Biological Husbandry

A scientific approach to organic farming

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FOREWORD

The International Institute of Biological Husbandry was founded in 1975 to promote the scientific development of biological or organic agriculture, as a viable alternative to orthodox modern agriculture. Its first international symposium was held at Wye College, Ashford, Kent, on August 26–30, 1980, attracting over 100 delegates—mainly scientists or practical farmers—from more than 20 countries. This volume includes most of the papers presented at that symposium.

Biological husbandry is a system of agriculture that seeks to maintain and improve productivity of land as far as possible by encouraging and enhancing natural biological processes, minimizing the use of chemical fertilizers or pesticides. It is based on traditional methods and has been developed—mostly by practical farmers—to incorporate much that is new in agricultural research and technology. Rejecting the use of resource-extravagant and energy-demanding chemicals, it stresses the need for further understanding and development of natural processes which help the farmer—processes that can be managed or manipulated in nondestructive ways to help him further. Supporters of biological husbandry see particular applications for it in poor countries, where unimproved traditional methods are no longer sufficient but where the insensitive introduction of orthodox, energy-consuming methods of farming leads rapidly to economic and agricultural disaster.

As the proceedings published in this book show, there is little doctrinal orthodoxy in biological husbandry—only a determination to try, in whatever ways may be appropriate to the circumstances, to produce good yields of high-quality food through stable, self-perpetuating and self-contained agriculture. The discussions that followed these papers, continuing well beyond the programmed hours, emphasized this point clearly. There was, however, an awareness of a need for far more research and systematic enquiry into the methods used in biological husbandry, and measurement of quantities and quality of yields obtained. If biological husbandry is to progress—to establish a level of credibility equal to that of orthodox farming—its supporters must themselves graduate beyond the levels of enthusiasm and mystique that have brought them so far, and develop a firm foundation of scientific theory, research and practice.

This volume shows that research is already in progress in many organizations throughout the world, and indicates the important future role for the International Institute of Biological Husbandry in coordinating and disseminating research information.

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INTRODUCTION: ORIGINS OF THE INTERNATIONAL INSTITUTE OF BIOLOGICAL HUSBANDRY

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I have been interested in the organic or biological approach to farming since about 1949 and, while trying to make a living in agriculture in various parts of the world, I have pursued this interest subsequently with a gradually growing determination to succeed.

Back in those days, organic farming was represented in the UK mainly by Friend Sykes, Newman Turner, Professor Lindsay Robb, Lady Eve Balfour and a few others. They were battling against far more difficult circumstances than we have now. There were, for example, Government subsidies on artificial fertilizers and lime, but none on rock phosphate and other so-called organic fertilizers. Any farmer using organic methods was therefore saving the taxpayer money, but also considerably increasing his costs. One cannot at all blame the conventional farmer of that time: after having had all sorts of weed and growth problems he was suddenly presented with magical products that killed the weeds and left the crop nice and clean. Such weeds as poppies and charlock ceased to be a nuisance almost overnight. As far as growing heavier crops was concerned, a few bags of the correct fertilizer were all that was needed, instead of handling (often literally, by handfork) tons of manure.

All over Great Britain, wherever corn is growing, can be seen evidence of those times—broken-down and empty cattle sheds and cattle courts. Many cattle were kept solely for their manure value, and very often were unprofitable as far as a farm enterprise was concerned.

A growing market for agricultural chemicals developed, and new products frequently appeared, but things started to go wrong. For instance, in the Okanagan Valley in British Columbia where I lived for some time, a great many apples and pears are grown. In those days lead arsenate was used as a spray for various orchard pests and there was no mite problem at all, presumably because lead arsenate did not kill off the predator of the mite. Then came the wonder drug DDT, and instead of lead arsenate (which was fairly unpleasant and somewhat dangerous) growers switched to the full use of DDT, which killed off every pest imaginable. Suddenly they had a mite problem, and they have had it ever since. Of course, this was the simple effect of killing off the mite predator. Unfortunately, mites are more persistent and reproduce more rapidly than a predator, unless the predator is allowed complete freedom to live naturally. At that time not much significance was attached to this, but we know the progress of chemicals since those years.

