A CASE STUDY OF SOME BIOLOGICAL INTERACTIONS IN NO-TILL CORN

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ABSTRACT

A CASE STUDY

OF SOME BIOLOGICAL INTERACTIONS

IN NO-TILL CORN

By

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Corn (*Zea mays* L. 'Pioneer 3780') was grown in a very old fescue-bluegrass sod on Spinks loamy sand soil with No-Till, chisel plow, and moldboard plow treatments. The irrigated corn yields averaged 13,100, 14,186, and 14,148 kg/ha for the No-Till, chisel plow and moldboard plow treatments, respectively. Corn on No-Till plots was severely damaged by wireworms and had to be replanted, a fact which undoubtedly contributed to lower yields.

Tillage systems influenced corn root weights which were higher in the plowed soil than in the No-Till soil at both the 0-15 and the 30-40 cm depths.

Moldboard plowed or chiseled soils, initially loose and open at the surface, became more compact with time. By late summer, bulk densities of the surface soil had increased until they were greater than in the No-Till soil.

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The surface soil (0-5 cm) of the No-Till plots was slightly more acidic than the soil of other treatments. The organic C and total N levels at this depth were significantly higher in the No-Till plots.

Soil samples were collected in the fall of 1975 and the spring of 1976 for evaluations of arthropod populations. The numbers of soil Collembola and Acarina under a No-Till system were substantially higher at both the 0-5 and 0-15 cm depths than with plowed treatments. These investigations were exploratory and should stimulate interest in No-Till corn production and in the recycling of soil organic matter as related to tillage treatments.

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Mohamed Nazeem Shams

A THESIS

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To my Father

This thesis is dedicated to him.

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INTRODUCTION

No-Till crop production is a recent innovation made possible by easily available specific herbicides and the development of special planters. This minimum tillage method involves making a narrow slot in untilled soil so that seed can be planted where soil moisture levels are adequate for rapid germination. The most common device for doing this today is the fluted coulter, although equipment of other design exists.

Many believe that No-Till should be used by more farmers because many hectares of arable land in Michigan and elsewhere are well suited to this practice. Despite this, adoption by farmers has been slow, probably because variable degrees of success and failure have been obtained with No-Till methods.

The experience of farmers and researchers show that No-Till was most successful on medium and coarse-textured soil where herbicides were effective, where insect and disease problems did not develop and where soil had desirable physical properties.

Many of the engineering, agronomic, and economic aspects of No-Till crop production have been investigated but there is relatively little information available on the biological processes. The purpose of this project was to inventory soil organic matter levels, species diversity and populations of soil fauna. This study should serve as a basis for future investigations.

REVIEW OF LITERATURE

No-Till Corn Yields

Perhaps Sprague (1952) was the first to publish on No-Till methods when he reported on "Substitution of Chemicals for Tillage in Pasture Renovation." The first work on corn was by Barrons and Fitzgerald (1952) of the Dow Chemical Company. Later Davidson and Barrons (1954) reported on the use of 2,2 -dichloroporpionic acid (dalapon) and (2,4-dichlorophenoxy) acetic acid (2,4-D) in both corn and soybean production. Yields on conventionally plowed and chemically treated plots were similar. This report stimulated interest by both farmers and researchers alike in the concept that eventually was labeled "No-Till."

The book "No Tillage Farming" by Phillips and Young (1973) has been the basic reference for farmers. The optimistic evaluations of opportunities with No-Till have led many to experiment with this crop production method. The authors state that this method should increase yields.

The Soil Conservation Service of the United States Department of Agriculture (1975) promotes the No-Till concept on the basis of comparable yields while stressing 13 advantages including lower production costs and better erosion control.

Agronomists at Michigan State University feel that the No-Till concept is well adapted to many sites and should be used more extensively. They, however, are less enthusiastic than others on the use of the concept on naturally, poorly drained soil that is relatively high in organic matter and on fine-textured soil. Research in several states has been summarized in a practical way by the Cooperative Extension Service at Michigan State University. Four bulletins have been published under the series title, "No-Till Corn."

