Biointensive Sustainable Mini-Farming: I. The Challenge

John C. Jeavons

ABSTRACT. The purpose of this paper is to: briefly describe current challenges in food production systems, land availability, water availability, genetic resources, human resources and per capita needs in light of an increasing global population; make a case for an alternative vision of effective, small-scale production (with a potential for long-term buildup of marginal soils) compared to conventional agriculture; and demonstrate that such a complementary, more decentralized system, where individual families take responsibility for what they grow and eat, may be productive, efficient, robust, flexible, resource-conserving, environmentally sound and strongly sustainable while encouraging and maintaining a higher degree of social and resource equity and stability for the people of this planet. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com> © 2001 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. Biointensive, small-scale, high-yielding, resource-conserving, organic

Population will increase rapidly, more rapidly than in former times, and 'ere long the most valuable of all arts will be the art of deriving a comfortable subsistence from the smallest area of soil.

–Abraham Lincoln, 1857

John C. Jeavons is Executive Director, Ecology Action, 5798 Ridgewood Road, Willits, CA 95490. He has a BA from Yale University and is the recipient of the following awards: Boise Peace Quilt Award–1988, Giraffe Award for Public Service–1989, Santa Fe Living Treasure Award–1989, Steward of Sustainable Agriculture–2000. Nominated for World Food Prize–1993 and 1995.

THE CHALLENGES

To meet the challenges of increasing world population levels, many believe that a rough doubling of food production by 2050 is theoretically possible, but that the elements needed to accomplish it are not now available or in process. The United Nations in Agenda 21 reviewed the world's environmental, soil, and food situation and described goals for future food production through farming. These included: reducing chemical use, conserving and rehabilitating soil, improving farm productivity, conserving plant genetic resources, and developing effective organic farming techniques. The Asian Vegetable Research and Development Centre has observed that it will soon be essential to produce large amounts of calories from small areas through vegetable crops in order for there to be enough food for people.

THE BACKGROUND

This paper draws on Ecology Action's experience with *biologically intensive agriculture* for a 27-year period from 1972 through 1998. The specific form of farming being practiced has been named "Grow Biointensive" Sustainable Mini-Farming to distinguish it from other biointensive–biologically intensive–forms of agriculture that have appeared more recently and may use mechanical cultivation, pesticides and/or techniques not used by Ecology Action's approach. The "Grow Biointensive" method has been derived directly and indirectly from many similar practices developed independently in different parts of the world 1,000 to 4,000 years ago such as those in China, Greece, Bolivia, Peru, Mexico, Japan and more recently in France, Russia, Ireland and other parts of Europe (Biointensive History Citations, 1845 to 1991). One purpose is to describe the potential of this method as an applicable form of agriculture in today's world. (The method is described in detail in Part 2 of this series of articles.)

Ecology Action, a small non-profit organization located in California, has built on these forms of traditional agriculture, relearning techniques that are thousands of years old, discovering the scientific agronomic principles that underlie them, and developing written "how-to" materials for their replication in virtually all the global soils and climates where food is grown. The rediscovery of the principles involved in Grow Biointensive agriculture was facilitated by the work of Englishman Alan Chadwick, who brought similar food-raising practices to the

University of California-Santa Cruz in 1967 (Bronson, 1970/1971). Ecology Action studied this work closely.

Many authorities have indicated the efficiencies of small-scale agriculture–some up to five times conventional agricultural yields. Globally, the small-scale experience has often demonstrated an "inverse relationship between farm size and productivity" (Wortman, 1976; Popenoe, 1982; Small-Scale Farming Citations, 1979 to 1998). Those making these evaluations have included representatives of the Rockefeller Foundation and the Institute for Tropical Agriculture.

After decades of research, Dr. Robert Netting cites numerous examples of this effectiveness in such diverse regions, cultures and climates as Nigeria, Mexico, Switzerland and Asia. The groups studied by Netting have demonstrated how smallholder family households employ simple tools, intensive labor, detailed knowledge of the local environment, and skillful management and organization to produce their own food and surplus crops for trade or market. He discovered that land tenure by individual family households provided farmers with the incentive to carefully conserve and sustain resources, and that long-term agricultural and social stability was a product of this smaller, more local control of land and labor. This approach contrasts to large-scale, energy-expensive, mechanized, specialized, capital-intensive practices pursued by conventional agriculture (Netting, 1993). More recently, small-scale farming has made an important difference in Russia. In 1997 fifty percent of Russia's agricultural production "was on household plots of less than an acre each. These represented some 14 million acres, or 3 percent of all [Russian] farmland" (Matloff, 1998).

Catalyzing long-term Grow Biointensive agricultural research, development and educational programs has been a goal of Ecology Action since 1972. Only recently have sufficient data been collected and evaluated to call for an academic initiative. Grow Biointensive Sustainable Mini-Farming practices demonstrate *a potential of enabling people to double their food production regionally while using a fraction of the resources used by conventional practices per pound of food produced.* This experience of Ecology Action and others around the world is not meant to be exhaustive or totally definitive. Instead it illustrates a key *pattern* with a capacity for significantly increased yields, combined with significantly reduced resource consumption. As a result, these practices seem to be worthy of serious long-term statistical evaluation by the agricultural academic community, so that the importance of their applications to soil fertility, food production and resource conservation may be determined in relation to a planet with a diminishing per capita soil, water, fertilizer and energy base.

