (1970).

The Collembola were divided into two ecological groups

Table 1

Catalog of Field Preparations and Data Collections

=====

Dates

April	18	48 soil samples were taken to survey the fauna.
May	8	48 soil samples were taken to survey the fauna.
	11	Soil was tilled, corn was planted, and 150 kg/ha of 6-24-24 fertilizer was applied.
	15	90 samples were taken, 10 from each plot. Three replicates were included.
	18	.47 cc/m ² of Atrazine was applied to No-till Atrazine plots.
	31	90 samples were taken, 10 from each plot. Three replicates were included.
June	12	.94 cc/m ² of Atrazine was applied to No-till Atrazine plots.
	14	60 samples were taken, 5 from each plot. Four replicates were included.
	28	Sprinkler irrigation was installed. 12.7mm of water was supplied.
July	8	84 samples were taken, 7 from each plot. Four replicates were included.
	10	38.1mm of water was supplied.
	18	38.1mm of water was supplied.
	25	84 samples were taken, 7 from each plot. Four replicates were included.
	28	25.4mm of water was supplied.
August	16	84 samples were taken, 7 from each plot. Four replicates were included.
Sept.	8	84 samples were taken, 7 from each plot. Four replicates were included.
	28	84 samples were taken, 7 from each plot. Four replicates were included.
October	18	84 samples were taken, 7 from each plot. Four replicates were included.
	20	The corn was harvested.
Nov.	8	84 samples were taken, 7 from each plot. Four replicates were included.

Table 2

Air and Soil Temperature C

Sampling Dates	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
Air 1m	17	18	17	22.5	25	26	26.5	22	14	6
Soil 15cm	17	13	17.5	18	22.5	19.5	22	14.5	12	5.5

Figure 1. Daily Maximum and Minimum Temperature

Figure 2. Daily Precipitation

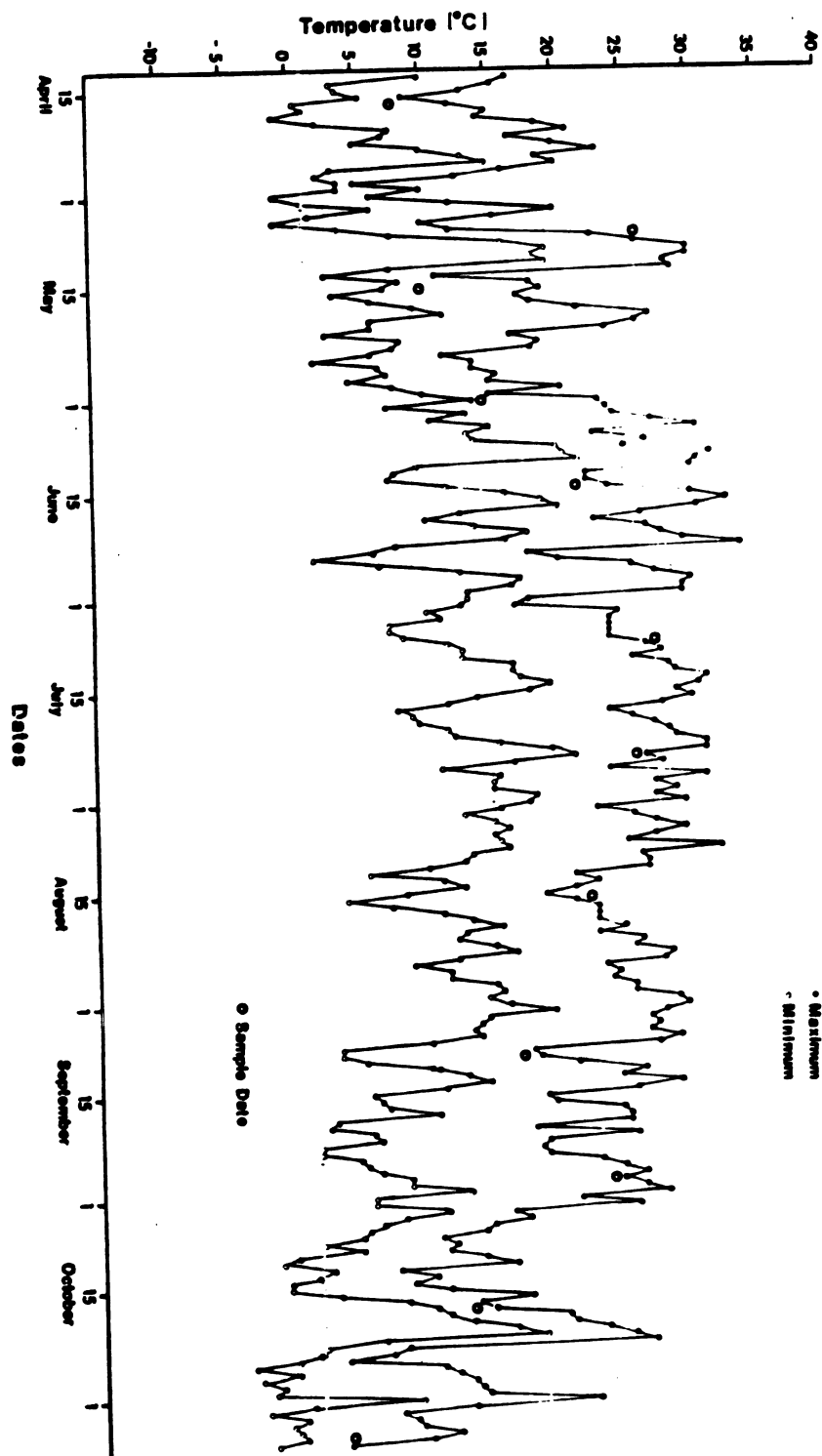


Figure 1.

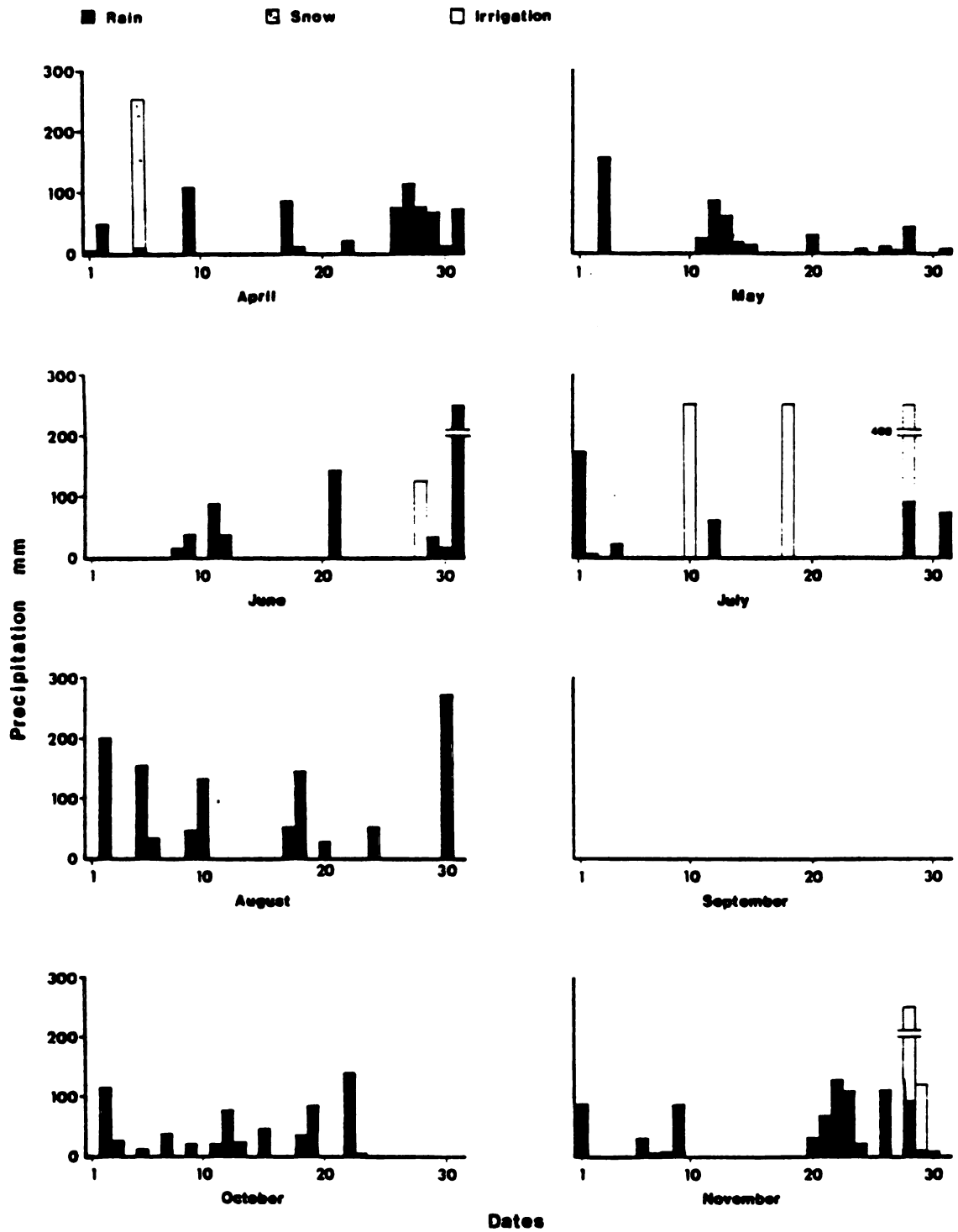


Figure 2.

on the basis of that portion of the soil they inhabit. Collembolan species of the family Sminthuridae living on the soil surface were grouped as "epigeic" Collembola. Collembolan species living within the soil were grouped as "edaphic" Collembola. One epigeic Collembola species, Sminthurinus elegans (Fitch) was collected in sufficient numbers to analyze separately. Four edaphic species were numerous enough to analyze separately. These species were, in order of their abundance, Brachystomella parvula (Schaffer), Tullbergia granulata (Mills), Lepidocyrtus pallidus (Reuter), and Isotoma notabilis (Folsom).

Acarina were separated into suborders: Prostigmata, Cryptostigmata, Mesostigmata, and Astigmata. Of the Prostigmata, the family Pyemotidea was analyzed separately. The cryptostigmatid family Opiidae and mesostigmatid family Rhodacaridae were analyzed separately.

Extraction efficiency of the Tullgren funnels was estimated as follows. After extraction, 20 samples taken June 18, 1980 were immersed in a saturated sugar solution. Arthropods previously trapped in the soil, floated to the surface and were counted.

The following two-way cross classification model with interactions was used to generate f-ratios, estimate mean numbers of selected arthropod groups collected at each sample date, and calculate 95% confidence intervals for each mean:

$$Y_{ji:kl} = u + T_i + S_j + P_{i:k} + TS_{ij} + e_{ji:kl}$$

where,

u = Mean common to all observations.

T_i = The effect due to the i th treatment, there are three treatments.

S_j = The effect due to the j th sample date, there are 10 sample dates.

$P_{i:k}$ = The effect due to the k th treatment plot replicate, there are four plots in each treatment.

TS_{ij} = The effect due to the i th treatment on the k th sample date. There are 30 treatment-sample date interactions.

$e_{ji:kl}$ = The residual random term corresponding to $Y_{ji:kl}$.

All possible linear contrasts were performed with the treatment, treatment plot replicate, and treatment-sample date interaction classifications. Treatment contrasts were tested for differences between treatments in the mean number of selected arthropods collected over the entire growing season. Treatment plot replicate contrasts were tested for differences among replicate plots of a given treatment in the mean number of selected arthropods collected over the entire growing season. Treatment-sample date interaction contrasts were tested for differences between treatments in the mean number of selected arthropods collected at each sample date.

RESULTS AND DISCUSSION

Extraction Efficiency

The results of the extraction efficiency analysis are provided in Table 3. These values are used for comparing Tullgren funnel efficiency of other investigations. Analysis showed that for a 72 hour extraction period, 51.8% of the

Table 3

Percent Extraction Using Tullgren Funnels
Determined by Floatation

=====	
Taxa	% Extraction
Total Collembola	51.8
<u>Brachystomella parvula</u>	50.0
<u>Tullbergia granulata</u>	40.0
Total Acarina	35.8
Pyemotidae	72.8
Opiidae	11.1
Rhodacaridae	40.0

Collembola were extracted. Of the Collembola found in numbers large enough to analyze, 50% of the Brachystomella parvula and 40% of the Tullbergia granulata were extracted. Acarina efficiency was 35.8%, with 76.6% of the Pyemotidae, 40% of the Rhodacaridae, and 11.1% of the Opiidae extracted.

Discrepancies in extraction efficiency between investigations stem from different extraction periods, efficiency determination techniques, and soil characteristics. After a 42 hour extraction period, Tamura (1976) handsorted dried soil and obtained funnel efficiencies of 16% and 18% for Collembola and Acarina respectively. Those values are substantially less than the values reported here. Aside from

the various efficiency methods used, differences are a result of unequal extraction times. Loduvic (1962) reported that at 15 C the majority of Collembola were collected after 4-10 hours, while the Acarina took 80-100 hours. Loring (1979) estimated Tullgren funnel efficiency with the same funnels and determination procedures used in this study. The chief difference between the studies was the soil type. Loring (1979) had a Spinks loamy sand compared to the Celina loam of the present study. In his study, Loring (1979) collected only 3% of the Tullbergia granulata and 95% of the Pyemotidae.