1. Guidelines (Nelson et al.)
2. Fertilizer and Liming Practices (Vitosh and Warncke, 1976)
3. Soils (Robertson et al., 1976)
4. Weed Control (Chase and Meggitt, 1976)

These bulletins suggest that great care must be exercised if success is to be obtained. They interpret the statement by Lowell Burchett (1975) of Kansas State University, as reported in the Soil Conservation Service bulletin, that "to switch to No-Till, two things have to change. . . your mind and your planter." The bulletins also reflect the thinking and research of Cook et al. (1949, 1950, 1951, 1958, 1964) pioneers in tillage investigations.

Research reporting practical problems associated with No-Till is scant. Apparently researchers recognize some of the problems, but side step others by reporting primarily on projects where adequate crop stands were obtained, herbicides were effective, and where pests presented no special problems. Numerous observations suggest that these are practical problems that must be recognized before comparable or improved yields can be obtained.

Agreeing with the writings of Phillips and Young (1973), Doster (1972) reported higher yields from No-Till methods in a four-year continuous corn experiment. Shear and Moschler (1969) made similar observations. Triplett *et al*. (1968), while investigating effects of crop residues, found that yields were improved by soil-water relationships associated with increasing return of crop residues.

Publications, such as those cited above, stimulated interest in the No-Till concept. As a result there have been many workshops and conferences organized on a state, regional or national basis. Jacobson (1967), Griffith (1972), and Linford (1973) organized and edited papers presented at such meetings. These compilations illustrate the numerous publications now available on this topic.

Soil Conditions in No-Till Corn

In the first publication on No-Till corn, Davidson and Barrons (1954) reported that the percent water stable aggregates in soil of uncultivated (No-Till) plots was significantly higher than in the cultivated plots, and that soil moisture levels were significantly higher. These conditions caused superior growth rates early in the season. Similar observations have been reported many times since then, although specific data to support the observations are somewhat limited.

By far the most common physical condition evaluated in studies on No-Till corn is that of bulk density. Thomas et al. (1975) did not measure any significant differences caused by tillage while others interpreted differences in terms of relative compaction. Chancellor (1971), for example, interpreted bulk density as one parameter which can be used to measure a state of compaction. Gill and Trouse (1972) related compaction to vehicular traffic. Therefore, No-Till soil normally is expected to be less compact than soil subjected to traffic with conventional equipment.

The lower bulk density values associated with No-Till methods are related to several factors including the presence of surface mulches as well as reduced traffic. Woodruff (1972) related wind erosion potentials to amounts of surface residues. The greater the residues the smaller the soil losses. Harrold (1972) reported similar observations in regard to water erosion. Edwards (1972) reported that surface residues reduce movement of hazardous chemicals.

Several, including Lal (1974), observed the formation of strong crusts on conventionally tilled soil while, on No-

Till, crusts usually failed to develop due to surface mulches. If crusts were formed, they were of a different nature, being more thin and fragile.

While the chemistry in No-Till soil has received considerable attention, the specifics seem to be related to time of application as well as placement of fertilizer, lime, and manure. Singh et al. (1966) showed that corn grown on untilled soil utilized superphosphate as well or better than corn grown on plowed soil.

Ester (1972) observed higher K levels in the leaves of corn grown on untilled soil, He also reported that soil pH levels decreased in the 0-7.5 cm level as a result of surface applied N. Shear and Moschler (1969) and Thomas et al. (1975) made similar observations.

It seems that, with one possible exception, No-Till methods present no special problems in using fertilizer. The exception is related to the practical use of banded planting time fertilizer. Vitosh and Warncke (1976) observed that placing fertilizer in a band 5 cm to the side and 5 cm below the seed was difficult to achieve with standard No-Till planters. They reported that some farmers solved the problem by widening the tillage strip through the use of two fluted coulters.

