Research on Transition from Conventional to Sustainable Agriculture: The Rodale Farming Systems Trial

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Introduction

This paper describes the Rodale Farming Systems Trial (FST), one of the longest running experiments in the United States that compares conventional and organic practices. The experiment is in its 14th year and it is probably the most carefully studied 10 acres in Pennsylvania. Rather than discuss a single transition experience, however, this paper will describe several transitions that have been observed since the inception of the experiment.

Results and Discussion

Farming Systems and Transition Effects

When Dr. Dick Harwood, then Director of Research at the Rodale Research Center, began this study in 1981, his goals were to document both the biological and the economic transitions from conventional to organic farming. The three cropping systems were defined as low input-animal, low input-cash grain, and conventional cash grain (Table 1). A diverse crop rotation characterizes both low-input systems, while a corn and soybean rotation is somewhat typical of Corn Belt farming systems (Figure 1).

During the first five years of this study, the transition effect on yield was documented. During the 1981-84 period, the low-input system's corn grain yield was about 80 percent of the conventional system's yield. From 1985 to the present, the yields of the three cropping systems have on average been about the same. One might ask, Is this it? Is this the transition?

Further research on these systems has shown that there were at least two factors responsible for the transitional effect on corn yield. One factor was biological, i.e., low nitrogen availability in the two low-input systems in the early years. By 1985, both systems either had nitrogen-fixing cover crops or animal manure additions, or both at two points in the rotation cycle. This cumulative effect seemed important in increasing the amount of crop-available nitrogen as compared with the earlier years of the experiment.

A second factor that helps to explain the yield transition effect was a "learning curve" associated with mechanical weed control. During the first three years of the experiment, the staff responsible for field operations was still learning about the utility of the rotary hoe for early weed control, and were not aware of the proper timeliness and precision needed for effective weed control with this implement. This lack of knowledge has also been identified as a significant constraint by many practicing organic farmers in surveys and interviews.

Economic Implications

With regard to the initial transition, two studies on the economic implications of conversion to organic farming have been conducted using this data set. The first showed that the crop rotation entry point had a significant effect on the net return during the first five or six years of the transition (Duffy et al., 1989). The low-input rotations that started with corn rather than a leguminous cover or hay crop, which would add nitrogen and carbon to the soil, were less profitable than those that started with soybeans, small grains, or hay crops. Overall, the average profitability of the systems regardless of crop entry point were low input-animal > conventional cash grain > low input-cash grain.

A second economic analysis showed that even the least profitable system, low input-cash grain, had the same net return as the conventional system by the 9th year after conversion (Hanson et al., 1990). This 9-year economic transition period can be reduced if 1) the U.S. farm program encouraged crop rotations rather than corn-based systems, 2) hay crops were sold from the low-input cash grain system, and 3) the farmer enters the transition period with nitrogen-fixing rather nitrogen-demanding crops.

Table 1. Description of the Rodale Farming Systems Trial (from Peters et al., 1992).

Parameter	Low Input-Animal	Low Input-Cash Grain	Conventional Cash Grain
Crops grown	Corn (grain), corn silage, soybeans, wheat, legume hay	Corn (grain), soybeans wheat, oats, barley, legume green manure	Corn (grain), soybeans
Surface condition[1] of soil from 1/86- 12/90	Bare 7%, Live plants 73%, dead residue 20%	Bare 8%, Live plants 69%, dead residue 23%	Bare 8%, Live plants 42%, dead residue 50%
Primary tillage	Moldboard plow (4 times in 5 years)	Moldboard plow (5 times in 5 years)	Moldboard plow (5 times in 5 years)
Weed control	Rotary hoe, cultivate (corn and soybeans only)	Rotary hoe, cultivate (corn only)	Herbicides (both corn and soybeans)
Nitrogen fertility	Beef manure (applied to corn only), residual hay	Legume (red clover/alfalfa) green manure	Starter fertilizer, urea, ammonium nitrate
Potassium fertility	Potassium sulfate (1989) 124 lb K/a, Beef manure-257 lb K/a (5 yr total)	Potassium sulfate (1989) 124 lb. K/a	Potassium sulfate (1989) 124 lb. K/a; starter fertilizer
Phosphorus fertility	Beef manure-209 lb P/a (5 yr total)	None	Starter fertilizer
Lime	Ca limestone (1989) 3000 lb/a	Ca limestone (1989) 3000 lb/a	Mg limestone (1982) 8000 lb/a
Additional features	Frost seed legumes into small grains	Frost seed legumes into small grains, relay crop soybeans into small grains	None

[1]Assume that the soil surface is bare for one month after plowing and planting a new crop. If a green manure cover crop or hay crop is established with the onset of winter, this period is considered to be under live plant cover even though the plants arc dormant.

