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Workshop Papers and Authors
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Introduction to the Workshop

Jules Janick

The organic movement has progressed from a small band of idealists to a national and international force with strong political influence. This topic has continued to engender passion and fervor and is constantly in the news. In the past, some of the proponents of the organic movement have scorned science and technology, considering them to be the cause of our problems rather than the cure. As a result, science and the organic movement have had an adversarial relationship. Today, the very word "organic" has a visceral effect on the one side, comparable perhaps to the word "chemical" on the other. Nevertheless, there seems little doubt that the organic movement, in the guise of its various synonyms—sustainable agriculture, the green movement, organic farming, the environmental movement—will be a determinate force in horticulture in the 1990s.

This workshop examines the roots of the organic and environmental movements and investigates their scientific, antiscientific, and emotional basis with emphasis on horticulture. We see that the organic movement is "no alien implant" but may be considered the reappearance, in contemporary guise, of a long tradition. We hope this workshop will alter our way of thinking about the problem so that horticultural science and the organic movement can fulfill their mission to improve the well-being of humankind.

The first paper, "The Early Roots of the Organic Movement" by Ronald F. Korcak, reviews the origins of our understanding of plant nutrition and, specifically, the changing perceptions of the role of organic matter (humus) in the soil. The science of plant nutrition is based on the demonstration that plants absorb inorganic salts from the soil and CO_2 from the air and metabolically transform them into complex organic materials. Green plants are self-nourishing (autotrophic) with respect to organic compounds. This is demonstrated by the fact that plants grown with nutrient solutions are identical to plants grown in soil. Despite the fact that plants normally do not absorb organic molecules into their roots, soils and inorganic nutrient solutions are not equivalent substrates, because soil is a living, dynamic system. Plant nutritionists and agriculturists do not belittle or underestimate the importance of organic matter or soil organisms to plant nutrition in soil systems. It is also fair to say that in the real world this fact has been ignored in many agricultural systems where short-term responses to inorganic fertilizers have been emphasized with little attention given to other consequences of these practices. The typical grower considers the choice of replacement of essential elements to soil systems, as a consequence of crop withdrawal or natural deficiency, to be a purely economic decision. The organic movement, on the other hand, considers synthetic chemicals or fertilizers to be not only poisonous but also ritually unclean; their application is considered a symbolic act tantamount to sin. The emotional dispute over nutrient source, i.e., the distinction between organic vs. nonorganic source for fertilizer materials, is a difference akin to distinctions of religious dietary laws and prohibitions. Consequently, the dispute between the proponents of organic agriculture and agricultural science resembles a conflict of opposing values—more a religious dispute than a scientific controversy.

"Sir Albert Howard and The Indore Process," by David R. Hershey, introduces the genesis of the modern organic movement through the career of a scientifically trained agriculturist who was an iconoclast to the agricultural establishment of his time. Howard is best known for his advocacy of a composting system for the recycling of plant refuse and organic waste materials to improve soil properties. His advocacy of a questionable hypothesis that there is a direct connection between soil health and plant health led to ridicule by the scientific community. However, his agricultural philosophy was popularized by J.I. Rodale, an unconventional publisher and promoter who single-handedly attacked the medical and agricultural establishment while establishing a successful magazine empire. Rodale, ferociously opposed to agricultural dependence on fertilizers and pesticides, as well as the conventional medical establishment, was convinced that nutrition held the key to health, and although many of his ideas in this area were weird, his emphasis on nutrition and exercise was prescient. The career of this apostle of nonconformity is reviewed by William C. Kelly in "Rodale Press and Organic Gardening."

Caula A. Beyl, in "Rachel Carson, *Silent Spring*, and the Environmental Movement," presents the background for one of the most influential books of the 20th century, a work that brought the environmental hazards inherent in pesticides to public consciousness. The events leading to public concern over DDT, as well as the response to the thalidomide disaster, mark the beginnings of the environmental movement, a defining event in our culture. The environmental movement, conceived in fear and born in crisis, struck a responsive chord in the United States during the late 1960s. The movement has proved to be a force to be recognized. The buzzwords "organic" and "natural," shamefully exploited by the consumer-oriented food and cosmetic industries, replaced the epithets "science" and "technology." The clamor over pollution made agricultural technologists painfully aware of the long-range implications of their actions. Despite a concerted attack by the agribusiness complex and early widespread disinterest by the academic community, the issue refused to go away, especially when the achievements of agricultural science kept food supplies in surplus and prices of agricultural commodities depressed.

The effect of the organic movement on contemporary agriculture is underscored in Silviero Sansavini and Joerg Wollesen's "The Organic Farming Movement in Europe," a survey demonstrating the extent of agricultural change in direct response to the movement. Formerly, the organic concept found a willing advocate in the home-gardener but had little or no effect on commercial agriculture. This is no longer the case in Europe. Part of the response may be passed off as a simple reaction to a discovered market niche, but the scope of the organized responses reflects a fundamental change in attitude in growers and consumers, an awareness of the possibility of a more ecological approach to agriculture. Miklos Faust, in the final article "Organic Gardening and Ecosystem Alteration," makes the point that the problem at issue is the interrelationship of biological systems and that an ecological approach must provide the solution to the problem of sustained agricultural productivity.

Department of Horticulture, Purdue University, West Lafayette, IN 47907-1165.

Early Roots of the Organic Movement: A Plant Nutrition Perspective

Ronald F. Korcak

Additional index words. humus theory, Justus von Liebig, plant nutrition

Lord Walter Northbourne first used the term "organic farming" in 1940 as a chapter heading in his book *Look to the Land* (Northbourne, 1940). That same year, coincidentally, was also the 100th anniversary of Justus von Liebig's monograph *Organic Chemistry in its Application to Agriculture and Physiology*. The fundamental tenet of Liebig's doctrine was the development of the mineral nutrient theory of plant nutrition. About 100 years later, the primary American proponent of organic farming, J.I. Rodale, cited Liebig as the founder of the fertilizer industry (Rodale, 1945), which he probably was, and the N–P–K mentality in agriculture. The basis for these remarks was that "up to that time the humus theory had been the guiding basis for agriculture" (Rodale, 1945). What exactly was the humus theory? How did it evolve? Was it a viable theory? What was the role played by the pivotal player, Liebig? This review follows the evolution of plant nutritional theories from the early use of crop rotations in China, to the development of the humus theory, and finally to the time and work of Liebig and his influence on theories of plant nutrition.

Introduction

Plant growth has been both a curiosity and a source of much documentation and experimentation since the beginnings of agriculture. The "substance" of plants has been explored and debated since the time of the early Greek philosophers. The current dichotomy over the source of plant nutrients between the organic vs. inorganic fertilizer camps is not new. Democritus of Abdera (≈460–360 BC) proposed what would currently be considered as an atomic philosophy of matter:

> Mother earth when fructified by rain gives birth to crops for the nourishment of man and beast. But that which came from earth must return to earth and that which came from air to air. Death, however, does not destroy matter but only breaks up the union of its elements which are then recombined into other forms. (Browne, 1943)

This atomic, cyclic, and nonconvertible chain of elements through the soil–plant–animal system was opposed by Aristotle's (384–322 BC) mutual convertibility of the four elements: earth, water, fire, and air. Since, according to Aristotle, the material constituents of the world were formed from unions of these four elements, plants assimilated minute organic matter particles through their roots which were preformed miniatures (Browne, 1943). This concept of "organic" nutrition of plants, evolving into the humus theory of plant nutrition, held for more than 2000 years, until the time of Justus von Liebig.

The course of experimentation and thinking on the subject of plant nutrition, from the post-Greek philosopher period until the time of Liebig's 1840 monograph, is the concern of this review. Liebig's monograph laid the foundation of a plant mineral nutrient theory that was a precursor for the fertilizer N–P–K mentality of crop fertility. The use and/or abuse of synthetic mineral fertilizers subsequently became the bane of the organic farm movement.

Early investigations

The beneficial responses observed from using green manures and animal manures and the use of crop rotations on crop growth have directly influenced the development of plant nutrition theories. The earliest record of the benefits of green manures dates back to the Chou dynasty (≈1100 BC) in China (Pieters, 1927). Later (≈500 BC), Tsi gave the following advice: "They (green manures) are broadcast in the fifth or sixth month, and plowed under in the seventh or eighth month ... Their fertilizing value is as good as silkworm excrement and well-rotted farm manure" (Pieters, 1927).

King (1911) concluded from travels in the Orient, notably China, that the practice of deliberately adding organic matter to the soil dates back at least 4000 years and summarized his observations as: "This is a remarkable practice in that it is very old, intensive application of an important fundamental principle only recently understood and added to the science of agriculture, namely, the power of organic matter, decaying in contact with soil, to liberate from it plant food."

Early Roman compilations of agricultural practices that enumerated the use of organic manures and crop rotations were accumulated by the prolific agricultural observer Cais Plinius Secundus (AD 23–79), better known as Pliny the Elder (Browne, 1943). He enumerated the advantages and disadvantages of most animal manures and recommended the use of green manures (Browne, 1943). "It is universally agreed by all writers that there is nothing more beneficial than to turn up a crop of lupines, before they have podded, either with the plough or the fork, or else to cut them and bury them them in heaps at the roots of trees and vines."

Though Pliny and subsequent writers over the centuries extolled the benefits of manuring from a scientific viewpoint, little advance was made on the reasons for these benefits. Generally, the Aristotelian concept of the four elements held sway into the Middle Ages. The Middle Ages, generally, represent a quiescent period devoid of any advances in science and technology—no less in the understanding of plant mineral nutrition. Some notable exceptions to this void would have profound influences on the development of a theory of plant nutrition near the end of the Middle Ages.

Post-Middle Ages

Philippus Theophrastus Paracelus (1493–1541) gained fame as the first scientist to lecture in German, in lieu of the traditional Latin, allowing for understanding and involvement in science among lay persons, and recognition of the importance of experimentation in chemistry (Browne, 1943). More germane to plant nutrition, he initiated a new concept of plant nutrition, which was not aligned to the Aristotelian four elements. He stated:

> ... So also every vegetable of the earth must give nutriment to the three things of which they consist. If they fail to do that the prima Condita (first substance) perish and die in their three species. These nutriments are earth and rain, that is the Liquor, each of the three parts of which nourishes its own kind—sulfur for sulfur, mercury for mercury, and salt for salt, for Nature contains these, one with the others. (Browne, 1943)

A modern-day interpretation of this passage indicates that the nourishment of plants requires three principles: organic constituents (sulfur), water (mercury), and mineral matter (salt). There is even a hint at the "law of the minimum" concept of plant nutrition. Although the "three-principle" theory of Paracelus differs only slightly from that of Aristotle's four elements, it represents, as Browne (1943) points out, a "break with an outworn tradition."

The search for the true "substance" of plants and a continuance of the break with the four elements of Aristotelian theory was furthered by Bernard Palissy (1510–1589). Considered by some to be the founder of agricultural chemistry (Browne, 1943), Palissy relied on observation and experience in making practical theories for manuring: "Manure is carried to the field for the purpose of restoring to the latter a part of what had been removed ... Proceeding thus you will restore to the soil the same substances that have been removed by previous crops and which following crops will regain to their advantage."

U.S. Department of Agriculture, Agricultural Research Service, Fruit Laboratory, Beltsville, MD 20705.

The idea that the same substances will be reused by other crops would become central to the development of the humus theory of plant nutrition 200 years later. Palissy also helped to overthrow the concept of heat as important in the growth of plants. Through the ages, the heat given off by a pile of composting manure probably drew the attention of many observers. This readily noticeable trait coupled with the fire element of Aristotle was thought to be the "substance" from which plants benefited from manuring. Palissy had observed that the benefits of marl (as a soil amendment) were long term and, therefore, not explicable in terms of heat.

No chronology of the early development of plant nutrition would be complete without mention of Jan Baptista van Helmont (1577–1644) and his infamous potted tree experiment, which lasted 5 years (Browne, 1943). The experiment, in brief, consisted of growing a 5-lb willow tree in a capped, earthen vessel containing 200 lb of oven-dried soil. After 5 years, with the addition of only water, the tree weighed ≈169 lb and the redried soil just 2 oz less than 200 lb. The conclusion was that the 164-lb gain in tree weight was derived from water. Unfortunately, no mention is ever made if van Helmont weighed the water applied during the experiment's 5 years. If he had, his conclusion, obviously, would have been different. Van Helmont had performed prior experiments with combusting charcoal and found 1 lb of ash from 62 lb of charcoal. The other 61 lb consisted of the "spirit of the wood," which he coined "gas" (Browne, 1943). Had he measured the water applied and applied his spirit of the wood concept, plant nutritional theory may have been advanced by ≈100 years.

Eighty years later, the classic water culture experiment of John Woodward (1665–1728) dispelled the concept of water as the sole substance of plants (Russell, 1926). Woodward, in 1699, noted better spearmint growth in water containing garden soil than when grown in rain water, or impure water (from the Thames River).

Although van Helmont believed that the growth substance of plants was water, it was likewise known that salts were an important plant constituent. This idea was generated from the many early decomposition and distillation experiments of plant materials. Two 17th century chemists, Johann Glauber (1604–1668) and Gabriel Plattes (ca. 1600–1655), exemplify the early knowledge of the importance of salts and their relation to both manures and plant nutrition (Browne, 1943). In response to the lack of manures brought about by the havoc of the Thirty Years War, Glauber invented what may be considered the first manure substitute, or chemical fertilizer, to fill the void. He called the material "philosophic dung" or "fattening salt" and noted:

> Of this salt, which we may use instead of dung, there is great diversity, for it is prepared of Wood-ashes, of Stones burnt to Lime, and of other bodies putrefied by length of time. But the Chief of all these is Salt-petre, being the salt of Vegetables, Animals and Minerals putrefied, especially because it is endowed with a certain occult and sweet Fire. (Browne, 1943)

Glauber did not realize that this organically based "fertilizer" added N–P–K as well as lime to soils. Saltpeter (potassium nitrate) was thought to be a constituent of plants, not a nitrate source; therefore, by addition to the soil, one was adding an intrinsic part of the plant and thereby maintaining the "fatness" of the soil (Russell, 1926). The term "fatness" was coined by Plattes as the crop-sustaining ingredient of soils (Browne, 1943). He considered both the air and soil as valuable in plant nutrition: "All fruits are compounded of a double substance, the one terrestriall and the other aethereall, and for the most part, the want of the terrestriall part causeth ill successe" (Browne, 1943).

The fatness of the soil, akin to its organic component, could be removed either by crops or carried away by erosion. Rudiments of this concept of a soil's fatness can still be found today in the adage "living off the fat of the land."

Coincident with the work of Glauber and Plattes was a change in the English system of agriculture from manorial to closed farms. Not only was individual initiative greater, but newer crops allowed for more farm animals and, thus, more manure. New rotation systems, such as the Norfolk rotation (Porteous, 1960), eliminated the fallow year but included a legume crop for feed or for green manure. Green manuring with legumes became the mainstay of rotation systems in continental Europe as well. By the end of the 17th century, much debate in Germany centered on whether or not the legume crop should be harvested or turned under (Pieters, 1927).

