LNC93-057

ANNEX 3

Comparison of a Conventionally Managed Cropping System With an Integrated Cropping System: The Role of Cover Crops in Management

A research proposal submitted by
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General Introduction

Cropping systems that emphasize high productivity typically require high energy purchased inputs, such as pesticides and commercial fertilizers. While there is general agreement that the ever increasing demand for food and fiber must be met, concern over the environmental degradation of agricultural systems caused by human activity has prompted the search for more sustainable systems (Stinner and House, 1989). Sustainability in this context refers to agricultural systems that are environmentally sound, profitable and productive, and that maintain the fabric of the rural community (Keeney, 1990). The focus here will be on the "agricultural systems", even though recent initiatives in community-level research and social integration underscore the close association between production agriculture and community interaction.

Consistent with much of the corn belt, corn is the major cash grain crop grown in Michigan. The advent of corn grown in monoculture began at the end of World War II with the plentiful availability of inexpensive fertilizer. This factor, combined with rapidly improved hybrids and modern technology culminated in efficient and intensive corn production that produced inconceivable yields (Olsen and Shaw, 1988). As the disadvantages of monocropping became evident through massive soil erosion losses, pest and disease epidemics and weed problems, crop rotations (once commonly used when legume N was the most plentiful N source) once again became an alternative to continuous corn. Corn grown in rotation with soybean gained in popularity with increased market demand and a government program for soybeans. The benefits of corn in rotation include improved soil conditions, enhanced N availability, and better pest and disease control (Crookston, 1984, Higgs et al., 1990). Consequently, crop rotation is often considered as a best management practice (BMP) that can complement other practices (such as integrated pest management, soil nitrate testing etc) designed to lessen production agriculture's environmental impact. Approximately 20% of Michigan corn is grown in rotation with wheat and soybean, and it is conceivable that the aforementioned BMPs, including crop rotation could be more widely adopted as their benefits are clearly demonstrated to producers. For example, states in the northcentral region have encouraged producers to use the presidedress nitrate test (PSNT) before applying fertilizer (Bundy, 1990, Vitosh, 1991). Much of the testing of the PSNT was conducted on farmer fields, and this may expedite the adoption of such a practice by producers at large.

There is currently a heightened awareness among legislature and regulatory bodies, and a more educated public that agriculture is still the largest non-point source of pollution (NRC, 1989). Of particular concern are agricultural areas in very close proximity to watersheds, because of the potential for leaching of inputs into groundwater. The problem is further exacerbated with soils that are conducive to such leaching. For example, there are areas of southwest Michigan that contain very sandy coarse-textured soils where groundwater contamination from fertilizer nitrate has been documented (Cummings, 1984). Groundwater contamination may call for more corrective measures than presently in place, because some studies indicate that despite the use of BMPs such as fertilizing for realistic yield goals, and splitting N applications, N loss to groundwater still exceeded the EPA recommended drinking water level (Brinsford and Staver, 1991; Magdoff, 1991).

There is an emphasis now being placed on more "integrated" systems (Harwood, 1985). These systems focus on biological interactions of cropping systems by moving away from single species specialization to biological diversity within the system (Francis et al., 1990). Integration in this study will be achieved via crop diversity, including crop rotation effects over time and by measuring the more short-term effects of a cover crop within a crop management system. The framework for the emphasis on crop diversity and its attendant effects on microbial activity evolved in part out of ecological theory (Odum, 1977) and in Michigan is being tested at the Long Term Ecological Research (LTER) site. The LTER is the only agricultural site out of 11 NSF ecological facilities designed for such research. The rigorous hypothesis testing of basic ecology principles provides a basis for designing more biologically focused cropping systems. As systems are conceived that progress toward sustainability, they will need to be tested under on-farm conditions because producers inclined to implement these systems often rely upon knowledge transfer from their own farmer associations (Thompson and Thompson, 1989). An appropriate "middle ground" between the basic research conducted at the LTER site and direct on-farm application is the Living Field Laboratory (LFL) core experiment which implements testing commonly used cropping systems (corn-soybean-wheat) in Michigan across several levels of diversity and management schemes. Beyond solely gaining knowledge about a system, the goal of the LFL is to simultaneously maintain high productivity and biological stability over time. In this type of experiment designed to parallel on-farm conditions, it will also be possible to derive some of the costs associated with a particular system; cost has been identified as a key barrier to farmer acceptance (Dobbs et al., 1988).