Soil Biological and Physical Implications

One transition is still taking place, i.e., changes in soil biological and physical properties. With the help of a number of collaborators from U.S. Universities and the U.S. Department of Agriculture's Agricultural Research Service, we have been able to document some of these changes, especially in soil organic carbon and total nitrogen. In both low-input systems, organic carbon increased during the first 10 years of the experiment, while in the conventional system the carbon levels decreased (Wander et al., 1994, Table 2). Soil nitrogen levels follow similar trends. The net impact of these changes includes a greater proportion of water stable aggregates in the low-input systems (Wander, 1992; Friedman, 1993), greater soil respiration rates in the low-input systems (Fraser, 1984; Doran et al., 1987), greater diversity of soil biota in the low-input systems (Werner and Dindal, 1990), and higher water infiltration rates in the low-input systems (Peters et al., 1992).

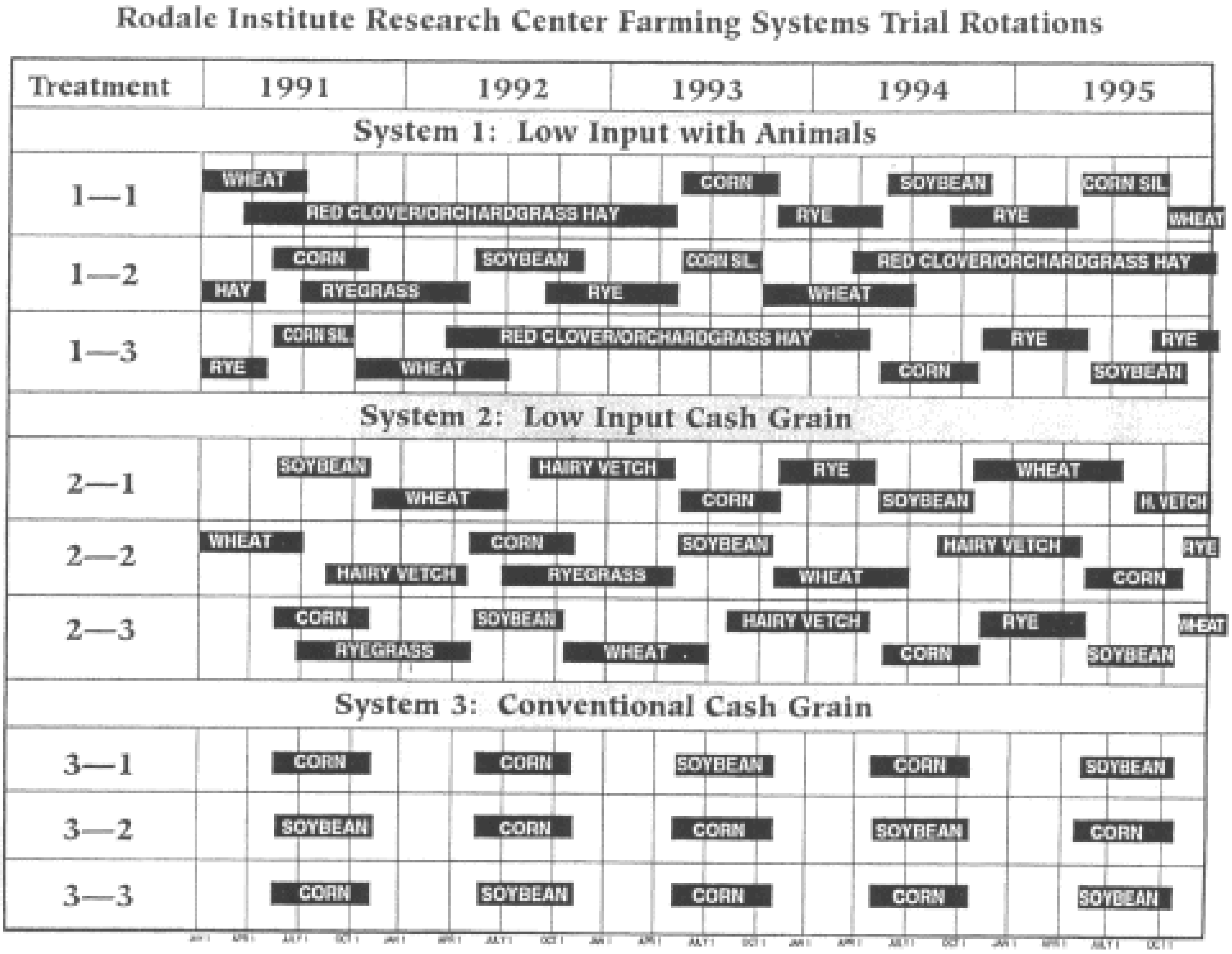

Figure 1. Crop Rotation Diagram for the Farming Systems Trial for the 1991-1995 Crop Rotation Cycle

Table 2. Total Carbon Content of Soil as Affected by Treatments in the Rodale Farming Systems Trial (from Wander et al., 1994).

Farming System	**1981**[1]	**1990**
	(%C)	
Low Input-Animal	2.27 a[2]	2.34 a, b[3]
Low Input-Cash Grain	2.36 a	2.45 a
Conventional Cash Grain	2.23 a	2.13 b

[1]Soils were collected in 1990 from 0-10 cm depths from blocks 1-5 and 8 in crop-entry point plots producing corn and soybeans. Corresponding archived 1981 soil samples were obtained from the Rodale Institute Research Center.
[2]Animal = organic animal based, Cover Crop = organic cash-grain based, and Conventional = conventional cash-grain based; rotation treatment means within columns followed by different letters are significantly different based on Fisher protected LSDs ($p<0.05$).
[3]Statistics for C90 were performed on residual values generated by regression of C90 and C81; this was done to remove initial spatial C distribution effects.

One collaborator has taken a closer look at cropping system effects on mycorrhizal fungi associated with corn and soybean roots in the three rotations (Douds et al., 1993). He has found a greater abundance of certain mycorrhizal types associated with the low-input systems, and an increased ability of soils in the low-input systems to infect host plants in con-trolled environment studies. This could provide the mycorrhizal-infected plant roots with additional capacity to absorb water and nutrients, especially phosphorus. It is impossible to determine the exact cause and effect relationship of the cropping system on mycorrhizal abundance, but it is believed that the increased amount of live cover provided in the low-input rotations was a factor. As shown in Figure 1 the low-input surface cover systems was about 70 percent compared with only about 40 percent for conventional cash grain.