In the late 17th century, John Mayow (1643–1679) and Nehemiah Grew (1641–1712) recognized the importance of air in plant growth, and in the New World, John Winthrop (1606–1676) promoted the importance of salt and the manufacture of fertilizer saltpeter (Browne, 1943). Grew conceptualized the root as a mouth into which entered a watery nutriment solution from the soil, along with air. The "principles" of plant growth were preformed, carried into the plant, and then filtered among the various plant parts. John Woodward, noted earlier for his classic experiment refuting van Helmont's water-only theory of plant nutrition, continued Grew's argument for preformed entry of nutriment into the plant. He further elaborated that different plants require different "corpuscles" (the preformed substances of plants) and "... that every kind of vegetable requires a peculiar and specifick matter for its formation and nourishment ... If therefore the soil, wherein any vegetable or seed is planted contains all or most of these ingredients ('corpuscles'), and those in due quantity, 'twill grow and thrive there; otherwise 'twill not grow" (Browne, 1943).

According to Woodward, the soil could be regenerated only with a "new Fund of matter" by fallowing, which enabled rain to supply a new stock, or by manuring, particularly with vegetable manures, since they would serve "for the formation of other like bodies" (Browne, 1943). Woodward's concepts of the importance of earth in the nutrition of plants were advanced by his contemporary, Jethro Tull (1674–1740). Although best known for his ideas concerning tillage, Tull believed that fine particles of soil entered the root; therefore, the finer the soil particles, via tillage, the better the growth. "And Earth is surely the Food of all Plants, that with the proper share of the other elements, which each Species of Plant requires, I do not find but that any common Earth will nourish any Plant" (Browne, 1943).

In regards to the use and nutritional value of manures, Tull ascribes their benefit to the enhanced mechanical and physical properties of the soil:

> All sorts of Dung and Compost contain some Matter, which, when mixt with the Soil, ferments therein; and by such Ferment dissolves, crumbles, and divides the Earth very much; This is the chief, and almost only Use of Dung ... This proves, that its (manure) use is not to nourish, but to dissolve, i.e., Divide the Terrestrial Matter, which affords nourishment to the Mouths of vegetable roots. (Browne, 1943)

The phlogiston period

The doctrine of the phlogiston school of early agricultural chemistry was that all substances that are changed by ignition contain a common combustible matter (Browne, 1943). The most important influence of this doctrine on plant nutrition was the general assumption that plants generated alkalis (Russell, 1961).

Advances of a plant nutrition theory during this period resulted primarily from the work of Francis Home (1719–1813). He not only recognized the importance of pot studies and plant analysis (Russell, 1961), but also added fire and oil to the list of important factors (air, water, earth, and salt) in plant nourishment:

> I join, in some measure, with all these; and assert that plants are nourished by these bodies, united with two others, oil and fire in a fixed state. These six principles together, in my opinion, constitute the vegetable nourishment. (Browne, 1943)

Oil was considered one of the "natural principles" that was introduced to earth in rain, and fire was found "in all bodies." Home's work marks one of the cornerstones in plant nutrition theory, i.e., a multitude of factors are considered to explain the nourishment of plants.

Like Home, Johann Wallerius (1709–1785) considered plant nutrition a multifaceted science. Regarding plant growth in general, Wallerius believed, "Plants derive no growth from any mineral earths ... The substances that promote plant growth must be (1) identical or analogous with substances preexisting in the plant, or (2) capable of being transmuted and combined into a nature that belongs to plants" (Browne, 1943). Therefore, humus was the "nutritiva" or source of plant food while all other soil constituents were the "instrumentalia" that assisted in making this food available (Russell, 1961).

Other notable discoveries during the phlogiston period would have profound influence on the development of plant nutritional theories. These include the discovery of O_2 by Joseph Priestly (1733–1804) and his work on the purification of air by plants and the discovery by Jan Ingen-Housz (1730–1799) that plants give off CO_2. Air, or more properly "fixed air," became the important principle of plant nutrition and, as Priestly stated, "the principle is phlogiston" (Browne, 1943).

THE HUMUS THEORY OF PLANT NUTRITION

The beginning of the 19th century coincided with the chemical revolution in agricultural science. However, remnants remained of those who believed in the Aristotelian four principles, phlogiston adherents, and transmutation power of plants. Before advancing through this period of achievement in agricultural chemistry and plant nutrition to the time of Liebig, it is worth exploring what the humus theory of plant nutrition was and how the pre-Liebig scientific community accepted or rejected this theory.

The idea that increasing soil organic matter, either by plant residues or animal manures, increased soil fertility and hence crop yields had been realized, as we have seen, for centuries. This readily verifiable role of organic matter, or humus, combined with the later question concerning the source of C for plant growth, led to the humus theory of plant nutrition. As noted earlier, Wallerius in 1761 was the first to allude to the idea that humus was the food of plants (Kononova, 1961). A half century later, Albrecht Thaer (1752–1828) is credited with formulating the theory of the humus nutrition of plants (Waksman, 1942).

Humus was considered the sole and direct source of plant nutrients. Waksman (1942) summarizes the humus theory, which had gained the support of early chemists, including Theodore de Saussure (1767–1845) and Sir Humphrey Davy (1778–1829):

> According to this theory, plants feed upon substances which are similar to them in nature. The organic matter of the soil, or the soil humus, was regarded as the chief nutrient for plants and the major source of soil fertility. The roots of the plants were believed to extract the humus from the soil and to transform it into plant substance, by combining it with water. Plant nutrition was thus considered as similar to animal nutrition, both plants and animals feeding upon complex organic bodies. As regards the function of minerals in plants, some of the protagonists of the humus theory believed that these were not essential for growth; they were believed to act as stimulants rather than as nutrients. Others looked upon minerals as mere accidental plant constituents, or as the skeleton substances of plants similar to the bones of animals.

The Modern Period

Theodore de Saussure, the eminent Swiss chemist, in his *Chemical Researches on Plants* (1804), overthrew many of the transmutation and "principle" concepts of his predecessors. As Russell (1961) stated, de Saussure's "concise and logical arguments" are refreshing compared to the "lengthy and often wearisome works of earlier writers." Among the accomplishments accorded de Saussure are the elucidation of plant respiration; the recognition that soil, not air, was the supplier of N; the realization of the active role of the root as an absorber of water and salts, not as a mere filter; the realization that ash constituents of plants all occur in humus; and debunking the idea that plants generate potash (the salt principle of his predecessors) (Russell, 1961). About 36 years later, Liebig erroneously argued that air was the source of plant N (ammonia) and that this supply limited growth.

De Saussure, however, was a defender of the humus theory. His general conclusions of plant nutrition included:

> That fertile soil contains a mixture of soluble and insoluble organic substances and that the entrance of the former into the plant through the roots is a most important aid for the nourishment which they derive from air and water.
>
> That plants obtain their nitrogen almost wholly by absorption of the soluble organic substances: direct experiment shows that they do not assimilate it to an appreciable extent in the gaseous condition ... (Browne, 1943)

Contradictory evidence for and against the concept that plants had the power of transmutation to produce the principle of growth, and controversy over the importance of organic vs. inorganic nutrition of plants, reached an interesting stage by 1838. A prize was offered in Germany for the most satisfactory answers to the questions: Do the so-called inorganic elements, which are found in the ashes of plants, occur in these plants when the exterior sources of these elements are eliminated? Are these inorganic elementary constituents so essential that the vegetable organisms have constant need of them for their complete development (Browne, 1943)? The prize was awarded to A.F. Wiegmann (1771–1853) and L. Polstroff for their conclusions from an experiment comparing plant growth in a synthetic soil vs. sand alone. They concluded, in part, "The inorganic constituents of plants can in no respect be regarded as products of their vital activity either as formations from unknown elements or as peculiar derivations of the four elements known to make up organic substances" (Browne, 1943).

In regards to inorganic nutrition and manuring, Wiegmann noted that "... the soil has been so robbed by the previously harvested crop of the inorganic materials which are necessary for plant development that another crop of the same kind (even when the ground is plowed and newly fertilized with an animal manure deficient in the necessary mineral element) is unable to find the requisite amount of plant food that is necessary for its complete development" (Browne, 1943).

Opposition to the humus theory was to come from many sides. Experiments with humus extracts led Wiegmann and Polstrof to conclude that humus plays an insignificant role in plant nutrition (Browne, 1943). Carl Sprengel (1787–1859) also ascribed little nutritive value to organic matter:

> The conviction should have been reached long ago that humus is not such an important substance as we have been led to believe and that the current doctrine of humus (the humus theory) is exceedingly full of contradictions ... I have come more and more to the conviction that plants can entirely dispense with it (humus). (Browne, 1943)

Sprengel supported de Saussure's opposition to the old theory of transmutation of mineral elements by plants and suggested that the mineral elements of plants are derived from without. The supply of mineral elements depends on the chemical composition of the soil. Much work by Sprengel involved classifying fertilizing materials (Browne, 1943). He separated organic fertilizers from mineral materials such as lime, clay, and a host of salts. These and other details of Sprengel's writings, such as those on the effects of minimum and maximum factors on the growth of crops, led Browne (1943) to conclude that "... Sprengel should always be remembered as the one who paved the way for Liebig ..."

Among the last eminent pre-Liebig scientists was Jean-Baptiste Boussingault (1802–1887). Boussingault's most significant impact on plant nutrition was his initiation of the first series of field experiments (Russell, 1961). Boussingault and his contemporary Gerardus Mulder (1802–1880) were both proponents of the humus theory of plant nutrition.

In 1840, the Chemical Section of the British Association for the Advancement of Science requested a report on the state of organic chemistry (Bradfield, 1942). The invitee was Justus von Liebig. The opening paragraph of his *Organic Chemistry in its Application to Agriculture and Physiology* would define organic chemistry, and, according to many, the rest of the text would have dramatic implications on the practice of agriculture and plant nutrition. The opening paragraph states, "The object of organic chemistry is to discover the chemical conditions essential to the life and perfect development of animals and vegetables, and generally to investigate all those processes of organic nature which are due to the operations of chemical laws" (Bradfield, 1942).

Justus von Liebig

Justus von Liebig (1803–1873) was recognized as one of the most distinguished chemists of his day (Fig. 1). His combined activities as investigator, editor, teacher, and writer were unequaled during his career (Browne, 1942). His theory of the mineral nutrition of plants has dominated the thinking of most students of soils and plant nutrition. Moore (1947) perhaps presents the best condensed interpretation of Liebig's theory: "The soil was a sort of reservoir from which man could take out no more than he put in."

Two important plant nutrition-related controversies were broached by Liebig: the controversy concerning the source of C and that concerning the source of N in plant nutrition.

The humus theory held that humus was the source of C. Liebig argued, in a typical scathing attack on his contemporaries and predecessors, that prior experiments on humus as the C supplier "... are considered by them as convincing proofs, whilst they are fitted only to awake pity" (Russell, 1961). Liebig claimed that plants had an inexhaustible supply of carbonic acid in the air. According to Liebig, humus was primarily a source of CO_2 from decomposition, but the role of this CO_2 was to aid in the solubility of inorganic soil constituents (Kononova, 1961). An additional benefit of this humus-derived CO_2 was the increased absorption by leaves as it diffused from the soil (Waksman, 1938).

Later, however, Liebig does attribute one role of humus as a C supplier to plants, but in a nonhumus-theory form, e.g., humus in an altered state. "Humus does not nourish plants, by being taken up and assimilated in its unaltered state, but by presenting a slow and lasting source of carbonic acid which is absorbed by the roots, and is the principle nutriment of young plants at a time when, being destitute of leaves, they are unable to extract food from the atmosphere" (Waksman, 1942).

Liebig seems to waver as to the role of humus as the source of plant C. His opinion that humus per se was not assimilated by plants was "proof" that the humus theory was not valid.

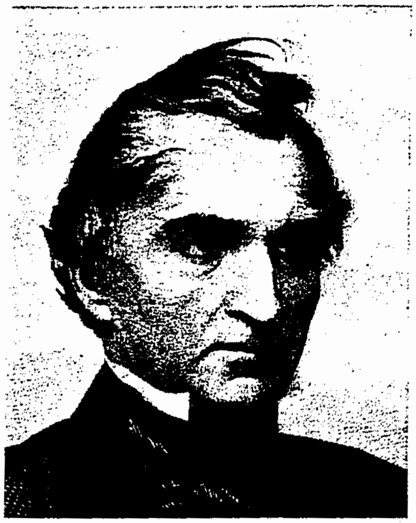

Fig. 1. *Justus von Liebig (1803–1873).*

Similar vacillations by Liebig can be found on the topic of the source of plant N. Liebig maintained that atmospheric ammonia, not humus-derived N, was the source of plant N. However, Liebig's stance on this important question is of interest. In his original monograph, Liebig states, "Cultivated plants receive the same quantity of nitrogen from the atmosphere as trees, shrubs, and other wild plants; but this is not sufficient for the purposes of agriculture" (Browne, 1943).

In subsequent editions, the last portion of Liebig's statement was changed to read "... and this is quite sufficient for the purposes of agriculture ...," a change that was to have a profound impact (Browne, 1943). What caused Liebig to alter this most important sentence is not known. Liebig was intrigued by the problem facing the colonists in Virginia, who, after a century of wheat and tobacco production without the addition of manure, were now abandoning their lands. He ascribed this development to the century-long drain on the mineral elements in the soil, not to insufficient N or a reduction in soil humus. This conclusion was consistent with Liebig's concept of an atmospheric source of plant N.

Liebig did recognize, however, that animal manures were important sources of N (Bradfield, 1961). He had experimented with cow manure (low in N) and human urine (high in N) and reported more favorable gluten production from wheat grown from the latter amendment. Three pages later in his monograph, Liebig notes the following, which probably could be found among the pages of many present-day organic magazines: "It should be the care of the agriculturalist so to employ all the substances containing a large proportion of nitrogen, which his farm affords in the form of animal excrements, that they should serve as nutriment to his own plants" (Bradfield, 1942).

Liebig's theories on the atmospheric source of ammonia-nitrogen for plant growth led John Lawes in 1843 to establish the now infamous Broadbalk Field wheat experiment at Rothamsted (Russell, 1926). These experiments showed the value of phosphates and alkali salts, which Liebig had emphasized, but they also vividly showed Liebig's mistake in relying solely on an atmospheric source of N. The initial studies led Lawes to formulate a "patent manure" consisting of a mixture of superphosphate, phosphate of ammonia, and silicate of potash (Russell, 1926). A similar artificial manure was patented by Liebig (1845), but since it was based on the ash composition of plants, its use was short-lived.

Besides these observations and opinions on the current controversies of his day, Liebig also noted the relationship of plant ashes to crop requirements and that water extracts of humus yielded little or no residue upon evaporation (Howard, 1940). He espoused the concept that ash analysis would foretell which salt would need to be applied to obtain a full crop. Acceptance of this concept led to the downfall of the humus theory, since the two concepts could not coexist. However, the ash concept often is cited as one of Liebig's false conclusions in relation to the value of organic manures.