Justification For the Proposed Research:

"Comparison of a Conventionally Managed Cropping System With an Integrated Cropping System: The Role of Cover Crops in Management"

The effects of cover crops in agronomic systems have been studied and verified (Hargrove, 1991; Power, 1987). These effects can be described as long-term, in which measurable differences in a parameter do not vary in only one or two growing seasons as in the gradual buildup of organic matter or improvement of soil structure to reduce soil erosion (Follett and Stewart, 1985); or short-term, as in the case of rapid nutrient uptake from legume residue. As the LFL undergoes "conversion" in the highest integration level (three crops and four cover crops in four years), the stability of long-term effects such as soil biotic activity will be determined at the end of the rotation. Long-term experiments are essential, especially in crop rotation experiments, and provide a vast amount of useful information (Peters et al., 1992, Raimbault, 1991; Dick et al., 1986).

The forthcoming hypotheses (page 6) are based on short-term (before the completion of a singular rotation in a given management type) effects for several reasons. First, there is a limited amount of time to measure the important long-term effects in an experiment that has just been installed the previous year. Secondly, my focus is on *management* of two cropping systems in the LFL; with the goal of maximum productivity, as is the case on-farm. Decisions sometimes are made as the system is being studied, for example, after the first growing season, a cover crop that exhibited inconsistent growth was replaced with a cover crop that performed consistently. The effect of the new cover crop will still be measured following the season it was added to the rotation; the key factor is that a management decision took precedence over the need to learn more about the ineffective cover crop.

This research is both crucial and timely. The growing concern over degradation of water resources in agricultural watersheds may lead not only to stronger restrictions, but more serious enforcement of existing regulations (Kiplinger Agricultural Letter, 1994). The LFL site has two very important characteristics that makes this study ideal: it is located near a watershed, and it contains coarse, sandy soils that are sensitive to leaching. With the aid of intact lysimeters, we can closely monitor nitrate leaching. This short-term approach will allow testing of hypotheses that are of immediate concern to farmers, especially as compliance with EPA regulations becomes a more pressing issue. For example, the question will be addressed, "does inclusion of a scavenger cover crop reduce nitrate leaching?" At the end of a growing season (including over winter), data is available to answer this question (based on conditions of the LFL).

Another important issue is the cost of integration. Farmers are continually seeking to set a price on the cost of including a cover crop in their rotations. A comparison of a conventional with an integrated system (continuous corn and corn in rotation with and without cover) may result in similar crop yields, but the net returns may widely differ, as the cost of managing a system that includes cover crops is factored in. These short-term effects must be weighed in consideration of longer term transitions of the more highly integrated system. For example, after twelve years, Chase and Duffy (1991) found that a conventionally managed continuous corn system had higher yields than a reduced input rotation, but net returns were similar as production costs were lower in the reduced input system.

The LFL allows for testing across a broad range of management types, crop and substrate diversity, and chemical input variables. In focusing on the management types that the majority of Michigan producers would be most likely to adopt (an integrated system as opposed to a completely organic system), the goal of providing producers an alternative system with short-term (quantified during course of the study- such as reduced leaching) and longer term (quantified after the study- such as soil organic matter) effects is achieved.

