

Organics outperform conventional in long running trial

Since 1981 the Rodale Institute in the US has been conducting a side-by-side comparison of organic versus conventional grain-based farming systems, the longest such study ever conducted. Their results indicate that organic systems compare favourably in terms of yields and economics with conventional systems while using less energy, less water and no pesticides. Here David Pimentel reports on the first 22 years of this trial.

The experimental farm at the US-based Rodale Institute is devoted to state-of-the-art research trials for chemical-free crop production. Among the most innovative initiatives is a long-term study that compares the performance of organic with conventional grain production. From 1981 to 2002, field studies were carried out on 6.1 hectares (ha) at the Rodale Institute Farm Systems Trial in Kutztown, Pennsylvania where the soil is a moderately well-drained silt loam and the growing climate sub-humid temperate.

Study design

Three different cropping systems were tested with eight replicates of each:

Conventional cropping

The conventional system used synthetic fertilizer and herbicides and represented a grain and row-crop farming unit. Its simple five-year rotation (corn, corn, soybeans, corn, soybeans) is used by many commercial operations in the Midwest of the US. More than 40 million ha of land are in this production system in North America. The fertilizer and pesticide applications followed Pennsylvania State University Cooperative Extension recommendations. Crop residues were left on the soil surface to conserve soil and water and the conventional system had no more exposed soil during the growing season than the organic comparisons. However, it did not have cover crops during the non-growing season.

Organic animal-based cropping

This is a typical livestock system in which grain crops are grown for animal feed and not for sale. A more complex five-year rotation was operated that included corn (maize), soybeans, corn silage, wheat, and red clover-alfalfa hay. A rye cover crop was also grown before the corn silage and soybeans. Aged cattle manure was the nitrogen source applied at a rate of 5.6 metric tonnes per ha (dry), two years out of every five, before planting corn. Additional nitrogen came from the incorporation of the red clover-alfalfa hay crops. The total nitrogen applied per hectare was 40 kg per year or 198 kg per year when corn was

planted. Weeds were controlled by mechanical cultivation, weed-suppressing crop rotations and relay cropping in which one crop acted as a living mulch for another.

Organic legume-based cropping

This was a cash grain system without livestock. Like the conventional system it produced grain for sale every year, however it did not use synthetic fertilizers, relying instead on nitrogen-fixing green manure crops. The rotation system included hairy vetch (winter cover crop), corn, rye (winter cover crop), soybeans, and winter wheat. The hairy vetch winter cover crop was incorporated before corn planting. The initial five-year rotation was modified twice before reaching this final format. The total nitrogen added averaged 49 kg per year (140 kg in a year when corn was planted). Both organic systems included a small grain (such as wheat) grown alone or with a legume. Weeds were controlled as in the organic animal-based system.

Crop yields under normal rainfall

For the first five years (1981-1985) corn yields averaged 4222, 4743 and 5903 kg per ha for the organic animal, organic legume and conventional systems respectively with the yield for the conventional system significantly higher than for either organic system. However, after this transition period there was no significant difference between yields for the three systems: 6431, 6368, and 6553 kg per ha for the organic animal, organic legume and conventional systems respectively.

Average soybean yields from 1981 to 2001 were 2461, 2235, 2546 kg per ha for the organic animal, organic legume and conventional systems respectively. The lower value for the organic legume system was due to the failure of the soybean crop in 1988 when conditions were too dry to support relay intercropping of barley and soybeans. If 1988 is taken out of the analysis, soybean yields are similar for all systems.

Crop yields under drought

The ten year period from 1988 to 1998 had five years in which the total rainfall from

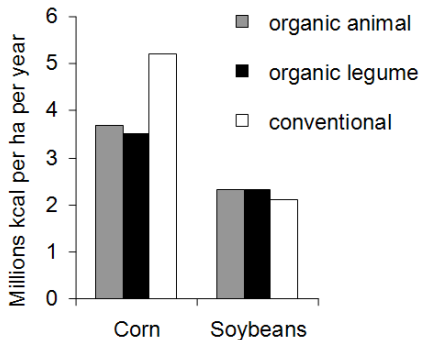
April to August was less than 350 mm (compared with 500 mm in average years). Average corn yields in those five dry years were significantly higher (28% to 34%) in the two organic systems: 6938 kg per ha for the organic animal, 7235 kg per ha for the organic legume systems compared with 5333 kg per ha for the conventional system.