The study of Biointensive practices has revealed several *biologically intensive economies of small-scale*. How many people have experienced plants growing in widely spaced rows in nature? In contrast, a *densely woven, living blanket of biodiversity* can be observed if natural systems are encouraged. When natural systems are mimicked in organic Grow Biointensive farming practices, yields up to Green Revolution-type high productivity may be obtained with normal open-pollinated seeds while just a fraction of the water, nutrient and energy resources are consumed per pound of food produced. If the techniques are utilized in their entirety, the fertility of the soil can be *built* and *maintained* at the same time. Grow Biointensive practices, when used properly, have the capacity to build the soil in terms of humified carbon in the upper one to one-and-one-half inches of the soil–one key measure of soil-building–up to 60 times faster than occurs in Nature–at a time when conventional practices in the U.S. are depleting the soil about 18 times faster than happens naturally (Maher, 1983; Ecology Action, 1996).

Agricultural systems based on natural systems can offer greater long-term economy and also can possess a *stronger level of sustainability*. Current conventional agricultural systems, in contrast, have depleted and are continuing to significantly deplete regional environments, and demonstrate *less strong levels of sustainability*. As a result, their initially naturally based soil systems are not responding well. It has been observed that the economic consequence to agriculture from these soil system losses is major, and that a *basic correction* of the problems involved would be much less expensive than trying to minimize them by balancing out their negative effects with technological solutions.

A PERSPECTIVE AND A PROJECTION OF FUTURE CONDITIONS

Soil

Normally it takes 500 years for nature to build 1 inch of topsoil. To grow good crops agriculturally, 6 inches of topsoil are required. Therefore, approximately 3,000 years are needed to build up a reasonable agricultural soil. In contrast, the 5,454 kilograms (12,000 pounds) per acre of soil being lost due to wind and water erosion in the U.S. is an annual average loss of 0.09 centimeter (0.0356 inch–approximately 1/28th of an inch) of soil over 0.4 hectare (1 acre). Since only 1/500th of an inch of topsoil is being built up naturally as an annual average in the U.S., the soil depletion rate each year occurs approximately 18 times faster than the soil is formed in nature. In developing nations, soil is being depleted up to 36 times faster than it is being formed in nature; and, in China, 54 times faster (derived from: Soil Conservation Service, 1994). It is essential to find a way to reverse these losses to our soil base.

Given the projected increases in population in the coming decades, the amount of cropland per person is expected to decrease as urban sprawl overtakes land previously used for agricultural production and as the rural areas lose their fertility (Gardner, 1996, pp. 12-19). *Food security* is an increasing concern in countries everywhere and with reason. *By the year 2014 there may be an average reduction in farmable soil to as little as 836 square meters (9,000 square feet) per person*–down from 2,787 square meters (30,000 square feet) in 1977 and 2,043 square meters (22,000 square feet) in 1988–for the 90% of the world's people expected to be living in developing countries, and some of this soil will be needed to preserve key non-farm genetic diversity. (This is based on a probable world per-person farmable area projection from 1977 to 2014 derived from the data in *UN-FAO Yearbook–Production* for the years 1977 through 1996 and extended by a conservative progression through 2014 combined with a conservative world population level for 2014 of approximately 6.7 billion people and a developing nations population of approximately 6.0 billion–about 90 percent of the world population.)

In contrast, a Master's of Science thesis at the University of California, Berkeley in 1983 indicated that Biointensive practices (as performed by Ecology Action on Syntex Corporation land at the Stanford University Industrial Park) built up the humified carbon level in the upper 1 to 1.5 inches of the soil, which began as only 'C'-horizon material, to a level in about 8 years that would have taken nature alone 500 years to accomplish. Therefore, this thesis indicated that Biointensive techniques may have the potential to build soil up to 60 times faster than it can be developed by nature alone. If utilized, this technique may make possible not only the maintenance of sustainable soil fertility, but also the reclamation of deteriorated and marginal lands (Maher, 1983).

Grow Biointensive agricultural practices, *fully and properly* used, can produce a greatly increased level of nutrition per unit of area, thus leaving fragile ecosystems uncultivated and protecting genetic plant and animal diversity in the wild. These practices can accomplish this in part by utilizing: (1) a combination of certain varieties of grains in 60% of the growing area, that produce high levels of carbonaceous dry matter per unit of area for compost in addition to a significant amount of calories for diet; (2) special root crops in 30% of the growing area, such as potatoes, sweet potatoes, salsify, burdock, garlic, and parsnips, that produce large amounts of calories per unit of area; and (3) salad/salsa/stew sauce-type vegetable crops in 10% of the growing area for additional vitamins and minerals.

". . . worldwide, prime farmland is rare. The FAO estimates that only 11 percent of the world's soil can be farmed without being irrigated, drained, or otherwise improved" (Markwart, 1999). "With soil erosion exceeding soil formation in many areas, parts of the Earth are slowly being drained of their inherent fertility" (Brown et al., State of the World, 1998). "Approximately 30% of the world's arable crop land has been abandoned because of severe soil erosion in the last 40 years . . ." (Rural Advancement Foundation International, 1997). "Mechanical cultivation and the production of continuous row crops have resulted in soil loss through erosion, large decreases in soil organic matter content, and a concomitant release of organic carbon as carbon dioxide to the atmosphere" (Houghton et al., 1983). "Where the topsoil has been entirely removed, or where it has been severely eroded, crop yields are from 20 to 65% lower than on non-eroded soils." (See also: Soil Conservation Service, 1994; Barrow, 1991; Parr et al., 1992; Pimentel et al., 1995; Ribaudo, 1989; Doran, 1996; Karlen et al., 1992, p. 49.)

Population

Currently, about 213,699 people net are added to the global population daily (United Nations, 1998). As a result, the planet in one sense "needs" at least 19,853 more hectares (34,341 acres) of farmable land daily (752 square meters or 7,000 square feet/person) to produce just a vegan diet, given conventional U.S. agricultural practices (see also: Brown and Kane, 1994; Cohen, 1995; Pearce, 1998; Mossat, 1996). This underscores the continuing need for family planning initiatives to maintain population levels within available farmable soil levels.

Water

Water Scarcity and Population

By 2050, the average person in the world is expected to have only 25% of the fresh water that was available in 1950 (Meadows, 1999).