Soil Nitrogen Dynamics

An important change in nitrogen dynamics, or the way that nitrogen cycles through these three systems, is also occurring, probably as a result of the biological changes already discussed. In addition to changes in total soil nitrogen, the partitioning of nitrogen between crop plants and soil has been documented (Harris, 1993). More nitrogen is "stored" in the form of microbial biomass and organic nitrogen in soil of the low input-cash grain system (66 percent) compared with the conventional system (21 percent).

The implication of a "tighter" soil nitrogen storage system is that less nitrogen may be lost from the low-input systems through leaching. Thirty six intact soil core lysimeters were installed for this experiment in the fall of 1990, and preliminary data validates the hypothesis of tighter cycling in the low-input systems. Total nitrogen leached from the conventional corn and soybean system after two years was 49 kg/ha as compared with 37 kg/ha in the low input-animal system, and 35 kg/ha in the low input-cash grain system, even though all three received similar amounts of nitrogen prior to corn planting (Harris et al., 1993). In the low-input systems, nitrogen is in the form of animal manure and green manure crops rather than chemical fertilizer. Further analysis of the data and continued collection of leachate from experimental plots will provide valuable information about (1) long-term trends in soil nitrogen dynamics and (2) crop rotation effects in organic farming systems.

Summary and Conclusions

In summary, there is still much to learn about soil biology in organic farming systems. This paper provides only a brief description of some of the significant changes observed in the Rodale Farming Systems Trial. To study changes in soil biology resulting from farming practices, long-term cropping systems trials are needed with appropriate control plots and replications. Single factor studies are also needed in conjunction with intentionally confounded "systems studies" in order to establish cause and effect relationships, and also, to understand the context within which these factors interact. A number of transitions have already occurred in the Rodale Farming Systems Trial, while other changes and transitions may yet occur as these systems continue to evolve.

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