During the extreme drought of 1999 (total rainfall between April and August was 224 mm) the organic animal system had significantly higher corn yields (1511 kg per ha) than the organic legume (421 kg per ha) or conventional system (1100 kg per ha). Crop yields in the organic legume system were low because the hairy vetch winter cover crop had used a large amount of soil water. Soybean yields responded differently to the drought. Yields were 1800, 1400, 900 kg per ha for the organic legume, organic animal and conventional systems respectively. These yields were all significantly different from each other.

The higher yields of the organic systems under drought conditions can partly or entirely be explained by increased water retention of the soil. Over the 12-year period from 1990 to 2002 the volumes of water percolating down through the soil were 15% higher in the organic animal system and 20% higher in the organic legume system compared to the conventional system. This will increase groundwater recharge and reduce runoff in the organic systems. Soil water content was also measured in 1995, 1996, 1998 and 1999 in the organic legume and conventional systems. Significantly more water was retained in the soil of the organic legume system explaining its higher soybean yield in 1999.

Besides the Rodale Institute Farm Systems Trial many other studies have quantified relative yields of organic versus conventional systems with variable results depending on crop, growing conditions, and technologies employed. In some studies organic and conventional yields are similar, whereas in others, yields are notably higher within conventional production. For example, European field tests indicate that yields of organically grown wheat and other cereal grains is 30% to 50% less than that of conventional grain production. However, this lower yield appears to be caused by lower nitrogen-nutrient inputs in the organic systems. In the Rodale Institute Farm Systems Trial yields were comparable under average conditions and indeed the organic systems produced higher yields under conditions of drought due to the improved water retention of the organically farmed soils. In the Rodale trial the nitrogen input was optimized and did not limit growth except in the first three years of the study. These results indicate that where nitrogen levels are optimized organic yields can match, or in some cases exceed, that of conventional systems. The question of yields has long been contentious with some of the most ardent critics of organics implying that organic farming threatens food security due to reduced yields. These results from the Rodale Institute should go some way to silencing such critics.

Figure 1. Energy use comparison



Energy inputs

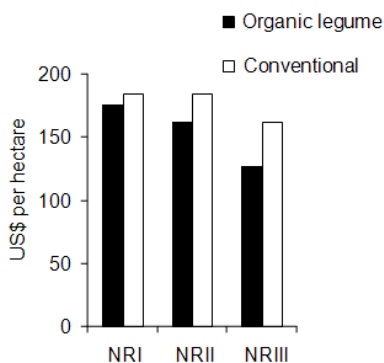
Energy inputs to the different systems included fossil fuels for farm machinery, fertilizers, seeds, and herbicides. About 5.2 million kilocalories (kcal) of energy per ha were invested to produce corn in conventional systems. Energy inputs for the organic animal system were 28% less and for the organic legume systems were 32% less. Conventional fertilizers were produced using energy from fossil fuels whereas legumes and/or cattle manure were used in the organic systems. Energy inputs for the different soybean production systems were similar at 2.3, 2.3 and 2.1 million kcal per ha for organic animal, organic legume and conventional respectively (figure 1).

While there was little difference in energy input into the organic and conventional soybean systems, significantly less fossil fuel was used to produce corn in the organic systems. This reduced energy use will reduce carbon dioxide released into the atmosphere so contributing less to global climate change.

Economics

Three economic studies of the Farm System Trial have been carried out over the 22-year period it has been running. In the first two studies (after nine and 15 years) the rotation used in the organic systems was still being developed. A third study was carried out after the rotation used in the organic systems had been perfected. Many organic grain farmers in the Mid-West of the United States have adopted this 'Rodale rotation', and so, there is par-

Figure 2. Economic comparison



Net returns from a 400 ha farm; NRI - net return; NRII - NRI minus transitional costs; NRIII - NRII minus all labour costs.

ticular interest in comparing this optimized rotation with the conventional system.