". . . per capita water supplies worldwide are a third lower now than in 1970 due to the 1.8 billion people added to the planet since then . . . The projected increase in the world's population is resulting in a greater urban demand for water" (Postel, 1996, p. 28). Therefore, agricultural production will be forced to use water more efficiently. Organic agricultural systems including Biointensive practices are both more water-efficient and more "drought-proof." A 15-year study recently completed by the Rodale Institute has demonstrated such a resilience (Drinkwater et al., 1998).

"The UN's 1994 medium population projection suggests that by the middle of the coming century, [under] the low projection . . . the proportion [of the world's population] would be 44 percent, or 3.5 billion people living in 51 water-short countries out of a total world population of 7.9 billion. Clearly, the extent of water shortages will depend to a large degree on which trajectory world population follows" (Engleman and LeRoy, 1994, p. 8). "Worldwide, agriculture accounts for about 65 percent of all the water removed from rivers, lakes, and aquifers for human activities, compared with 22 percent for industries and 7 percent for households and municipalities . . ." (Postel, 1996, p. 13).

Natural Rainfall vs. Irrigation

". . . Today, 84 percent of the world's cropland is watered only by rain, while 16 percent benefits from the greater control afforded by farmers applying water" (Postel, 1996, p. 49). "As per capita fresh water supplies plummet in many nations, formidable forces constrain future irrigation projects, and thus any accompanying gains in yield" (Brown et al., 1998, Vital Signs, p. 42).

Global Warming

". . . An international group of scientists has concluded that a 1 to 2 degree Celsius [1.8-3.6 degrees Fahrenheit) warming along with a 10 percent decrease in precipitation–well within the realm of possibility in some areas–could reduce annual runoff by 40-70 percent. Such a drop would have staggering economic environmental consequences on regions already short of water–forcing land out of irrigation, reducing hydroelectric power production, wiping out many species, and greatly constraining urban growth and the quality of life" (Postel, 1996, p. 88).

Meeting Water Demands and Growing Sufficient Food

". . . within the next 25 years, providing sufficient water to meet projected food needs on a sustainable basis will be extremely difficult. . . . food production from both fisheries and pastured livestock is already reaching its limits, so that nearly all of the additional food needed by 2025 will need to be produced on croplands. . . . when degradation of currently utilized croplands is taken into account, the potential for significantly expanding total cropland area is low. Therefore, the necessary annual increase in agricultural productivity of at least two percent per year must come *almost entirely* from increased productivity *per unit area* for plant crops. . . . Water supply is a key factor for determining plant crop productivity per unit area. Doing more with less is the first and easiest step along the path toward water security. By using water more efficiently, we in effect create a new source of supply" (Williams, 1998).

Energy

"Human influence on the planet has increased faster than the human population. For example, while the human population more than quadrupled from 1860 to 1991, human use of inanimate energy increased from . . . 1 billion megawatt hours/year . . . to 93 billion . . ." (Cohen, 1995). Oil availability is expected to peak at about 2005 and natural gas at about 2020 (Oil and Gas Journal Special, 1997). Current estimates of practically available fossil fuel reserves project crude oil to be depleted within 35 years (Flavin and Lenssen, 1990; Campbell and Laherrere, 1998). Fossil fuels will become more scarce in the future, making fuel, artificial plant nutrients, and crop protectants for agricultural use much more expensive. *Without these inputs, the area needed to produce an annual diet for one person by U.S. current conventional commercial agricultural practices might conservatively be estimated to increase as much as threefold, due to productivity decreases resulting from a reduction in availability of inexpensive nitrogen fertilizer inputs*–from a current range of approximately 1,612 to 3,901 square meters (15,000 to 42,000 square feet) to as much as 4,836 to 11,705 square meters (45,000 to 126,000 square feet) in the future (developed in part from: Watt, 1974, pp. 39-40).

Atmospheric Carbon Dioxide, Global Warming and Climate

Carbon dioxide is one of the major gases responsible for the Greenhouse Effect. Some carbon dioxide in the atmosphere is normal, but currently in our atmosphere there is an excess of approximately 65 metric gigatons (gigaton = G ton = 1 billion tons) [update] of carbon in the form of carbon dioxide, largely from the burning of carbon-based fossil fuels, deforestation, and insustainable farming practices (Volk, 1994, p. 48). This excess atmospheric carbon dioxide has been shown to be responsible for at least one-half of the Greenhouse Effect, the long-term effects of which are difficult to prove but which will probably increase or decrease regional temperatures, sea levels, and/or snow and ice coverage around the world, depending on the conditions and premises involved, to extremes non-optimal to most living beings and ecosystems.

"Soil organic matter . . . is the major global storage reservoir for carbon" (Rural Advancement Foundation International, 1997, p. 81). Grow Biointensive Sustainable Mini-Farming and other approaches such as sustainable agroforestry may be able to remove all excess Greenhouse Effect-causing atmospheric carbon dioxide developed since 1976 and expected to be developed through 2016 while producing more food and conserving resources. This could be made possible by the increased amount of carbon tied up in increased crop plant populations per unit of area and the increased organic matter levels in the soil. An increased number of trees on the planet would assist greatly (Ecology Action, 1999). "Stabilizing the climate will ultimately require reducing global carbon dioxide emissions by 60 to 80 percent" (Flavin and Lenssen, 1990, p. 7).

Climate change models predict greater severity and frequency of extreme weather events in the future (Karl et al., 1996). Should an average increase in temperature of 5 degrees Celsius (9 degrees Fahrenheit) occur, some scientists believe the result could be a reduction of up to 50% in U.S. food production. In the first eight months of 1998, the average world temperature was 0.4 degrees Celsius (0.7 degrees Fahrenheit) warmer than in 1997 (Flavin, 1998). Changes in climate will require agricultural production systems to be environmentally robust. At the core of environmental robustness is diversity. Grow Biointensive agricultural practices encourage both plant and soil microbe diversity.