I first became interested in organic farming because of problems with our Guernsey herd in Kent. The book by Newman Turner, *Fertility Pastures*, seemed to have the right answers. Human nutrition was of no interest to me then: I have always been more interested in the quality of food grown for stock than in that of food grown for human consumption. After all, humans in Great Britain and other developed countries can eat what they choose, but stock have to eat what they are given, or go hungry. Nevertheless, I must admit that human nutrition is of interest now, because of the different problems for humans these days.

We organic enthusiasts of those early years had to work on a basis of traditional husbandry, but with modern machinery if available. We had to follow careful rotations, whereas the conventional farmer could forget about the worry of rotations and grow the same crop for several years without too many problems. Any problem that did arise just meant finding the right cure from the right agrochemical company, and applying it properly. If it did not work it was generally thought to be because the farmer's application was wrong, the weather was wrong, or it was the wrong cure for that particular problem. The failure was never attributed to the chemical.

Conditions have not altered very much to date, but specialist machines are being developed for the organic farmer; various products, such as the seaweed range, have been marketed, and the organic farmer of today is far more than just an updated 1930s farmer.

When, eventually, I owned a farm in New Zealand and tried to run it organically, I was faced with problems to which I could not find any answers. Going to agricultural colleges was useless and, to a certain extent, still is: you would be given a chemical answer, or told that you would go bankrupt if you farmed organically. All the free advice from commercial firms was, again, chemical, because there was little money for any company in producing for organic farmers. So, like every other organic farmer I tried to find my own answers—quite often without satisfaction.

Returning to England in 1972, I worked for the Soil Association, and started the Soil Association Organic Marketing Company for setting standards of production and marketing members' crops. This was not entirely appropriate, so it was decided to form a separate Farmers' Cooperative, owned and run by farmers. With the help of colleagues I formed Organic Farmers & Growers Limited, which has progressed reasonably well. Now we have farmers all over the UK and are being recognized as a serious commercial concern by the farming community and agricultural business. However, soon after forming this company, I realized that I was going to have to answer a lot of queries from farmers, and the more successful the company became, the more farmers there would be with problems to be answered. The questions then arose, of where to find the answers, and how to develop organic farming to keep it viable with ever-worsening national economic circumstances. It was obvious that it would be necessary to interest scientists in these particular research problems and to develop better methods, but there was no institute or organization to attract scientists at that time. I therefore founded, again with the help of colleagues, the International Institute of Biological Husbandry Limited, a nonprofitmaking organization with educational and research objectives.

The purpose of the Institute would be to gather together information, sort it and disseminate it on a world-wide basis. Building up a catalogue of problems and solutions, we would at the same time be encouraging research, so that our farmers could look forward to ever-increasing crops and ever-increasing economic success. The overall aim of the Institute is to provide a sound scientific base for biological husbandry.

I have been extremely lucky in finding scientific colleagues of various disciplines and of great enthusiasm, ability and willingness to cooperate. This has already made a great difference to the future of biological husbandry, and bears out my original contention—that if the right organization could be formed, the scientists wishing to work in this particular field would certainly be found.

Looking to the future, I see biological agriculture developing along two lines. There will always be pure organic husbandry, working to the Number One standard of Organic Farmers & Growers Ltd, which does not permit the use of any artificial salts, pesticides or other agrochemicals, and which involves certain methods of cultivation, rotation, etc. There will also be the other standard—involving a complete biological approach to management and to all basic techniques, but with the use of chemicals for problem-solving or crop topping-up, which will not do any harm to the biological life or condition in the soil. Although this approach has caused some arguments, I see no problem at all in following both lines, provided that one is absolutely honest about what one is doing.