Although results are often inconsistent, studies on the efficiency of Tullgren funnels have yielded two generalities. Because efficiency is varied between groups, care must be taken when estimating population sizes for ecological studies (Sheals, 1957). Smaller species, particularly those with poorly developed locomotor structures, have lower efficiencies than larger, more mobile species (Haarlov, 1962; Tamura, 1976).

General

Neither tillage nor Atrazine had an effect on the number of arthropod groups in the field. Differences were observed in the abundance of certain groups. A complete checklist of all arthropods collected during the study is provided in Appendices A, B, and C.

Samples taken to establish base population levels were not included in the analysis. These samples were taken at random from the entire study area before plots were established. For this reason, these samples could not be compared

statistically with samples taken from defined plots.

Plot Bias

Linear contrasts were tested to identify plot biases using data of taxa collected in sufficient numbers to analyze. Replicate grass control plots did not differ significantly ($p > 0.05$). Differences between the number of arthropods collected from no-till control plots and No-till Atrazine plots were found ($p > 0.05$). Although differences between replicate plots were found, plot bias was not considered an important factor for the following reasons: 1) Differences between replicate plots were not consistent for all groups analyzed. No single plot had high or low population levels for all taxa. 2) Differences were restricted to No-till control and No-till Atrazine plots. This indicated that undisturbed the study area was probably uniform. Differences observed were caused by treatment and not plot condition or location.

Collembola

The epigeic Collembola were affected by No-tillage. Significantly fewer ($p > 0.05$) Sminthuridae were collected from tilled plots than grass control plots. The populations decreased in each treatment during June and then increased during July (Figure 3). The Sminthuridae population reached maximum levels on July 25 in the tilled plots and August 16 in grass control plots. Sminthurinus elegans resembled other Sminthuridae in that significantly fewer ($p > 0.05$) numbers were found in tilled plots than grass control plots on May 15 and 31. After mid-June however, S. elegans populations

Figure 3. Mean Population Levels of Sminthuridae

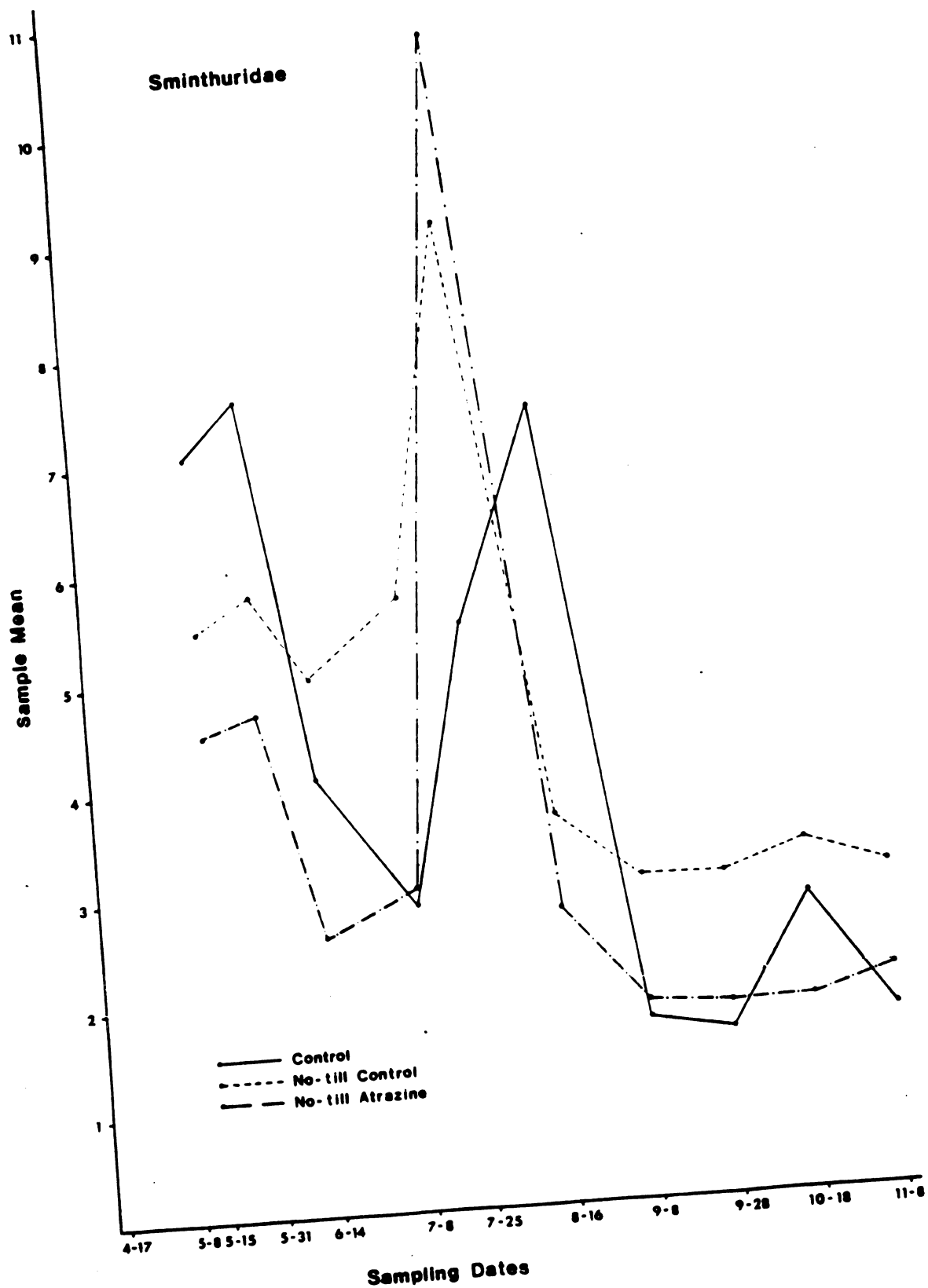


Figure 3.

in grass control plots did not differ significantly ($p = 0.05$) from population levels in No-till control plots (Figure 4).

Atrazine did not adversely affect the Sminthuridae. No significant differences ($p = 0.05$) were observed between the population levels in No-till control and No-till Atrazine plots. Unlike other Sminthuridae, S. elegans populations increased only in No-till Atrazine plots during July. On July 25 significantly more ($p = 0.05$) S. elegans were collected from plots treated with Atrazine than those that were not. The July 25 increase in the S. elegans population occurred when much of the original ground cover had been reduced to mulch in the No-till Atrazine plots. Increased available organic matter on the soil surface may have had a positive affect on fungal and nematode populations S. elegans feed upon (Snider, R. J., personal communication).

The edaphic Collembola were affected by tillage. Initially, few Collembola were collected from any of the plots. Populations increased rapidly in all treatments and were most numerous by the end of July. In general, populations in each treatment differed in numbers, but not trend (Figure 5). Throughout the study more Collembola were found in grass control plots than tilled plots. Tillage was not found to be significant ($p = 0.05$) until June 14 (Figure 5). This indicated that microenvironmental changes initiated by tillage rather than actual tillage processes contributed to the decline. The occurrence of Brachystomella parvula was very similar to that of the edaphic Collembola as a group. B. parvula was more numerous in grass control plots than either

Figure 4. Mean Population Levels of Sminthurinus elegans

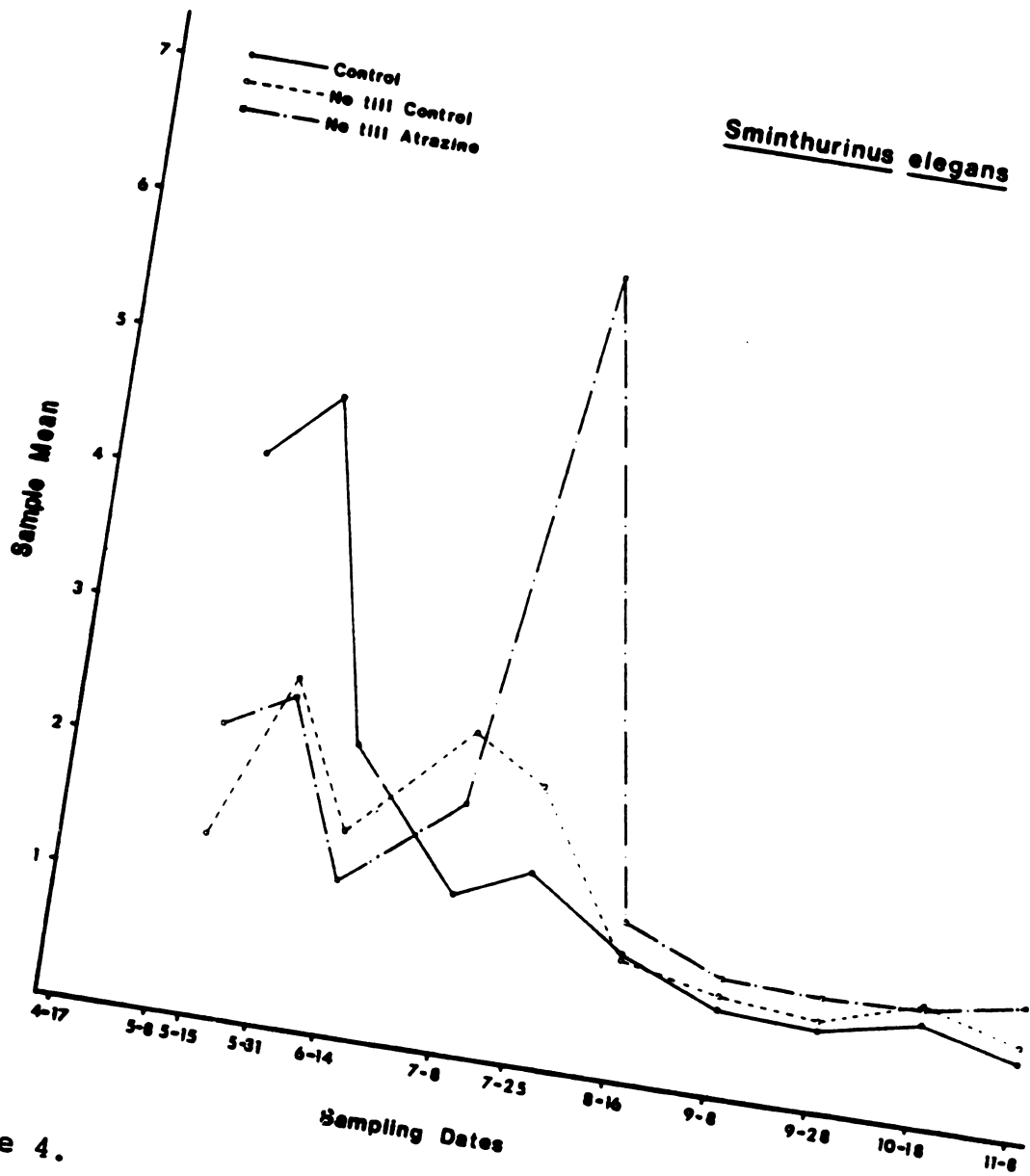


Figure 4.

Figure 5. Mean Population Levels of Collembola

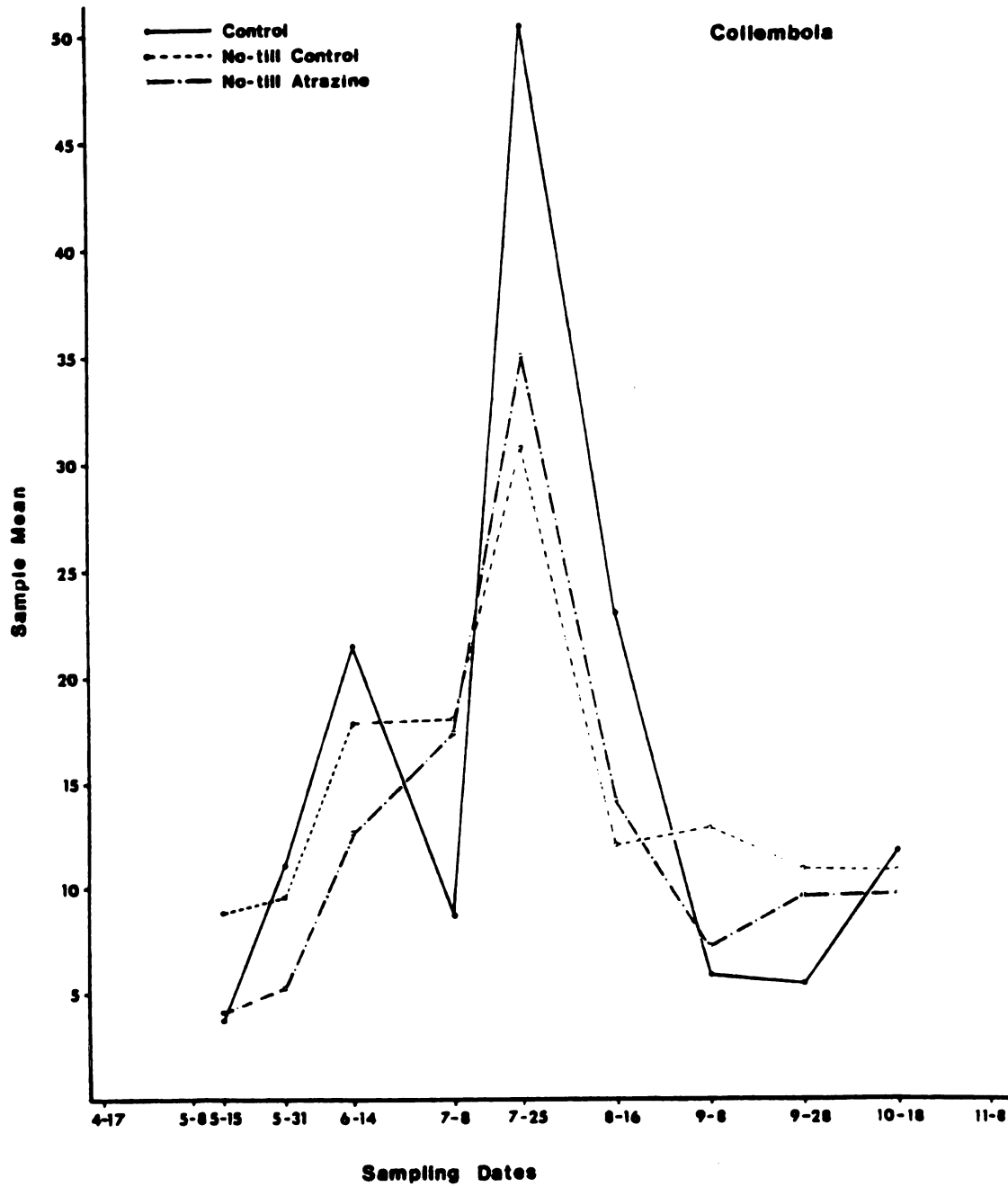


Figure 5.