Conclusions

The evolution of plant nutrition theory has been outlined from the fundamental observations of ancient writers, who believed that manures produced better crops, to the time of Justus von Liebig, when visual observations were merged with the chemistry of the day. The mysterious heat given off from the composting of manures and the resulting brownish-black liquor provoked the curiosity of many through the ages. If we ascribe this progression in plant nutrition theory to the "scientific advancement" achieved in all fields, one also realizes that this progression was not independent of the society then in existence. Thus, Glauber's salt, one of the early saltpeter mineral fertilizers, was not only the product of his scientific endeavor but also a reaction to the devastation of the Thirty Years War. Similarly, in Liebig's time, according to Sykes (1949) in England, the establishment of artificial manures was not only due to Liebig's theories but also helped "... by the decline in agricultural technique; by the necessity to reduce agricultural costs; and by the influences, everywhere in evidence, which were compelling the farmer to get more out of the land, to put less into it, and to diminish costs at every turn."

Nor does the progression of a theory necessarily produce a perfect correlation with truth. The abstract notion that plants contained a "force" or "creative power" to transmute substances was finally toppled by Liebig. However, although Liebig knew of the benefits of manures from a N standpoint, he opted, erroneously, for a purely atmospheric origin for plant N. The fact that Liebig was a "compiler and summarizer" of the importance of mineral nutrients placed his mineral element theory on an unsound foundation (Marschner, 1986). However, this became the primary reason for the work of Lawes and many other scientists to follow.

Twenty years after the publication of Liebig's monograph, the science of microbiology began to flourish (Waksman, 1938); after another 20 years, Darwin published his study on the effects of earthworms (Darwin, 1976). Studies in soils and plant nutrition would no longer be considered in the context of an abiotic system. The dynamic nature of soil and the role of humus as a microbial media were not and could not be envisioned in Liebig's day.

Epilogue

Given the state of knowledge during Liebig's career, one would be hard-pressed to accept his summations as the harbinger of doom for the world's production of food and fiber via the route of the chemical fertilizer industry. Current plant nutrition theory recognizes the ionic uptake of nutrients from the soil through the root. Selectivity exists and varies between plant species as to which elements are taken up and to what extent. However, this occurs independent of the source of the nutrients, either synthetic or organic fertilizers.

What then is the controversy between synthetic chemical fertilizer and organic fertilizer users? Ultimately, if the plant uses N from dried blood or ammonium nitrate in a similar fashion, why should one be a better approach? The arguments, pro or con, run the gamut from a concept of a "living earth" to economics and human health. Many of the contentions between the organic and chemical fertilizer proponents are not germane to plant nutrition per se. However, there are several points that have direct bearing on plant nutrition. Included among these are nutrient concentration and release rate, a dead vs. a living system, and economics. Numerous citations on the abuses and the benefits (albeit short term) of chemical fertilizers can be made. Research on slow-release fertilizers, fertilizer placement, split applications, and the like are examples of a desire to maximize nutrient uptake with a concurrent increase in yield. However, concepts such as using fertilizer as "cheap crop insurance" on high-value crops are abusive.

According to Balfour (1947), Liebig's theory of mineral plant foods was a "rather naive theory" since it considered only mineral salts. As noted earlier, a concept of a dynamic, living soil was beyond the scope of Liebig or any of his contemporaries. It is, perhaps, more unfortunate that, even today, this view is still held by many.

The driving force behind the acceptance or rejection of the mode of providing nutrients to the plant was, as with the advent of Glauber's salt, and is economics. Turning the economic wheel in either direction may not be the role of those wearing the cap of plant nutritionist, but we can hope future roads may be paved that lead to an enhanced appreciation of the dynamics underlying the nutrition of plants.

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Sir Albert Howard and The Indore Process

David R. Hershey

Additional index words. compost, history, organic agriculture

Sir Albert Howard (1873–1947) (Fig. 1) is considered to be one of this century's most important advocates of organic agriculture (Conford, 1988). Born in England, Howard received advanced education at Wrekin College, Royal College of Science, South Kensington, and St. John's College, Cambridge. He was employed as a lecturer in agricultural sciences at Harrison College, Barbados, in 1899. From 1899 to 1903, he was a mycologist and agricultural lecturer in the Imperial Dept. of Agriculture for the West Indies. He subsequently served for 2 years as a botanist at the Southeastern Agricultural College, Wye, England. His most important work occurred in India where he was the imperial economic botanist to the Indian government from 1905 to 1924 and director of the Institute of Plant Industry, Indore, from 1924 to 1931. His first wife Gabrielle Matthaei, whom he married in 1905, died in 1930; he married her younger sister Louise in 1931. Both his wives were capable agricultural scientists. Howard was knighted in 1934 for his contributions to Indian agriculture (*Times of London*, 1947).

Howard is remembered not so much for his extensive and sound scientific work, but more for his popular writings, which supported controversial viewpoints involving organic agriculture and criticisms of the agricultural research establishment. His book *An Agricultural Testament*, published in 1940, summarized most of these concepts along with many of his research experiences. Howard acquired his reputation as an organic agricultural extremist due largely to his exaggeration of fundamentally sound ideas.

Soil and health

A key idea advanced by Howard was that plant and animal diseases were due to unhealthy soils (Howard, 1943). This idea went beyond the

Assistant Professor.

Department of Horticulture, University of Maryland, College Park, MD 20742-5611.

Fig. 1. *Sir Albert Howard.*

scientifically sound relationship that soils deficient in one or more elements essential for animals, but not for plants, may produce crops unhealthful for animals. Howard's idea was that any plant, animal, or human disease was caused by unhealthy soil, and that if the soil was made healthy by organic techniques, there would be no diseases. This extreme, if not preposterous, view still is embraced by some proponents of organic agriculture. Despite his scientific background and the lack of scientific data to support such a total cause-and-effect relationship between soil health and disease, Howard championed this theory using testimonial and circumstantial evidence. For example, the extraordinary health of the Hunza people, who practiced a primitive type of organic agriculture in the Himalayas, was attributed to their organically grown food (Rodale, 1948). Other factors, such as their heredity, active lifestyle, and environment, were not considered, and a cause-and-effect relationship between organically grown food and health was simply assumed. Howard did participate in studies where human or animal health and disease resistance improved dramatically when diets were supplemented with organically grown produce rather than with chemically fertilized produce (Rodale, 1948). These studies apparently lacked a control treatment, since there was a complete switch to organically grown produce. Despite the lack of sound data, Howard provided the organic agriculture cause a strong advocate, because his stature as a scientist lent credibility.

Agricultural research establishment

Some of Howard's strongest criticisms were aimed at the agricultural research establishment. Many of his criticisms appeared valid then and still seem valid today. For example, he questioned the need for the bloated bureaucracy that controlled agricultural research, the excessive paperwork, the extreme specialization of agricultural researchers, the overuse of statistics, the emphasis on maximizing agricultural profits rather than on sustainability, the separation of science and practice, and the emphasis on "learning more and more about less and less" (Howard, 1943). Howard believed that individual investigators should receive broad interdisciplinary training and be given resources and freedom from administrative constraints so that they could tackle whole problems on their own, rather than give each specialist a small piece of the problem.

One of Howard's most notable attacks was on the "NPK mentality" in agricultural research (Howard, 1943). He criticized Liebig's overturning of the humus theory of plant nutrition, because Liebig had little knowledge of practical agriculture. As he often did, Howard exaggerated his valid point that too often scientists simply focused on soil chemistry, with fertilizers as the cure-all for agricultural problems, rather than also consider soil biological and physical properties. His experiences in India demonstrated that soil physical properties often could be the major reason for crop failures.

Reputation

These very negative and scientifically flawed attacks ruined Howard's stature in the scientific community but made him a hero to many nonscientists, especially organic agriculture proponents. This loss of his scientific reputation is unfortunate, because an examination of his scientific work reveals that Howard was a most capable and highly productive scientist. He was a good example of his ideal—that agricultural scientists should be generalists and work closely with the land and the practical world of agriculture. In fact, when he first arrived in India as imperial economic botanist, he was supposed to do laboratory work only. However, he insisted that he be given a plot of land so he could grow plants (Howard, 1954).

His unscientific attacks in *An Agricultural Testament* are not reconcilable with his work as a scientist. Rather, they were the views of Howard the crusader, who probably intentionally exaggerated the arguments to convince people to adopt his views. Howard believed that loss of soil fertility seriously threatened the future of agriculture and that recycling organic materials via composting was necessary to avoid an agricultural catastrophe. While most would agree that agriculture is still strong more than 40 years after his death, society now is moving closer to many of his views on agricultural sustainability and composting. Composting is becoming increasingly important as a partial solution to solid waste disposal problems, and public paranoia about pesticide safety and pollution caused by fertilizer and pesticide runoff is leading to a reexamination of organic and sustainable agricultural techniques.

Howard's harsh criticisms of the scientific establishment of his time resulted from a lifetime of frustrations with the bureaucratic inertia and ineptitude that hampered him throughout his career. Howard's seemingly deliberate exaggeration of the benefits of organic agriculture could be viewed in the most charitable light as a tactic in his fight to have composting techniques adopted. Howard's target audience was not the scientific community but farmers and everyday citizens who did not understand science. His exaggeration cannot be condoned, despite the fact that it is a standard procedure in politics and advertising.

Howard should not be considered an organic extremist in the mold of Rudolph Steiner and his biodynamic agriculture, which contends that manure rotted inside a buried cow horn has magical properties (Thompkins and Bird, 1989). In fact, Howard clearly stated that he did not believe Steiner's bizarre theories (Howard, 1943). Rather, Howard probably belongs in a class by himself, since he was an accomplished scientist and effective crusader for composting and the natural maintenance of soil fertility.

Indore Process

The Indore Process was Howard's name for the composting process he developed in Indore between 1924 and 1931 (Howard and Wad, 1931). Composting was not invented by Howard, nor was he the only composting advocate of his day. The widespread use of composting in Chinese agriculture greatly impressed Howard (King, 1926). When Howard arrived in India, however, plant wastes often were burned, and much of the animal manure was dried and used as fuel. Since fertilizer was too expensive for most Indian farmers, Howard advocated composting of organic wastes as a source of plant nutrients and for improving soil properties.

The Indore Process is not greatly different from modern composting processes. Plant wastes, animal manure, limestone or wood ashes to neutralize acids produced during decay, water, and air were the necessary ingredients (Fig. 2). Plant stalks often were laid in the roadway so cart traffic would crush them into small pieces, which would compost more readily. Urine earth (soil that had absorbed livestock urine) was crushed in mortar mills. The preferred method was to make compost in pits $30 \times 14 \times 2$ ft deep, but in the rainy season pits could not be used. The piles were turned and moistened periodically; these are still typical practices.

The Indore Process became well known because Howard promoted it extensively. A large-scale composting facility was established at the experiment station at Indore, and optimal composting methods were developed after extensive research. Courses were set up to certify people in composting so that they could instruct others. Howard's publications on composting were circulated widely, and the Indore Process was adapted for use in a wide variety of climates and crops, even for English town wastes.

Other research work

Besides composting, Howard worked on a wide array of agricultural problems, including wheat and tobacco breeding, mycorrhizae, root system distribution, irrigation, soil aeration, plant competition, weeds, plant disease, fruit tree cultivation, budding, fruit transport, and human disease. One of his greatest economic successes was in breeding the superior 'Pusa' strains of wheat, which by 1925 were planted on at least 7.5 million acres in India. These wheat strains were not only superior in yield, but also of much greater quality for milling and baking than previous Indian wheat varieties. The economic impact was substantial, since the 'Pusa' wheat sold at a premium price and, unlike previous Indian cultivars, was of adequate quality for the export market.

Trees and grass. One of Howard's most notable studies examined the effect of grass on fruit trees and was published in the prestigious *Proceedings of the Royal Society* (Howard, 1925). Howard grew eight fruit tree species—custard apple, mango, peach, plum, lime, guava, litchi, and loquat—in plots with and without grass. Yields were measured, annual root growth patterns determined, soil CO_2 content measured, root systems excavated down to 20 ft, and the effects of aeration trenches examined. General conclusions were that grass greatly inhibited tree growth and that the lack of soil O_2 under grass appeared to be an important cause of the decrease in growth in all but one species.

Soil diseases. Howard used the term "disease" very loosely, applying it to all types of soil problems, including erosion, formation of alkaline soils, and low soil aeration (Howard, 1943). His discussion of erosion and alkaline soil problems was in keeping with accepted theories, and he cited such well-known authorities as Hilgard. Poor soil aeration was a major problem in India. Howard solved this problem with a variety of low-technology methods, including incorporating potsherds into the soil, adding compost, and using deep-rooting plants as natural soil aerators (Howard, 1954).

Lathyrism. One of his most intriguing research projects involved lathyrism, an incurable paralytic disease associated with the consumption of *Lathyrus sativus*, a pulse (Howard, 1954). Although a serious problem, 45 years of research by numerous scientists had not revealed a solution. In 1921 Howard was asked to grow *Lathyrus* for Indian medical studies on lathyrism. He quickly solved the problem simply by his routine standard of using pure seed in research, which necessitated hand removal of all weed seed. *Lathyrus* seed was nearly always contaminated with seed of *Vicia sativa angustifolia*, a persistent weed. *Vicia* seed was nearly identical to pulse seed. The pure stands of *Lathyrus* that Howard grew caused no disease when eaten, and scientists quickly identified a toxic alkaloid in the *Vicia* seeds grown in Howard's pure stands. Howard also provided a low-technology solution for peasant farmers—sow *Lathyrus* in rows rather than by broadcasting, so *Vicia* seedlings could be identified easily and pulled before they set seed. Howard's rapid and simple solution to this long-standing problem was a tribute to his ability and gave him another example of what he considered to be the general ineptitude of much of the scientific research of his era.

Spike disease. In 1915 peaches exhibited spike disease, which is characterized by leaf drop, stunting, and, eventually, death. Everyone assumed the disease was caused by a pathogen. However, Howard carefully studied the trees and found that the problem was one of faulty budding that resulted in a poor union of stock and scion. Howard considered the supposed pathogen as a lazy way to explain a problem (Howard, 1954).

Fruit transport. One of the most vexing problems Howard solved dealt with improving the shipping of fruit by railroad in India. The original situation was chaotic and inefficient. Fruits were packed in whatever container was available. Most containers lacked ventilation and did nothing to prevent bruising. Fruits often where packed with wet leaves, which promoted fruit decay, and the railroads charged not by total weight, but individually based on the size and shape of each container. After years of battling bureaucratic inertia, Howard convinced the fruit industry and the railroads to adopt a uniform system of reusable packing containers and a reasonable system of assessing shipping charges (Howard, 1954).