In the Institute, our first college is coming into being and we hope that this development will spread to other countries. It is essential to provide these facilities to fulfil the wishes of many students who are very disillusioned with the usual agricultural colleges and institutes. In addition, when a farmer changes to biological methods he may need some tuition, because many have forgotten (or have never known) the older traditional farming methods. Many of us consider that successful organic farming requires more skill, foresight and planning than farming which relies on chemicals.

The Conference at which the papers published in this book were given was the first conference on biological husbandry in the United Kingdom with such an emphasis on a scientific approach. It is hoped that this book may provide a basis for a textbook on biological principles that will be renewed continually as the years go by and as more developments are perfected.

My colleagues put in a tremendous amount of work on the Conference and on these papers; I thank them very much for their efforts. Dr David Hodges and his colleagues at Wye College are particularly to be thanked for running the conference so well. I hope they see it as I do—a great advance towards making biological farming the farming of the future—which it undoubtedly is.

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AN AGRICULTURE FOR THE FUTURE

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Introduction

The title of this chapter—also the title of the conference of which this volume is the Proceedings—poses a number of questions. What is meant by an agriculture for the future? Will the present system of agriculture serve humanity into the future? If so, why is an alternative agriculture needed? What potential alternatives are there to the present system? In order to ensure that most important of needs, a continuing and adequate food supply, mankind has to possess or to develop an agricultural system which can provide enough food to supply the needs, not only of the present world population but also of that of future population growth, until this can be brought under control. This agricultural system must also be one which is adaptable to various levels of development and industrialization, and which does not rely too heavily on nonrenewable resources, or on fuels whose depletion could endanger its long-term continuity. Another important factor is that an agriculture for the future must have a minimal impact on the natural environment—the biosphere—on the overall integrity of which we rely ultimately for our well-being and even survival.

The present system of modern Western agriculture (called here conventional agriculture), which is practised to the exclusion of almost any other system in the industrialized countries, and which in recent years has been introduced more and more into the developing countries, does not easily fulfil these, or other, criteria for 'an agriculture for the future'. The first part of this chapter outlines the reasons why I think that conventional agriculture does not fulfil these criteria: the second part considers potential alternative systems, biological agriculture in particular.

An assessment of conventional agriculture

While recognizing that the development of conventional agricultural techniques has resulted in great increases in productivity, the negative aspects of the system must be considered as well, in order to make a true assessment of its impact and potential. In summarizing the problems associated with conventional agriculture, it should be recognized that some are specifically the result of the system, and others are caused by the interaction between agriculture and various political, economic and social factors which are part of our way of life.

BIOLOGICAL AND ECOLOGICAL FACTORS

Effects on soil

Man's increasing impact on the environment is resulting in a world-wide tendency towards the degradation and erosion of soils (Eckholm, 1976; Hare, 1980). Although many of the factors causing this are nonagricultural, nevertheless failure to practise an environmentally sound agriculture does result in unacceptably high rates of soil erosion or degradation (*see for example* Pimental and Krummel, 1977; Rennie, 1979).

Effects of pesticides

Widespread use of pesticides has been followed by a number of detrimental effects. Pesticide resistance, particularly of arthropods, has now become a serious world-wide problem. By the late 1970s, well over 200 pest species had developed resistance to one or more of the major pesticide types (Watson and Brown, 1977; Brown, 1978). Unfortunately, the development of resistance among arthropod pests has not been paralleled by a similar development among the predators and parasites which normally control the pests (Croft, 1977). As pests develop resistance, so pesticides lose effectiveness—but the problem still remains, necessitating the development of new pesticides. However, the substantial costs and risks involved in developing a commercially viable product (Goring, 1977) seriously reduce the incentive to discover new pesticides. The extensive application of pesticides to monocultures of crops over a number of seasons can give rise to new pest species from insects which previously had no significant impact upon the crop. This phenomenon arises from the ecological imbalance caused by the destruction of predator insects and the consequent removal of natural controls on potential pest species. Examples of secondary pests developing on cotton intensively sprayed with pesticides have been quoted by Van Den Bosch (1971).