No-till control or No-till Atrazine plots. Tillage was not found to be significant ($p > 0.05$) until June 14 (Figure 6).

Lepidocyrtus pallidus and Isotoma notabilis were also affected by microenvironmental changes caused by tillage. L. pallidus was more numerous in grass control plots than tilled plots in June, late July, and early fall (Figure 7B). I. notabilis was more numerous in grass control plots than tilled plots in mid-summer and early fall (Figure 7A).

Edaphic Collembola appeared not to be adversely affected by Atrazine. The L. pallidus and I. notabilis populations in No-till control and No-till Atrazine plots did not differ (Figure 7A and 7B). The B. parvula populations in No-till control and No-till Atrazine plots significantly differed only on July 25 and August 16 (Figure 6). Tullbergia graulata was not affected by tillage throughout the study (Figure 7C). Significantly more ($p > 0.05$) T. granulata were found in No-till Atrazine plots than No-till control or grass control plots on September 28, October 18, and November 8 (Figure 7C).

These results reflect differences in niches Collembolan species occupy and the subsequent changes these habitats underwent after each treatment. The epigeic Collembola were in direct contact with farm equipment traffic while edaphic Collembola were shielded from much of this activity. This may explain why fewer epigeic Collembola were found in tilled plots than grass control plots immediately after tillage, while edaphic Collembola were not significantly affected. Later differences in epigeic population levels that arose

Figure 6. Mean Population Levels of Brachystomella parvula

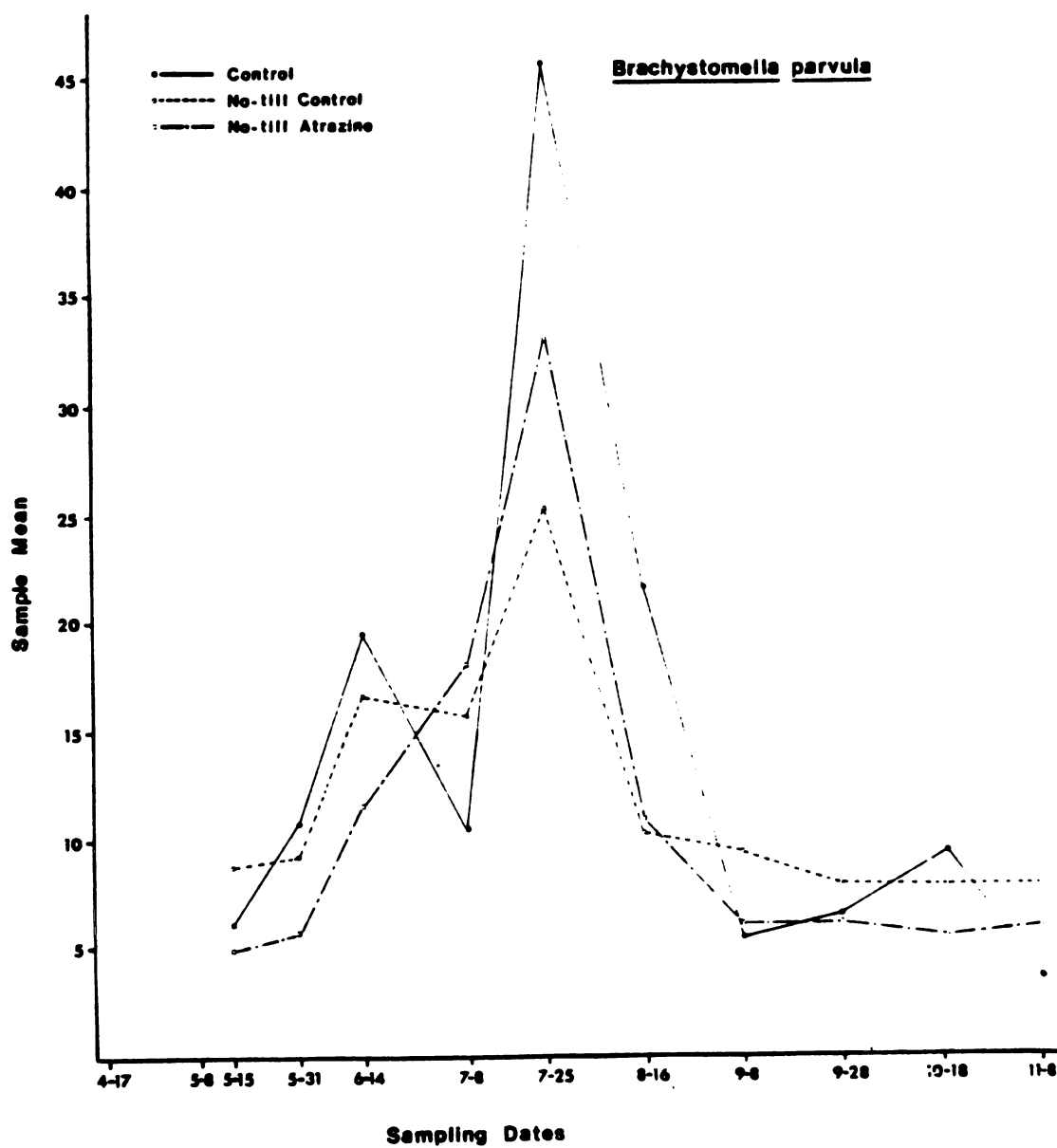


Figure 6.

Figure 7A. Mean Population Levels of Isotoma notabilis

Figure 7B. Mean Population Levels of Lepidocyrtus pallidus

Figure 7C. Mean Population Levels of Tullbergia granulata

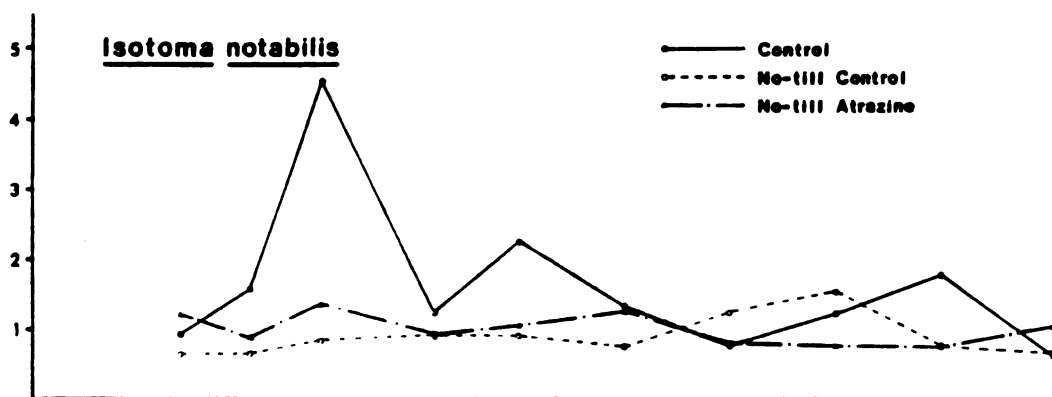


Figure 7A.

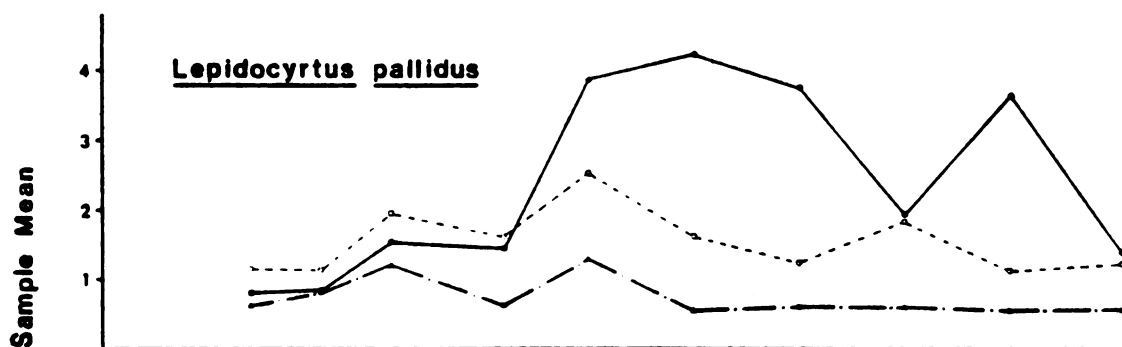


Figure 7B.

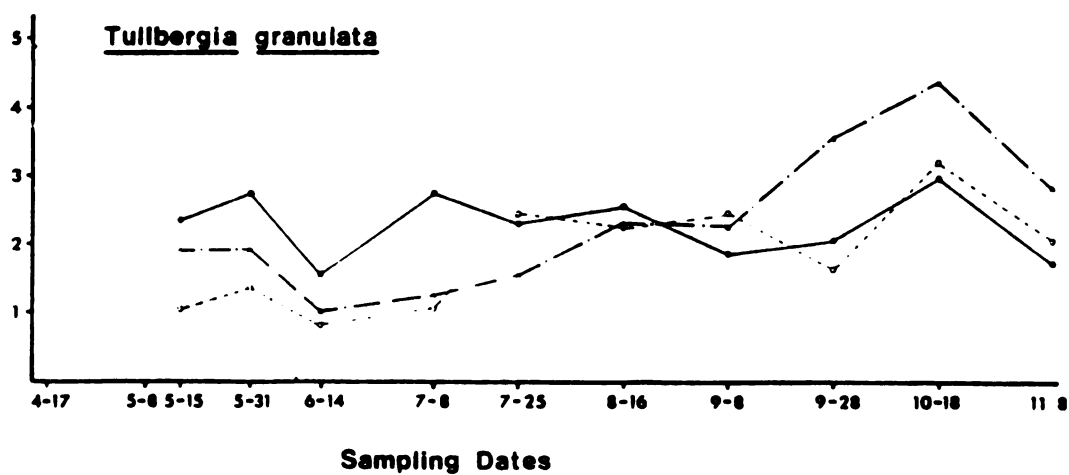


Figure 7C.

between treatments were a result of changes that occurred on the soil surface. Field observations made during the study, showed surface vegetation in No-till Atrazine plots had been eradicated and corn emerged by mid-June. The decaying vegetation and newly emerged corn created a habitat markedly different from the original grassland. The sharp increase in S. elegans population in No-till Atrazine plots during July may have been a response to habitat changes incurred by Atrazine (Figure 4).

Edaphic Collembola were affected by changes that occurred within the soil. Tillage alters the soil structure resulting in changes in soil microenvironment (Aleinikova & Utrobina, 1975). Collembola living in the soil were affected by microenvironmental changes rather than actual tillage processes. The nature of these changes, and means of their action on edaphic Collembola populations cannot be determined from these data. Because No-till control and No-till Atrazine were found not to differ significantly for the majority of edaphic species analyzed, Atrazine was not an important factor.