Corn root penetration into the soil is considered to be an indication of soil conditions. Mannering et al. (1971) showed a close correlation between corn root distribution and tillage systems, especially at the 8 to 30 cm depth. In contrast, Lal (1974) reported that different tillage treatments had no effect.

In conclusion, it appears that whether or not No-Till methods greatly improve soil conditions as related to corn growth is dependent upon the nature of the soil.

Biological Interactions in No-Till Soil

Very few references are available on biological interactions in No-Till soil. Agronomists apparently have ignored this area. Entomologists and zoologists have been active in areas other than those involving tillage. At the moment it is necessary to extrapolate from population studies under forest or prairies conditions to those of intensive field crop production. There are few guidelines for doing this.

Where corn is planted in grain stubble or in sod fields, Nelson *et al*. (1976) report that rodents may cause problems where runways are obvious. In the present discussion, the role of macrofauna, especially mammals, is ignored because in soil used for field crop production, populations are usually low.

Soil faunal activity may influence productivity by altering the physical and chemical composition of organic matter. The overall physical condition of the soil may be altered by increasing the size or number of pores, channels and burrows in the soil (Sommers and Biederbeck, 1972).

Earthworms are important macrofauna, especially in undisturbed pasture or forest soils. Earthworms decompose organic litter located on the surface of soil as well as materials below the surface, in addition to stimulating the activity of other decomposing organisms (Burges, 1967). A comprehensive study of earthworms was made by Edwards and Heath (1963). They noted that large litter fragments were removed three times faster from bags to which earthworms had access than from others from which they were omitted.

Darwin (1881) estimated the annual worm-cast production on four different soils. He stated that earthworms were able to produce an annual worm-cast of between 18,532 and 44,774 kg/ha. He also estimated that earthworm activity could bring about 0.5 cm annually to the soil surface. Graff (1969) observed a 20 to 25-fold increase in casting on No-Till plots over plowed barley stubble. Lal (1974) found that tillage resulted in a great decrease in numbers of earthworm casts. Water infiltration rates were significantly lower in the plowed areas. Ehlers (1975) estimated the number of earthworm channels in tilled and untilled soil at 4 depths. He found 333, 78, 63 and 4 percent more channels in the untilled areas at depths of 2, 20, 30, and 60 cm, respectively. These data partially explain the observations of

Lal (1974).

Insect problems with No-Till are minor, at least in the thinking of many. Regardless of this, Lucas *et al*. (1976) reported that replanting in an old grass sod was necessary because of wireworm problems. Nelson *et al*. (1976) recommend planter seed box treatment for such pests as wire-worms, grubs, slugs, and cutworms. Ruppel (1975) reports that cornroot worms are likely to be problems "where corn follows corn without rotation." He recommends the use of insecticides where appropriate.

Other fauna apparently derive their energy from feeding more on dead organic matter. Populations and activities as related to No-Till methods of crop production have not been well investigated. Collembola are among the most numerous of all soil fauna, (Snider, 1967).

Hale (1963), Dunger (1956, 1958) and Schuster (1956) demonstrated that Collembola populations increased rapidly when ample energy was present. As many as 100,000 Collembola per m^2 produce an average of 183 cc of feces annually. Schaller (1950) showed that 0.2 cm of soil was brought to the surface annually by Collembola. Poole (1959) suggested that Collembola are active in the dissemination of fungi and in breakdown of excrement from large arthropods. He also found that soil fungi are readily decomposed by species of large Collembola, allowing the smaller species to feed in a direct manner on the humus.

Burges (1967) found that Collembola may be involved in making chitinous material accessible for use again by other soil organisms. A good correlation between humus production and soil organism activity was observed by Wallwork (1970). MacFadyen (1963) showed that, while the small-sized decomposers such as Collembola have a good decomposition capability, the cryptostigmatid Acarina have a low metabolic rate. Ambrozad and Nosek (1967) showed that Collembola are involved in maintaining a favorable balance between bacteria and fungi.

