MASTER

Comparison of Mineral Element Cycling Under Till and No-Till
Practices: An Experimental Approach to Agroecosystems Analysis

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Comparison of Mineral Element Cycling Under Till and No-Till

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The soil fauna of cultivated agronomic systems is notoriously impoverished, supporting low populations of soil arthropods in comparison with uncultivated, natural forest or grassland ecosystems (Edwards and Lofty, 1969; 1973). Tillage practices can cause appreciable disruption of soil structure and biological communities (Allison, 1973). Cultivated soils also show large decreases in organic matter compared to untilled soils (Brady, 1974). Typical modern agricultural techniques replace naturally occurring soil structure and function with a virtually sterile medium for culture of a single crop species at high density. It is ironic that much of our knowledge of physical and chemical properties of soils, and even microbial properties, is derived from studies of such highly modified systems. Knowledge of soil zoology is more nearly based upon studies of undisturbed systems.

In the past decade several developments have converged to promote an increased interest in soil zoology of agronomic systems. One development is the utilization of an ecosystem viewpoint, emphasizing holistic approaches (Harper, 1974). A major catalyst has been the use of nutrient cycling as an integrating paradigm for evaluating whole ecosystems performance and response to disturbance (Bormann and Likens, 1967). The interactions of major ecosystem processes (primary production, consumption, decomposition and abiotic processes) have been evaluated using nutrient flows, in a variety of natural or managed ecosystems, as evident by several papers at this symposium. Another development has been the increasing adaption of minimum tillage or no-tillage agronomic practices (Pereira, 1975). Whatever their other benefits, reduced tillage practices result in richer soil biota, including invertebrates (Edwards and Lofty, 1973; House, 1979). Increased awareness of the importance of mycorrhizal associations for some crop systems has suggested that tillage practices might be modified. Increasing costs of energy for cultivation and chemical amendment, and awareness of the need to reduce sediment and chemical pollution of waterways, are additional considerations leading to reduced cultivation practices. In any event, reducing tillage allows soil biological components and processes to operate in a manner similarly to those in undisturbed ecosystems.

In this paper we give an overview of a research project which is attempting to integrate the approaches of agronomy and ecosystem ecology. We are attempting to apply methodologies and approaches of ecosystem study, in particular nutrient cycling, as a means of evaluating performance of agronomic systems. Specifically, we are comparing structure, function and nutrient dynamics in a set of no-tillage and conventional plots.

No-tillage or minimum tillage farming excludes or reduces plowing and smoothing the soil prior to planting (Phillips and Young, 1973). Seeds are planted in the residue from the previous crop. The only disturbance to the soil is the narrow cut for the seed furrow. Special planting equipment is used for this operation. Conventional tillage usually entails six or more trips across the field (plowing, disking, planting, cultivating at least once, herbiciding and harvesting). No-tillage requires only one trip each for planting, herbiciding and harvesting, and thus is energetically more efficient than conventional tillage. Important benefits from no-tillage practices are conservation of soil and water resources. Also, as described above, perturbation of soil structure is substantially decreased. However, there are some disadvantages to no-tillage: Weed problems can be severe, although companion planting can reduce weed growth (Phillips and Young, 1973). Some studies (Musick and Petty, 1974) have shown increased insect problems in no-tillage. Still, no-tillage farming is increasingly popular.

The research project described here is currently in its second year of development, and is the joint effort of several ecologists at the University of Georgia. Results given here are fragmentary and preliminary, but representative. Data are presented on plant growth, decomposition, soil microarthropods and nutrient leaching. Other information on canopy consumers, soil, fertility, microbial processes, soil microarthropods and chemical transformations is not yet ready for reporting.

The foundation for our experimental approach is the general hypothesis that no-tillage practice leads to nutrient and energy conservation. Biotic and abiotic components of soil, left undisturbed, are organized into a well-defined structure, with the result that nutrient cycling reduces loss of nutrients from the system. This paradigm is supported by watershed studies (Bormann et al. 1974; Waide and Swank, 1976) showing that in forested areas (highly structured systems) internal cycling greatly exceeds throughput. Plowing once or twice yearly is a major perturbation which destroys the soil system's structure and function, and recycling of nutrients becomes minimal. Conventionally tilled farm land is in essence kept in a very early successional or immature state by man-induced subsidies. No-tillage farming allows soil structure to develop. Biotic components remain relatively undisturbed and therefore the no-tillage system should have more of its recycling processes intact.