By definition, pesticides are highly toxic chemicals. Very few have a high degree of specificity in relation to their target organisms: rather, they are normally broad-spectrum compounds which have a relatively indiscriminate effect on wildlife as well as pests. Many cases of the effects of pesticides on nontarget insects, as well as on fish, birds and mammals, have been described by authors such as Carson (1962), Rudd (1964, 1975) and Gillett (1970). Pesticides have frequently been reported as having only transient effects upon soil microorganisms, although soil processes such as nitrification are very sensitive and may be sharply inhibited by some pesticides (Vlassak, Govindaraju and Verstaeten, 1977). However, although much is known about acute effects of pesticides upon the soil microflora, there are few data on long-term chronic effects of repeated pesticide exposures (Parr, 1974).

Pesticides are also toxic to humans. In spite of all the precautions taken in the production and application of pesticides, their high toxicity can and does result in poisoning and death. Although the organochlorine pesticides do not have a very high acute toxicity, others such as some organophosphorus compounds are highly toxic, with a lethal dose of less than 5 mg/kg body weight (Hodges, 1977a). Accurate data on cases of acute pesticide poisoning or death are not easily obtained, while the possible long-term chronic effects of pesticide exposure are even more difficult to determine. Nevertheless, the World Health Organization (WHO, 1975) has estimated that approximately 500 000 cases of acute poisoning occur annually, with a fatality rate of about 1 per cent, and both Rudd (1975) and Davies (1977) consider that pesticide exposure is a serious and increasing world-wide health hazard. Long-term effects may occur in humans as a result of chronic exposure to low pesticide levels over periods of time, particularly because some pesticides, such as toxaphene, have been shown to be mutagenic (Hooper *et al.*, 1979) or such as BHC, DDT, dieldrin, mirex or kepone, to be carcinogenic in rodents (Davies, 1977; Ames, 1979). Long-term effects could result, as much from the presence of many pesticides as ubiquitous contaminants throughout the environment, as from continuing new applications. For example, a wide range of chlorinated hydrocarbons have been detected as residues in human fat (Ames, 1979) and also in human milk (Aubert, 1977; Ames, 1979).

Use of fertilizers

The almost complete reliance of conventional agriculture upon the use of soluble fertilizers for the renewal of soil fertility may result in a number of problems which can arise from the excessive application of fertilizer nutrients. Because large inputs of fertilizer are often required for maximum production, there may be an overlap between those amounts of fertilizer leading to high productivity and those causing ecological problems. The potential detrimental effects of fertilizers on plants have been summarized by Phillips (1972) as: reduction in germination; retardation of seedling growth; scorching; increase in soil acidity, and development of nutrient imbalances. Other effects can be development of root damage (Imai, 1977) and increased susceptibility to disease, as well as reduction of legume root nodulation and plant mycorrhizal associations. Day, Doner and McLaren (1978) have summarized the environmental effects as follows: '. . . too much nitrate fertilizer can lead to water pollution, can result in soil humus reduction and can disturb the atmosphere composition'. In spite of the need for a high fertilizer input for productivity and the problems that this may engender, the efficiency of fertilizer uptake apparently can be quite low. For example, the National Academy of Sciences of the United States of America (NAS, 1975) stated that, in the USA, only 50 per cent of nitrogen fertilizer and only 35 per cent of phosphorus and potash are recovered by crops. In the tropics, losses of fertilizer nitrogen may be even greater, with recovery averaging only 25–35 per cent for rice crops.