Most Cryptostigmata appear to be more active in the later stages of decomposition than in earlier stages (Edwards and Heath, 1963; Drift, 1963). Also they concluded that Cryptostigmata were not active in primary decomposition; however, most of them correlate well in numbers with the later stages of decomposition.

Mite activity is important in the dissemination of fungal spores, which may stick fast to the surface of the body or may be conveyed in the mite gut (Wallwork, 1967). Crossley and Witkamp (1964) suggested that mites create important conditions for the physical breakdown of litter with the transmission of organic material in their mouthparts. Thus, soil fauna play an important role in the decomposition of organic matter as well as in altering the physical condition of soil.

MATERIALS AND METHODS

Field Experimental Plots

Field experimental plots were established on the University farm in 1975 by Dr. R. E. Lucas, Department of Crop and Soil Sciences, Michigan State University. The area represented an old sod. While records are not available, the grass is believed to be a minimum of 15 years old. It was primarily fescue and bluegrass.

The soil is a Spinks loamy sand (soil management group 4a) which is naturally well drained and droughty. The plots were irrigated in July and August with 7 cm of water each month.

Tillage treatments, randomized and replicated 4 times, were made in the spring of 1975 and included a moldboard plow, chisel plow and a No-Till treatment which involved killing the grass with herbicides and then planting with an Allis Chalmers No-Till planter. Plots were 6 x 12 m in size.

The No-Till and chisel plow plots were sprayed with paraquat at the rate of one pint per acre, plus two pounds of atrazine. The plowed plots received only atrazine.

Paraquat was applied before any tillage treatments were made but the atrazine was applied immediately after planting.

Pioneer 3780 hybrid was planted on all plots on April 30. The No-Till plots had to be replanted on May 20 because of excessive wireworm damage.

Fertilizer was applied as a basal treatment across all plots. One hundred sixty pounds of 5-20-20 was used at planting time. Urea was sidedressed on May 30 and 31 at the rate of 130 pounds of nitrogen per acre.

Average populations of corn plants were determined by counting the number of plants in 5 rows of each plot and are reported as plants per hectare.

Corn grain yields were determined with hand harvest methods involving the weight of husked ear corn. A constant shelling percentage was assumed. Yields are for 15.5 percent moisture grain.

Root samples were taken from only the moldboard plowed and the No-Till plots. In July, samples were collected at a distance of 7.5 cm to the side of a plant near the end of a plot. An iron frame measuring 10 x 10 x 15 cm was used to collect both soil and roots. Roots were separated by washing through a 40 mesh sieve. They were then dried at 72^{o} C and weighed in agreement with standards outlined by Mengel and Baker (1974).

In August a different method was used on the same plots. A 60 cm circle around a single plant to a depth of one meter was excavated. Roots were separated from soil as previously described.

Soil temperature evaluations were made by inserting a standard soil thermometer unto the soil to a depth of 5 cm at 5 locations per plot at each sampling time (Nov. 3, Nov. 11, 1975, and March 24, April 23, 1976).

Bulk density evaluations were made by the Blake method (1965). A total of 20 cores were taken from each treatment (5 per plot) to a depth of 7.6 cm in Summer 1975. Samples were dried at 105^{o} C for 48 hours.

Soil samples for carbon, nitrogen, and pH evaluations were collected soon after the soil thawed in the early spring of 1976. Nine subsamples were taken with a standard 2.5 cm probe at three increments of depth to 15 cm.

Laboratory Analyses

Organic carbon evaluations were made with the wet digestion method of Walkley (1947).

Soil organic matter estimates were made by multiplying the organic carbon valve by 1.72.

Total nitrogen was determined by the semi-micro Kjeldahl method outlined by Bremner (1965).

Soil reaction levels were evaluated with a Sargent (PBL model) potentiometer in a 1:1 soil to distilled water suspension.