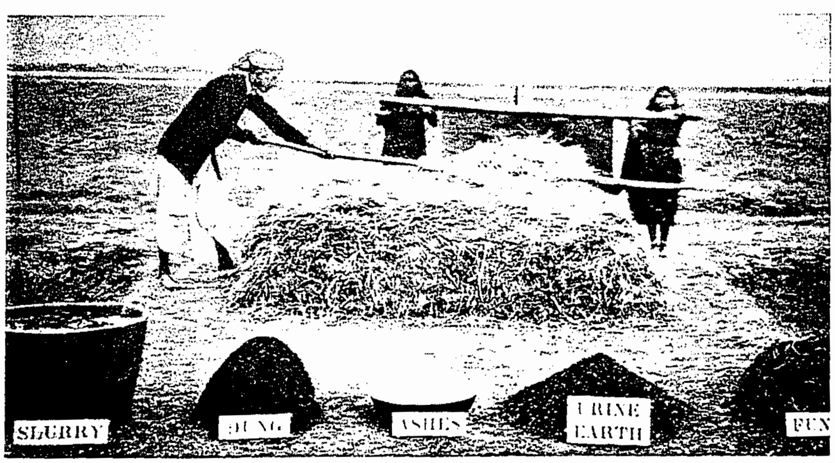

Fig. 2. *Indian compost-making in the rainy season when the pile had to be formed on top of the ground rather than in a pit.*

Conclusion

Howard was an extraordinarily capable agricultural scientist who made many advances for agriculture in India during the first third of the 20th century, including promoting modern systems of fruit cultivation, composting, irrigation, and soil aeration and developing genetically improved wheat and tobacco cultivars. Often overshadowing these accomplishments were his writings at the end of his career on the ideal of recycling all organic waste materials by composting to maintain the "health" of the soil. While this concept of composting plant and animal wastes and the use of compost to improve soil fertility and structure is fundamentally and environmentally sound, Howard went beyond established fact to embrace the idea that all plant and animal diseases were due to "unhealthy" soils. He also made several extreme criticisms of the contemporary agricultural research establishment, which, in retrospect, were unjustified. Yet, most of Howard's controversial writings, such as *An Agricultural Testament*, were generally scientifically sound and logical. Unfortunately, several ideas relating to soil health and disease, exaggerated beyond logic, ruined Howard's scientific reputation and marked him as an organic agriculture extremist.

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Rodale Press and Organic Gardening

William C. Kelly

Additional index words. J.I. Rodale

Agricultural opinions in the United States drastically changed following the economic collapse of farming in the late 1920s and the dust storms and the exodus of farmers due to the Dust Bowl in the 1930s. Many thought agriculture had failed and new methods of farming must be found. The most successful new system of agriculture was the establishment of the Soil Conservation Service (SCS), with Hugh H. Bennett as its chief. Bennett was a forceful, charismatic speaker who caught the imagination of the agricultural community and, especially, college students and young farmers. SCS had dramatic success on the highly erodible soils in the southern United States. Terracing, strip cropping, and rotations together with lime and superphosphate reclaimed abandoned farmland. A familiar "before and after" picture was a nondescript cow in a pasture with three hoof–soil contacts visible and a Hereford standing knee-deep in clover. Obviously, that could not happen in 1 year, but it actually did happen over several years. The Tennessee Valley Authority (TVA) pilot farms were important in promoting lime and superphosphate. The key to the success was preventing erosion and rotating crops with a legume. Raising the pH and supplying phosphorus ensured good stands of legumes.

One popular conclusion from the success of the SCS programs was that improving the soil not only increased the carrying capacity of the pastures but also improved the nutritive value of the forage. W.A. Albrecht, Head of Soils, Univ. of Missouri, was a leading voice in promoting the idea that improving the soil by fertilization and increasing the organic matter improved the nutritive value of forage. In fact, the conclusion that soil fertility was an important factor in the health of animals and humans was so widely accepted that the U.S. Plant, Soil, and Nutrition Laboratory was established in 1941 as a U.S. Dept. of Agriculture (USDA) Regional Laboratory at Ithaca, N.Y. The mission of the laboratory was to study the soil–plant–animal relationship as it affected the health of animals and humans.

Fruit and Vegetable Science Department, Cornell University, Ithaca, NY 14853.

Agricultural critics

E.H. Faulkner's book *Plowman's Folly* appeared in 1943, condemning the moldboard plow as the cause of all agricultural misfortunes. He argued that crop residues should not be buried but allowed to remain on top of the soil to prevent wind and water erosion. The claim was made that decreases in soil organic matter had led to increases in San Jose scale, Colorado potato beetle, and various new insect pests and plant diseases. The book was a national best-seller and received much publicity in the press.

Also in 1943, Louis Bromfield published *Pleasant Valley*, a somewhat romantic account of his 3-year farming experience in Ohio. He was a well-known novelist and essayist who returned from France in 1940 to his home state and bought three adjacent farms. Bromfield was an active promoter of SCS methods and embraced most of Sir Albert Howard's ideas, as well as those of Faulkner. He rejected Howard's composting system because of the labor involved. Bromfield drew much more attention when he published *Malabar Farm* in 1948. This book documents the experiences on the farm since *Pleasant Valley*. He stressed soil conservation, rotations, and tillage equipment as well as the importance of soil organic matter in the production of nutritious feed and food. Malabar Farm attracted many visitors and received national coverage in the newspapers and magazines.

The most influential person on agricultural systems turned out to be the most unlikely individual imaginable—one without any agricultural training or experience. J.I. Rodale (1898–1971), born in the lower east side of New York City as Jerome Irving Cohen, was known to friends and associates as J.I. (Fig. 1). Raised in the city, he was sickly as a youngster, had poor vision, and was nonathletic. He studied and tried several body-building systems, especially those of Bernarr McFadden, who also promoted a healthy diet and moderate exercise. Rodale went to night school to study accounting and became a federal income tax auditor. Later, he and his brother began manufacturing electrical supplies, and during the Depression, they moved the plant to Emmaus, Pa. J.I. wanted to be a writer and started publishing magazines to carry his work but met with no success (Greene, 1971; Jackson, 1974).

Sir Albert Howard's 1940 book *An Agricultural Testament* had little impact on the U.S. agricultural community, but Rodale became a zealous believer in Howard's philosophy and farming system. He bought a farm to practice the system and started a magazine in 1942 entitled *Organic Farming and Gardening* with Howard as an associate editor. One-thousand copies of the first issue were mailed to farmers to solicit subscriptions,

Fig. 1. *J.I. Rodale (1898–1971).*

with only 10 takers, but Rodale persevered. He soon learned that gardeners were easier to influence than farmers, and the magazine's name was changed to *Organic Gardening*; it became profitable after 16 years.

The agricultural academic community rejected the organic gardening concepts and vigorously discounted Rodale's claims. The extreme polarization of the two groups slowly began to soften only after 25 years.

Organic gardening

Because J.I. was such a good promoter, public awareness of his ideas far exceeded that which would be expected based on the circulation of the magazine. Outrageous claims (at least to horticulturists) were made about human health and plant diseases and insect pests. For example, Rodale claimed that the increase in cancer deaths after 1945 was caused by an increase in fertilizer use, while ignoring the fact that life expectancy also increased during that time. He contended that organically grown vegetables had more vitamins than those grown with chemical fertilizer, in spite of scientific evidence to the contrary.

The U.S. Plant, Soil, and Nutrition Laboratory could have been an important ally for Rodale, since the mission of the laboratory was to study the soil–plant–animal relationship. An early study investigated W.A. Albrecht's claim that lime and phosphate increased the nutritive value of forage. Unfortunately, this was not true, because the fertilization changed the botanical composition of the forage by promoting the growth of legumes. The nutritive value of the grass did not change with fertilization nor did the legume, just more legume was produced, and legumes are much more nutritious than grasses.

Other studies found that soil and mineral nutrition had little, if any, effect on the vitamin content of vegetables. The vitamin C content of fruit and leaves was influenced by the amount of light falling on the plant part. The age of the plant part, storage conditions after harvest, and sunlight were by far the most important factors affecting the vitamin content of plants. Studies that found a close relationship of soil and human health involved cobalt, iodine, and selenium—elements that are not essential for plant growth.

The agricultural community was proud of the large increase since 1945 in production per acre and per hour of labor made possible by fertilizers and pesticides. To reject all the advances in production and adopt a labor-intensive system such as organic gardening was unthinkable to farmers and agricultural scientists.

Rodale Press continued the magazine and published many books on organic gardening, including two encyclopedic treatises on organic gardening and composting. *Prevention*, a health-related magazine, was started in 1950 to expound the organic philosophy. In 1960 both magazines had a circulation of ≈260,000; by 1980 *Organic Gardening* circulation had grown to 1,300,000 and *Prevention* to 2,400,000.

One cannot accurately explain all the factors involved in the increased popularity of Rodale Press publications. The exodus of the people from cities to the countryside was probably the major factor until the mid-1960s. Space was available for gardens, and home gardening became an important hobby. These new gardeners were suspicious of pesticides and used organic methods with enthusiasm. There is no doubt that the vegetables they grew were much better than those bought in the supermarket, but not necessarily as a result of their growing technique.

The great increase in subscriptions came after 1965 when young people started their anti-establishment social revolution. A part of that revolt was a rejection of technology (at least some) and a return to the simpler life, including growing one's own food. For those with a romanticized view of farming, growing food was a bitter disappointment. Most were unaware of the USDA Cooperative Extension Service, and those that contacted the extension service would reject it as being part of "the establishment." These "homesteaders" came to rural counties because of cheap land and were not welcomed by conservative farmers. Cooperative Extension personnel feared they would be overwhelmed by these new people and could not serve commercial farmers satisfactorily.

Organic Gardening magazine and Rodale Press books became the major source of information for this new group of gardeners. Horticulturists have a jargon that can be baffling to someone with no agricultural background. We believe that our home-garden bulletins are simple and easy to understand, but perhaps this is only true for someone who has gardened or has been around gardeners. Rodale Press publications are written by writers with no agricultural background. They write in a clear, easy-to-read, positive, and enthusiastic manner. "You can be successful" was the underlying theme in all of the publications. In contrast, horticulturists usually insist on warning readers about possible failures if directions are not followed exactly in the use of fertilizers and pesticides.

Rodale always stressed that organically grown food was healthy, and that idea reinforced another tenet of the subculture: the virtue of simple, unprocessed food. One cannot conclude that Rodale Press caused young people to reject the establishment, but Rodale Press certainly profited from the anti-establishment ethos.

Horticulture and the environmental movement

The changes wrought by the decade of the 1960s also had an impact on Colleges of Agriculture, especially in the plant sciences. We experienced an explosion in enrollment in horticulture courses during the 1970s, but these declined in the 1980s to previously normal enrollments by 1990. Over time, the polarization between land-grant colleges and Rodale Press decreased to the extent that a few organic gardening courses began to appear about 1970, serving mostly students who were not in the applied agricultural departments. J.I.'s son Robert (Fig. 2) had been president of Rodale Press since 1954. He became the principal spokesperson for *Organic Gardening* in 1971 after his father died while being interviewed on the Dick Cavett television show. Since the organic philosophy was firmly established, Robert used reason rather than frontal attack to promote his ideas. Robert died tragically in 1990 in an automobile accident while touring the Soviet Union.

The circulation of *Organic Gardening* began to decline after 1980, partly because of fewer new gardeners. Young people were no longer interested in plants and gardening. Also, the format of *Organic Gardening* magazine was changed to attract a new audience. It began to emphasize landscaping and home beautification with less space devoted to traditional gardening. There was a precipitous drop in circulation among its traditional audiences and little increase in new readers. The magazine then was changed back to its original format, emphasizing growing fruit and vegetables the organic way. The circulation rebounded and reached 600,000 in 1991.

The organic movement in the United States, although part of a long tradition, owes its impact on the American consciousness to the ebullient personality of J.I. Rodale, the "apostle of nonconformity." His is a well-known American story of a man who broke the bonds of a traditional immigrant family to pursue an incredible career as tax expert, entrepreneur, publisher, farmer, editor, linguist, and playwright. He became a scourge of the medical and agricultural establishment, taking on land-grant universities and experiment stations as well as the Federal Trade Commission and the American Medical Association, whom he fought successfully in legal battles. Although many of his ideas were outrageous, he became a "secular prophet" in his own time based on his prescient support of good nutrition as a source of health and well being, combined with hostility toward agricultural dependence on fertilizers and chemicals.

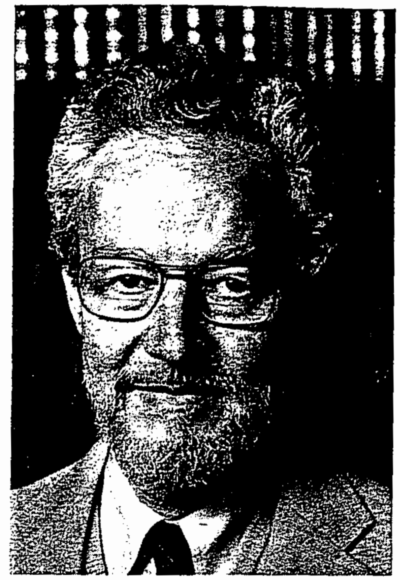

Fig. 2. *Robert Rodale (1930–1990).*

Horticulture always has been in a state of change and is usually in the forefront of adopting new technology. We must occasionally stop and consider where we are going. There is a segment of the population convinced that organic gardening is the only way. Rather than disenfranchise them again, we must provide them with educational services. After all, we do know plant science and can provide scientific information without confrontation. Organic methods are labor-intensive and very difficult for intensive vegetable culture, but that is the grower's decision, not ours. We must learn from each other. Who knows what the future holds?

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Rachel Carson, *Silent Spring*, and the Environmental Movement

Caula A. Beyl

Additional index words. pesticide, DDT, organic movement, organophosphates

Almost 30 years after its publication, the book *Silent Spring* (Carson, 1962b) is instantly recognized, evoking ominous images of DDT, bird and fish kills, and pesticide danger. The book can still galvanize reaction in readers and engender controversy.

Carson's message was delivered in a vivid, beautiful, and effective style, and the book's credence was enhanced by Carson's substantial reputation as a scientist and a writer. Also, the book arrived soon after the tranquilizer thalidomide was revealed to cause birth defects, adding to *Silent Spring*'s impact (Brooks, 1970; Eiseley, 1962). Carson did what few authors have been able to—she tied the diverse facets of information about pesticide abuse and ubiquitous exposure, biological magnification, and environmental impact into one story that was eminently readable and understandable by a general public not steeped in science. The first chapter, "A Fable for Tomorrow," much-criticized because it was a fictional account resembling a Gothic tale, tells of a town where "all life seemed to live in harmony with its surroundings" (Carson, 1962b). Then a "strange blight" falls upon that town and the countryside "famous for its abundance and variety of its bird life." The description of the blight and its effects gripped the reader in a way that no cold, calculated recitation of fact could. The unfolding of omnipresent danger compels attention to the message. When she wrote *Silent Spring*, Carson had no illusions about what the book could accomplish. When the manuscript was almost finished, she wrote to a close friend, "It would be unrealistic to believe that one book could bring a complete change" (Brooks, 1972). She herself failed to anticipate the enormous and enduring impact of *Silent Spring*.