FARMING: CONVENTIONAL AND BIOINTENSIVE

The Production and Environmental Record of Conventional Agriculture

"Conventional agricultural practices, producing a larger amount of food for the world's people than ever before, have been seen as the 'most efficient in history.' At the same time, however, the environmental degradation of soil, water, nutrient and energy resources has occurred at an unparalleled rate. Globally, grain production began to level off in the 1990s as increased chemical fertilizer inputs ceased to produce increased yields. The point of diminishing returns has been reached" (Brown and Kane, 1994).

Small-Scale

Approximately 85% of U.S. farmers obtain yields slightly less than the U.S. average, 14.5% produce yields about twice the U.S. average and about 0.5% obtain yields up to four times this average. Grow Biointensive farmers, with an average buildup in skill and soil fertility and without high water, fertilizer and energy inputs, may produce about two times the U.S. average–thereby being in the upper 15th percentile of farmers (Ecology Action, 1975-1976).

Transportation

The average piece of food consumed in the U.S. travels approximately 1,400 miles. "Americans once fed themselves–with a few exceptions. . . . Today, one-third of all fresh fruit and 12 percent of all vegetables consumed in the United States come from other countries. Even staples, like tomatoes (31.4 percent), come from abroad. And the numbers keep growing. Imports are up more than 50 percent since 1990" (Hoyle and Flatley, 1998). The utilization of Grow Biointensive production efficiencies on "greenbelt" farms in and near cities holds significant potential in an increasingly urbanized world. This kind of more-local food growing would mean fresher food available to large numbers of people and greatly reduced transportation costs. In addition, local Community-Supported Agriculture (CSA) farms could produce freshly grown complete diet packages for retail sale to nearby neighborhoods with almost no transportation expenses.

Food Supplies

"Grain reserves averaged the equivalent of 81 days of global consumption between 1982 and 1993, but have fallen steadily since then, dropping to 48 days' worth in 1995" (Gardner, 1996. p. 12). Generally 60 days of grain food reserves are required to "fill the food pipeline," and politicians and food specialists worry when reserves fall below this level. In 1998 the reserves climbed to a 64-day supply with a projection of 62 days for 1999 (USDA, 1999), but it must also be kept in mind that *the world has consumed more grains than it has grown* for eight of the last 12 years (1987 through 1998), and population and environmental pressures are increasing the vulnerability of this situation [During 7 of the previous 12 years (1975 through 1986) and 8 of the 12 years before that (1963 through 1974) *the world produced more grain than it consumed*] (USDA, 1998).

Seeds

". . . Biotechnology has not produced any yield-raising technologies that will lead to quantum jumps in output, nor do many researchers expect it to. Donald Duvick, for many years the director of research at the Iowa-based Pioneer Hi-Bred International, one of the world's largest seed suppliers, makes this point all too clearly: 'No breakthroughs are in sight. Biotechnology, while essential to progress, will not produce sharp upward swings in yield potential except for isolated crops in certain situations' " (Brown and Kane, 1994, p. 25). The loss of the world's agricultural genetic base is not necessary. Globally endangered seed varieties are often preserved unknowingly in small farm pockets. Small farms (and gardens) are key locations for the preservation and acclimatization of seeds. New seed strains which are adapted to particular climates and soils and which are resistant to local pests and diseases can be developed in these locations. In addition, seed yields obtained with Grow Biointensive practices can be up to two to four times conventional yields per unit of area and can be grown in or near the area in which they are intended to be used.

Fertilizer and Nutrients

"The principal reason for the slower growth or stabilization of fertilizer use in many countries is that the amount being used is approaching the physiological capacity of crops to absorb nutrients" (Brown et al., 1998, p. 44). "As more and more countries turn to imported grain, the nutrient cycle is further disrupted. The United States, which exported close to 100 million tons of grain a year during the eighties, suffered a heavy loss of soil nutrients. The nutrients in the wheat from Kansas and the corn from Iowa were ending up in the sewage discharges of St. Petersburg, Cairo, Lagos, Caracas, and Tokyo" (Brown and Kane, 1994, p. 124).

". . . According to one calculation, it takes the equivalent of 53 million barrels of oil–worth more than $1 billion–to replace with fossil fuel-based fertilizers the amount of nutrients yearly discarded in U.S. sewage" (Postel, 1992, p. 127). "Most fertilizer inputs–whether chemical or organic–are nutrient substitutes for the nutrients harvested from the soil in the form of crops, eaten by people, and then flushed away into sewage systems. Rarely are these nutrients recycled properly into the soils from which they came. The human sewage from one person from all year, under certain cropping and recycling conditions, can contain most of the nutrients needed to grow a complete, balanced diet for one person for all year on a small-scale agricultural basis" (Beeby, 1995).

Since 1972, Ecology Action has generally added the same amount, or less, of purchased nutrients (in organic form) *per unit of area* in comparison with conventional agriculture. With Grow Biointensive's potential of two to four times the yield per unit of area, this means the potential of a *reduction* in the use of purchased fertilizer nutrients to one-half to one-quarter per pound of food produced, or less. The yield *per plant* in these intensively planted areas, which have an increased plant population per unit of area, can sometimes be equal to those in less-densely planted areas and sometimes even greater. This is different than in conventional intensively planted areas where the total yield per unit of area increases, but the yield per plant usually decreases.

The Question

The question for the global community at this point is: Are there any agricultural approaches that might meet all of these challenges in an environmentally sound, universally affordable and effective manner?