Samples for evaluation of arthropod numbers were collected in November 1975 and in March and April of 1976. Red flags were placed in the center of each plot as reference points for the samples. Samples were collected in the corn row using a standard, hand-driven sampler (6.25 cm in diameter and 15 cm deep). Three samples per plot were collected and placed in plastic bags which were taken to the laboratory for extraction. The values reported are average numbers per sample per plot.

The entire sample was used in the November sampling. However, in the spring the samples were subdivided to represent 0-5, 5-10 and 10-15 cm depths.

Fauna extraction was achieved with a Tullgren funnel, as described by Kevan (1962). Heat from 25 watt light bulbs dried the soil, and the fauna moved downward and finally out of the soil falling into ethyl alcohol. After three days the wattage was increased to 30 for another 3-day period.

Under the direction of Dr. R. J. Snider, soil fauna were identified and divided into several groups. With the aid of a microscope, the number in each group was determined.

RESULTS AND DISCUSSION

The first step in obtaining high yields with No-Till corn is to produce an adequate stand. Because wireworm damage greatly reduced populations on the No-Till plots--much more than on other plots--the No-Till plots had to be replanted. Even after replanting, there were gaps down the row. Immediately after emergence, plants from border rows were transplanted into the gaps, thus making the populations on all treatments comparable. Populations averaged 50,100 plants per hectare.

Corn grain yields were high due primarily to the use of irrigation water on soil that because of its sandy nature is droughty and does not usually have soil structure problems. There was no difference in yields on the plowed plots (Table 1). Yields on the No-Till plots were lower, averaging 13,100 kg/ha. The slightly decreased yield was associated with the necessity to replant.

When root samples were collected in July with the 10 x 10 x 15 cm sampler, the moldboard plowed plots contained significantly more roots (2.30 gm) than the No-Till plots (1.68 gm). Whether this reflects tillage method or the necessity to replant is not known. Regardless, the average yields produced were directly related to corn root weights in July.

The circular sampling procedure was used in August

Table 1. Corn grain yields under three tillage systems.

Tillage Treatment	Yield
	kg/ha
Moldboard plow	14,186
Chisel plow	14,148
No-Till	13,100
LSD (0.01)	692

in an attempt to more realistically sample root growth. Average root weights in the surface soil of both treatments were remarkably similar (Table 2). This possibly reflected a similar stage of development in all plots that may have been attained by this time but not when samples were collected a month earlier. The difference in root weight at the 30-40 cm depth was statistically significant and possibly reflects the longer growth period of corn on the moldboard plowed plots.

Soil temperatures regulate many biological as well as chemical reactions. Temperature evaluations were made when the soil was sampled for soil fauna. Average temperatures in the No-Till plots were significantly lower than in the chisel or the moldboard plowed plots at each time of measurement (Table 3). This was possibly due to the differences in organic matter in and on the surface of the soil.

Whether a difference of approximately 2 degrees significantly affects biological activity is not well known. Considering the time span, theoretically, the total effect on biological activity could be great. The direct relationship between temperature of surface soil and both yields and root weights probably should be somewhat discounted because of developmental differences resulting from the necessity to replant the No-Till plots.

Average bulk density values are reported in Table 4. As an after thought samples were also taken 10 to 20 meters out of but adjacent to the plot area. The "grass" treatment in this table reflects the original condition of the soil before herbicide use.

Table 2. Corn root distribution as affected by two tillage systems

Sample Depth	Tillage Treatment		LSD
	No-Till	Moldboard plow	(0.05)
cm	---------------- gm	-------------------	
0-10	17.14	17.65	NS
10-20	5.28	5.44	NS
20-30	1.10	1.49	NS
30-40	0.12	0.39	0.14

Table 3. Soil temperatures at soil fauna sampling time as related to three tillage systems.