Rachel Carson, the woman

Examination of Carson's early life does not indicate she was the type of person to take on the mantle of crusader. Born in Springdale, Pa., in 1907, she was a quiet child, describing herself as somewhat solitary and having spent a great deal of time in woods and beside streams, learning the birds and the insects and flowers (Brooks, 1972). She had always intended to be a writer and published her first story at age 11. While preparing in college for a writing career, Carson changed majors from English to biology after taking a required biology course, even though she was warned that "there was no future for women in science apart from teaching in high schools or obscure colleges" (Gartner, 1983) and that "science was too rigorous a field for women" (Hynes, 1989). While she was pursuing undergraduate and graduate degrees, it never occurred to her that it would be possible to combine the two areas that interested her so much—writing and biology. A fellowship for summer study at Woods Hole Marine Biological Laboratory after her undergraduate degree gave her the first chance to see the ocean (Fig. 1). She completed her master's degree from Johns Hopkins Univ. in 1932. No one reading the title of her master's thesis, "The Development of the Pronephros During the Embryonic and Early Larval Life of the Catfish (*Inctalurus punctatus*)," would guess that this is the same author who later wrote captivating best-sellers about the sea.

Her first professional position after graduation, as a part-time script writer for the then Bureau of Fisheries, led to 17 years with the Fish and Wildlife Service, culminating in the position of editor-in-chief (Gartner, 1983). It was during this time that she began writing about the sea; her first book, *Under the Sea Wind*, appeared in 1941. Although the book was reviewed favorably by the scientific community, the public was preoccupied with the aftermath of Pearl Harbor and sales were low. Carson's royalties were less than $1000, which almost convinced her that book writing was a poor financial gamble (Brooks, 1972). But her second book, *The Sea Around Us*, which appeared in July 1951, reached the best-seller list in September and was selling more than 4000 copies a day by December. Carson established a pattern, for this and future books, of releasing chapters for magazine publication before the book was published. Her third book, *The Edge of the Sea*, was released in 1955 after serialization in the *New Yorker* magazine (Brooks, 1972). The phenomenal success of her books enabled Carson to resign from her position with the U.S. Bureau of Fish and Wildlife Service in 1952 (Gartner, 1983). She received many awards, recognition, and even honorary doctorate degrees for her books. Thus, when *Silent Spring* appeared, she was not only a well-known "scientist cum author," but she had the necessary financial foundation and lack of constraints imposed by government or university ties to write with an extraordinary sense of freedom.

In the 3 years after publication of *The Edge of the Sea* and before she began work on *Silent Spring*, Carson continued to write. She produced a script about clouds for the television program "Omnibus" and an article for *Woman's Home Companion*, "Help Your Child to Wonder" (Brooks, 1972).

Silent Spring was a radical departure from her previous writings on the wonders inherent in the sea. She did not decide casually to take up the cause of pesticides and their impact on the environment, but assumed the burden rather reluctantly. In 1958 she received a letter from Olga Huckins, a former writer for the *Boston Post*, describing the devastation wrought upon insects and particularly bird life in her private bird sanctuary north of Cape Cod by an aerial spray of DDT and fuel oil for mosquito control. Huckins had hoped that Carson would be able to find someone in Washington who could help stop further mass spraying. When she was unable to get action, Carson realized that she

Fig. 1. *Carson in 1929 when she was awarded a fellowship for summer study at Woods Hole Marine Biological Laboratory. This was the year that she first viewed the ocean.*

Department of Plant and Soil Science, Alabama A&M University, Normal, AL 35762.

Fig. 2. *Carson in 1962, holding* Silent Spring. *The book dramatically changed public perceptions about the use of pesticides.*

would have to do it herself (Graham, 1970). *Silent Spring* grew from a magazine article into a full-blown book that took 4 1/2 years to write.

Undertaking a book on the topic of pesticides and the environment with particular attention to the persistent chlorinated hydrocarbons required a tremendous amount of personal courage. At that time, publicity about DDT was voluminous and overwhelmingly positive. It had the advantages of being inexpensive and easy to make (Brooks, 1970). It was not considered a hazard to human health if used with discretion (Whorton, 1974). One clipping service of an American newspaper accumulated almost 21,000 items about DDT in 18 months between 1944 and 1945 (Davis, 1971). Even though there was early recognition of the problem with DDT's persistence, accumulation in animal fatty tissues, biological magnification through the food chain, and reports of immunity developed by the common housefly (Brooks, 1970), Carson knew "that by taking up her pen to write honestly about this problem, she had plunged into a sort of war" (Graham, 1970).

She finished *Silent Spring* in spite of personal and family pressures—the adoption of her 5-year-old, grandnephew Roger Christie, the loss of her mother after a long illness, and recurring personal illnesses, including arthritis, an ulcer, staphylococcus infections, and ultimately cancer (Gartner, 1983). *Silent Spring* first appeared as an extended three-part article in the *New Yorker* (Carson, 1962a). The responses, both pro and con, were immediate and overwhelming. Even before release, Houghton Mifflin was threatened with a lawsuit because of putative inaccuracies in the representation of chlordane and heptachlor (Brooks, 1972).

Silent Spring—Action and reaction

Silent Spring became an instant best-seller (Fig. 2), remaining on the *New York Times'* list for 31 weeks (*Newsweek*, 1964). The advanced release in the *New Yorker* resulted in more than 50 newspaper editorials and roughly 20 columns (Hynes, 1989). By the time the book was published in Sept. 1962, advanced sales already had reached 40,000 copies, and by December 100,000 copies had been sold (Brooks, 1970). By the end of the year, more than 40 bills in different state legislatures had been introduced governing the regulation of pesticides use (Hynes, 1989). The book is still in print.

There were serious attacks. In the *Saturday Evening Post*, Edwin Diamond stated, "Thanks to a emotional, alarmist book called 'Silent Spring,' Americans mistakenly believe their world is being poisoned" (1963). The *New York Times* printed "She tries to scare the living daylights out of us and, in large measure, succeeds" (1962). This contrasts with what LaMont Cole, professor of ecology at Cornell, wrote in the *Scientific American*: "Errors of fact are so infrequent, trivial, and irrelevant to the main theme that it would be ungallant to dwell on them" (Cole, 1962).

Personal attacks were made on the author in an attempt to counter and diffuse the enormously persuasive case that she had built. She was labeled a "bird lover," "cat lover," "fish lover," "nun of nature," and "priestess of nature" (Graham, 1970). She was accused of "worrying about the death of cats but not caring about the 10,000 people who die daily from malnutrition and starvation in the world" (Diamond, 1963). It is true that she liked cats—her favorite often kept her company when she wrote. [Her love of cats seems hard to reconcile with her love of birds, but cats, she said, were only being "true to their own nature" (*Life*, 1962)]. Much of the personal attention focused on her being an hysterical, unmarried woman—a spinster. *Life* magazine stated that she was "unmarried but not a feminist" and quoted her as saying, "I'm not interested in things done by women or by men but in things done by people" (*Life*, 1962).

She may not have been a feminist in the classical sense of the label, but she was proud of her achievements as a woman. She was one of the first few women other than secretarial staff in the Fish and Wildlife Service (Hynes, 1989), and in 1963 she was the first woman to receive the Audubon medal for conservation achievement (Vosburgh, 1964). Many of her detractors would have liked to forget that she was truly a scientist and had received excellent training. She thoroughly researched the information used in *Silent Spring* because she wanted it to be "built on an unshakable foundation" (Brooks, 1970); it included 54 pages of references. That she was a scientist as well as an author was acknowledged in the citation on the Audubon medal (Vosburgh, 1964):

> Distinguished scientist, gifted writer,
> Sensitive and perceptive interpreter of
> the ways of nature,
> Who authored a book called SILENT
> SPRING;
> Through it she alerted and aroused the
> public about needless and dangerous
> chemical pollution of our environment
> And sounded a timely warning that
> technology, run away from science, can
> be a threat to man.

She also was accused of being biased and hysterically overemphatic (Brooks, 1972; Udall, 1964). The *New York Times* book review stated, "*Silent Spring* is so one-sided that it encourages argument, although little can be done to refute Miss Carson's carefully documented statements" (Milne and Milne, 1962). *Life* magazine said, "there is no doubt that she has overstated her case" (*Life*, 1962), but also pointed out that the case for chemical pesticides that was being aired by chemical manufacturers was just as one-sided, but in the other direction. Parodies of *Silent Spring* were written and released in an effect to counter or soften the message. One such parody was entitled "The Desolate Year" and described a bleak future without pesticides. Another called "Quiet Summer" depicted a boy and his grandfather eating acorns—as a result of lack of pesticides they had been forced to "live naturally" (Brooks, 1972). Fact kits were distributed to members of the medical profession (Brooks, 1970; Graham, 1970); one developed by the Nutrition Foundation contained copies of critical book reviews, a defense of chemical pesticides, and a letter from the president of the foundation indicating that the "book was distorted" (Brooks, 1972; Graham 1970). Their defense of chemical pesticides as they were used centered around four main points. First, that chemical sprays and other advanced technology had made possible huge surpluses of agricultural commodities. Second, that chemical pesticides had been instrumental in eliminating many diseases whose vectors were insects. Third, that while chemical pesticides did disrupt the "balance of nature," it was in favor of man. And fourth, that pesticides were safe when used properly (*Senior Scholastic*, 1962). Carson also was accused of exaggeration and sensationalism: "...what I interpret as bias and oversimplification may be just what it takes to write a best seller" (Diamond, 1963).

Was there bias? Was the implied link to cancer an oversimplification? The *Economist* accused her of making a "propaganda play" with the cancer statistics implying an "alarming" increase in cancer (1962). The implication that chemicals in the environment were the cause of cancer was implicit in *Silent Spring* without provision of a specific cause-and-effect relationship. We are now much more cognizant about the wide range of carcinogens in our environment, and many pesticides are now known to be carcinogens. It is still unclear whether Carson exaggerated the cancer threat and its link with pesticides by interpreting cancer statistics in a manner that supported her assertions, or whether she was correctly intuiting the threat. Cancer statistics are not easy to interpret if cancer death is considered apart from incidence, and the data can be obfuscated even further by making a critical examination of the statistical base used (Gartner, 1983).

Public attitudes and perceptions at that time are reflected in political cartoons that appeared in various newspapers and magazines, and Brooks' biography of Carson (1972) has an excellent collection. One that appeared in the *New Yorker* in 1963 depicts a woman standing in front of a display of pesticides in a garden store saying to the salesperson, "Now, don't sell me anything Rachel Carson wouldn't buy" (*Newsweek*, 1963).

Why did *Silent Spring* so arouse the pesticide industry and agricultural community? Many of those who attacked the work apparently did not read it carefully or did not care to report it accurately (Brooks, 1970). Diamond stated, "Nor has anyone, with the possible exception of Miss Carson, proposed to abolish pesticides" (1963). Did she advocate banning pesticides, as was stated and implied many times by those trying to minimize the book? Her feelings concerning pesticide use are best summarized on page 12 of *Silent Spring*: "It is not my contention that chemical insecticides must never be used. I do contend that we have put poisonous and biologically potent chemicals indiscriminately into the hands of persons largely or wholly ignorant of their potential for harm." In *Audubon* magazine she wrote, "We do not ask that all chemicals be abandoned. We ask moderation. We ask the use of other methods less harmful to our environment" (Carson, 1963). Countering claims that she was advocating a back-to-nature philosophy, she said, "We must have insect control. I do not favor turning nature over to insects. I favor the sparing, selective and intelligent use of chemicals. It is the indiscriminate, blanket spraying that I oppose" (Frisch, 1964). Two weeks after her death this was reemphasized in the *New Yorker*: "She was not a fanatic or a cultist. She was not against chemicals, *per se*. She *was* against the indiscriminate use of strong, enduring poisons capable of subtle, long-term damage to plants, animals, and man" (1964).

The evolution of the book's title in a sense reflects the evolution of its message, which is as much about human arrogance as it is about specifics. The tentative first title, *The Control of Nature*, became *Man Against the Earth* and ultimately *Silent Spring* (Brooks, 1970). The theme of a spring without the songs of birds was reinforced by two lines from Keats on the motto page, "The sedge is wither'd from the lake, And no birds sing." Carson believed that humanity does not stand alone and that, like all other living things, we are a part of our environment. Anything that threatens our environment ultimately threatens us. She also challenged the concept of safe tolerances, citing examples of synergism and chronic effects. She maintained that people have a right to live without being endangered by wide-scale pesticide application about which they have no choice and from which no recourse. Considering the ability of insects to develop resistance to chemical pesticides, she suggested that there are ecologically safe alternatives (many of which are commonly used today). She gave us a different view of pesticide persistence, not as an asset but as a danger. In the case of the chlorinated hydrocarbons, she pointed out that they were subject to biological magnification through the food chain. She felt that the maximum permissible tolerances established by the government gave a false sense of security and did not reflect cumulative or interactive effects. She maintained that chemical pesticides in use at that time were not selective and did not distinguish pest from beneficial. It was far better to control insects that caused diseases or destroyed crops

Fig. 3. *The Rachel Carson stamp issued in 1981.*

with methods that did not wreak havoc with the entire natural world (Carson, 1962b). It is hard to believe, looking at this from a 1991 perspective, that this message could have generated such angry rebuttal and response.

Some of the subtleties conveyed in *Silent Spring* were missed even by those who later wrote about the crucial role that Carson played in helping alert the public to the need for an environmental movement. In a footnote to the introduction to Hynes (1989), there is a description of a classic cartoon that had come out concerning Carson. The footnote states, "A grasshopper prays, 'God bless Momma and Poppa...and Carson.'" In fact, the "grasshopper" was a praying mantis, and the author missed the whole concept of protecting beneficials that was exploited by the cartoon.

The day after Carson's appearance on CBS Reports on 3 Apr. 1963 to defend *Silent Spring* against a panel of agricultural, government, and chemical representatives, Senator A. Ribicoff said before the Senate, "there is an appalling lack of information on the entire field of environmental hazards. We face serious questions, but we are woefully short of answers" (Brooks, 1972). His statement repeated the assertion on page 13 of *Silent Spring*, that "we have allowed these chemicals to be used with little or no advance investigation of their effects on soil, water, wildlife, and man himself." In her testimony before the senatorial subcommittee that stemmed from *Silent Spring*, Carson reiterated that she did not advocate abandoning pesticides but called for tighter supervision (*Newsweek*, 1963). She also called for the right of individuals to protection against pesticides applied by others, legal redress for those harmed by them, restrictions in sale and use to those capable of understanding the hazards, approval of new pesticides only if no existing methods were available, and full support to research new methods of pest control minimizing chemical pesticides.