REFERENCES

Barrow, C.J. 1991. Land Degradation. Cambridge University Press, Great Britain.
Beeby, J. 1995. Future Fertility. Ecology Action, 164pp.
Biointensive History Citations (1845-1991):
Armillas, P. 1971. Gardens on swamps. Science, November 12, Vol. 174, pp. 653-661.
Buchanan, K. 1970. Transformation of the Chinese Earth. Praeger, 335pp.
Coe, M.D. 1964. The Chinampas of Mexico. Scientific American 211, pp. 90-98 and 144.
Courtois-Gerard, M. 1845. Manuel Pratique de Culture Maraichere. J. Hetzel et Cie, Paris, 336pp.

Crews, T.E. and Gliessman, S.R. 1991. Raised field agriculture in Tlaxcala, Mexico: an ecosystem perspective on maintenance of soil fertility. American Journal of Alternative Agriculture, November, pp. 9-16.

Duhon, D. 1984. A History of Intensive Food Gardening. 136pp., distributed by Ecology Action, Willits, CA on a limited basis by permission of the author.

Erickson, C.L. 1988. An archaeological investigation of raised field agriculture in the Lake Titicaca basin of Peru. In: Experiments in Raised Field Agriculture. Dept. of Anthropology, University of Illinois, Champaign-Urbana, pp. 205-221.

Erickson, C.L. and Candler, K.L. 1988. Raised fields and sustainable agriculture in the Lake Titicaca basin of Peru. In: Browder, J.O., ed. 1998. Fragile Lands of Latin America–Strategies for Sustainable Development, Westview Press, Boulder, CO.

King, F.H. 1972. Farmers of Forty Centuries. Rodale Press, 441pp.

Marx, G. 1990. Bolivia sows ancient fruits. Chicago Tribune, September 2, Section 1, p. 5.

Mullen, W. 1986. Secrets of Tiwanaku–how ingenious farmers built an empire that inspired the Incas and rivaled Rome. Chicago Tribune Magazine, November 23, pp. 10-19, 23-27, and 29-32.

Painter, J. 1991. Archaeology makes edible impact–revival of ancient agricultural techniques makes Bolivian raised-bed potato project pay. The Christian Science Monitor, October 9, pp. 12-13.

Bronson, W. 1970-1971. The lesson of a garden. Cry California, Winter, pp. 4-16.

Brown, L.R. and Kane, H. 1994. Full House. W.W. Norton. 261pp.

Brown, L.R., et al. 1998. State of the World–1998. W.W. Norton.

Brown, L.R., et al. 1998. Vital Signs–1998. W.W. Norton.

Campbell, C.J. and Laherrere, J.H. 1998. The end of cheap oil. Scientific American, February, pp. 78-95.

Cohen, J.E. 1995. Population growth and earth's human carrying capacity. Science, July 21, p. 341.

Doran, J.W., et al. 1996. Soil, health and sustainability. In: Advances in Agronomy. Academic Press.

Drinkwater, L.E., et al. 1998. Legume-based cropping systems have reduced carbon and nitrogen losses. Nature, Vol. 396, November 19, pp. 262-265.

Ecology Action. 1975-1976. Informal phone survey.

Ecology Action. 1996. Worldwide loss of soil and a possible solution. 1pp. Based on the statistics given in: Summary Report 1992 National Resources Inventory. 1994.

Ecology Action. 1999. Biointensive sustainable mini-farming and other approaches may be able to remove all excess greenhouse effect-causing atmospheric carbon dioxide while producing more food. 7pp.

Engelman, R. and LeRoy, P. 1994. Sustaining Water: An Update. Population International p. 8.

Flavin, C. 1998. Global climate: the last tango. World Watch, November-December, p. 11.

Flavin, C. and Lenssen, N. 1990. Beyond the Petroleum Age: Designing a Solar Economy. Worldwatch, p. 7.

Gardner, G. 1996. Shrinking Fields. Worldwatch Institute.

Houghton et al. 1983. Changes in the carbon content of terrestrial biota and soils between 1860 and 1980: A net release of CO_2 to the atmosphere. Ecological Monographs, Vol 53, pp. 235-262.
Hoyle, J.C. and Flatley, K.A. (researchers). 1998. Growing US food imports. The Christian Science Monitor, May 14, pp. 10-11.
Karl et al. 1996. Indicies of climate change for the United States. Bulletin of the American Meteorological Society, Vol. 77, pp. 279-292.
Karlen, D.L., et al. 1992. Soil and crop management effects on soil quality indicators. American Journal of Alternative Agriculture, Vol. 7, Nos. 1 & 2.
Maher, D.E. 1983. Changes in carbon content in a soil under intense cultivation with organic amendments. Master's of Science thesis, Soil Science Department, University of California–Berkeley, 228pp.
Markwart, A. and Moore, M. 1999. Prime farmland: will we have enough? The Furrow, Spring, pp. 10-13.
Matloff, J. 1998. Despite U.S. Aid Dire Russian Winter. Christian Science Monitor, November 12, pp. 1 and 7.
Meadows, D. 1999. After two centuries, it's still not clear if Malthus was right. Timeline, January/February, pp. 12-13.
Mossat, A.S. 1996. Ecologists look at the big picture. Science, September 13, p. 1490.
Netting, R. 1993. Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable Agriculture. Stanford University Press. From: Hiestand, K. 1998. The importance of smallholders. Ecology Action Newsletter, November.
OGJ Special. 1997. Depletion patterns show change due for production of conventional oil. Oil and Gas Journal, December 29, pp. 33-37.
Parr, J.F., et al. 1992. Soil quality: attributes and relationship to alternative and sustainable agriculture. American Journal of Alternative Agriculture, Vol. 7, Nos. 1 & 2, p. 5.
Pearce, F. 1998. The rise of the wrinkles. New Scientist, June 20, p. 51.
Pimentel et al. 1995. Environmental and economic costs of soil erosion and conservation benefits. Science, Vol. 267, pp. 1117-1123.
Popenoe, H.L. 1982. Lecture. Third International Conference on Small-Scale and Intensive Food Production, Santa Barbara, California, 1972. See also: Intensive Food Production on a Human Scale. Transcript of the Third International Conference on Small-Scale and Intensive Food Production. Strategies for small farmers, Ecology Action, Palo Alto, CA, pp. 102-119.
Postel, S. 1992. The Last Oasis. W.W. Norton.
Postel, S. 1996. Dividing the Waters: Food Security, Ecosystem Health, and the New Politics of Scarcity. Worldwatch.
Ribaudo. 1989. Water Quality Benefits from the Conservation Reserve Program. USDA-ERS, Ag. Econ. Rept. No. 606, U.S. Govt. Print. Off., Washington, DC.
Rural Advancement Foundation International. 1997. Human Nature: Agricultural Biodiversity and Farm-Based Food Security.
Small-Scale Farming Citations:
Barret, C.B. 1993. On price risk and the inverse farm size–productivity relationship. University of Wisconsin-Madison, Department of Agricultural Economics Staff Paper Series no. 369.