ENERGY AND RESOURCE FACTORS

During the past decade many reviews have stressed the energy and resource intensiveness of conventional agriculture, and have commented on the relatively poor energy efficiency, the ratio of energy produced by crops over the energy needed to produce them, when compared with many traditional agricultural systems (*see* Pimentel *et al.*, 1973; Steinhart and Steinhart, 1974; Leach, 1975). During times of cheap, abundant energy such inefficiency did not matter but, since the oil crisis of 1973, increasing prices and shortages of oil, natural gas and minerals mean that the main tools of conventional agriculture, fertilizers and pesticides, have become increasingly more expensive. Such escalating costs can cause problems for agriculture in the developed countries, but far more so for many developing countries which need to increase food production but may not have the resources to produce or buy the necessary compounds. Pimentel and Krummel (1977) have commented on the impossibility, in energy terms, of ever being able to provide the world population with an American-style diet produced by high-technology conventional agriculture. Conventional agriculture is very wasteful in energy and mineral resources in that it is almost entirely a linear process. Industrially produced plant nutrients are used to grow crops, and the farm products pass out into the community, normally to be lost to agriculture, each crop needing fresh nutrients and energy inputs. Although this is largely a sociopolitical problem in which the community must decide whether or not to recycle all its wastes, nevertheless conventional agriculture often has not seriously attempted to recycle those wastes (straw, slurries, etc.) which remain under its control. The energy and resource constraints facing agriculture seem unlikely to improve in the foreseeable future.

ECONOMIC AND SOCIAL FACTORS

Mechanization

One of the major factors associated with the development of conventional agriculture has been the continuing trend towards mechanization and the consequent loss of manpower from the land. This trend has usually been considered to be an increase in agricultural efficiency. In the West, where this process has been taking place over many years, the workers leaving the land have been able to move to towns and cities to obtain urban and industrial jobs. Even so, considerable social problems have arisen, particularly due to rural depopulation. A recent example of this trend can be found in the EEC where, between 1960 and 1976, half of the original 16 million agricultural workers moved from the land.

The Green Revolution

The application of conventional agricultural methods to developing countries, and particularly the comparative rapidity with which those changes have taken place in recent years, has often contributed to the worsening of social conditions instead of improving them. Some of these changes are a direct result of the Green Revolution which was originally intended to improve conditions in the developing countries. Much has been written about the Green Revolution in recent years, both for and against it. In the areas where it has worked well there is no doubt that the production of the two main crops, rice and wheat, has increased greatly (Gill, 1978). Nevertheless, with its need for the specific inputs of credit, fertilizers, pesticides, seeds and irrigation in order to obtain its high yields, it often turns out to be a package of agricultural technology which is unsuited to the needs of many farmers and smallholders in developing countries. Analyses of the impact of the Green Revolution on world food production have come to differing conclusions but, in the opinion of many analysts, it has failed to meet its early expectations. Among the more pessimistic reviews, Griffin (1974) has calculated that the Green Revolution has not resulted in an acceleration of food production in any part of the Third World. Aziz (1977) has gone further in stating that annual increases in food production in developing countries have dropped from 3.1 per cent in 1952–62 to 2 per cent in 1972–75, in spite of the Green Revolution. The complex and capital-intensive nature of Green Revolution technology has often resulted in benefits to large farmers, to the detriment of the smaller ones, in the loss of the jobs of many agricultural labourers, and in increases in social and class divisions (Havens and Flynn, 1973; Castillo, 1977; ILO, 1977; Ledesma, 1977). Chang, one of those associated with the development of the new strains of high-yielding rice, admits that the intensive techniques required for this rice-growing technology have resulted in 'devastating epidemics of diseases, insect pests, or both', and considers that the high-yielding varieties do not produce as well on farms as in the research institutes (Chang, 1979). He believes that the full potential of these varieties can be achieved only by increasing inputs of fertilizer, irrigation, pest controls, credit and all the industrial and governmental support normally provided to farmers in the developed countries. Many developing countries are unable to provide these inputs at the required levels.