Impact

Publication of *Silent Spring* resulted in a request to President J.F. Kennedy's Science Advisory Committee to study the problem. Their report, according to a statement published in *Science*, was a "thorough-going vindication of Carson's *Silent Spring* thesis" (Graham, 1970). The committee report criticized the federal government's eradication programs, such as those directed against the gypsy moth, fire ant, Japanese beetle, and white-fringed beetle (Greenberg, 1963). It called for improved coordination between federal agencies, immediate reduction of the use of DDT with eventual elimination as a long-term goal, echoed concerns about persistent pesticides, and raised alarm about a general nonchalance for human safety. The report exposed the loophole through which pesticides denied approval by the U.S. Dept. of Agriculture (USDA) could reach the public. If the manufacturer protested the USDA decision, the USDA was forced to grant certification, which was good for 5 years, unless the agency was able to prove the pesticide dangerous (Greenberg, 1963). This "protest registration" loophole was closed in 1964 (Brooks, 1970). The committee also called for expansion of research into specific controls, chronic effects, and synergism or potentiation of pesticide toxicity by commonly used drugs.

It is difficult to determine definitively what events directly resulted from the publication of *Silent Spring,* because by 1962 there was an awareness of the negative aspects of DDT and many of the "hard" pesticides by part of the scientific community (Hynes, 1987). DDT, which played a lead role in the book, was already under scrutiny for its ability to accumulate in fatty tissues of animals and, presumably, humans. Perhaps the most enduring effect of the book was to change public perception (Shea, 1973) of the role of pesticides from that of innocuous beneficial tools of man, having negligible costs, to a tool whose benefits may be offset by yet unknown costs. This changed perception was not confined to the United States. Carson's name and book were invoked many times before the House of Lords in England in 1963, resulting in controls on the use of aldrin, dieldrin, and heptachlor (*Newsweek*, 1964a). The book was published in France, Germany, Italy, Denmark, Sweden, Norway, Finland, Holland, Spain, Brazil, Japan, Iceland, Portugal, and Israel and stimulated environmental legislation in all of them (Brooks, 1972; Hynes, 1987).

Silent Spring was the impetus for the founding in 1967 of the Environmental Defense Fund, which later led the battle to ban DDT. The arguments used in the court hearings reflected the major points made in *Silent Spring* (Hynes, 1989). After 1962, multiple federal laws and hundreds of state laws were enacted governing protection of air and water, wildlife, and humans from the effects of pesticides, their manufacture, and disposal. The growth in federal environmental legislation was exponential (Hynes, 1989). In 1970 the Environmental Protection Agency was created with a mission to protect the total environment.

Silent Spring has been called one of the most influential books of the 20th century (Shea, 1973), and Carson was selected by *Life* magazine as one of the 100 most important Americans of the 20th century (*Life*, 1990). Unfortunately, she did not live to see anything but the immediate outcome of her work. Although she was dying of cancer, Carson did not lack a sense of humor. When queried about what she ate, she answered, "chlorinated hydrocarbons, just as everybody else does" (Graham, 1970). Even after her death in 1964 from heart disease and complications of cancer, awards and honors continued. The Rachel Carson National Wildlife Refuge in Maine containing 96% coastal salt marsh was dedicated in 1970 (Briggs, 1970). In 1980 President J. Carter awarded her the Presidential Award of Freedom accepted on her behalf by her adopted son, Roger Christie. The medal was inscribed in part, "...she created a tide of environmental consciousness that has not ebbed" (Gartner, 1983). In 1981 the Carson stamp (Fig. 3) was issued by the U.S. Post Office in Springdale, Pa., her birthplace (Gartner, 1983).

When she was asked why she did not defend her book more vigorously, she answered, "Let the course of events provide the answers" (Graham, 1970). Time has proven that she was as much prophet as writer and scientist. *Silent Spring* was a landmark event stimulating the growth of the environmental movement. How different this is from the prediction made by White-Stevens at the Synthetic Organic Chemical Manufacturer's Assn. in 1962: "On the whole, her book will come to be regarded in time as a gross distortion of the actual facts, essentially unsupported by either scientific experimental evidence or practical experience in the field" (Van Fleet, 1963). In 1972 a newspaper editor wrote of Carson, "A few thousand words from her and the whole world took on a different direction" (Murphy, 1991). There is hardly a newspaper or magazine now that does not reflect this increased environmental awareness in some form on its pages.

One wonders what Carson would choose to write about now.

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The Organic Farming Movement in Europe

Silviero Sansavini[1] and Joerg Wollesen[2]

Additional index words. history, regulation, organizations, systems, research

Introduction

Organic farming is a topic of marked interest in Europe today. The term "organic farming" is currently used to indicate those methods of crop and livestock production that seek to reduce outside energy inputs (some proponents would even include modern technology) as much as possible and to eliminate synthetic chemicals from the agricultural ecosystems. The aim is to reestablish an integral bond of agriculture with nature. The roots of the organic movement are ancient (see R.F. Korcak's paper in this Workshop), but the current reformulation is traceable to events initiated in Europe during the first half of the 20th century. These include the principles of biodynamics as embodied in the Anthroposophical Society founded by Rudolf Steiner of Austria in 1912, which currently operates through an international foundation called "Demeter"; biological farming (based on organic and microbiological concepts) propounded by Müller and Rusch of Switzerland in the 1950s; the importance of organic compost and lime-rich algae put forth by the Lemaire and Boucher of France; green manure, polyspecies pasturage, and crop rotation advocated by Howard and Balfour of England in the 1940s; and the role of organic composts championed by Draghetti of Italy in the 1950s.

These ideas have enjoyed a resurgence since the 1970s and have spawned several active movements attracting a limited but enthusiastic and tenacious group of adherents. Yet, with the exception of biodynamic agriculture, the movement's various strands tend in effect to converge about the common denominator of "organic/biological farming"—the result of a process of regulatory uniformity that also is driven by market forces.

[1]*Istituto di Coltivazioni Arboree, Univ. of Bologna, 40126 Bologna, Italy.*

[2]*Villa Belvedere, 2505 Desenzano (Bs), Italy.*

The International Federation of Organic Agriculture Movements (IFOAM), founded in 1972, is the main international umbrella organization and includes most of the organic-oriented grower, processor, and marketing associations as well as research and consumer-advocate groups. A "Continental Section" of the IFOAM has recently been established in Europe; it features several subsections covering large regional areas such as the Mediterranean. The IFOAM is proving to be an essential instrument for disseminating reliable information and developing a common "natural-organic" approach to agricultural and environmental issues.

The objective of this survey is neither to catalog organic farming techniques nor debate the experimental basis for the moment, but rather to provide an overview of the present position of the organic movement in Europe as it relates to market-oriented organic farms managed under mainstream economic criteria.

Development of organic farming in Europe

A rough idea of the increasing importance of organic farming can be gleaned from estimates made from the few data collected by scholars (especially Lampkin, 1990; see Table 1). They show that the average organic-crop area in the European Community (EC) as compared with total crop area ranges from 0.1% in Spain and Portugal to 0.4% in Germany and the Netherlands to 0.6% in Denmark. Slightly more than 10,000 farms are involved overall, or a total of ≈200,000 ha. These figures are certainly not high in absolute terms, but neither are they negligible, considering the strong motivating forces and the determination of the practitioners and the interest they have generated in consumers, who are increasingly attracted to the concept of "organic."

It should be stressed that the development of organic farming can be seen as a spontaneous phenomenon linked to "crop reconversions" that growers have gradually undertaken almost without government subsidies. Still, only a few European countries have enacted specific legislation regarding organic farming: France (since 1980), Austria, Denmark, Italy (regional only), and, to a certain extent, Spain, Norway, Finland, and the United Kingdom. These measures include crop standards, regulatory agencies and certification schemes, provisions for economic incentives, and the promotion or creation of specific extension services.

In deciding whether to embrace certain tenets of organic farming, ethical and emotional factors that strongly color the attitudes of growers and consumers are often considered before proven technical reports and positive economic performance. Some growers are willing to risk part of their crop and profits (not to mention professional reputation) in the conviction that they are fulfilling a social and cultural obligation. This accords with a conservation and ecological view that looks on agriculture as a restorer and steward of natural resources, coincident with a reduced dependency on technology. The view is that the production cycle of a farm should become, as far as possible, a "closed circuit" to recycle and reemploy the maximum amounts of organic elements, biomass, and waste products generated by livestock and crop operations.

For their part, consumers are captivatingly attached to a rustic and romantic concept of agriculture and rural areas. They tend to imbue an ideal agriculture with the principles of organic farming and attribute, by association, genuineness and healthfulness to "organic" produce. Organic producers in certain sectors have reaped benefits in terms of market niches they have carved for themselves, as shown by the distribution networks and hundreds of organic (mainly or only) retail outlets that have sprung up in the more developed European countries. In addition, the organic movement is associated with positive effects on consumer dietary habits typified by a reduced intake of calories, processed foods, red meat, and animal fat and an increase in fruits and vegetables. Yet, while the introduction of organic foods by certain large supermarket chains (e.g., IRMA in Denmark and Safeway in the United Kingdom) has promoted their sales to the mainstream consumer, other chains have encountered problems.

The prices consumers are willing to pay for these products, even without credible, certified labels, average ≈30% over the standard (although 50% to 100% for certain products is not uncommon), a difference that is especially notable in such sectors as dairy, cereals and legumes, vegetables, and, to a much lesser extent, fruits. The few reliable surveys published so far suggest that production costs are higher in terms of labor but lower in terms of technological input, with the overall unit-cost usually being higher because of a drop in per-unit yields compared with conventional agriculture (when the latter's goal is to maximize output).

Organic farming in Europe

Individual European countries have displayed a variety of responses to the challenge of organic farming.

Belgium

The Belgian situation is complex. It is dominated by the ASBL-Biogarantie, the umbrella organization charged with granting trademarks to member companies. As of 1990 there were four established groups: UNAB-Nubila, Probila-Unitiab, Nature et Progres, and Velt. There is still no specific legislation except for an "Arret Royal" regulating the advertising of organically grown products.

Table 1. ***Organic farming in Europe.***[z]

Country	Farms (no.) 1987	Farms (no.) 1990	Area (ha) 1987	Area (ha) 1990	Percentage of total area 1987	Percentage of total area 1990
EC						
Belgium	103	150	972	1,200	0.09	0.16
Denmark	253	520	4,000	15,500	0.55	0.60
France	2,660	3–4,000	40,000	40–60,000[y]	0.13–0.20	0.3–0.4
Germany	1,930	2,685	35,400	54,295	0.46	0.38
United Kingdom	618	700	8,619	16,000	0.09	0.27
Ireland	37	150	1,300	3,700	0.06	0.07
Italy	986	NA[x]	6,000	NA	0.03	0.04
Luxemborg	13	14	412	550	0.43	0.35
Netherlands	478	440	3,384	7,600	0.38	0.32
Portugal	7	61	185	550	0.01	0.01
Spain	328	500–1,000	2,700	5,500	0.02	0.06
Non-EC						
Austria	>700	1,250	>10,000	22,500		
Finland	<335	850	<2,050	11,000		
Sweden	500	1,900	7,500	29,000		
Switzerland	>1,010	NA	>11,800	NA		

[z]*Source: Okologie-Landbau, 78, 1991, p. 55.*
[y]*Probably overestimated.*
[x]*Data not available.*

Denmark

The country's first legislative measure concerning "ecological agriculture" was enacted in 1987 and included the establishment of a Council for Ecological Agriculture. The act makes provisions for product identification, a national regulatory agency, subsidies for farm conversion (1500 to 2200 DKr/ha the first year, 800 to 1180 the second, and 300 to 420 the third), and research funding.

France

Act 80/502, dated 7 Apr. 1980, represents the first law enacted by a European country on organic farming, defined simply as "agriculture without the use of synthetic chemicals." Its provisions include financial assistance and a national regulatory commission to oversee the adoption and enforcement of production or processing standards through an association acting as guarantor. To date, 14 such intermediary associations have been established, each with its own specific regional or national regulatory code: the ABF, ANAAB, CINAB, COMAC, EAP, FESA, FNAB, FNDCB, GGPAB, SIMPLES, SNAS, SOCOTEC, UNIA, UNITRAB. Worthy of note in this connection is the establishment of the ACAB, a national extension association, which in turn founded ECOCERT, a certification board for organic products. The board, which acts on applications received, currently boasts a clientele of >2500 growers and 300 marketing firms or information services. It has not been easy overcoming the diffident stance of French consumers vis-à-vis so-called organic products.

The demanding nature of the French market can be seen in the press exposés of fraud involving produce grown with chemical fertilizers or treated with pesticides, yet marketed under the Ministry of Agriculture's official AB ("organic farming") logo. Since Dec. 1988 the Ministry has attempted to remedy this situation by making it compulsory for all organic farmers to join one of the officially approved associations. Despite this measure, and the fact that infractions of the law carry fines as high as 250,000 francs and prison terms up to 2 years, the problem has not been fully eradicated, and the sanctioning power of some associations may be revoked. Indeed, new local oversight agencies, like COMAC, are being set up regionally to monitor growers and processors. These issues underscore the fact that the French system is an honor system requiring self-discipline from all members of the regulatory associations involved in the organic pipeline.

The first organic fruit plantations in the southern part of the country have limited production at the moment (e.g., barely 100 t•year^{-1} in the Gard, 200 t in the eastern Pyrenees). They emphasize apricot, cherry, peach, plum, strawberry, table grape, and kiwifruit. The most important monitoring bodies are Nature et Progres, Terre et Vie, Biofranc, Bioplampac, France Nature, UNIA, and Demeter. There are many special wholesale and retail operations. A privately funded organic farming research group called Groupe de Recherche en Agriculture Biologique (GRAB) has recently been formed, and it co-organized a workshop on organic agriculture with ACAB (ACAB-GRAB, 1990).

Germany

In Germany, there are eight oversight agencies that monitor the organic farming activities and practices of their members. Regulatory policies are now being extended to processing and marketing. The list of agencies (Table 2) includes Demeter (biodynamic farming), a rather complex umbrella organization covering various operational groups: Bioland (organic farming), Biokreis (organic group of eastern Bavaria), Naturland (natural farming), ANOG (Movement for Natural Growing of Horticultural Crops), and BOW (National Federation of Ecological Viticulture). These six groups in turn make up AGOL, the Consortium for Ecological Agriculture established in 1988, to which two recently founded associations, Neukoba (certified organic farming), and Bola (a federation for ecological agriculture) have applied for membership. Each of these eight groups has its own logo that also serves as a trademark.

The members of these associations are required to observe a regulatory code or specific guidelines concerning production, processing, or distribution, depending on the type of organization. For its part, the association, which charges a small percentage of billings as a membership fee, provides extension or consulting services, market oversight and product promotion, and consumer information. It also conducts one or two field inspections yearly and can decide whether to carry out further investigations, for example by commissioning private laboratories to run tests. If the findings are negative, the association issues a statement that is not a quality warranty but that certifies only that the produce meets organic-procedure criteria. The IFOAM reserves the right to check that organic procedures are in compliance via a special monitoring panel. The German government plays no oversight role, at least as long as national legislation is not enacted to impose mandatory standards.