Hypotheses:

1) An integrated cropping system (with cover crops) will utilize fertilizer and mineralized nitrogen more efficiently than a conventional (without cover crops) system chiefly in two ways:

a) Greater uptake of mineralizable N which reduces residual N loss through leaching after crop harvest

b) Providing a source of immobilized N from cover crop residue, which gradually becomes available over an extended period of time

Rationale

- Fertilizer efficiency has been defined as percentage of N recovered in the fertilized portion; or as grain yield increase due to applied N (Jokela and Randall, 1989). Efficiency in this study will be extended to include recovery of N by the cropping system; ie., with the cover crop present in the integrated system, increased residual N from fertilizer that would be lost will be recovered. Fertilizing for higher yield goals will result in greater N use efficacy in the integrated system than in the conventional system.

- Uptake of residual N by an N scavenging cover crop such as annual ryegrass will increase in proportion to that residual N available for uptake. Hence, in a corn-ryegrass ancillary trial with three N rates, maximum fertilizer levels can be established for an integrated system that includes an N scavenging cover crop.

2) An integrated system will generate returns comparable to or greater than a conventional cropping system

Rationale

- Producers who wish to implement an integrated system for short-term and long-term benefits have little access to information regarding associated costs of implementation. Economic analysis including direct input costs and gross returns will demonstrate that returns of the integrated system will be similar to a conventional system, and that long-term benefits (not analyzed in this study, but modeled in a collaborative study) will favor implementation of the integrated system.

Methods

LFL main experiment statistical design: Randomized complete block with four replications
40 plots at 15' X 50'

Management type (main plots): Conventional (broadcast herbicide, no cover crop)

Integrated fertilizer (banded herbicide, cultivation for weed control, cover crops

Crop rotation (sub plots):

Four year
Year 1- Corn interseeded with ryegrass
Year 2- Soybean
Year 3- Wheat frost-seeded with red clover
Year 4- Corn interseeded with a clover/ryegrass mix

Continuous corn
Interseeded with clover/ryegrass mix

Lysimeters- Comparisons of first year corn rotation and continuos corn between management types

Minimum data set and sampling protocol:

Soil sampling for soil N

- Deep samples (3 feet deep in 1 foot increments) taken mid-April and after harvest with Giddings soil probe (2" dia. auger)
  Three cores per plot, composited, dried at 96^{o} F, crushed and sieved through 10 mesh screen. Extracted with 1M KCl and analyzed for soluble N by Lachat autoanalyzer

- One foot samples taken with .75" soil probe, 5 cores per plot, processed as above
  To establish a soil N mineralization curve, samples will be taken as follows:
  deep sample mid April
  - two samples in May (mid-May and last week in May)
  - two samples in June (before sidedress)
  - one sample in mid-July
  - two samples in September

Minimum data set and sampling protocol (cont. from previous page)

Plant sampling and above ground biomass determination

- All crop biomass samples taken at physiological maturity. Plants will weighed wet, oven dried, weighed dry, and finely ground for ANCA mass spectrometer analysis (Harris and Paul, 1989) for total C and N. Specifically for each crop:

- Corn- ten stalks from one 50' row collected, ears separated from stover and milled, moisture determined. Corn ear leaf (5 leaves per plot) taken at silking, finely ground for ANCA mass spectrometer analysis

- Soybean- all plants in 5' of row will be taken from each plot

- Wheat- two one square meter sections will be taken from each plot, weeds will be removed from wheat biomass prior to weighing and drying, grain will be determined at plot harvest

- Cover crops- two one square foot sections will be taken from each cover crop plot. Ryegrass will not be separated from red clover in the mixed cover plots.

Lysimeter samples

- Monthly leaching volume will be determined; analysis of soluble N will conducted on the Lachat autoanalyzer

Data analysis

- Analysis of variance will be conducted to test hypotheses. Data will be normalized so that equal weighted comparisons will be made (for example, only limited comparisons can be made for lysimeter data in the two systems because the integrated system has lysimeters across all crops, whereas the conventional system only has lysimeters for two crops).

Nitrogen Fertilizer Recovery by an Annual Ryegrass Cover Crop Interseeded Into Corn

Purpose:

1) To determine uptake of fertilizer N in corn grown with or without interseeded annual ryegrass at three fertilizer rates; 0, 80 and 160 lbs/A.