Acarina

The Prostigmata were affected by tillage and Atrazine. Significantly fewer numbers were collected from tilled plots than grass control plots. They were least abundant in No-till Atrazine plots. Populations in No-till control plots and grass control plots exhibited similar trends. In these treatments the Prostigmata were more numerous at the end of the growing season. The early growing season was marked

Figure 8. Mean Population Levels of Prostigmata

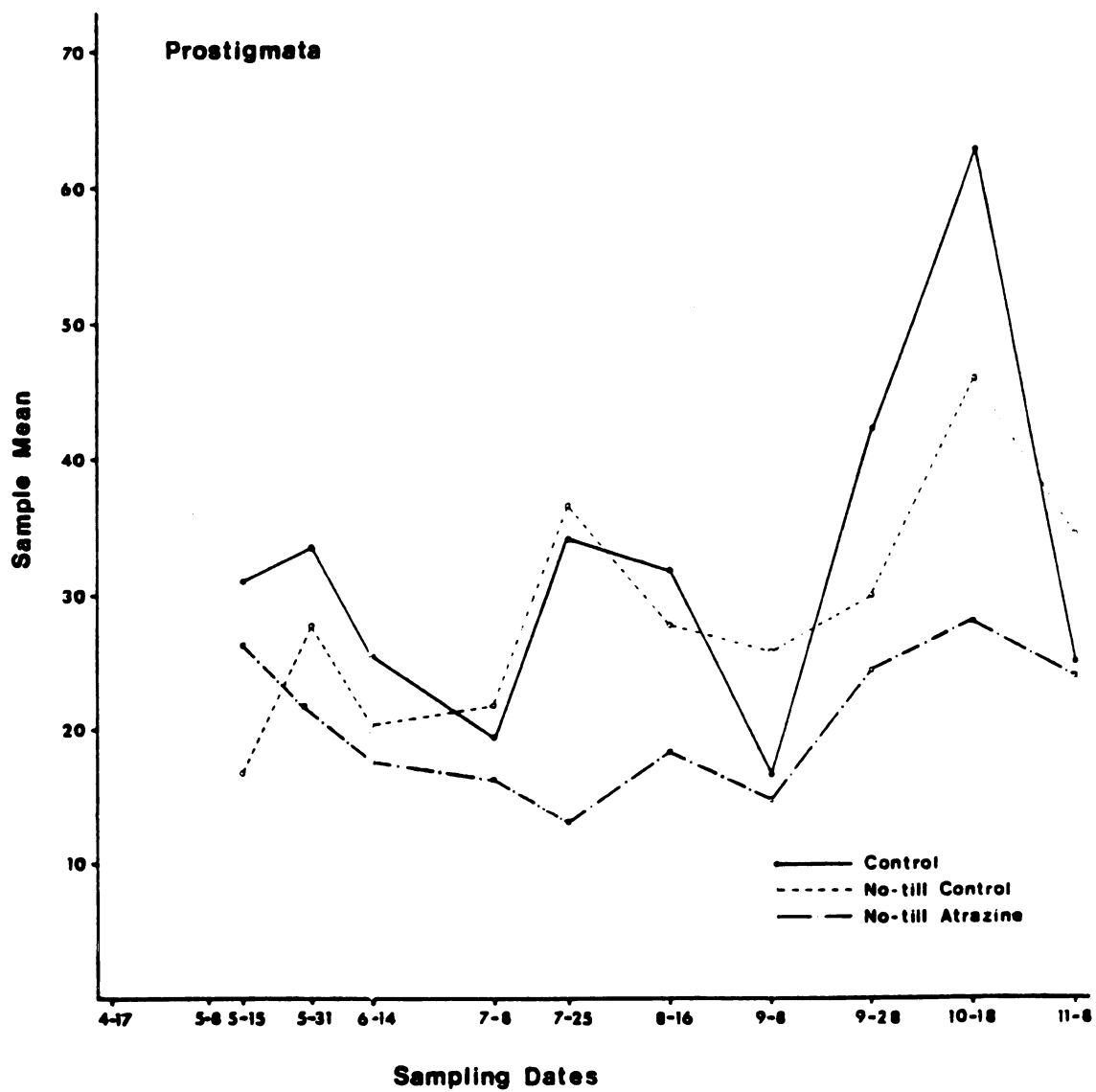


Figure 8.

Figure 9. Mean Population Levels of Pyemotidae

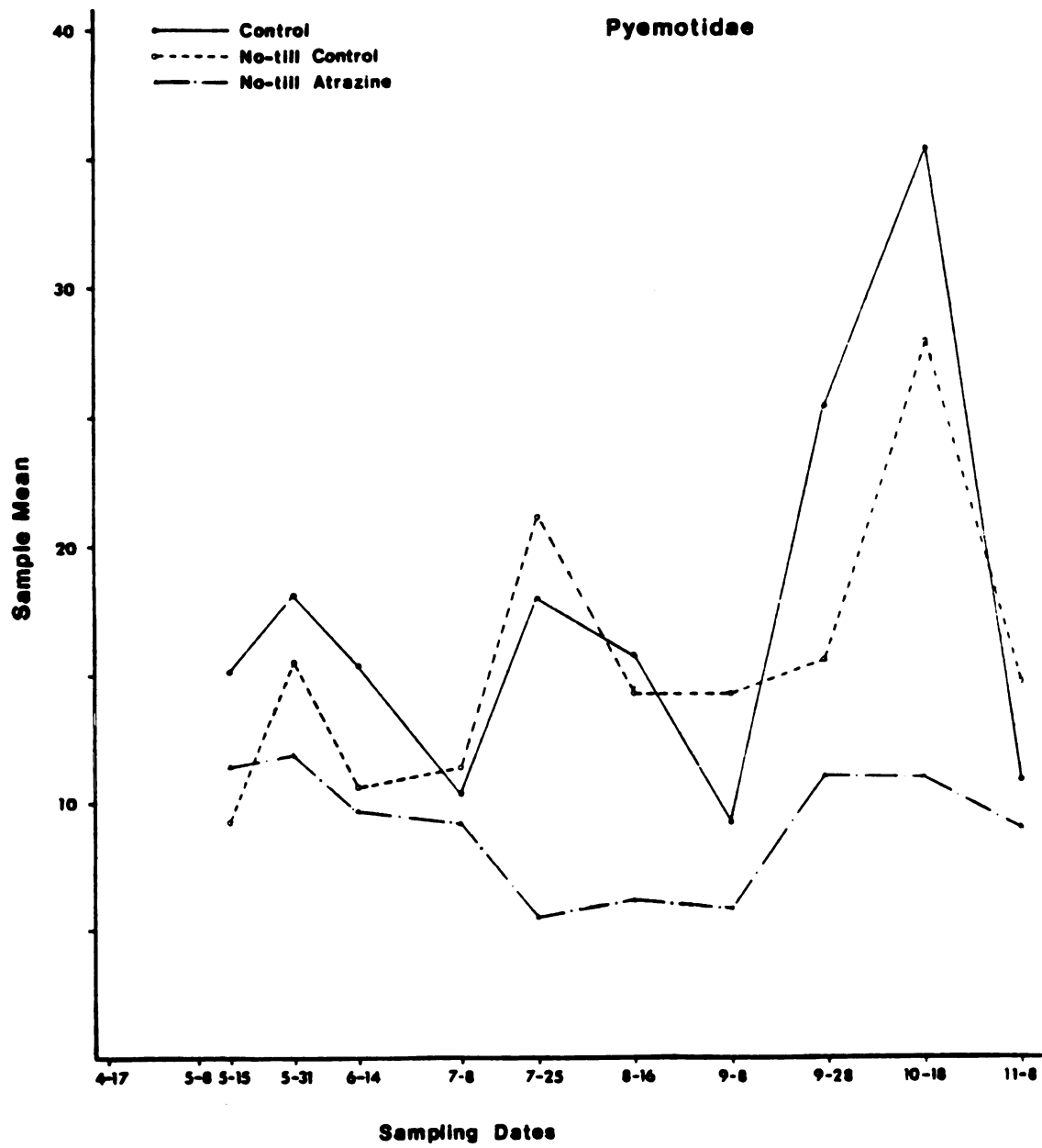


Figure 9.

Figure 10. Mean Population Levels of Cryptostigmata

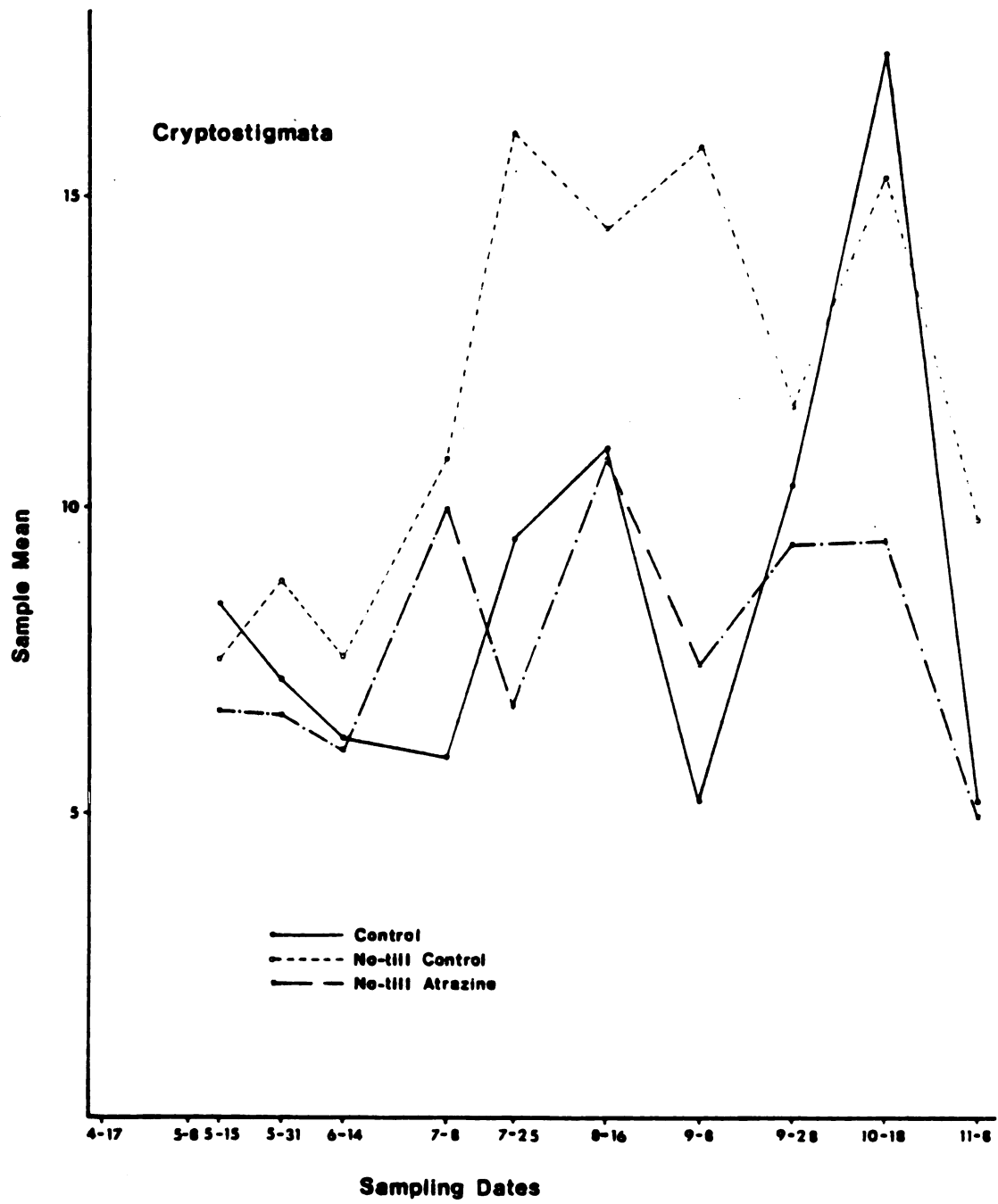


Figure 10.

Figure 11. Mean Population Levels of Opiidae

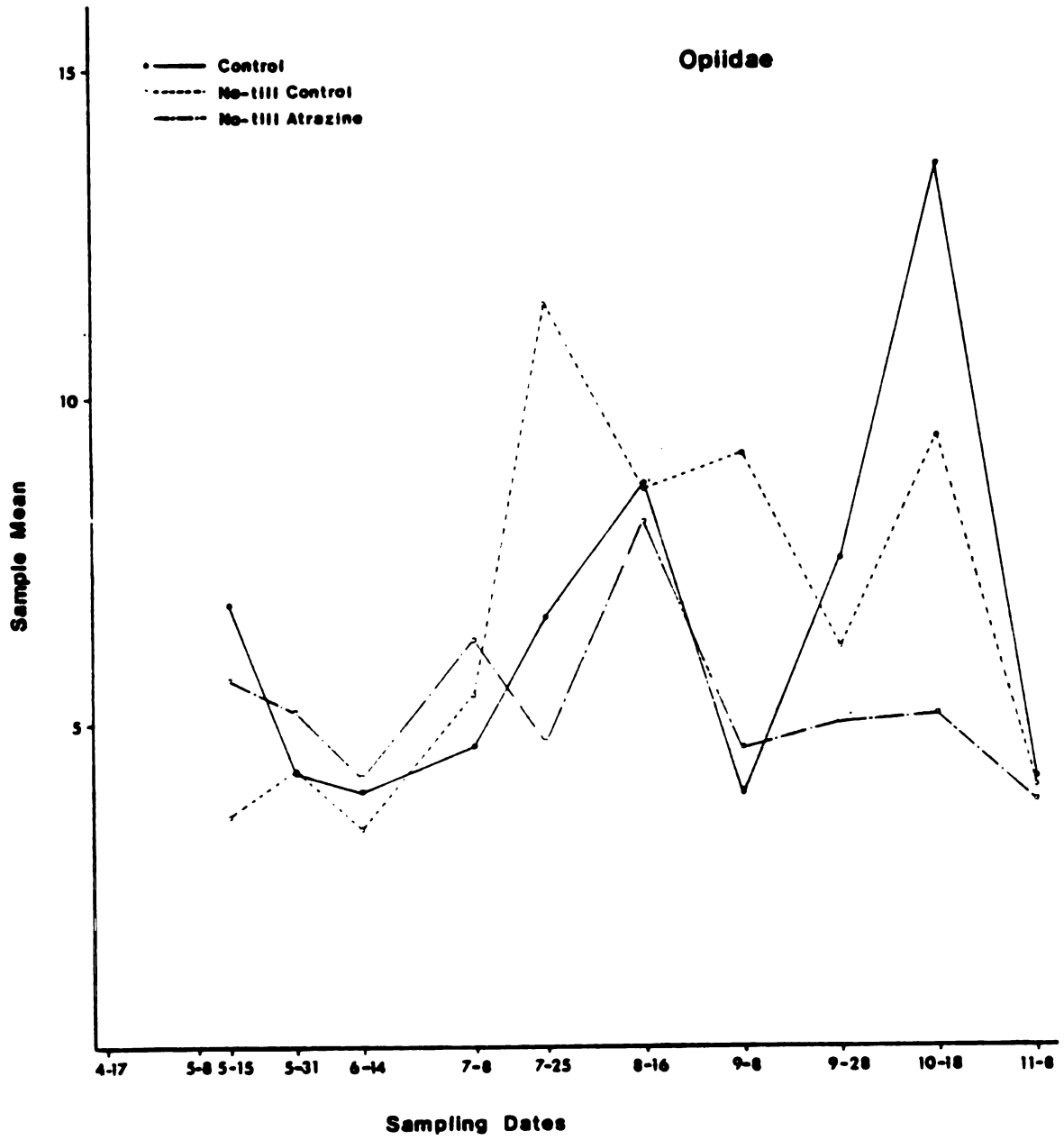


Figure 11.