EXPERIMENTAL DESIGN AND METHODS

Horseshoe Bend is a 40-acre tract of land located in Clarke County, Georgia. The area is an alluvial flood plain adjacent to the Oconee River (Barrett, 1968). The crop system we are using consists of eight $\frac{1}{4}$ acre plots, bordered on two sides by an old-field. As of May, 1978, the area which is now the crop system was in old-field vegetation, not having been cultivated for 12 years. In May, the area was cleared of vegetation to ground level. Eight experimental plots, randomly

selected, received either conventional plowing or no-tillage treatment. Following standard fertilizer applications, atrazine was used as a pre-emergence herbicide. Grain sorghum was planted using a no-till planter. In the fall of 1978, both till and no-till plots were planted in winter rye which was consequently mowed and chopped in the spring of 1979. Sorghum was again planted. Through-out, we have used standard cultural recommendations for sorghum in the Georgia piedmont.

Both above and below ground sorghum biomass was sampled at two week intervals using three 1-m² quadrats randomly located in each of the eight plots. Plant material was oven-dried to constant weight for biomass determination, ground, and subsampled for nutrient measurements utilizing a plasma emission spectrograph. Grain production was evaluated from similar 1-m² collections made at the time of harvest.

Litterbag techniques were used to measure rates of decomposition (Crossley and Hoglund, 1972; Edwards and Heath, 1963). Litterbags containing weighed crop residue were randomly distributed over the soil surface of each treatment soon after planting. Five bags per plot were randomly collected at approximately two week intervals. The residue was oven-dried to constant weight in order to calculate loss of material, ground and retained for nutrient analysis.

Soil microarthropods were sampled by extracting them from soil cores (5 cm dia. by 5 cm deep) on a modified Tullgren apparatus (Merchant and Crossley, 1970). Ten random cores were taken from each plot at two week intervals. The soil microarthropods were also sampled prior to plowing and planting. Gross counts by major taxonomic groups made on these samples are now available, and more detailed analysis of the faunal structure is continuing.

Because the experimental area is flat with minimal or no surface run-off, the major loss of nutrients is through the downward movement of ground water. Porous cup lysimeters (Soil Moisture Corp.) were used to measure the concentration of nutrients (NH₄, NO₃, P, K, Na) at a depth of 50 cm. This measurement is considered to represent loss concentration, since the area of nutrient uptake by sorghum is generally above 50 cm. The lysimeters were sampled approximately every two weeks. The ground water was analyzed for ammonia and nitrate nitrogen using colorimetric techniques. Cation and phosphorus determinations are being made with a plasma emission spectrophotometer.

RESULTS AND DISCUSSION

The results of these studies obtained so far confirm the advantages of no-till practices over conventional tillage. Only results from the summer of 1978 are available, and these results cover but a few of the process-level measurements.

Primary production in no-till and conventionally tillage plots, as revealed from harvests of sorghum, produced nearly identical plant biomasses by the end of the growing season. Figure 1 shows that sorghum

growth in no-till plots initially lagged behind growth in cultivated plots. Leaf formation and heading time also lagged behind in the no-till plots. A significant factor may have been the slower root development in no-till plots, which itself may have been influenced by an early-season drought. As Figure 1 shows, at the end of summer sorghum biomasses were similar in conventional and no-tillage systems. Biomass of weeds was higher in the no-till plots in the first week's samples, but thereafter weed biomasses were similar for the two treatments.

Weight loss by plant residue, as measured by litterbag techniques, is illustrated in Figure 2. In each treatment weight loss was slow, but increased abruptly in late summer. Litter confined in bags in the no-till plots lost weight more rapidly than that in the conventional tillage treatment, but final percentages of litter remaining were similar (Figure 2). The pattern of weight loss and decomposition of surface litter during the winter season may be of greater significance than results for the summer growing season. Total decomposition might be expected to proceed more rapidly under cultivation, since surface litter becomes incorporated into the mineral soil. However, the ameliorating effects of surface litter on abiotic microclimatic factors in no-till systems may negate this influence of cultivation, at least in some years.

Populations of soil microarthropods in conventional, no-till and old-field plots showed an initial decline followed by an increase later in the summer (Figure 3). Very low values obtained for microarthropod populations in cultivated plots during June or July (about 1000 per m²), but these numbers increased dramatically following July rains (Figure 3). A complete analysis of soil microarthropod responses to tillage practices in these plots has been developed (Weems, in preparation) and will be presented elsewhere. Similarly, pitfall trapping has been used to compare populations of surface-dwelling macroarthropods in these tillage comparisons (Blumberg, 1980).

While we are attempting to develop input-output budgets for several major nutrients, we are placing particular emphasis on nitrogen fluxes and transformations. Reid et al. (1969) suggested that nitrogen regimes are principally functions of immobilization and remineralization rates, processes largely mediated by microbial activities. While large gaseous fluxes of nitrogen occur in soil systems, leaching losses may be appreciable as well, particularly in the humid southeastern United States (Nelson and Uhlund, 1955). Figure 4 shows nitrate nitrogen concentrations in lysimeter collections at 50 cm depth in conventional and no-till plots. During the last half of the summer, nitrate concentrations in groundwater were significantly higher in the conventionally tilled plots. These data suggest that no-tillage practices retard nitrate loss via leaching. Further evaluation must be based on gaseous transformations as well as leaching losses.