Productivity

The increasing mechanization and capital-intensiveness of conventional agriculture has been considered to have resulted in increased efficiency and productivity. Although, when viewed in certain terms, its efficiency has increased, when considered basically in terms of productivity per man or per hectare, improvement in productivity is much less certain. First, in the case of productivity per man, although only a few farm workers 'in the field' actually produce the food, they are supported by many workers in the agricultural or associated industries. Thus in the US the whole food production and processing complex employs about 20 per cent of all workers (Pimentel *et al.*, 1973). Secondly, a number of recent studies have suggested that smaller, labour-intensive operations are more productive per hectare than large, highly mechanized farms (*see for example* Best and Ward, 1956; Britton and Hill, 1975; Perelman, 1975; Vale, 1977).

CONCLUSION

All the above factors, together with the probability that many crops grown under conventional practices are close to their maximum productivity, suggest that conventional agriculture may now be coming up against considerable environmental, social, energy and resource constraints, and further development along the same lines will be counterproductive. Indeed, it could be said that, during the past 30 or 40 years, conventional agriculture has increasingly followed a path of 'chemical development' which has now reached its maximum levels of productivity and is turning out to be a cul-de-sac. Even though the developed countries have plenty of food, and are even overproducing many commodities, on a global basis humanity is short of food and population is increasing. The overall world situation can be summed up by three short quotations. Boerma (1975), the then Director-General of FAO, considers that to meet the world's food needs between now and 2000 AD '. . . agricultural production will have to double every 18 years—a rate never before achieved over a sustained period . . .'. Olembo (1977) states that in order to match food supplies to growing population '. . . we must urgently and dramatically increase food production . . .'. Finally, Manocha (1975) considers that 'at the present time the land under cultivation has been under great agricultural stress, which in turn has put strains on the biological ecosystems of this planet. The "Green Revolution" in the poorer countries of the world cannot be maintained for an indefinite period and it is doubtful that the high yield per acre achieved in the developed countries can be expanded or even maintained for a long stretch of time'.

If this analysis is correct, and conventional agriculture does not have the potential to qualify as an agriculture for the future, what alternative system or systems are there? The alternatives to be considered here are biological agriculture and integrated agriculture.

Biological agriculture

Biological agriculture is a system of farming based upon the principle that agriculture is, first and foremost, a biological science. The term biological agriculture is one which, in recent years, has tended to supersede the original term, organic farming; however, *the two terms are virtually synonymous.* Biological husbandry has a wider meaning in that it includes biological systems of agriculture, horticulture, forestry, gardening, etc.

Biological agriculture can be defined as a system that attempts to provide a balanced environment, in which the maintenance of soil fertility and the control of pests and diseases are achieved by the enhancement of natural processes and cycles, with only moderate inputs of energy and resources, while maintaining an optimum productivity. The introduction, into a biological system, of chemicals such as fertilizers tends to short-circuit these natural processes and thus a proper interpretation of this definition does not allow the use of soluble fertilizers or synthetic pesticides in the system. A biological system in which some fertilizers and pesticides are used on a regular basis is more properly called integrated agriculture (*see below* (p. 9)). The aims of biological agriculture are to develop:

1. A sustainable agriculture, i.e. a system which maintains and improves soil fertility such as to guarantee adequate food production into the foreseeable future

2. A self-sufficient or, more realistically, a self-sustaining agriculture; i.e. a system which relies as much as possible upon resources from within its own area and which is not reliant upon large quantities of imported resources. This applies particularly to the developing countries and fertilizers, etc.
3. An agriculture which takes as its guide the working of biological processes in natural ecosystems. It must always be remembered that agriculture is primarily applied biology and is most likely to be successful when it accepts and follows biological principles.

Aim 3 is most important—it is the basic principle of biological agriculture. All agricultural systems interfere with natural processes and are frequently a gross simplification of natural ecosystems. Nevertheless, it is possible to devise a system of agriculture which is founded on basic biological principles and which does not attempt to ignore, or to contravene, these principles. Biological agriculture is such a system. From aim 3 one can derive a number of points which can be considered as the basic principles of biological agriculture. They are:

1. The health of soil, plant, animal and man are linked by a common nutritional cycle
2. The health of the whole cycle will be diminished by a loss of soil fertility or by any imbalance introduced into the soil by improper husbandry practices
3. All living materials and waste products must be returned to the soil for the maintenance and improvement of its fertility
4. This return is necessary for the purification of waste materials, which would otherwise cause pollution, and for the recycling of essential elements
5. The soil should retain an ordered structure, with decomposing material on the surface and humus-enriched soil below. This implies a minimum of soil disturbance
6. As in natural ecosystems, plants and animals should coexist, each as mixed communities; crop rotations and mixed stocking constitute a practical expression of this principle
7. As far as possible the soil should always be covered by living and decaying material
8. The resources of an area are usually adequate for sustained growth in that area.

The necessity for taking 'natural conditions' as the basic model for agricultural practice is most important because all living things have evolved to fit precisely into such conditions and any significant deviation from them is likely to put stress upon the crops or animals being farmed. For example, the complex biological system represented by plant roots, associated microflora and soil organisms in general (Matile, 1973), which has developed into its present complexity over millions of years of evolution, cannot be short-circuited by chemical means without risk of damage to the health of the soil and of the plant.

Other basic concepts behind biological agriculture are:

1. It concentrates on building up the biological fertility of the soil so that the crops take the nutrients they need from the steady turnover within the soil. Nutrients produced in this way are released in harmony with the needs of the plants, and are not presented to the plants in excessive amounts at any time. Biological soil fertility is directly related to the development and maintenance of a high level of organic matter. Organic matter is stressed here rather than humus: the former is a highly complex mixture of organic materials in varying stages of decomposition and in a state of dynamic interaction with the soil life; the latter is well-decomposed organic residues which do not support the full spectrum of biological activity. Organic matter performs a wide range of very important functions in a fertile soil, indeed it can be said to be one of the most important factors in the development of a biologically fertile soil. When applied to the soil in the right way, organic matter has a wide range of effects—physical, chemical and biological—which not only develop the soil structure and fertility but also can help to control pests and diseases within the soil and on the plants (Baker and Cook, 1974). The combination of all the properties and effects of organic matter is what helps to produce the fertile soils which are the basis of biological agriculture. Conversely, it is the reduction of soil organic matter levels in conventional farming which can cause many problems
2. Control of pests, diseases and weeds is maintained largely by the development of an ecological balance within the system and by the use of various cultural techniques such as rotations and cultivations. Practical experience has shown that plants grown in a biological system tend to be less susceptible to disease
3. Biological agriculture attempts at all times to work on a cyclical basis, which is the only way a sustainable and self-sufficient agriculture can be maintained. Biological farmers recycle all wastes and manures within the farm, but the export of products from the farm results in a steady drain of nutrients. In a situation where conservation of energy and resources is considered to be important, a community or country would make every effort to recycle all urban and industrial organic wastes back to agriculture and thus the system would require only a very small input of new resources to 'top up' soil fertility. The potential availability of enough organic wastes to maintain soil fertility has been discussed by, among others, Hodges (1977b), Nager (1977) and El Bassam and Thorman (1978). The production of fertilizers, particularly nitrogenous fertilizer, is a very energy-intensive process. Because biological agriculture uses few, if any, of these compounds in maintaining soil fertility, its energy intensity often can be shown to be less than that of conventional agriculture. Lockeretz *et al.* (1976) have shown that, largely because of the use of fertilizers, conventional agriculture can be about 2.3 times as energy-intensive as biological agriculture, while Crouau (1977) calculates the figure at 2.5 times as energy-intensive.