Figure 12. Mean Population Levels of Mesostigmata

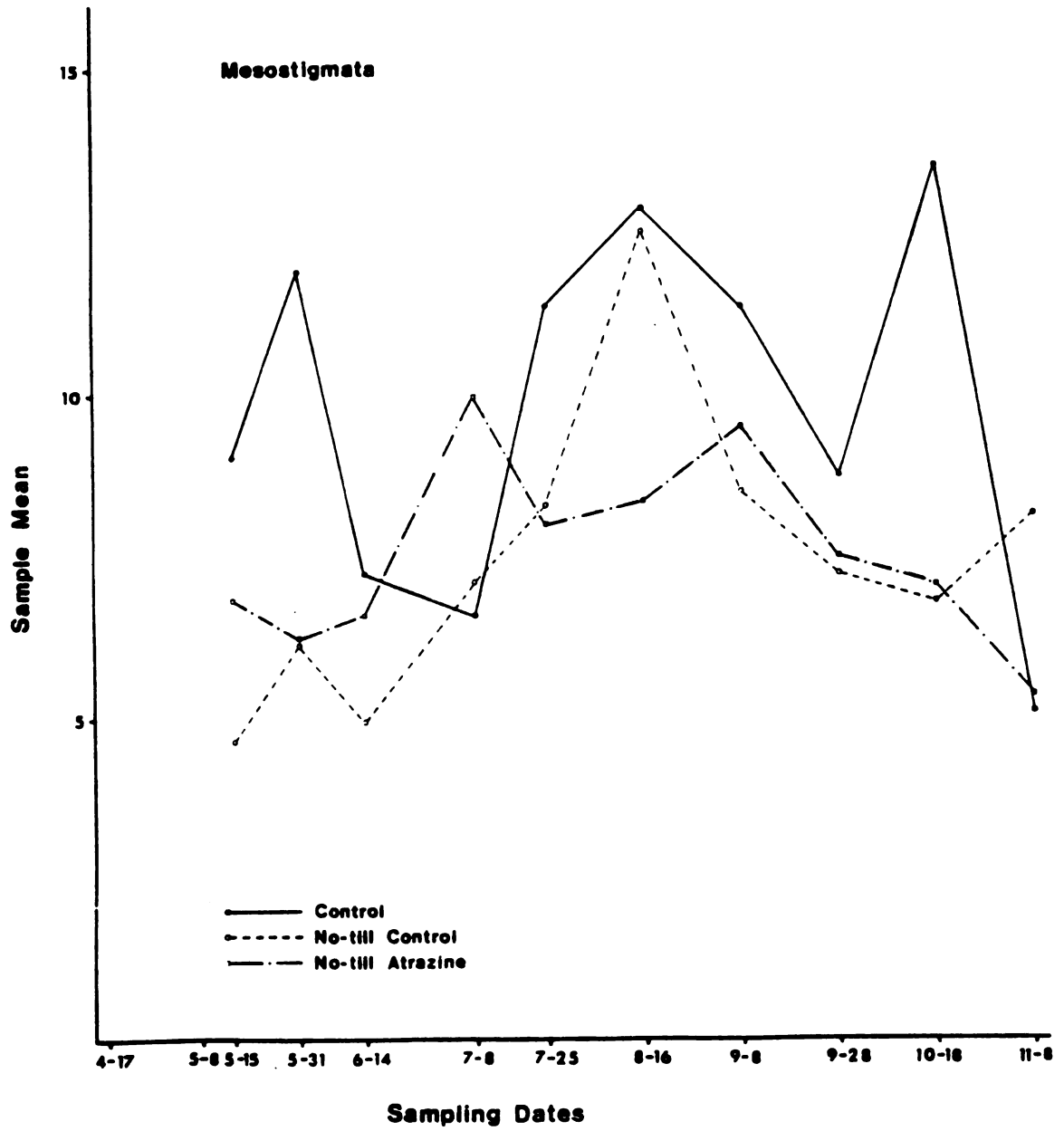


Figure 12.

with fluctuations (Figure 8). From the end of July through October significantly fewer Prostigmata ($p < 0.05$) were found in no-till Atrazine plots than grass control plots. The Pyemotidae showed an overall trend similar to the Prostigmata (Figure 9). This was expected as they were the dominant mite family.

The Cryptostigmata were affected by tillage and Atrazine. Populations in each treatment did not differ until the third sampling date. The Cryptostigmata were most numerous in No-till control plots (Figure 10). Similar results showing an increase of Oribatid mites after cultivation were reported by Shaddy and Butcher (1977). They attributed the increase to microenvironmental changes incurred by tillage. An increase after tillage was not found in No-till Atrazine plots or grass control plots. Peak abundance in grass control plots was attained in October. The Opiidae showed an overall trend similar to the Cryptostigmata as a group (Figure 11). They were most numerous in No-till control plots, but, did not sustain high numbers as long as the Cryptostigmata. The Opiidae population in grass control plots increased sharply in October, while in No-till Atrazine plots they did not appear to recover from tillage.

The Mesostigmata were affected by tillage and Atrazine. Significantly fewer ($p < 0.05$) Mesostigmata were found in tilled plots than grass control plots on May 15 and 31 (Figure 12). In grass control plots three population peaks were observed. These occurred in late May, mid-August, and mid-October. In No-till control plots a single peak in

abundance occurred during mid-August. The population fluctuated in No-till Atrazine plots, but no peaks are evident. The Rhodacaridae were also affected by tillage and Atrazine (Figure 13). Unlike the Mesostigmata, the Rhodacaridae recovered in No-till control plots and then followed a trend similar to those in grass control plots. The Rhodacaridae responded favorably to Atrazine. Although fluctuations are seen in No-till Atrazine plots, they are not as intense as those in grass control and No-till control plots (Figure 13).

The Astigmata were affected by tillage. Significantly more ($p < 0.05$) Astigmata were found in No-till control plots than No-till Atrazine and grass control plots (Figure 14). The latter two treatments differed significantly only on September 8.

Age Structure

An analysis of the effect of Atrazine and No-till farming on the population age structure of Brachystomella parvula was performed. Because no measure of when B. parvula reaches maturity was available in the literature and attempts to rear them in the laboratory to obtain this information failed, it was assumed that members of the smallest size class devoid of pigment were juveniles. Qualitatively, juvenile B. parvula population levels in each treatment were negligible until July 25 (Figure 15A). On this date an increased number of juveniles were collected from grass control plots, followed by No-till control and No-till Atrazine plots. After July 25 the number of juveniles found in each treatment returned to the previously low levels. Statistically, No-till

Figure 13. Mean Population Levels of Rhodacaridae

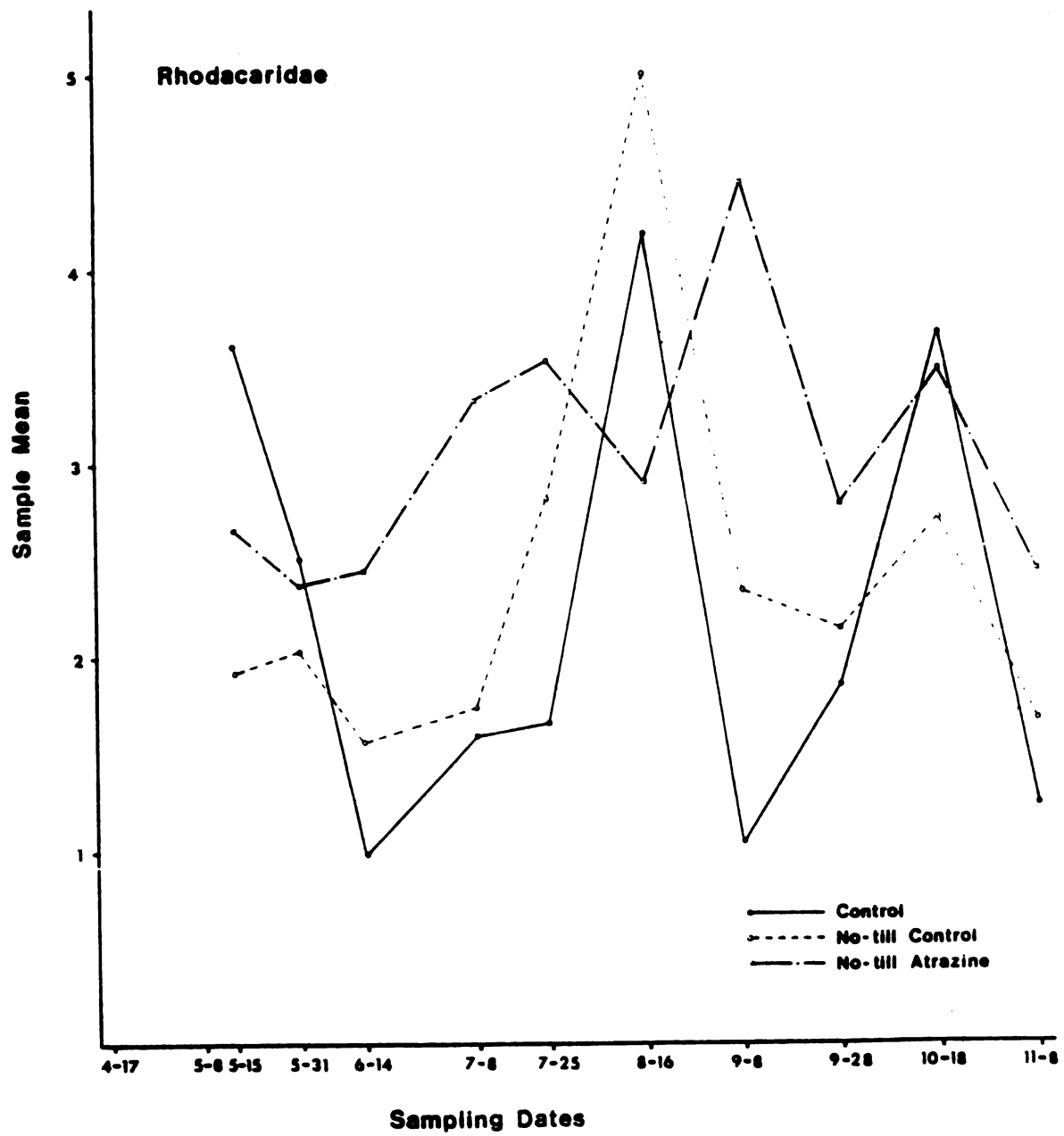


Figure 13.