Berry, R.A. and Cline, W.R. 1979. Agrarian Structure and Productivity in Developing Countries. Johns Hopkins University Press.

Carter, M.R. 1984. Identification of the inverse relationship between farm size and productivity: an empirical analysis of peasant agricultural production. Oxford Economic Papers, no. 36, pp. 131-145.

Corni, G.A., April, 1985. Farm size, land yields and the agricultural production function: an analysis for fifteen developing countries. World Development, pp. 518 and 531.

Ellis, F. 1993. Peasant Economics: Farm Households and Agrarian Development, 2nd edition, Chapter 10. Cambridge University Press, Great Britian.

Feder, G. 1985. The relationship between farm size and farm productivity.

Journal of Development Economics, no. 18, pp. 297-313.

Lappe, F.M. et al. 1998. World Hunger: 12 Myths, 2nd edition. Grove/ Atlantic and Food First Books.

Prosterman, R.L. and Riedinger, J.M. 1987. Land Reform and Democratic Development, Chapter 2. Johns Hopkins University Press. "1985 Congressional Budget Office figures, U.S. farms in the smallest size class had 94 percent higher total output per acre (in dollars) and 85 percent higher net profit per acre than farms in the largest size class" (calculated from data presented in chapter 5, table 3, of: Marty Strange. 1988. Family Farming: A New Economic Vision. Food First Books). (From: Lappe, F.M. et al. 1998. World Hunger: 12 Myths, 2nd edition. Grove/Atlantic and Food First Books.)

Tomich, T.P., et al. 1995. Transforming Agrarian Economies: Opportunities Seized, Opportunities Missed. Cornell University Press, pp. 124-136.

Soil Conservation Service. 1994. Summary Report 1992 National Resources Inventory. U.S. Department of Agriculture, Washington, DC.

United Nations. 1997 and other relevant volumes. UN-FAO Yearbook–Production.

United Nations. 1998. United Nations Population Fund moves day of six billion based on new population estimates. UNFPA News, October 28, p. 1.

USDA. Production, Supply & Distribution. 1998. USDA Electronic Database, updated December.

USDA. Production, Supply & Distribution. 1999. USDA Electronic Database, February.

Volk, T. 1994. The soil's breath. Natural History, November, p. 48.

Watt, K.E.F. 1974. The Titanic Effect. Sinauer Associates, p. 41.

Williams, G. and Williams, P. 1998. Water everywhere . . . but not enough for growing food. HortIdeas, Vol. 15, no. 9, Summer, p. 1. (Review of: Postel, S. 1998. Water everywhere but not enough for growing food. BioScience, August, pp. 629-636.)

Wortman, S. 1976. Food and agriculture. Scientific American, September, vol. 235, no. 3, pp. 31-39.

RECEIVED: 06/20/00
REVISED: 01/08/01
ACCEPTED: 01/28/01

Biointensive Sustainable Mini-Farming: II. Perspective, Principles, Techniques and History

John C. Jeavons

ABSTRACT. The purpose of this paper is to briefly describe the: principles for a more productive, resource-efficient and environmentally sound agriculture; the philosophical foundation for this kind of farming; the historical agricultural systems leading to Ecology Action's "Grow Biointensive" system: the French intensive, the Biodynamic, and Alan Chadwick's Biodynamic/French intensive approaches; and a description of Ecology Action's system. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com> © 2001 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. Biointensive, small-scale, high-yielding, resource-conserving, organic

PRINCIPLES FOR A MORE PRODUCTIVE, RESOURCE-EFFICIENT, AND ENVIRONMENTALLY SOUND AGRICULTURE

A viable, strongly sustainable agriculture system will promote:

John C. Jeavons is Executive Director, Ecology Action, 5798 Ridgewood Road, Willits, CA 95490. He has a BA from Yale University and is the recipient of the following awards: Boise Peace Quilt Award–1988, Giraffe Award for Public Service–1989, Santa Fe Living Treasure Award–1989, Steward of Sustainable Agriculture–2000. Nominated for World Food Prize–1993 and 1995.

- high productivity
- promotion of a healthy environment
- environmental stability and robustness
- resource-conservation
- flexibility
- a balanced sharing of farming power among local, regional and national levels, and
- a diverse and strong social fabric.

"GROW BIOINTENSIVE" SUSTAINABLE MINI-FARMING–PHILOSOPHICAL FOUNDATION

One of the most important aspects of this method's potential is that its *maximization of yields and minimization of resource consumption combined with a significant enhancement in soil fertility need not be fully developed in order to produce a major difference locally and globally.* At *intermediate* yield levels, that can be realized with a moderate increase in skill and soil fertility; combined with an improved understanding of diet involving a focus on the amount of caloric yield per unit of area for different crops: *approximately twice the people in the world might be fed while using one-half, or less, the water, purchased nutrients (in organic form), and energy per pound of food produced when compared with conventional mechanized chemical, or organic, agricultural practices.* In addition, this level of productivity might enable up to one-half the world's arable land to be left in wild to preserve essential plant and animal genetic diversity.