2) To determine partitioning of fertilizer N in corn grown with or without annual ryegrass interseeded; and concentration of labeled N in grain and stover

Higher N fertilizer rates may be called for in systems that include non-legume cover crops to scavenge N, even if experimentally this means "overloading" the system in a research trial to determine peak levels (Meisinger et al., 1990). Insufficient N may result in less biomass than needed, and the cover crop may not recover significant N when it is critical to do so. In this experiment, a moderate and a high rate of fertilizer N will be applied to corn with and without interseeded annual ryegrass. The results will give an indication of the level of fertility needed to maintain high crop yields while effectively scavenging N. Labeled N in microplots will allow for following uptake of fertilizer N into the system crop components for two consecutive growing seasons.

Methods

The experiment will be conducted at KBS, north of the LTER experiment, on a soil type similar to the LFL . The experimental design is a randomized complete block with four replications. The main plots are corn without cover and corn with cover. Sub-plots are three N rates, 0, 80 and 160 pounds/A. Main plot size will be 50 X 15 feet. Labeled enriched ^{15}N (5 atom %) will be applied in 4 X 5 foot microplots contained within the main plots. The main plot fertilizer will be banded NH_4N0_3, and the microplot will be fertilized with a solution of the NH_4N0_3 containing the labeled N. A backpack C02 pressurized sprayer will be used to apply the solution. Starter P will be applied if called for, N fertilizer will be applied at sidedress, microplots will be covered with plastic to avoid mixing from the main plot fertilizer.

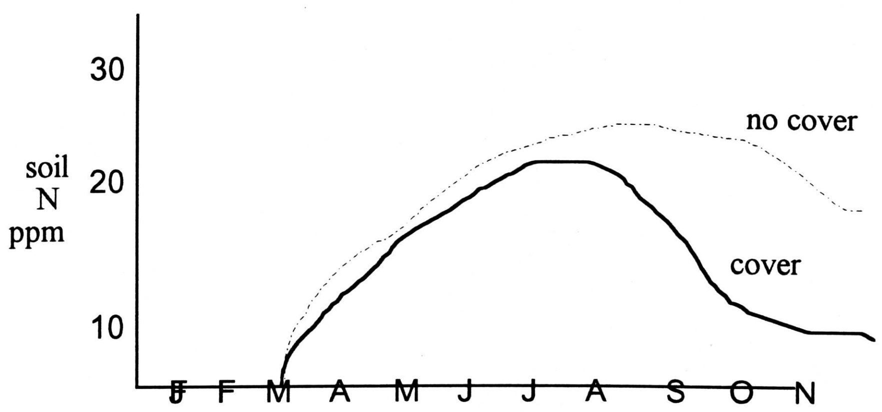
Measurements-

- Soil soluble N- In the main plots, 3 foot deep soil samples at one foot increments will be taken in the early spring and in fall after harvest, one foot samples will be taken biweekly as soil temperatures rise in spring to establish a mineralization curve. A microplot deep soil sample will be analyzed for uptake of labeled fertilizer N after harvest. Perhaps only one or two one foot soil samples will be taken from the microplot during the growing season. Soil from microplot holes will be returned.

- Plant samples- Biomass at harvest for total N- corn and annual ryegrass. Sampling protocol used in LFL experiment will be used here. Annual ryegrass biomass taken again the following spring for ^{15}N uptake and total N prior to killing.

Expectations

If hypothesis 1) is verified, there should be a reduction in N leaching in the fall to winter months, as shown below. In the ancillary rate trial, higher cover crop biomass should result in a higher rate of N scavenging.



Results from this management oriented study can later be superimposed on the longer-term measurements that reflect the integration effects. This data is an important part of the larger framework for the experiment. Microbial biomass data, compost substrate effects, economic analysis and other focus areas will add to the broad scope of the LFL mission. As results are discussed and exchanged among the researchers, my emphasis will continue to be application of the information to the clientele we serve, both producer and community.

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