Figure 14. Mean Population Levels of Astigmata

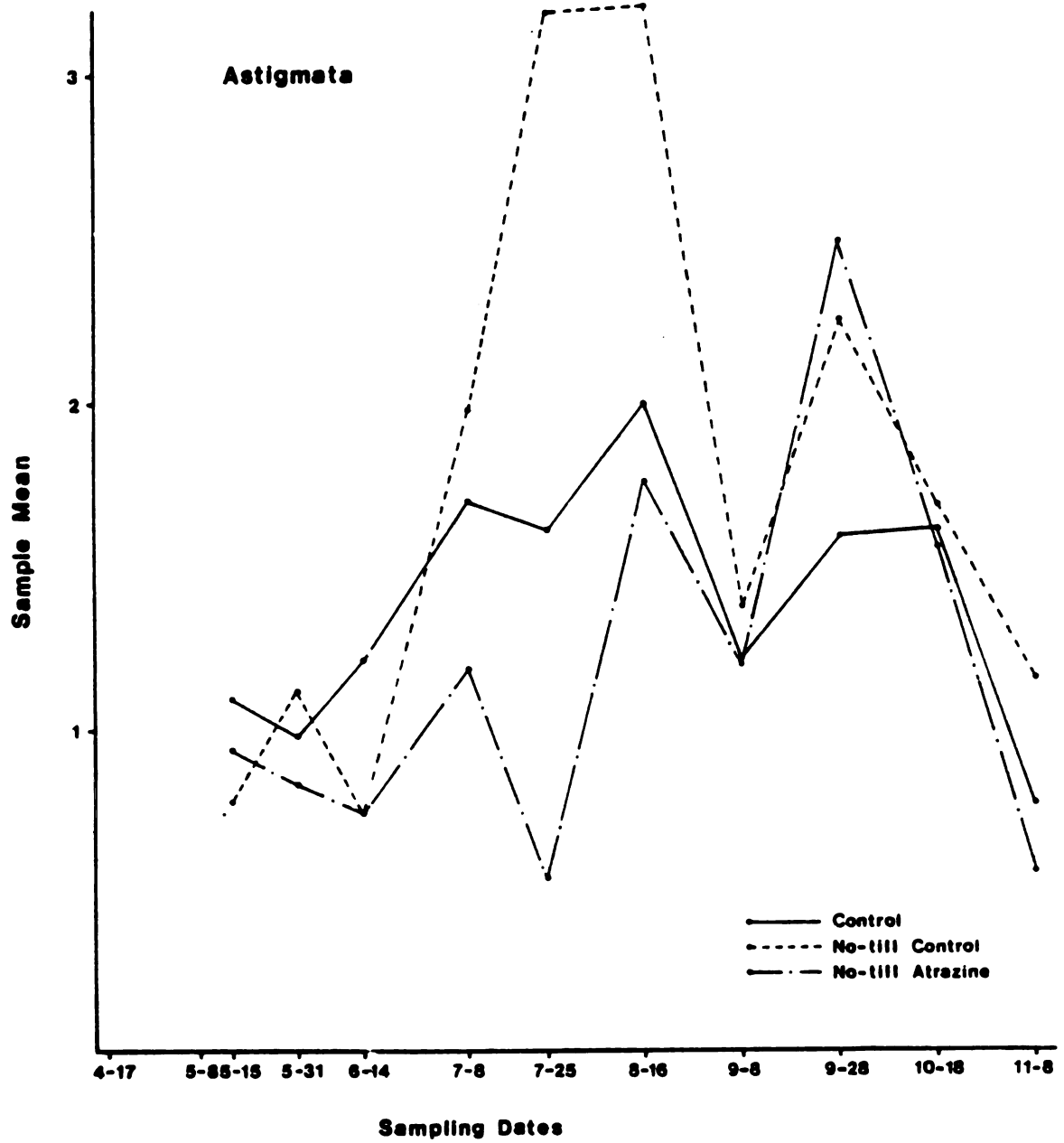


Figure 14.

Figure 15A. Mean Population Levels of Juvenile Brachystomella parvula

Figure 15B. Percentage of Juveniles in Brachystomella parvula population

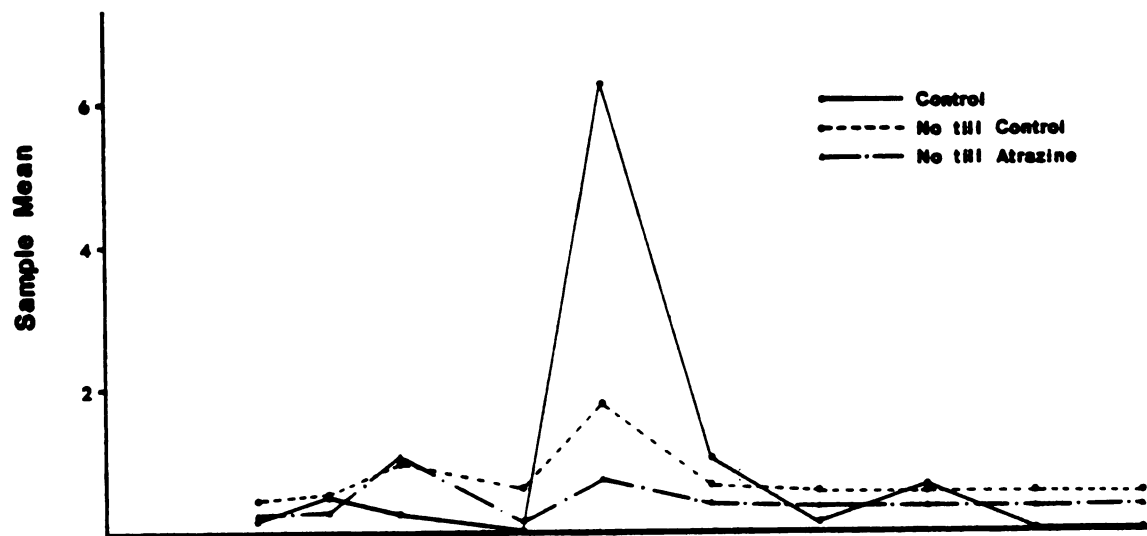


Figure 15A.

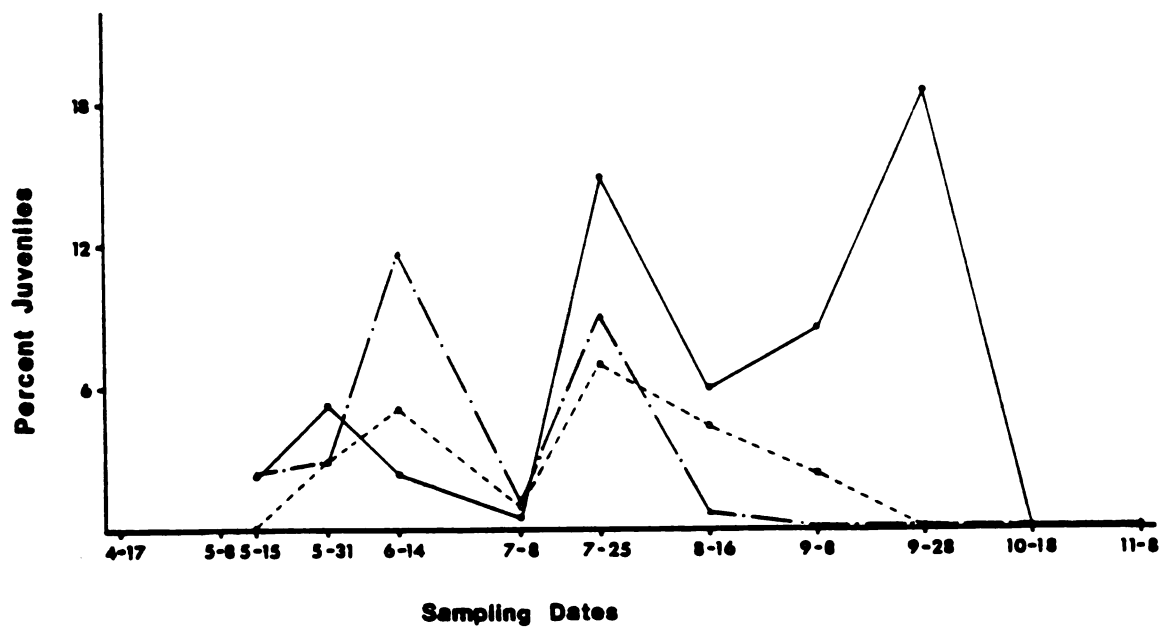


Figure 15B.

control and No-till Atrazine populations differed ($p = 0.05$) only on July 8 and 25. Significantly more ($p = 0.05$) juveniles were found in grass control plots than no-till control and No-till Atrazine plots on July 25.

Juveniles were expressed as a percentage of the total population (Figure 15B). No-till control and No-till Atrazine populations had similar trends. Each had peaks occurring in mid-June and late July. During mid-June and late July juveniles constituted a larger portion of the population in No-till Atrazine plots. After late July the proportion of the juveniles accounted for less than 1% of the B. parvula population in No-till control and No-till Atrazine plots. The percentage of juveniles in grass control plots rose and declined three times at eight week intervals beginning in late May. The influx of juveniles in grass control plots occurred two weeks earlier than in tilled plots. The second influx in grass control plots coincided with that of the tilled plots. The third influx occurred in late September.

These data suggest that juvenile B. parvula were affected by tillage but not Atrazine. Significantly fewer ($p = 0.05$) juveniles were found in tilled plots than grass control plots. Although No-till control and No-till Atrazine populations differed significantly on selected dates overall the populations did not differ significantly ($p = 0.05$). Furthermore, when the number of juveniles was expressed as a percentage of the total population, No-till control and No-till Atrazine populations followed similar trends while grass control populations followed a different

one.

CONCLUSION

No-tillage significantly reduced Collembola, Mesostigmatid, and Prostigmatid mite populations. Only epigeic Collembola were directly affected by No-tillage. Alterations in Edaphic Collembola, Prostigmata, and Mesostigmata populations were the result of changes in the soil microenvironment. Astigmata and Cryptostigmata populations increased after tillage. These results are in agreement with Edwards and Lofty (1975).

Atrazine directly affected only the Prostigmata. Fewer Prostigmata were collected from Atrazine treated plots after the herbicide was applied and for the remainder of the study. Other changes in arthropod populations occurred after surface vegetation had died and corn had emerged. This suggested that habitat alterations caused by Atrazine and not direct toxicity were involved. Similar conclusions were drawn by Curry (1970).

The population age structure of B. parvula was altered by No-tillage. Fewer juvenile B. parvula were collected from No-till control and No-till Atrazine plots than grass control plots. It was difficult to accurately assess the impact of the alteration since conclusions would have been based on data collected from one growing season. However, if this trend were to continue, fewer B. parvula would reach maturity to reproduce in No-till plots.

RECOMMENDATIONS

This study and others performed at Michigan State University have determined that No-tillage and herbicides affect arthropod populations to varying degrees. Furthermore, with the implimentation of more sophisticated statistical analyses we are now able to determine when during the growing season arthropods are affected by different treatments. If the following recommendations are executed, a better understanding of how herbicides affect these animals and the consequences of the effects could be obtained.

- 1) Before the soil is tilled or treated with herbicides the sampling area should be defined. This would enable researchers to determine immediate treatment effects. As it was, in this study, no definitive conclusions could be drawn on the initial disturbances.
- 2) More environmental parameters should be measured. If done frequently, a regression could be developed to determine the relative importance of each parameter.
- 3) The soil should be analyzed periodically for herbicide concentration. A relationship between arthropod population levels and herbicide concentration could be established.
- 4) Continue this project for many growing seasons and follow community succession. Huhta (1979) has provided a summary of the effectiveness of a few indices of succession. By following community succession, changes in species composition could be monitored.

APPENDICES

**Appendix A. Checklist of Arthropods Collected From No-till
Control Plots**

APPENDIX A

CHECKLIST OF ARTHROPODS COLLECTED FROM GRASS CONTROL PLOTS

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SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8	Total
NUMBER OF SAMPLES	30	27	20	28	28	28	28	28	28	27	272

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COLLEMBOLA

Brachystomellidae

<u>Brachystomella parvula</u>	92	201	343	223	1212	504	83	119	197	36	3010
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Entomobryidae

<u>Entomobrya multifasciata</u>	0	0	0	0	0	0	0	0	1	0	1
<u>Lepidocyrtus pallidus</u>	5	6	18	23	90	93	87	36	83	20	461
<u>Lepidocyrtus paradoxus</u>	0	0	1	0	1	5	0	3	1	1	12
<u>Lepidocyrtus violaceus</u>	0	0	0	0	0	0	0	0	0	0	0
<u>Psuedosinella sexoculata</u>	1	0	0	1	1	5	0	2	3	1	14
<u>Psuedosinella violenta</u>	11	27	36	17	56	34	28	31	43	19	302

APPENDIX A (continued)

=====											
Hypogastruridae											
<u>Hypogastrura manubrialis</u>	1	0	14	20	49	26	11	15	5	1	142
Isotomidae											
<u>Isotoma notabilis</u>	14	31	87	29	58	29	16	29	45	12	350
<u>Isotoma viridis</u>	0	0	0	6	9	1	6	1	3	3	29
Neelidae											
<u>Neelus minutus</u>	4	0	2	1	1	1	1	0	7	5	22
Onychiuridae											
<u>Onychiurus encarpatus</u>	6	11	3	3	25	4	31	8	14	2	107
<u>Tullbergia granulata</u>	31	40	4	39	26	31	14	20	45	9	259
Sminthuridae											
<u>Arrhopalites sp.</u>	0	0	0	0	1	0	0	0	0	0	1
<u>Deuterosminthurus russata</u>	5	16	8	1	0	1	0	0	0	0	31
<u>Sminthurinus elegans</u>	109	111	31	16	23	9	1	0	41	1	305
<u>Sminthurinus sp.</u>	17	3	0	2	32	0	0	0	2	1	57
<u>Sphearidia pumilis</u>	38	37	12	18	54	18	3	0	28	2	210

APPENDIX A (continued)