Date of Measurement	Tillage Treatment			LSD (0.01)
	Moldboard plow	Chisel plow	No-Till	
	------------ Degrees C		---------------------	
November 3	14.1	13.7	13.2	0.38
November 11	13.3	12.9	12.3	0.43
March 24	11.4	10.7	9.4	0.47
April 24	16.8	15.6	14.7	0.43

Bulk density values tended to be directly related to soil temperature, root weights and yield although for reasons previously mentioned, some caution is urged in relating bulk density to root weights and yields.

Total N and C analyses are reported in Table 5. Since moldboard plowing represents more of a mixing action than other treatments, the lower values for both N and C in the 0-5 cm sample were anticipated, although both elements were higher than expected in this Spinks soil. It was assumed that N and C had built up to these levels over a period of many years during which the plot area had been under continuous grass cover. This concept appears valid when it is realized that the average C level for similar soil used for corn production in Michigan is only 0.75 percent (Mokma *et al.*, 1976). The higher N and C values in the surface samples of the No-Till and chisel plowed plots represent a more concentrated source of food and energy for many kinds of soil organisms.

In the moldboard plowed soils, total N did not change with depth. In the soil of the chiseled plots total N levels were highest in the 0-5 cm level. This was also the case with the soil in the No-Till plots.

In regard to C, levels increased with depth in the moldboard plowed plots. In the No-Till plots C levels decreased with depth. Since chisel plowing represents a more drastic tillage treatment than No-Till and a less intensive treatment than moldboard plowing, the intermediate values were expected.

Table 4. Bulk density of surface soil as related to three tillage systems and grass cover.

Tillage Treatment	Bulk Density
Moldboard plow	1.54
Chisel plow	1.49
No-Till	1.42
Grass (control)	1.35
LSD (0.05)	0.085

Table 5. Distribution of total N, organic C and organic matter in soil under three tillage systems.

Tillage Treatment	%C			%N			%O.M.		
	Depth (cm)			Depth (cm)			Depth (cm)		
	0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15
Moldboard plow	1.11	1.18	1.24	0.11	0.10	0.11	1.91	2.03	2.14
Chisel plow	1.63	1.17	0.91	0.13	0.10	0.11	2.81	2.02	1.57
No-Till	1.93	1.15	0.90	0.15	0.10	0.12	3.33	1.98	1.55
LSD (0.05)	0.31	NS	0.21	0.02	NS	NS	0.51	NS	0.31

Soil organic matter levels are reported primarily for interest and to suggest the location and quantity of food available to soil organisms. The values were obtained by multiplying total C by 1.72.

Carbon and N levels in the 0-5 cm depth were inversely related to bulk density, temperature, root weights, and grain yield. The significance of this is not clear except as related to characterizing the environment for soil organisms. With organic matter levels higher on the No-Till plots, more food and energy is available for soil organisms. Soil organisms, in turn, do influence soil physical properties. For example, animal traffic can serve to maintain pore systems in undisturbed soil, thereby contributing to lower bulk densities than in soil disturbed by tillage.

Moldboard plowing had two effects upon the surface soil. First, the organic matter near the surface was diluted by mixing with lower mineral soil layers. Secondly, the surface soil was exposed more directly to both wind and sun which increased drying rates after a rain. This would have influenced soil organism populations and activities. Drier soil conditions may explain, at least partially, why damage from wireworms was less evident on the moldboard plowed plots.

The data in Table 6 illustrates the variation in soil pH associated with tillage treatments and depth. The soil in the moldboard plowed plots had the highest and most uniform

Table 6. Soil pH levels under three tillage systems.

Treatment	Depth (cm)		
	0-5	5-10	10-15
Moldboard plow	7.26	7.10	7.11
Chisel plow	6.79	6.56	7.05
No-Till	6.43	6.86	7.10
LSD (0.05)	0.06	0.49	NS

pH. Levels in the soil of the No-Till plots probably reflect the leaching of basic cations from the 0-5 and 5-10 cm depths. All pH levels, regardless of treatment, were considered to represent a good root environment for corn.