In the long run, and particularly in the context of this discussion, the value of biological agriculture as a potential agriculture for the future depends largely upon its ability to produce enough food to feed the world. In recent years numerous experimental results have shown that inputs of manures or other organic fertilizer materials are capable of producing crop levels as great as, and sometimes greater than, the equivalent chemical fertilizer inputs (*see for example* Ionescu-Sisesti *et al.*, 1975; Mathers, Stewart and Thomas, 1975; Cooke, 1976, 1977; Nilsson, 1979). In summarizing the results of the long-term comparative trials carried out at experimental stations such as Rothamsted, Thorne and Thorne (1978) state: '. . . in recent years, with improved tillage and weed-control practices, plots treated with farmyard manure now yield somewhat more than those receiving equivalent amounts of nutrients in inorganic fertilizers.' Hodges (1977b) has reviewed a number of reports which examined the productivity of biological agriculture in comparison with its conventional counterpart. The general conclusions drawn from these reports are that, for most crops and products, biological agriculture can be as productive as conventional agriculture. A very recent report from the United States Department of Agriculture (USDA, 1980) supports this conclusion. Of much greater significance for increased food production, particularly in Third World conditions, is the development in recent years of what is called the Biodynamic–French Intensive method (Jeavons, 1974, 1976; Kaffka, 1976). This is a small-scale, labour-intensive, minimal energy-input technique for growing vegetables which, it is claimed, can produce significantly higher levels of output than its conventional horticultural equivalent. Other biologically based, intensive and highly productive systems of agriculture/horticulture from the Third World have been reported by King (1926), Clayton (1964) and Gleave and White (1967).

Integrated agriculture

Integrated agriculture is a system which attempts to combine aspects of both the biological and the conventional systems. In general, this system maintains soil fertility as much as possible by biological means (such as the recycling of all manures and wastes) but also adds moderate amounts of chemical fertilizers in order to attain maximum yields. Some experimental studies have suggested that the combination of manures and fertilizers can be more highly productive than either separately. Control of pests and diseases in this system may be by integrated control—primarily the use of cultural and biological techniques, backed up where necessary by pesticides and herbicides.

Conclusions

After nearly 40 years of intensive research and development, conventional agriculture appears to have reached a position where, although it is highly productive under Western conditions, it is becoming subject to a number of environmental and other constraints. Significant further increases in productivity seem unlikely as a result of extensions of conventional technology but, even if they are, the problems associated with these constraints will almost certainly increase. The widespread application of conventional technology to developing countries is possible only if enormous economic resources are allocated to such a project. Many developing countries are unlikely to possess these resources, even if the technology is applicable to their needs. The evidence available at present suggests that biological agriculture is capable of competing with conventional agriculture, and that it has attained this position of apparent parity without the backing of extensive research support. It seems likely that the present position of biological agriculture is similar to that of conventional agriculture 30 or 40 years ago and that, if an extensive research effort is applied to its development, it has an enormous potential for food production while remaining an environmentally benign system with relatively low energy and resource requirements. The need for extensive research has been highlighted by the recent report from America (USDA, 1980). In particular, the development of biological techniques along the lines of the Biodynamic–French Intensive method are urgently required to enable the poorer parts of the Third World to begin working towards self-sufficiency in food production. Biological agriculture is an ideal system in these circumstances because it is potentially adaptable to all levels of agriculture, from the smallest peasant holding to large-scale mechanized agriculture.

The widespread development and application of efficient biological techniques requires not only research, but also the political decision within individual countries or areas to develop satisfactory means of recycling organic wastes and thus to reuse the nutrients removed from the land as food. The present method of disposing of wastes so that they are permanently lost to agriculture is an irresponsible misuse of finite resources. However, once a decision has been made to develop recycling techniques, then efficient biological agriculture becomes possible and adequate food production can be assured for the future. During any period of transformation from conventional to biological agriculture, particularly if it occurred on a large scale, it would probably be advisable to introduce a phase of integrated agriculture because complete withdrawal of the use of fertilizers often results in a drop of productivity before biological soil fertility can be established.

All that has been said in this paper can be summed up by quoting a few words from Dr Sicco Mansholt, the former EEC Commissioner for Agriculture and Netherlands Minister of Agriculture: 'If we utilize biological means we shall be able to farm for ever. There are no limits set here. As long as there is sun, water, soil and microorganisms, we shall—in as much as we maintain an ecological balance—be able to maintain an assured production' (Mansholt, 1979).

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