Table 2. ***Organization of the organic farming movement in Germany.***

Agency[z]	Year established	Farms (no.)	Area (ha)	Cropping system
Demeter (Biodyn)	1924	1,098	23,914	Organic-dynamic
Bioland	1971	1,623	36,343	Organic
Biokreis	1979	150	2,151	Bavaria–organic
Naturland	1982	401	10,830	Natural soil
ANOG	1962	78	2,009	ANOG
Ecovin	1985	76	285	BOW
Neukoba	1988	?	?	Organic control
Bola	1988	?	?	Ecological

[z]These agencies are coordinated by the AGOL Federation located at the Darmstadt Research Inst. (Source: Okologie-Landbau 78, 1991, p. 55).

Each of these associations has its own management charter. For example, Demeter is a multifaceted organization and includes the Darmstad Agro-Biodynamic Inst. Its board of directors includes representatives from several independent bodies or concerns that play a key role in formulating group policy, production flow, and planning such services as research and consulting, regulatory codes and contracts to safeguard production, product quality standards, processing, distribution and retailing guidelines, and consumer relations and advertising. Members pay fees ranging from 1% to 3% of their billings and are free to set their own prices and to sell to whomever they wish. Demeter certifies the produce of its members, legally safeguards their rights, prevents fraud, and conducts field inspection and laboratory testing. It should be noted that in the first few years of a farm's conversion to organic techniques, the Biodyn trademark replaces Demeter's.

Two other private concerns—Okosiegel ("Ecoseal") and Biocontrol System—also offer inspection and certification services to those farms that do not belong to any of the eight associations mentioned above.

Germany's entire organizational setup needs to be sanctioned by national legislation. As with Italy, this probably will come about as soon as the EC enacts its own measures, but there are many political hurdles still to be overcome.

Events appear to be outstripping intentions. At least 50% of Germany's organic produce market is completely unregulated. The lack of nationwide regulatory provisions has enabled imported, generally uncertified organic products to penetrate German markets. Nevertheless, the entire market enjoys benefits from the success of the officially approved products. The fact that organic farming is stressing overall quality suggests that present quality levels are unsatisfactory, especially in regard to small-scale processing products, such as juices.

There are currently >2000 retail outlets (Naturkostläden). The opening announcement of the largest "ecological" supermarket at Gerestried, Munich, noted that most of its 2500 items were foods and that projected first-year sales should reach ≈2 million DM. The Federal Environmental Agency recently awarded AGOL funding for a research and consultancy project entitled "Development and Testing of a Marketing Program for Ecologically Grown Products and Foods for the General Public: Canteens and Restaurants." The European Research Institute for Biodynamic Farming, headquartered at Darmstadt, has been conducting organic-farming research for at least a decade; research is also ongoing in university departments and experimental stations at Bonn, Giessen, Kiel, Kassel, Witzenhausen, and Triesdorf (Table 3).

United Kingdom

The United Kingdom boasts a certain tradition in the field of organic agriculture that includes several research centers. The main ones are the Elm Farm Research Station at Hampstead Marshall in Berkshire, where a very interesting project is underway on stockless arable rotations, and the Aberystwyth Centre for Organic Livestock and Agroecology, directed by N. Lamkin at the Univ. of Wales, which is primarily concerned with economic research and consultancy. The Soil Assn., which was established in 1948 by Lady Eve Balfour in the wake of Howard and Balfour's organic theories, still plays a key role in research and also issues a trademark for organic food products. The U.K. government has set up a body to supervise standards, inspection procedures, and labeling as a consumer protection measure.

Italy

Italy still has no national legislation, despite the many bills drafted either separately or together by the various political parties or by the Ministry of Agriculture in 1990. Legislation is stalled in parliament awaiting the EC guideline measure. Meanwhile, however, laws on organic farming have been passed by the more active of the regional governments (the Lazio, Veneto, Friuli, Trentino-Alto Adige, Marches, and Umbria regions). Although most of these measures have remained largely on paper for lack of enforcement regulations, their provisions call for official recognition of organic growing techniques, incentives, and subsidies for farm conversion (e.g., 200,000 lire/ha in Emilia-Romagna and 300,000 lire/ha in the Marches for green-manuring) and a (promised!) extension service.

Growers have responded to this public-sector inertia with various initiatives. They have established a number of regional cooperatives and associations committed to observing the IFOAM standards and to marketing organic-labeled produce either directly or through affiliated retail outlets. Of a total of ≈10,000 ha of organic crops, 3000 ha are under conversion and 1500 under biodynamic farming, and some regional authorities have made a few extension service agents

Table 3. ***University courses in organic agriculture in Europe.***

Country	Town	Hours (no.)	Subject
Austria	Innsbruck	?	Agro-ecology
	Vienna	26	Animal organic farming
Belgium	Gembloux	52	Biological agriculture
Denmark	Frederiksberg	26	Alternative agriculture
Germany[z]	F. Wilhelm Univ.	?	Intro to organic agriculture
	Giessen	26	Technique and conventional agriculture alternatives
	Kiel	26	Crops in organic agriculture
	Nurtingen	26	Alternative methods
	Hohenheim	26	Yield in alternative production in plants
	Hohenheim	13	Alternative agriculture for animals
	Hohenheim	13	Marketing of organic crops
	Hohenheim	13	Economy in alternative agriculture
	Hohenheim	13	Special crops in alternative agriculture
	Munich (Weihenstephan)	13 × 4	Alternative agriculture
	Witsenhausen	26	Introduction to alternative agriculture
	Witsenhausen	26	Agriculture and ecology

[z]Seminars and laboratory not included.

available in the field and for laboratory analyses. Most of these groups are part of the AIAB (the Italian Organic Farming Assn.), a prevalently grower-oriented organization, which began issuing in 1991 an organic procedure warranty ("Garanzia AIAB"). Another association now being established with a code of standards along the lines of IFOAM (tests included) is the Interprofessional Federation for Organic and Biodynamic Agriculture (FIABB), which will open membership to the processing industry, marketing firms, extension agents, retailers, and consumers as well as growers. Its agenda is ambitious: to represent all the sectors of the organic-product industry at national and international levels; to become the main policy and legislative lobby; to promote and advertise organic products; to set up joint programs with public research agencies and bureaus of standards; and, of course, to monitor affiliates and check regulatory and certification systems.

The monitoring of organic produce in Italy has received a boost from 25 large cooperatives that have joined in establishing an oversight consortium. Currently, only 1000 out of an earmarked 25,000 total hectares comes under the definition of "organic."

The Italian market has a nationwide network of >400 retail outlets for organic products from a wide variety of sources, many of which have unverified warranties and partly documented labels. The main items are cereals (wheat, rice, corn, and such minor species as millet), some soybean, milk and yogurt, fruits, including citrus and juices, vegetables, oil, and wine. Despite the rather high prices organics command, the industry foresees a rapid expansion for organic products. Problems, however, are anticipated: with N (probably the primary one in Italy, as in many other countries), for it is closely linked with organic livestock, with dairy and horticultural production, and with "organic" fruit due to the ban on certain chemicals considered essential for fruit production (Tringale, 1990).

The Netherlands

The Dutch Platform for Biological Agriculture, the government-recognized lobby and consultant for public research programs, is the umbrella federation for the biodynamic and ecological agriculture sectors, each of which numbers ≈200 growers, as well as such "nature" groups as the Small Earth Foundation, the Alternative Consumers Assn., and a few conservation and environmental organizations. There is no national legislation. There is, however, what may be Europe's longest-running comparative experiment of model farms at Nagele. The number of retail outlets for organic products now stands at >300, about 50 of which are also health-food shops. The main trademarks are Demeter-Biodyn and Eco. It bears reiteration that the country's leading supermarket chain, Albert Heijn, has decided to promote integrated rather than organic foods.

The Dept. of Ecological Agriculture was established at Wageningen in 1981. It has the only program in Europe offering an undergraduate degree and a postgraduate MS.

Spain

National legislation was enacted on 10 Apr. 1989 to regulate "ecological farming." Its provisions include the establishment of an oversight board to draft the regulatory codes of production, an official registry of affiliated growers, the monitoring methods approved by the Ministry of Agriculture to be used by the board in managing the service, and, in the future, a trademark for organic produce. "Vida Sana" is the country's dominant organic organization; nearly half the certified organic area in Spain is in olive groves, and much of the remainder is either citrus or intensive vegetables for export.

Switzerland

Switzerland has a certain propensity for organic farming, in that far less of its agriculture has been involved in today's dominant intensive and monoculture approaches than is true for other countries. Currently, there are at least seven large associations in addition to the Oberwil Research Institute for Organic Farming, one of the most important organic research organizations in Europe. The institute, which also includes individual growers, has four departments: soil and fertilization, plant protection and landscape ecology, socio-economic projects, and education service. Much of the historical merit for the development of organic farming goes to Müller, who established the first nucleus of organic farmers in the 1950s.

Today, growers are represented by VSBLO, the Swiss Federation of Organic Farming Movements (Demeter, Italian Switzerland's AB, Biofarm, Biogermuse AVG, Progana, SGBL, Swiss Foundation for the Promotion of Organic Farming), whose logo is a bud. Despite the rigorous production regulations established by VSBLO, there is as yet no national legislation covering organic farming, although several cantons, such as Basel and Bern, have passed measures providing incentives for organic growing and farm conversion. These subsidies include ≈2000 Swiss francs per farm for training, a similar sum for equipment purchasing, and a small amount more for conversion. Worthy of note is the fact that as of 1991 (i.e., 10 years after conversion) ethological norms will become part of farm management practices for livestock operations: intensive breeding methods in cages (e.g., for chickens) are to be prohibited.

The market share of organic produce has risen steadily up to now: its reputation is good and fraud rare, and prices seem to be profitable despite the rather small amount of produce currently on the market. Yet the fact that the predominant Migros supermarket chain has begun offering a Migros-Sano line of integrated rather than organic products may signal, as we have noted, that organic farming and its produce are reaching a plateau in Switzerland, and that consumers are resistant to pay high prices for these products.

Also noteworthy is the interaction of the various associations and public sector research and education institutions. Comparative testing of crops grown under the three DOC techniques (Demeter, Müller-Rusch, conventional) has been under way since 1972 at Oberwil's IRAB and will undoubtedly have political effects, but no conclusive data on the performance of organic and conventional crops have been released.

Organic farming systems

While it is impossible to examine all the systems of organic farming, they do have certain common features that can be traced through sector, species, or type of farm. The first is the tendency toward a self-sufficient management of the ecosystem without outside energy inputs, and there are those who maintain that the energy balance should be managed by taking into account a given area rather than the individual farm. Similarly, it is necessary to determine real energy efficiency per output (not just per hectare of organic systems), including such inputs as cultivation for weed control, N-fixing crops, and the transporting and spreading of certain "natural" fertilizers and compost. Clearly, the ecosystem is disrupted wherever intensive farming systems exist (e.g., high-density fruit and vine production). Thus, it would be unfeasible to apply organic-farming models without first imposing a suitably long period of conversion and adaptation for integrated production programs. It will be important to convert to genetic material that is well-adapted to a given environment and contains intrinsic resistance to stress, diseases, and pests. These genotypes do not always exist.

Another feature is the recovery and/or conservation of soil fertility by promoting the reactivation of biological, biophysical, and biochemical processes (revising edaphic symbioses). It is, however, not possible to evaluate the recovery of fertility or balance of the ecosystem except over the long term (up to 20 years or more) and, hence, the emphasis is on reassessment of the soil's organic material and humus. This also bears upon those questions linking sustainable agriculture and soil fertility, which in turn should help to focus greater attention in the future on the rhizosphere, especially on root/mycorrhizal relationships and functions.

There is a need to consider the farm as a viable economic entity that is an integral part of its surrounding natural environment and to view the animals and plants, the soil and climate, and the "ecological infrastructure" (the landscape) as interdependent and inseparable parts of a whole. This is the reason that organic farming is associated with mixed cropping practices and that there is strong support for linking livestock with mixed grass and fruit crop systems. Organic farms are required to keep livestock when growing certain crops.

There is much support for interspecific groupings in orchard plantations, a system that has historically and economically been moving toward monoculture. The dominant concept for grasses (and with due reservations for fruit) is yearly rotation to prevent disorders deriving from soil sickness, fertility loss, and erosion; to reduce pest load and enhance the natural resupply of organic matter and N; and to facilitate nutrient migration in soil layers.

Some groups advocate the closed-circuit farm, a management system independent of outside energy inputs. The concept is designed to increase active and long-lasting soil humus content by adapting crops and livestock operations, as well as by limiting tillage to a minimum. Yet, obviously, the use of outside inputs is inevitable despite the desire to ban all synthetic chemical or readily soluble fertilizers. For example, livestock breeders are allowed to purchase feed within certain limits (a set percentage of overall requirements) so long as the number of head does not exceed given thresholds per unit of area. There are similar mandatory thresholds set for natural and organic fertilizers.

Research Feedback

There are as yet insufficient field trials, yield data, or economic information to assess objectively whether organic farming can succeed in the marketplace without the external input of subsidies. Yields of grasses and oil seeds generally diminish by 10% to 30% (20% to 50% is the range in Germany) and are subject to severe losses, in the short term at least, whereas in orchard crops this gap can either disappear completely or markedly increase, depending on pest infestation, severity, and control. Uncontrolled attacks can wipe out profits, if not yields, altogether. In any event, higher prices to cover the almost inevitably greater incidence of per-unit product cost can be foreseen. Thus, it is also necessary to devise adequate cost–benefit models for farms and to devise a uniform table of crop management techniques as reference standards.

Reinken's test data (1988) are instructive in this connection. The trials were designed to compare organic and conventional growing techniques for apples and were based on the input of 80 t manure/ha, an excessive rate in any case. While the findings showed the economic viability of the organic approach, they also underscored its marked limits, including diminished fruit quality and greater incidence of scab. Vogtmann (1990) points out that it is not simply a matter of comparing the performance of the two approaches (for the organic can show unsatisfactory results in the short term) as much as of testing crop systems that call for low outside inputs.

A Swiss study (Besson et al., 1990) reported multiyear findings of comparative testing on conventional and DOC organic systems under a seven-crop rotation of grasses and eight regimes of organic fertilization. Their findings show increased biological activity in the organically dressed soils, yet the soluble nutrient contents decreased and the soil was very slow to attain balance under the organic regime. In Oberwil, Switzerland, Schmid (1990) reported an appreciable activity of *Rumex obtusifolius* in root extracts in trials involving 40 natural composts tested against fungal disorders in apple (even soybean lectin has proved to be active against scab). A number of studies on biological control of apple diseases using microorganisms are underway at Wadenswil.