"Grow Biointensive" Sustainable Mini-Farming practices and an understanding of which crops provide a high level of caloric and/or carbon productivity per unit of area per unit of time can make it possible to grow a vegan diet for one person for all year on as little as 371 square meters (4,000 square feet) at reasonably obtainable *intermediate-level* yields (Diet Citations: Ecology Action, 1984-1997: estimate based on Ecology Action Diet Design practices growing key diet crops combined with the growing of compost crops for sustainable soil fertility). Since many of the world's people currently have only enough rainfall to satisfactorily raise food on an area this size (based on an article in: World Monitor, 1993) *and since, by the year 2014, ninety percent of the world's people (those in developing countries) are expected to have an average of only 836 square meters (9,000 square feet) of arable land upon which to raise their food,* this potential agricultural effectiveness

could become very important (UN FAO Yearbook–Production: Based on probable world farmable area projection from 1977 to 2014 combined with an anticipated 2014 world population level of approximately 6.7 billion people and a developing nations population of about 6.0 billion). It is even more important when one realizes that *conventional mechanized chemical and organic agricultural techniques* currently require:

- about 650 square meters of farmable soil (7,000 square feet) to raise a *vegan diet* that contains no animal products [this 1998 level is based on 1998 seed stock use and chemical fertilizer applications estimated from yields in: USDA Yearbook–1998. A *post fossil fuel era* estimate might be approximately three times as much, or 1,950 square meters (21,000 square feet), due to reductions in yield resulting from reduced chemical nitrogen fertilizer inputs],
- 1,393 to 2,787 square meters (15,000 to 30,000 square feet) to raise an *average U.S. diet* with an average amount of meat, milk, eggs and cheese [this 1998 level is based on 1998 seed stock use and chemical fertilizer applications estimated from yields in USDA Yearbook–1998. A *post fossil fuel era* estimate might be 4,180 to 8,561 square meters (45,000 to 90,000 square feet)], and
- approximately 3,623 to 5,852 square meters (39,000 to 63,000 square feet) to raise a *diet high in animal products* [this 1998 level is based on 1998 seed stock use and chemical fertilizer applications estimated from yields in: USDA Yearbook–1998. A *post fossil fuel era* estimate might be approximately 12,541 to 17,558 square meters (135,000 to 189,000 square feet)].

Thus, by 2014, with the current agricultural methods and diets, only 41% of the global population might be sustained nutritively [based on probable world farmable area projection from 1977 to 2014 (UN-FAO Yearbook–Production, 1997) combined with an anticipated 2014 world population level of approximately 6.7 billion people]. So, in fact, the major ways in which the world is currently farming and eating will not provide sufficient nutrition for most of the world's people as early as 14 years from now, in 2014, unless some dramatic changes occur in the way food is raised and/or in the diets eaten.

An additional aspect of Grow Biointensive techniques is their potential for a dramatic reduction in water consumption per pound of food produced, compared with conventional agricultural practices. Biointensive may use water as much as three to eight times more effectively per pound of food produced when compared with conventional agriculture: for grain and seed crops as little as 33% of the water may be used per pound of food produced; for vegetables as little as 12% depending on the soil type, climate, water availability and the crops grown. An actual example of this effectiveness can be found in Machakos, Kenya, an area where there is reportedly "not enough water" to grow citrus. Morris Makiti, one of the teachers first trained in Biointensive in that country, applied what he learned by sprouting seeds from grapefruit he bought at the local village market. He then created an orchard of 1,000 thriving trees grown with Biointensive practices (Ecology Action, 1996).

A FEW HISTORICAL NOTES

China

Four thousand years ago the Chinese were using a biologically intensive, "miniaturized" form of agriculture (Buchanan, 1970). The Chinese grew food with this approach and maintained soil fertility for thousands of years without depleting the soil significantly. As recently as 1890 this way of farming enabled them to grow all the food for one person on about 538 to 668 square meters (5,800 to 7,200 square feet), including animal products used at that time (developed from: King, 1972).

Biosphere II

Despite all its challenges, the people in Biosphere II, using techniques based in part on those rediscovered by Ecology Action, were able to raise about 83% of their low-calorie diet during a two-year period within a "closed system" on approximately 274 square meters (2,957 square feet) per person (Marino, 1998). This experience indirectly demonstrated that a complete year's diet for just one person could be raised on the equivalent of 330 square meters (3,562 square feet)–less than the Chinese in 1890. In contrast, conventional agriculture in the United States requires approximately 2,787 square meters (30,000 square feet) to produce an average diet–while bringing in inputs from other areas and soils in order to make even this possible (this is based on 1998 seed stock use and chemical fertilizer applications estimated from yields in: USDA Yearbook–1998).

In contrast with Biosphere II and conventional United States agriculture, about 1,486 square meters (16,000 square feet) in the year 2000 will be required to raise all the food for one person given actual agricultural practices being used and actual diets being eaten in developing countries in 1998 [based on probable projection from 1977 to 2000 (UN-FAO–Production, data for years 1977 through 1997)].

THE HISTORICAL AGRICULTURAL SYSTEMS LEADING TO ECOLOGY ACTION'S GROW BIOINTENSIVE SYSTEM

The French Intensive Approach

French intensive techniques were developed in the 1600's, 1700's and 1800's outside Paris. Crops were grown on a 45-centimeter (18-inch) depth of usually composted horse manure, a fertilizer which was readily available at the time. The crops were grown so close to each other that when the plants were mature their leaves would barely touch. The close spacing provided a mini-climate and a living mulch which reduced weed growth and helped hold moisture in the soil. During the winter, glass jars were placed over seedlings to give them an early start. The gardeners grew up to nine plantings and harvests each year and could even grow melon plants during the winter (Biointensive Citations, 1658-1972).