The larger faunal forms such as earthworms were not well represented with the sampling technique used. Only a limited number of fauna related to suspected economic losses such as wireworms were found. With the sampling methods used it appeared that populations of those fauna were not related to tillage treatments.

Various species of Collembola (springtails), including _Isotoma_ (_Desoria_) _sp_. "_S_" and _virdis_, _Isotomurus_ _palustris_, _Sminthurinus_ _elegans_ and _henshawi_, _Entomobrya_ _multifasciata_ and _unostrigata_, _Lepidocyrtus_ _paradoxus_ and _violaceous_, and _Tullbergia_ _granulata_, were identified under the supervision of Dr. R. J. Snider. The dominant species in the November 1975 samples were _Isotoma_ (_Desoria_) _sp_. "_S_" and _Tullbergia_ _granulata_.

In Tables 7 and 8, _Isotoma_ (_Desoria_) _sp_. "_S_" represents a species, that to date, has not been described. The _Isotoma_ species and _Tullbergia_ _granulata_ were present in larger numbers than any other species. From these data, it is obvious that plowing, whether it be with a moldboard or a chisel plow, greatly reduces collembolan populations (at least temporarily).

In the spring of 1976, the same two species were again

Table 7. Average populations (0 to 15 cm) of dominant Collembola species as related to three tillage systems (Fall 1975).

Tillage Treatment	*Isotoma* (*Desoria*) *sp.* "*S*"	*Tullbergia granulata*
	Numbers/30.7 cm^2	
Moldboard plow	1	3
Chisel plow	16	13
No-Till	77	8
LSD (0.05)	59	NS

Table 8. Average populations of dominant Collembola species as related to three tillage systems (Spring 1976).

Tillage Treatment	*Isotoma* (*Desoria*) *sp.* "*S*" Depth (cm)			*Tullbergia granulata* Depth (cm)		
	0-5	5-10	10-15	0-5	5-10	10-15
	Numbers/30.7 cm^2					
Moldboard plow	6	3	4	14	13	15
Chisel plow	16	10	7	36	21	7
No-Till	104	18	3	17	18	5
LSD (0.05)	88	NS	NS	NS	NS	NS

dominant (Table 8). In this sampling, the cores were divided into three parts representing 0-5, 5-10 and 10-15 cm depths. In all cases, the sum for the three depths in Table 8 is substantially greater than the numbers found to 15 cm the previous fall (Table 7).

The largest relative increase for both species occurred in the moldboard plowed plots where total numbers were 13 to 14-fold greater in the spring than in the fall. With the other two treatments, the increase was about 2-fold for the *Isotoma* species and 5-fold for *T. granulata*. As in the fall, the No-Till surface soil (0-5 cm) appeared to be a particularly favorable environment for the *Isotoma* species. In the case of *T. granulata*, differences for treatment were not significant, although the data suggest that this species had increased in numbers to greater depth in soil tilled with the moldboard plow. On the other hand, chisel plowing may have been the most favorable treatment for *T. granulata* in shallow surface layers (0-5 cm).

Numbers of Collembola, in general, were directly related to C and N levels and inversely related to bulk density and temperature. The implications of such observations as related to soil management and crop yields is not well known.

The only other group of soil fauna found in large numbers were the Acarina (mites). Mite populations as related to tillage treatments were similar to the Collembola in that plowing greatly and significantly reduced numbers

(Table 9). This was the situation in both the fall and spring samplings. Average Acarina populations in the spring of 1976 were two to three-fold greater than in the fall of 1975. As in the case of the collembolan *Isotoma* species, untilled surface soil was particularly favorable for their development (Table 10).

A poor representation of nematode populations was expected with the extraction methods used. However, a number were casually observed in some of the samples. A summary of the observations presented in Tables 11 and 12 is reported here, because some species of nematodes are known to cause production problems.

Using standard statistical evaluation methods, it appeared that tillage treatments did not affect nematode populations. Nevertheless, by selecting the 10 percent level of confidence in place of the standard 5 percent level, nematodes were recovered in larger numbers from the surface soil (0-5 cm) of the No-Till plots. It is realized that this observation should be checked with acceptable standard methods for collecting nematodes.