The organic corn-soybean rotation was compared with the conventional corn-soybean rotation over the period from 1991 to 2001 (figure 2). Without price premiums for organic produce the net return for both rotations were similar: \$184 per ha for the conventional and \$176 per ha for the organic legume system. When the costs of the transition period (1982-1984) were included the net return for the organic rotation were reduced to \$162 per ha while the return on the conventional system remained the same. Including the cost of family labour reduced the returns on the conventional system to \$162 and on the organic system to \$127. However, even including both the costs of transition to organic and the demand on family labour in the organic rotation the price premium required to equalize the returns on the conventional and organic systems was only 10% above that of the conventional product. Price premiums for organic products almost always exceed this. This indicates that going organic can be profitable for farmers and economic considerations should not be a deterrent to transitioning to organic production. The organic system required 35% more labour but because this is spread out over the growing season the hired labour costs are similar under both systems.

Soil organic matter

Soil carbon is a measure of soil organic matter and was measured in 1981 and 2002. In 1981 there was no significant difference between systems but by 2002 soil carbon levels in the organic animal and organic legume systems were significantly higher than in the conventional system, 2.5%, 2.4% and 2.0% respectively. The annual carbon input (based on above-ground biomass of plants and manure added) was the same in the organic legume and conventional systems but around 12% higher in the organic animal system.

Soil organic matter is the basis for productive organic farming and sustainable agriculture. It improves water retention allowing higher yields within the organic systems in dry years. It is an important source of nutrients and is associated with increased biodiversity. In this trial the soils of the two organic systems had higher concentrations of mycorrhizal fungi, important in assisting crop plant growth and disease resistance in organic systems. Microbial activity was also higher in the organic systems and other studies have shown an increase in microarthropods and earthworms in organic systems. This increased biodiversity can provide vital ecological services including crop protection.

Soil fertility

Soil nitrogen levels were measured twice, in 1981 and again in 2002. Initially the three systems were similar, with each of their soils containing around 0.31% nitrogen. However, by 2002 the conventional systems remained the same while nitrogen levels in the organic animal and legume systems had increased significantly to 0.35% and 0.33% respectively.

Nitrate leaching

The concentration of nitrate leaching from soils in all systems varied from 0 to 28 parts per million (ppm) throughout the year and was highest in June/July. 20% of samples collected from the conventional systems exceeded 10 ppm which is the regulatory limit for drinking water in the US while 10% and 16% of the samples from the organic animal and organic legume systems exceeded the nitrate limit. Over the 12 years of monitoring (1991 - 2002) all three systems leached between 16 and 18 kg of nitrogen as nitrate per ha per year. These levels are low compared to those recorded in other published trials but the numbers of samples exceeding drinking water standards for nitrate were significantly higher from the conventional systems than from the organic systems. However, they still indicate the need for progress within all systems to manage nitrate leaching.

Herbicide leaching

Four herbicides were applied in the conventional system: atrazine to corn, pendimethalin to corn, metolachlor to corn and soybeans, and metribuzin to soybeans. Between 2001 and 2003 atrazine and metolachlor were detected in leachate from conventional systems. In the plots where corn was planted after corn and atrazine was applied two years in a row the concentration of atrazine in leachate sometimes exceeded 3 ppm. While this is the drinking water standard in the US it is far in excess of concentrations recently found to adversely affect frog development. When metolachlor was applied two years in a row in a corn after corn treatment its concentration in leachate peaked at 3 ppb. No herbicides were used on the organic plots.

Conclusion

The organic systems produced equivalent yields and the economics of these systems was favourable. The organic systems offered increased environmental benefits from improved soil organic matter, improved water conservation including increased groundwater recharging, and no herbicide leaching. The increased water retention in soils made the organic systems more tolerant of drought resulting in higher yields compared to the conventional system in dry years. The lack of synthetic pesticides eliminates the harmful effect of these chemicals on non-target organisms. Increased microbial activity was associated with increased organic matter. As a result overall public health and ecological integrity could be improved through the adoption of these practices, which decrease the application of pesticides and commercial fertilizers.

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