=====												
ACARINA												
PROSTIGMATA												
Bdellidae	2	1	3	1	3	3	0	2	0	0	15	
Eupodidae	83	62	45	32	101	56	33	59	141	49	612	
Nanorchestidae	22	25	2	1	11	6	1	64	124	3	259	
Neophyllobidae	3	2	1	0	2	1	0	0	0	0	9	
Penthaleidae	1	0	0	0	3	0	0	0	0	0	4	
Pyemotidae	231	303	154	75	292	221	12	501	778	106	2673	
Rhagidiidae	33	7	7	24	56	44	14	30	32	18	265	
Scutacaridae	125	122	4	2	51	63	2	30	122	10	531	
Stigmaeidae	0	1	1	1	3	41	7	3	2	0	59	
Tarsonemidae	13	10	7	2	18	25	2	55	107	13	252	
Tetranychidae	0	0	0	0	0	0	0	2	0	0	2	
Trombidiidae	0	1	0	2	1	0	0	0	1	0	5	
Tydeidae	5	4	5	18	32	20	11	56	77	117	345	

APPENDIX A (continued)

Immature Prostigmata	1	1	14	6	6	0	7	4	2	0	42
CRYPTOSTIGMATA											
Epilohmannidae	10	4	1	0	0	14	0	0	1	11	41
Immature Epilohmannidae	1	0	1	0	0	0	0	0	0	0	2
Eupthriacaridae	1	1	2	0	0	0	0	0	3	0	7
Opiidae	105	25	15	41	96	142	20	121	290	26	881
Oribatulidae	3	29	23	8	39	13	5	44	42	3	209
Tectocepheidae	3	8	1	2	15	11	0	6	26	1	73
Immature Cryptostigmata	1	10	1	2	1	0	0	0	0	0	15
MESOSTIGMATA											
Ascidae	13	3	2	20	71	52	5	56	101	18	341
Laelapidae	14	10	8	4	32	24	6	27	48	15	188
Phytoseiidae	21	13	16	5	22	17	2	11	5	0	112
Rhodacaridae	78	40	0	17	19	83	2	24	75	7	345
Immature Mesostigmata	29	153	47	37	59	49	11	16	22	0	423

APPENDIX A (continued)

=====												
Unidentified Mesostigmata	5	2	0	1	14	16	9	10	25	1	83	
ASTIGMATA	9	5	9	26	24	32	13	23	24	0	141	
ARANAEA	1	0	1	0	3	2	2	2	3	0	14	
CHILOPODA	1	0	0	0	0	2	4	1	0	0	8	
DIPLODA	9	4	2	4	2	0	0	3	8	0	14	
PAUROPODA	4	1	3	3	8	6	0	9	5	2	41	
SYMPHYLA	41	6	16	45	35	64	16	60	58	11	352	
INSECTA												
DIPLURA	27	25	8	41	38	53	35	12	35	17	291	
PROTURA	1	1	2	0	2	4	0	0	0	0	10	
COLEOPTERA	8	4	5	9	0	11	1	10	7	2	57	
COLEOPTERA LARVAE	2	2	3	22	33	26	12	4	3	2	109	
DIPTERA LARVAE	0	0	29	0	0	0	0	0	0	3	32	
HOMOPTERA	14	27	15	13	13	12	6	14	10	13	137	
HYMENOPTERA	0	0	0	0	0	0	0	1	0	0	1	

APPENDIX A (continued)

Formicidae	55	36	21	14	21	42	20	10	41	8	268
LEPODOPTERA LARVAE	0	0	0	0	3	2	0	0	0	0	5
ORTHOPTERA	0	0	0	0	0	0	0	0	0	0	0
PSCOPTERA	0	0	0	0	0	0	0	0	0	0	0
THYSANOPTERA	88	76	43	58	34	34	21	30	22	11	417
CRUSTACEA											
ISOPODA	0	1	0	5	4	6	10	3	3	0	32

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**Appendix B. Checklist of Arthropods Collected From No-till
Control Plots**

APPENDIX B

CHECKLIST OF ARTHROPODS COLLECTED FROM NO-TILL CONTROL PLOTS

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8	Total
NUMBER OS SAMPLES	29	30	20	28	28	27	27	28	28	28	273

COLLEMBOLA

Brachystomellidae

Brachystomella parvula 53 70 179 218 486 69 43 14 10 12 1154

Entomobryidae

Entomobrya multifasciata 0 0 0 0 3 0 0 0 0 0 0 3

Lepidocryptus pallidus 6 5 18 15 40 16 4 21 1 4 130

Lepidocryptus paradoxus 0 0 0 1 2 0 0 0 0 1 1 5

Lepidocryptus violaceus 0 0 0 0 1 0 0 0 0 0 0 1

Psuedosinella sexoculata 0 0 1 0 1 2 0 0 0 0 0 4

Psuedosinella violenta 3 4 2 10 15 14 28 18 12 9 125

APPENDIX B (continued)

Hypogastruridae											
<u>Hypogastrura manubrialis</u>	3	2	5	41	45	4	14	2	1	4	121
Isotomidae											
<u>Isotoma notabilis</u>	6	8	6	11	11	7	19	28	8	8	112
<u>Isotoma viridis</u>	3	5	0	0	0	0	1	0	0	0	9
Neelidae											
<u>Neelus minutus</u>	5	0	1	0	2	0	1	0	5	5	19
Onychiuridae											
<u>Onychiurus encarpatus</u>	6	0	1	1	15	2	3	1	1	2	26
<u>Tullbergia granulata</u>	1	11	0	7	46	38	45	23	67	35	242
Sminthuridae											
<u>Arrhopalites sp.</u>	0	0	0	0	2	0	0	0	0	0	2
<u>Deuterosminthurus russata</u>	8	10	10	2	0	2	0	0	0	0	32
<u>Sminthurinus elegans</u>	20	57	16	47	38	5	1	0	8	0	141
<u>Sminthurinus sp.</u>	12	5	0	5	88	9	1	0	0	0	120

APPENDIX B (continued)

<u>Sphearidia pumilis</u>	38	19	15	23	102	3	0	0	1	0	201
ACARINA											
PROSTIGMATA											
Bdellidae	0	1	0	0	2	3	0	0	0	0	6
Eupodidae	29	44	13	16	31	37	25	37	101	75	408
Nanorchestidae	2	1	0	6	11	2	5	15	42	4	88
Neophyllobidae	0	1	1	0	4	1	1	0	0	0	8
Penthaleidae	0	1	0	0	0	0	0	0	0	0	1
Pyemotidae	24	249	90	146	411	159	160	238	511	194	2222
Rhagidiidae	15	13	15	20	38	47	33	24	14	39	258
Scutacaridae	0	61	1	3	55	69	61	55	122	46	473
Stigmaeidae	0	0	0	1	14	6	7	8	10	0	46
Tarsonemidae	0	36	5	4	37	23	4	24	42	31	206
Tetranychidae	0	0	0	0	1	0	0	2	0	0	3
Trombidiidae	0	1	1	0	0	1	0	0	0	0	3

APPENDIX B (continued)

Tydeidae	2	8	5	9	13	16	15	34	43	178	317
Immature Prostigmata	2	1	8	7	4	0	0	1	1	1	25
CRYPTOSTIGMATA											
Epilohmannidae	8	14	5	25	8	18	41	10	36	26	189
Immature Epilohmannidae	0	1	2	1	2	0	0	0	0	0	6
Eupthiracaridae	0	0	0	1	0	0	2	0	1	3	7
Opiidae	17	37	24	92	259	171	190	112	175	52	1129
Oribatulidae	0	5	6	16	9	32	22	22	18	28	158
Tectocepheidae	2	4	4	5	12	15	13	10	13	7	85
Immature Cryptostigmata	0	5	0	7	3	0	0	0	0	0	15
MESOSTIGMATA											
Ascidae	2	7	2	80	41	40	16	6	27	28	199
Laelapidae	1	1	1	6	18	8	30	15	23	18	113
Phytoseiidae	0	5	3	7	10	14	6	10	2	0	56
Rhodacaridae	9	13	4	12	42	98	28	25	39	10	269

APPENDIX B (continued)

=====												
Immature Mesostigmata	0	36	28	38	25	63	45	16	11	0	268	
Unidentified Mesostigmata	0	1	0	13	11	27	25	61	3	3	144	
ASTIGMATA	0	10	6	43	75	71	26	51	35	20	337	
ARANAEA	0	0	1	1	16	4	2	3	2	5	34	
CHILOPODA	1	0	1	1	4	2	7	1	1	5	23	
DIPLOPODA	1	1	9	0	9	2	12	9	4	7	50	
PAUROPODA	1	0	1	2	1	2	3	8	4	7	29	
SYMPHYLA	12	9	3	8	8	54	51	35	28	15	224	
INSECTA												
DIPLURA	6	6	3	14	18	22	7	5	11	6	98	
PROTURA	0	0	9	0	0	0	3	19	0	1	32	
COLEOPOTERA	6	6	1	9	3	11	8	4	8	4	60	
COLEOPTERA LARVAE	0	11	8	21	55	21	17	0	2	2	137	
DIPTERA LARVAE	1	0	0	0	0	0	0	0	0	0	1	
HOMOPTERA	8	30	13	13	4	4	6	28	20	6	133	

APPENDIX B (continued)

=====													
HYMENOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0
Formicidae	10	7	6	39	21	27	41	19	14	0	184		
LEPIDOPTERA LARVAE	0	0	0	0	0	0	0	2	1	0	3		
ORTHOPTERA	0	0	0	0	0	0	1	0	0	0	1		
PSCOPTERA	0	0	0	0	0	0	0	0	0	0	0		
THYSANOPTERA	27	91	57	43	58	22	27	7	8	5	345		
CRUSTACEA													
ISOPODA	2	1	1	8	5	9	12	18	2	1	59		

* * *

**Appendix C. Checklist of Arthropods Collected From No-till
Atrazine Plots.**

APPENDIX C

CHECKLIST OF ARTHROPODS COLLECTED FROM NO-TILL ATRAZINE PLOTS

=====

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8	Total
NUMBER OF SAMPLES	29	30	20	28	28	27	28	27	27	28	272

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COLLEMBOLA

Brachystomellidae

<u>Brachystomella parvula</u>	44	70	120	350	739	147	20	16	2	13	1521
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Entomobryidae

<u>Entomobrya multifasciata</u>	0	0	0	0	0	0	0	0	0	0	0
<u>Lepidocryptus pallidus</u>	3	8	13	2	20	0	1	1	0	0	48
<u>Lepidocryptus paradoxus</u>	0	0	0	0	1	0	0	0	0	0	1
<u>Lepidocryptus violaceus</u>	0	0	0	0	0	0	0	0	0	0	0
<u>Psuedosinella sexoculata</u>	0	1	1	0	0	2	0	0	0	0	4
<u>Psuedosinella violenta</u>	4	8	2	10	10	28	8	15	8	2	95

APPENDIX C (continued)

=====												
Hypogastruridae												
<u>Hypogarthura manubrialis</u>	2	4	22	24	55	55	9	29	15	10	170	
Isotomidae												
<u>Isotoma notabilis</u>	15	6	12	5	8	13	1	0	0	7	67	
<u>Isotoma viridis</u>	0	9	8	0	0	0	1	0	1	2	21	
Neelidae												
<u>Neelus minutus</u>	5	3	0	0	0	5	4	4	19	28	68	64
Onychiuridae												
<u>Onychiurus encarpatus</u>	0	2	0	1	4	9	26	29	43	13	127	
<u>Tullbergia granulata</u>	23	23	7	17	25	45	45	79	98	89	451	
Sminthuridae												
<u>Arrhopalites sp.</u>	0	0	0	0	0	0	3	2	0	0	5	
<u>Deuterosminthurus russata</u>	10	7	2	1	1	2	0	0	0	0	23	
<u>Sminthurinus elegans</u>	43	53	6	27	135	9	1	0	1	0	275	
<u>Sminthurinus sp.</u>	20	18	0	2	32	7	0	0	0	0	79	

APPENDIX C (continued)

<u>Sphearidia pumilis</u>	15	18	8	4	74	8	0	0	0	0	127
ACARINA											
PROSTIGMATA											
Bdellidae	0	0	1	0	0	0	1	0	0	0	2
Eupodidae	61	31	13	11	5	11	6	33	79	24	274
Nanorchestidae	9	7	0	4	0	4	1	4	9	7	45
Neophyllobidae	4	0	0	0	0	0	0	0	0	0	4
Penthaleidae	0	1	0	0	0	0	2	0	0	3	6
Pyemotidae	179	209	78	78	14	49	33	178	171	70	1057
Rhagidiidae	10	9	9	10	15	37	6	21	23	29	169
Scutacaridae	106	3	18	8	3	10	1	2	37	5	193
Stigmaeidae	1	0	0	1	8	37	31	79	27	23	207
Tarsonemidae	10	1	5	2	6	48	18	26	46	42	204
Tetranychidae	0	0	0	0	0	0	0	0	0	0	0
Trombidiidae	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C (continued)