Table 9. Average populations of Acarina as related to three tillage systems and sampling time.

Tillage Treatment	Sampling Time	
	Fall 1975	Spring 1976
	Numbers/30.7 cm^2	
Moldboard plow	17	34
Chisel plow	21	62
No-Till	91	194
LSD (0.05)	8	93

Table 10. Average populations of Acarina as related to three tillage systems and sample depth (Spring 1976).

Tillage Treatment	Depth(cm)		
	0-5	5-10	10-15
	Numbers/30.7 cm^2		
Moldboard plow	19	9	7
Chisel plow	37	18	8
No-Till	160	18	14
LSD (0.05)	98	NS	NS

Table 11. Nematode populations as related to three tillage systems and sampling time.

Tillage Treatment	Sample Time	
	Fall 1975	Spring 1976
	Numbers/30.7 cm^2	
Moldboard plow	2	22
Chisel plow	4	18
No-Till	4	40
LSD (0.05)	NS	NS

Table 12. Nematode populations as related to three tillage systems and sampling depth (Spring 1976).

Tillage Treatment	Depth (cm)		
	0-5	5-10	10-15
	Numbers/30.7 cm^2		
Moldboard plow	12	3	7
Chisel plow	10	5	3
No-Till	28	7	5
LSD (0.05)	NS	NS	NS

SUMMARY AND CONCLUSIONS

The purpose of this project was to inventory some soil conditions as affected by moldboard plowing, chisel plowing and No-Till, and to relate those conditions to specific biological activities in the soil.

Field experimental plots were established on a Spinks loamy sand soil. Corn was grown under irrigation. Treatments were replicated four times.

By replanting the No-Till plots after wireworms affected stands, populations were similar averaging 50,100 plants per hectare for all three treatments.

Corn grain yields were high due to irrigation and averaged 14,186, 14,148, 13,100 kg/ha, respectively for the moldboard plow, chisel plow and No-Till treatments. The lower yield of the No-Till treatments was attributed to the necessity to replant.

Root weights were higher on the plowed plots in July but were similar in August except at the 30-40 cm depth, when again they were higher in the plowed plots.

Bulk density values increased with intensity of tillage. The No-Till plots averaged 1.42 the chisel plowed plots 1.49

and the moldboard plowed plots 1.54.

Tillage methods affected the distribution of both N and C. Carbon levels were highest in the 0-5 cm depth of the No-Till soil and lowest in the moldboard plowed soil. Except for the plowed soil, levels decreased with depth. Nitrogen levels were also highest in the 0-5 cm depth on the No-Till plots and lowest on the moldboard plowed plots.

Average pH levels were lowest in the No-Till plots and increased with depth. The highest levels were in the moldboard plowed plots which had similar levels down to 15 cm.

Soil fauna populations showed a close relationship to position and source of food in that the highest populations were found in the soil of the No-Till plots at a depth of 0-5 cm. Also in these plots the soil was more porous than on any others because the bulk density values were the lowest.

In the fall samples, the Collembola *Isotoma* (*Desoria*) *sp*. "*S*" were present in largest numbers followed by *Tullbergia granulata*. Populations of both increased by the time samples were collected in the spring. The populations of Acarina were similar to the Collembola and also increased greatly in the spring sampling. This increase may be explained by the undisturbed condition of the soil since the previous spring coupled with available organic matter for food and an increase in fecundity.

Nematode populations represented relatively small numbers. Differences associated with tillage treatments were not statistically significant at the 5% level of confidence but were at the 10% level. The observed greater numbers in shallow surface soil under No-Till should be investigated further.

These investigations were important because they illustrate that tillage methods greatly affect biological activity in the soil. They suggest the need to investigate in more detail the nature and extent of such reactions especially in those soils used for intensive crop production.

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