Figures 1 - 4 are illustrative of the types of research data being collected in this field experiment. We emphasize the phenomena

pertaining to the soil constitute the major differences between the experimental systems. A generalized overview considers nutrient inputs and outputs in contrast with internal nutrient dynamics in these systems. The principal nutrient input for both systems is the fertilizer subsidy. Harvest of crops is a major nutrient output, but so are leaching and (for nitrogen) gaseous losses. The regulation of the latter nutrient export is a function of the soil system and is mediated by soil biological communities. It appears from our results to date, that the more intact soils of no-tillage agro-nomic systems should prove to be more conservative of nutrients.

ACKNOWLEDGEMENTS

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FIGURE 1. Above-ground biomass of grain sorghum in conventionally-tilled (CT) and no-tillage (NT) experimental plots, Horseshoe Bend Experimental Area, Athens, Georgia. 1978.

FIGURE 2. Retention of dry weight by litter confined in small mesh bags placed in conventionally-tilled (CT) and no-tillage (NT) experimental plots, Summer, 1978.

FIGURE 3. Total microarthropods in top 5 cm of conventionally-tilled (CT), no-tillage (NT) and old-field (OF) soils, Horseshoe Bend Experimental Area, Summer, 1978.

FIGURE 4. Nitrate-nitrogen concentrations in groundwater collections from porous cup lysimeters at depths of 50 cm in soils of conventionally-tilled (CT) and no-tillage (NT) plots, Summer, 1978.

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Fig 1

Fig 2

Fig 3

Fig. 4

VII INTERNATIONAL COLLOQUIUM OF SOIL ZOOLOGY

QUESTION OR COMMENT REGISTRY
FOR DISCUSSION SECTIONS OF THE PUBLISHED PROCEEDINGS

Please provide the answers in the blanks and spaces below; attempt to state the question or comment and responses as similarly as you can to that which you presented during the actual time of communication.

NAME OF PERSON ASKING QUESTION Fred Gould
(Please print)

SPEAKER'S NAME TO WHICH YOU RESPONDED Stinner

TITLE OF SPEAKER'S COMMUNICATION No-Till vs Tillage

Your COMMENT OR QUESTION (after your statement is recorded below this sheet will be given to the speaker for a response).

Did you monitor weeds?

SPEAKER'S RESPONSE:

Yes, we did. Biomass of weeds was higher in no-till plots in the first samples we took. By the end of the summer, the weed biomass in conventional tillage was just as high as in no-tillage.

(Please return this sheet to Dr. Dindal)

VII INTERNATIONAL COLLOQUIUM OF SOIL ZOOLOGY

QUESTION OR COMMENT REGISTRY
FOR DISCUSSION SECTIONS OF THE PUBLISHED PROCEEDINGS

Please provide the answers in the blanks and spaces below; attempt to state the question or comment and responses as similarly as you can to that which you presented during the actual time of communication.

NAME OF PERSON ASKING QUESTION

DR. C.A. EDWARDS

(Please print)

SPEAKER'S NAME TO WHICH YOU RESPONDED

B.R. STINNER & D.A. CROSSLEY

TITLE OF SPEAKER'S COMMUNICATION

TILL & NO TILL PRACTICES

Your COMMENT OR QUESTION (after your statement is recorded below this sheet will be given to the speaker for a response).

We have also found fewer attacks by stem borers in no till systems. The slow initial growth you reported was a normal response. We have always found slower initial root growth under no till but later in the season root growth catches up and overtakes that in ploughed soil.

SPEAKER'S RESPONSE:

I am not so sure about the nutrient situation. In England we ~~often~~ often have to add extra nitrogen to no till crops and less of other nutrients.

(No response by speaker)

(Please return this sheet to Dr. Dindal)

VII INTERNATIONAL COLLOQUIUM OF SOIL ZOOLOGY

QUESTION OR COMMENT REGISTRY
FOR DISCUSSION SECTIONS OF THE PUBLISHED PROCEEDINGS

Please provide the answers in the blanks and spaces below; attempt to state the question or comment and responses as similarly as you can to that which you presented during the actual time of communication.

NAME OF PERSON ASKING QUESTION Elizabeth Waldorf
(Please print)

SPEAKER'S NAME TO WHICH YOU RESPONDED Ben Stinner

TITLE OF SPEAKER'S COMMUNICATION Comparison of mineral element cycling under till and no-till practices: AN experimental approach...

Your COMMENT OR QUESTION (after your statement is recorded below this sheet will be given to the speaker for a response).

WAS insecticide applied in your conventional tillage? If not, how does this compare with agricultural practice?

SPEAKER'S RESPONSE:

No, we didn't apply any insecticide. This would not be unusual for grain sorghum in our area.

(Please return this sheet to Dr. Dindal)