=====												
Immature Mesostigmata	2	5	1	10	8	26	11	18	12	0	103	
ASTIGMATA	3	0	6	21	3	36	16	56	29	4	174	
ARANAEA	4	2	1	3	3	1	0	3	1	1	19	
CHILOPODA	2	0	0	1	1	2	5	6	2	1	20	
DIPLOPODA	5	2	4	6	6	3	0	3	2	0	32	
PAUROPODA	1	0	0	0	1	3	2	2	3	5	19	
SYMPHYLA	6	8	11	8	2	4	0	6	6	4	55	
INSECTA												
DIPLURA	7	22	14	4	1	14	0	12	5	5	84	
PROTURA	0	0	2	1	2	14	2	5	0	0	26	
COLEOPTERA	12	18	7	1	6	1	4	4	6	1	60	
COLEOPTERA LARVAE	4	3	21	5	4	5	2	3	0	1	48	
DIPTERA LARVAE	1	0	0	0	0	0	0	0	0	0	1	
HOMOPTERA	21	3	5	3	4	0	1	12	8	1	58	

APPENDIX C (continued)

=====												
HYMENOPTERA	0	0	0	0	0	0	0	0	0	0	1	1
Formicidae	55	28	25	23	13	14	22	5	10	5	200	
LEPIDOPTERA LARVAE	0	0	0	0	3	0	0	0	0	0	3	
ORTHOPTERA	0	0	0	0	0	0	0	0	0	0	0	
PSCOPTERA	1	0	0	0	0	0	0	0	0	0	1	
THYSANOPTERA	57	52	25	27	6	17	6	5	0	3	198	
CRUSTACEA												
ISOPODA	1	0	0	1	0	2	3	6	1	0	14	

* * *

**Appendix D. Means and 95% Confidence Intervals for Arthropods
analysed.**

APPENDIX D

MEAN NUMBER OF SMINTHURIDAE PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	7.04	7.62	4.07	2.85	5.42	7.35	1.67	1.53	2.74	1.66
+ —	1.23	1.44	1.47	1.24	1.24	1.29	1.24	1.24	1.24	1.24

NO-TILL CONTROL

Mean	5.46	5.78	4.97	5.67	9.07	3.60	3.00	2.92	3.24	2.92
+ —	1.29 **	1.26 **	1.41	1.24	1.24 **	1.26	1.24	1.24	1.24	1.24

NO-TILL ATRAZINE

Mean	4.50	4.68	2.59	3.00	10.78	2.74	1.83	1.78	1.80	2.03
+ —	1.28 **	1.27 **	1.47	1.24	1.26 **	1.26 **	1.24	1.26	1.26	1.34

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF SMINTHURINUS ELEGANS PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	4.19	4.69	2.17	1.19	1.44	.94	.65	.62	.76	.64
±	.83	.98	.99	.84	.84	.87	.84	.84	.84	.86

NO-TILL CONTROL

Mean	1.36	2.58	1.52	2.40	2.08	.90	.76	.72	.91	.72
±	.87	.86	.99	.84	.84	.86	.84	.84	.84	.84
	**	**								

NO-TILL ATRAZINE

Mean	2.18	2.46	1.16	1.82	5.86	1.19	.89	.86	.88	1.01
±	.86	.86	.99	.84	.86	.86	.84	.86	.86	.84
	**	**			**	**				

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF COLLEMBOLA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	3.76	10.67	21.25	8.88	50.56	23.82	5.85	5.42	11.88	10.00
+ -	6.75	7.96	8.10	6.83	6.93	7.12	6.83	6.83	6.83	6.84

NO-TILL CONTROL

Mean	8.63	9.55	17.92	18.12	30.80	12.39	13.24	11.12	11.05	10.09
+ -	7.10	7.96	8.10	6.84	6.83	6.97	6.84	6.84	6.84	6.84
			**		**	**				

NO-TILL ATRAZINE

Mean	4.24	5.31	12.32	17.67	35.17	14.13	7.24	9.65	9.71	8.92
+ -	7.03	6.98	8.10	6.83	6.97	6.96	6.84	6.96	6.96	6.83
			**		**					

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability level.

APPENDIX D (continued)

MEAN NUMBER OF BRACHYSTOMELLA PARVULA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	6.26	10.88	19.60	10.41	45.74	21.75	5.41	6.70	9.49	3.62
+ —	4.36	5.06	5.15	4.35	4.35	4.35	4.35	4.35	4.35	4.33

NO-TILL CONTROL

Mean	8.36	8.88	16.87	15.71	25.28	10.32	9.56	8.42	8.28	8.35
+ —	4.51	4.43	5.15	4.36	4.35	4.43	4.36	4.35	4.35	4.35
			**		**	**			*	

NO-TILL ATRAZINE

Mean	4.97	5.77	11.53	18.03	33.00	10.93	6.25	6.22	5.38	6.00
+ —	4.46	4.43	5.14	4.35	4.32	4.43	4.35	4.32	4.32	4.35
			**		**	**			*	

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF ISOTOMA NOTABILIS PER SAMPLE AND 95% CONFIDENCE INTERVAL

=====										
SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
=====										
<u>GRASS CONTROL</u>										
Mean	.91	1.58	4.54	1.22	2.26	1.31	.76	1.22	1.76	.61
+ —	.94	1.11	1.12	.95	.95	.99	.95	.95	.95	.97
=====										
<u>NO-TILL CONTROL</u>										
Mean	.61	.62	.81	.90	.90	.76	1.22	1.51	.79	.79
+ —	.99	.97	1.12	.95	.95	.97	.95	.95	.95	.95
			**		**					
=====										
<u>NO-TILL ATRAZINE</u>										
Mean	1.20	.88	1.36	.93	1.05	1.24	.79	.76	.75	1.01
+ —	.98	.97	1.12	.95	.97	.97	.95	.97	.97	.95
			**		**				**	
=====										

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF LEPIDOCYRTUS PALLIDUS PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	.81	.86	1.56	1.48	3.88	4.23	3.77	1.95	3.63	1.40
+ —	.64	.75	.76	.64	.64	.67	.64	.64	.64	.65

NO-TILL CONTROL

Mean	1.19	1.15	1.99	1.63	2.52	1.67	1.24	1.84	1.13	1.23
+ —	.67	.65	.76	.64	.64	.65	.64	.64	.64	.64
					**	**	**		**	

NO-TILL ATRAZINE

Mean	.65	.81	1.21	.63	1.30	.55	.60	.60	.56	.56
+ —	.66	.65	.76	.64	.65	.65	.64	.65	.65	.64
					**	**	**	**	**	**

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF TULLBERGIA GRANULATA PER SAMPLE AND 95% CONFIDENCE INTERVAL

=====										
SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
=====										
<u>GRASS CONTROL</u>										
Mean	2.35	2.75	1.57	2.76	2.30	2.56	1.87	2.08	2.98	1.71
+	1.05	1.24	1.26	1.07	1.07	1.11	1.07	1.07	1.07	1.09
=====										
<u>NO-TILL CONTROL</u>										
Mean	1.04	1.38	.81	1.06	2.45	2.24	2.46	1.63	3.20	2.05
+	1.11	1.10	1.09	1.07	1.07	1.09	1.07	1.07	1.07	1.07
=====										
<u>NO-TILL ATRAZINE</u>										
Mean	1.90	1.90	1.01	1.26	1.54	2.30	2.26	3.54	4.34	3.83
+	1.10	1.09	1.26	1.06	1.09	1.09	1.07	1.09	1.09	1.06
								**	**	**
=====										

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF PROSTIGMATA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	30.91	33.58	25.58	19.29	34.11	31.88	16.61	42.22	62.93	25.11
+ -	7.73	9.10	9.26	7.82	7.82	8.14	7.82	7.82	7.82	7.96

NO-TILL CONTROL

Mean	16.73	27.89	20.35	21.97	36.58	27.86	25.92	30.05	46.05	34.69
+ -	8.12	7.98	9.25	7.82	7.82	7.96	7.84	7.83	7.83	7.83
	**							**	**	

NO-TILL ATRAZINE

Mean	26.31	21.77	17.53	16.29	13.11	18.41	14.90	24.48	28.21	24.18
+ -	8.04	7.98	9.25	7.82	7.97	7.96	7.74	7.97	7.97	7.82
		*			**	**		**	**	

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF PYEMOTIDAE PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	15.25	18.73	15.74	10.72	18.47	16.51	8.47	25.93	35.82	11.99
+ —	4.35	5.12	5.12	4.40	4.40	4.58	4.40	4.40	4.40	4.48

NO-TILL CONTROL

Mean	8.57	16.03	11.21	12.92	22.38	13.60	13.60	16.21	25.95	14.63
+ —	4.57	4.49	5.21	4.41	4.40	4.49	4.41	4.42	4.41	4.41
								**	**	

NO-TILL ATRAZINE

Mean	12.83	13.67	9.47	8.36	6.06	7.32	6.75	12.14	12.03	8.07
+ —	4.53	4.49	5.21	4.40	4.49	4.48	4.41	4.49	4.49	4.40
					**	**		**	**	

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF CRYPTOSTIGMATA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	8.44	7.19	6.23	5.93	9.46	10.94	5.21	10.36	17.32	5.21
+ —	3.43	4.04	4.11	3.47	3.47	3.61	3.47	3.47	3.47	3.53

NO-TILL CONTROL

Mean	7.54	8.80	7.59	10.79	16.04	14.47	15.79	11.61	14.29	9.83
+ —	3.60	3.53	4.10	3.47	3.47	3.53	3.48	3.47	3.47	3.47

NO-TILL ATRAZINE

Mean	6.68	6.52	6.02	9.92	6.78	11.49	7.42	9.40	9.49	4.99
+ —	3.57	3.54	4.10	3.47	3.53	3.53	3.47	3.53	3.53	3.47

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF OPIIDAE PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	6.84	4.25	3.97	4.68	6.65	8.70	3.93	7.54	13.58	4.19
+ —	2.38	2.80	2.85	2.41	2.41	2.50	2.41	2.41	2.41	2.45

NO-TILL CONTROL

Mean	3.59	4.24	3.39	5.47	11.44	8.61	9.14	6.19	8.44	4.04
+ —	2.50	2.45	2.85	2.41	2.41	2.45	2.41	2.41	2.41	2.41
					**		**		**	

NO-TILL ATRAZINE

Mean	5.75	5.27	4.32	6.32	4.81	8.15	4.68	5.07	5.22	3.86
+ —	2.47	2.46	2.85	2.41	2.45	2.45	2.41	2.45	2.45	2.41
									**	

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF MESOSTIGMATA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	9.03	11.90	7.25	6.60	11.35	12.86	11.32	8.74	13.46	5.06
+ -	2.84	3.35	3.40	2.87	2.87	2.99	2.87	2.87	2.87	2.93

NO-TILL CONTROL

Mean	4.66	6.14	4.95	7.13	8.30	12.50	8.51	7.23	6.80	8.13
+ -	2.98	2.93	3.40	2.88	2.88	2.93	2.88	2.88	2.88	2.88
	**	**					*		**	

NO-TILL ATRAZINE

Mean	6.84	6.28	6.60	9.93	8.00	8.36	9.50	7.55	7.04	5.32
+ -	2.96	2.93	3.40	2.87	2.93	2.93	2.88	2.93	2.93	2.87
		**			**	**			**	

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF RHODACARIDAE PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	3.62	2.51	.98	1.59	1.66	4.17	1.05	1.84	3.66	1.23
+ —	1.08	1.27	1.29	1.09	1.09	1.13	1.09	1.09	1.09	1.11

NO-TILL CONTROL

Mean	1.92	2.03	1.51	1.74	2.81	4.97	2.33	2.20	2.71	1.67
+ —	1.13	1.11	1.29	1.09	1.09	1.11	1.09	1.09	1.09	1.09

NO-TILL ATRAZINE

Mean	2.64	2.41	2.48	3.30	3.54	2.89	4.44	2.77	3.47	2.41
+ —	1.12	1.11	1.29	1.09	1.11	1.11	1.09	1.11	1.11	1.09

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF ASTIGMATA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	1.09	.98	1.22	1.70	1.63	2.00	1.23	1.59	1.63	.77
+ —	.77	.91	.93	.78	.78	.81	.78	.78	.78	.80

NO-TILL CONTROL

Mean	.78	1.12	.74	1.98	3.09	3.11	1.38	2.26	1.69	1.16
+ —	.81	.80	.93	.78	.78 **	.80 **	.78	.78	.78	.78

NO-TILL ATRAZINE

Mean	.94	.83	.74	1.19	.54	1.76	1.01	2.50	1.56	.58
+ —	.80	.80	.92	.78	.80	.80	.78	.80 *	.80	.78

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

APPENDIX D (continued)

MEAN NUMBER OF JUVENILE BRACHYSTOMELLA PARVULA PER SAMPLE AND 95% CONFIDENCE INTERVAL

SAMPLING DATES	May 15	May 31	June 14	July 8	July 25	Aug 16	Sept 8	Sept 28	Oct 18	Nov 8
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GRASS CONTROL

Mean	.17	.49	.26	0.00	6.25	1.01	.11	.64	0.00	0.00
+ —	.65	.77	.78	0.00	.66	.69	.66	.66	.67	.66

NO-TILL CONTROL

Mean	.46	.52	.99	.61	1.79	.64	.57	.54	.54	.54
+ —	.69	.68	.78	.66	.66 **	.68 **	.66	.66	.66	.66

NO-TILL ATRAZINE

Mean	.25	.28	1.05	.15	.72	.38	.35	.35	.35	.35
+ —	.68	.68	.78	.66	.68 **	.67	.66	.68	.68	.66

The asterisks denote statistically significant differences from the Grass Control at the 0.10 (*) and 0.05 (**) probability levels.

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