Conclusions

In the wake of the undeniable progress achieved in the 1980s and the heightened interest of the European consumer (demand still appears to outstrip supply), organic farming appears to be on the verge of carving out a significant niche in overall agricultural production. The aim of the movement's various groups is to surpass the 1% threshold soon and to reach a 2% to 3% quota of overall agricultural output over the next decade, although the more optimistic IFOAM target is an ambitious 10% by the year 2000 (Haest, 1989). The higher prices commanded and received in the marketplace encourage expansion. For their part, consumers (at least the elite who buy them) seem to be unconcerned about paying 10% to 30% more for them in their "conviction" (though unproven) that these products are safer and healthier than conventional produce (Brombacher and Hamm, 1990). There are more than a few consumers who mistake a certification of method for a quality warranty. It is clear that organic farming has a beneficial effect on consumption in that consumers can make a more individual, personalized choice over a greater range of options.

Yet, despite these positive aspects, there remain many questions and doubts that in part explain the delay in the EC's passage of regulatory legislation until 24 June 1991. This measure, Regulation no. 2092/91, redresses the lacuna, although again only in part, as it covers organic crop production, including marketing rules, but not livestock (proposals for which will be submitted for decision in 1992). It is to be enacted in two stages: the member states will have 9 months from the official issuing date, 27 July 1991, to apply the prescribed controls on the produce of organic farmers, who in turn will have 12 months to adopt the rules for use of the "Organic Farming–EC Control Authority" label. Produce then can indicate organic farming as its growing method in trademarks and advertising. The statute also includes the approved list of produce and management techniques, exceptions being kept to a minimum. Farms have been granted a period of at least 1 year (up to July 1994) to convert from conventional to organic farming, during which time their produce must declare in advertising that any such farm is in the conversion phase.

While the measure has been favorably received by the public, which views it as a safeguard against fraud, it has provoked more than a few critical voices from organic farming proponents. On the one hand they feel a bit trapped by the rather stringent (at least on paper) inspection rules, yet on the other hand they complain that the guidelines regarding crop production and management practices (save the explicit norms on fertilization) are still somewhat vague. It can be assumed that conflicts will arise.

There are still many ways to misrepresent and make fraudulent claims as to production methods, a situation that is especially true for foreign suppliers (e.g., Hungary and Israel have "bent" IFOAM standards to meet local contingencies). Organization and implementation of controls raise consumer prices. Should supply increase to the point where organic farming is no longer profitable, the question will be raised if it must be self-supporting or be subsidized with public funds. For the moment, public funding in the various countries involved has been limited to incentives for conversion, but not as yet to cover the higher production costs of organic farms. Should this occur, it would be detrimental to conventional agriculture, which for the foreseeable future must provide our main source of food.

Human resource development in terms of education and training in organic farming, lacking in many countries, should be pursued and supported with adequate funding, as should research and training of research personnel. A recent study by Van Mansvelt and Kolster (1990) shows that the Netherlands, Germany, and Switzerland have the most advanced educational opportunities, i.e., university degree programs (Table 3). Other countries, including Italy, have been reluctant to pursue such a policy. Large agencies have changed their attitudes as organic farming gradually sheds its ideological tenets in favor of scientific proof. The FAO recently held a SARD-1991 conference on sustainable agriculture and rural development.

In the opening report at the FAO's Expert Consultation Meeting at Bern, Switzerland, Gejer (1990) recognized that organic farming is but a sector of sustainable agriculture, and lists a series of proposals and objectives that are identical, albeit markedly more emphatic, to those formulated by the OILB and ISHS in their joint 1989 manifesto on integrated agriculture. Those who maintain that in a few years' time organic farming will be merely a variation of integrated agriculture may be right after all.

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Organic Gardening and Ecosystem Alteration

Miklos Faust

Additional index words. soil–root zone, soil ecology, plant–pest interactions

At the simplest level, the word "organic" refers to a certain method of growing food. It can be defined negatively: organically grown produce is that which is grown without the use of chemical fertilizers and pesticides. More positively, as the English estate owner Friend Sykes (1888–1965) asserted: "Organic Farming... is another name... for Humus Farming. Organic methods are not, therefore, a matter of avoiding the use of artificials; they require that the cultivator should encourage the fertility which lies, actually or potentially, in the soil itself, and should regard the soil not as inert matter but as a living organism" (quoted by Conford, 1988). This reasoning can be extended from the soil to the plants themselves. Organic methods do not merely avoid pesticides but encourage the productivity potential of plants by regarding the plant–pest interaction not as an exclusive "either/or" process but as an ecological interplay of competitive organisms. Problems arise when a balanced ecosystem is altered, either because the plants were moved for economic reasons or the pests were moved by unnatural dislocation, causing the plant–pest interplay to become overwhelmingly in favor of the pests. Consequently, we must consider the soil–root-zone and the plant–pest ecosystems as two separate systems, both being susceptible to ecological adjustments.

Soil–root-zone ecosystem

The soil–root-zone ecosystem, discussed earlier in this Workshop, can be summarized quickly. Altering soil ecology, by means of improving humus in the soil, was advocated by R.H. Elliot in 1898 in his "Clifton Park" method (Conford, 1988) and by Sir Albert Howard in the Indore process (Conford, 1988). Elliot (1837–1914) was concerned about the application of artificial fertilizers. He developed his system in Roxburghshire and wrote that the soil fertility could be improved without artificial fertilizers by relying on deep-rooted plants and turf and root residues. Howard (1873–1947), the developer of the Indore process, worked from 1905 to 1931 in India and applied scientific knowledge to ancient techniques of composting to maintain soil fertility.

Soil fertility was a concern long before Howard's work. The Chinese have used night soil to improve soil fertility since ancient times. Entz (1854) recognized that replanting of grapes was not satisfactory unless the soil N status was improved. He advocated heavy manuring of the soil, or better yet, planting of alfalfa for 4 to 5 years until the productivity of the soil noticeably improved.

Nagyvathy (1822) was concerned with the quality of the soil itself and with the modifications that were needed to make it productive. He stated that a "balanced soil" (mixture of sand and clay) is the best for agricultural production, and that, in most cases, nature produced such soils, mixing clay with sand and sand with clay. Where nature did not comply, he said, it was the farmer's responsibility, and he should cover the land with good soil during the fall. He recommended using mud from the bottom of dried lakes for improving soil fertility. Nagyvathy stated that land improved with the right kind of soil would be productive longer than after any manuring treatment.

Of course, all these ecological adjustments were used before Liebig introduced artificial fertilizers. Synthetic fertilizers became increasingly important during the second part of the 19th century and throughout the 20th, until now it is impossible to design an agricultural land management system without them. What we can learn from the early period of agricultural farming is that we should consider the ecology of the system. For example, if soil leaches easily, fertilizers should be applied in small doses more often to maintain soil fertility.

In addition to fertility, soil structure needs to be maintained for maximum soil–root interactions. Nagyvathy, a county judge in Hungary, noticed that farmers who used four oxen to pull their plows plowed more deeply and had plenty of bread, compared with those using only two oxen, whose plowing was shallower and who had less to eat (Nagyvathy, 1822). These observations are directly related to the depth of the root zone, widely recognized as a necessity today.

There are some novel systems where adjustment of the ecosystem has greatly increased soil productivity. The Tisza River in Hungary used to flood its tributaries, frequently causing much loss of property and life. During the second part of the 19th century, the river was regulated, and flooding was eliminated. But it soon became obvious that the flood waters had regularly dissolved soil sodium, for after the floods were eliminated, the salinity of the soil became too high for the traditional wheat and corn production of the area. Adjustments were clearly necessary. Thus, in areas where the soil

Fruit Laboratory, Beltsville Agricultural Research Center, Agricultural Research Service, Beltsville, MD 20705.

could be leveled, rice fields were developed in which artificial, controlled flooding dissolved and washed away the sodium. In areas where the sodium content of the soil was too high or rice could not be planted, the solution was production of chamomile (*Matricaria chamomilla*), a plant that tolerates high sodium in the soil. Chamomile was used first as a folk medicine and later as a source of raw material for the pharmaceutical industry.

Plant–pest interactions

Alteration of plant–pest interactions can be cited from the time when this was the most effective means of decreasing pest damage. For comparative purposes, I need to mention that chemicals have been used in agriculture since antiquity (Smith and Secoy, 1975); but effective sprays were developed only near the turn of the 20th century (Smith and Secoy, 1976). "Bouillie Bordelaise," or bordeaux mixture, a mixture of lime and copper sulfate, originated in France in 1885 and was first used in Connecticut in 1893. Lime-sulfur, a mixture of sulfur and lime boiled in water, was first used in California in 1905.

Starting early in the 17th century, colonists made many unsuccessful attempts to establish *Vinifera* grapes in the eastern United States. Failures were due to lack of resistance of the imported grapes to native diseases and soil pests. It was gradually recognized that the wild native species could contribute resistance to these conditions. Between 1800 and 1850, such cultivars as 'Catawba', 'Isabella', and 'Concord' came to the scene, the grapes and their ecosystem were harmonized, and the hybrids became the foundation of the grape industry in eastern North America (Einset and Pratt, 1975).

Similar problems occurred when grape pests from the New World were introduced to Europe during the 19th century. Phylloxera (*Phylloxera vitifoliae*) is an insect that lives on the roots of grapes; it is indigenous to the eastern and central United States and was carried to France some time before 1860 (Einset and Pratt, 1975). Hybridization of native American species assumed importance in France when the devastations of phylloxera made it necessary to graft *Vinifera* grapes on resistant roots. The new rootstocks, developed with North American native grapes that were resistant to phylloxera, altered the relationship between pest and plant and allowed the production of grapes even in the presence of the insect.

During the 17th and 18th centuries, only imported pear cultivars derived from *Pyrus communis* were grown in North America. The trees were dying from an unknown malady. Then Peter Kieffer (1812–90), a gardener born in Alsace, France, who had immigrated to America in 1834, imported seeds of Sand Pear of China from a Belgian nurseryman. He grew the Sand Pear seedlings in his garden near Philadelphia. There were also some 'Bartlett' trees in his garden, and the two hybridized. One of the chance seedlings was able to cope with the malady (later identified as a bacteria, *Erwinia amylovora*). This seedling was introduced in 1863 and named 'Kieffer' in 1876 (Hedrick, 1921). Another chance seedling had a similar origin in the Philadelphia area, but whether it was from Kieffer's nursery is not known. It was carried to Georgia about 1850 by Major Le Conte and eventually named 'Le Conte' (Hedrick, 1921). The introduction of *P. ussuriensis*, another Chinese species, to Iowa in 1867 further enlarged the resistance pool against fire blight, a disease that was not even known until 1880 (Burrill, 1880). Sprays were not used against the disease until 1927 (Van der Zwet and Keil, 1979); scientific breeding for fire blight resistance started in 1908 (Brooks et al., 1967).

There were some early attempts to develop resistant vegetables during the 19th century. Chauncey Goodrich, a clergyman of Utica, N.Y., received a small quantity of South American potatoes in 1851 through the American consul in Panama. Using this stock, he was the first breeder to attempt to control late blight (*Phytophthora infestans*) of potato, and he introduced a cultivar named 'Garnet Chili' (Stevenson and Clark, 1937). This early discovery did not receive attention until potato breeding was undertaken actively by the U.S. Dept. of Agriculture in 1910. Results were evident by the early 1930s, and cultivars with virus resistance (latent mosaic virus and mild mosaic), resistance to common scab (*Actinomyces scabies*), fusarium, and leaf roll were produced by the U.S. Dept. of Agriculture, New York (Cornell) and Minnesota Agricultural Experiment Stations (Stevenson and Clark, 1937).

Yet another example is the tomato. Selection for resistance to fusarium wilt of tomato was started in 1910 by S.H. Essary of the Tennessee Agricultural Experimental Station and by C.W. Edgerton, of the Louisiana station. Two years later, Essary distributed a cultivar that became known as 'Tennessee Red'. In the same year, Edgerton announced his first wilt-resistant tomato, called 'Louisiana Wilt Resistant'. Although 'Louisiana Wilt Resistant' proved highly resistant to the disease, it was late and a poor yielder. Edgerton crossed it further and developed new cultivars by 1918. In 1912, J.B.S. Norton of Maryland began selection for wilt resistance; he distributed resistant selections in 1915. The U.S. Dept. of Agriculture started disease-resistance breeding of tomatoes in 1915, and in 1917 and 1918 introduced 'Norton Columbia' and 'Arlington', which were highly resistant to this disease (Boswell, 1937).

Improvement of beans started about the same time. The first cultivar resistant to common bean mosaic virus (Robust, dry shell bean) was introduced by F.A. Spragg of Michigan in 1913. By 1930 practically all bean introductions later listed by B.L. Wade carried some sort of resistance against anthracnose, bacterial blight, and even bean rust (Wade, 1937).

A different type of ecosystem adjustment was needed in dealing with weeds. Development of English, Dutch, or German land rotation was primarily designed to deal with weeds effectively. The succession of the plants in the rotation was crucial. In one example, from 1793 in Hungary (Nagyvathy, 1822), the planting succession of plots and the reasons for scheduling them in this order was as follows:

Fallow
Plowed twice to promote maximum weed seed germination.
Wheat
A poorly competing crop, planted in relatively weed-free soil after fallow.
Barley with clover
This is the 2nd year after fallow, barley is a better-competing crop, clover helps keep weeds down.
Clover
Enriches soil N, effectively crowds out weeds.
Rye or wheat
After the second cut of clover, there is time for only one plowing, but this is enough after clover. Rye is favored because it can be planted later than wheat.
Oat
A relatively high weed-producing crop, but it precedes fallow, which eliminates weeds.

In designing this system, the biology of the plants was superbly understood and ecological characters were used to maximize production.

Other systems also were noted for adjusting the ecosystem to eliminate weeds. Nagyvathy (1822) noted that when a field is infested with elder (*Sambucus nigra*) the best practice is to plant clover in that field. Cutting the clover twice also cuts and consequently weakens the elder; then plowing the field during a dry period completely eliminates the weed (Nagyvathy, 1822). He recommended finding the weakest links in the biology of the weed and exploiting it for the weed's elimination.

Organic agriculture and ecosystem adjustment

In discussing the "History of Organic Movement," we must ask, what is organic agriculture? The answer lies in understanding and adjusting the production ecosystem for maximum productivity. In the middle of this century, agricultural and horticultural production started to use chemicals in place of ecological adjustments. It appeared that chemicals could overcome certain problems, eliminate pests and weeds, control growth, and replace soil fertility. The use of chemicals started at the same time that science entered into agricultural production. The great increases in productivity (produced by general scientific knowledge) were not easy to separate from the effects of chemicals, and to many, perhaps, chemicals created the productivity.

A small group of idealists objected to the use of chemicals, and from this the "organic movement" grew into national and international dimensions. We now know that during the time we used chemicals extensively we neglected to study and adjust the ecosystems of agricultural production. When we began to remedy this problem with endeavors such as modern integrated pest management (IPM), for example, we were merely repeating what had been practiced on a less sophisticated level and with a limited number of crops during the last century. IPM immediately reduced, but did not eliminate, the need for chemicals without reducing productivity. What we must do now is increase our efforts in ecological adjustments of production that will further decrease the need for chemicals. We, probably collectively, can state that chemicals per se are not bad; but they must be environmentally compatible and used in a way that considers the ecology of the system.

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