The Biodynamic Approach

Biodynamic techniques were developed by Rudolf Steiner, an Austrian genius, philosopher and educator, in the early 1920's. Noting a decline in the nutritive value and yields of crops in Europe, Steiner traced the cause to the use of the newly introduced synthetic, chemical fertilizers and pesticides. An increase was soon noticed in the number of crops affected by disease and insect problems. These fertilizers were not deemed to be complete nutrient systems for the plants, but single, physical nutrients in a readily available, soluble salt form. Steiner believed that the fertilizers caused chemical changes in the soil which damaged its structure, killed beneficial microbiotic soil life and greatly reduced the soil's ability to make nutrients already in the air and soil available to plants.

Steiner recommended returning to the more gentle, diverse, holistic and balanced diet of organic fertilizers as a cure for the challenges brought on by synthetic, chemical fertilization. He also initiated a movement to scientifically explore the relationships–both beneficial and detrimental–which plants have with each other.

Biodynamics emphasized raised growing areas which mimic the advantages of plant growth in landslides. Two thousand years ago, the Greeks noticed that plant life thrives in landslides. The loose soil allows air, moisture, warmth, nutrients and roots to more optimally penetrate the soil. The large curved surface area between the two edges of the landslide provides more surface area for the penetration and interaction of the natural elements than a flat surface. Biodynamics developed the use of homeopathic herbal preparations for the optimum development and maintenance of soil health and the proper production of nourishing compost. It also utilized the forces of the planets and stars to optimize planting processes (Biodynamic Farming Citations, 1938-1988).

Alan Chadwick and the Biodynamic/French Intensive Method

During the 1960's, Alan Chadwick, an Englishman, combined biodynamic and French intensive techniques into the "biodynamic/French intensive method." Chadwick prepared the soil 60 centimeters (24 inches) deep through the process of "double-digging," used less compost than the French, depended much less on manure, used few homeopathic solutions, utilized some plant relationships and planted by the phases of the moon. The United States was first exposed to the combination when Chadwick brought the method to the four-acre organic Student Garden at the University of California's Santa Cruz campus in 1967. Chadwick, a horticultural genius, had been gardening for half a century and was also an avid dramatist and artist. The site he developed at Santa Cruz was on the side of a hill with a poor, clayey soil. By hand, Chadwick and his apprentices created a good soil and a veritable "Garden of Eden" within several years (Bronson, 1970/1971).

ECOLOGY ACTION'S GROW BIOINTENSIVE SUSTAINABLE MINI-FARMING APPROACH

Chadwick noted that his method produced up to four times the yield per unit of area and used only half the water per pound of food produced when compared with commercial agriculture, but he had collected no data about these and other aspects of his method. He taught by the apprentice system through a series of lectures and practical work in the field and did not believe in teaching by the written word. He prepared the soil differently for most crops, one example of which is Scarlet Runner Beans which required twelve different layers of soil and amendments throughout the 24-inch-deep growing area (Cuthbertson, 1978). Ecology Action made Chadwick's method more accessible and accountable by initiating a program of research, data collection, and documentation in reports and how-to publications. It also developed a system in which the growing areas for all crops are prepared the same way. This latter simplification has enabled more people to easily become involved in this form of food-growing. In addition, Ecology Action emphasized the growing of compost crops on a "closed-system" basis for the development and maintenance of sustainable soil fertility. Ecology Action's program of international networking and technical assistance is facilitating the adoption of the Grow Biointensive method globally.

THE EVOLUTION OF FARMING RESEARCH PERFORMED AT THE STANFORD UNIVERSITY INDUSTRIAL PARK AND WILLITS, CALIFORNIA, SITES

In January of 1972, Ecology Action, then located in Palo Alto, California, initiated its Biointensive Sustainable Mini-Farming Program. It began to collect food and biomass yield and resource consumption data on a wide spectrum of crops including vegetable, grain, fruit, nut, berry and fiber crops. The program's purpose was to determine how one could grow all one's soil fertility, diet, income, clothing, housing and other agricultural needs in the smallest area in a sustainable and globally equitable manner while preserving genetic diversity. The biologically intensive practices involved were ones which millennia before had been successfully utilized in agriculture. Many of these practices, when used properly, had proven sustainable for hundreds and even thousands of years.

Potential "economies of small scale" in this system include up to:

- a 200 to 400 percent (or greater) increase in caloric production per unit of area,
- a 67 to 88 percent reduction in water consumption per unit of production,
- the potential of a 100 percent (or greater) increase in soil fertility in a few years in C-horizon and many depleted soils–while produc-

tion increases and resource use is reduced (derived from: Maher, 1983),

- a 50 to 100 percent reduction in the amount of purchased organic fertilizer required per unit of production,
- a 99 percent reduction in the amount of energy used per unit of production,
- a 100 percent (or greater) increase in income per unit of area.

In an area as small as 9.3 square meters (100 square feet) with good soil, planning and choice of crops, all the *vegetables and soft fruits* needed for a whole year by one person can be grown in a six-month growing season. In addition, combined with a better understanding of how to maximize the production of nutrition per unit of area, "Grow Biointensive" practices may sustainably grow *a complete diet* for one person for all year in as little as forty 9.3-square-meter (100-square-foot) growing areas for a total of 371 square meters (4,000 square feet) of growing surface. When the right mixture of crops is selected, a good income may also be grown sustainably on as little as forty 9.3-square-meter (100-square-foot) growing areas and sometimes significantly less (Economic Mini-Farming Citations, 1983-1991).

THE "GROW BIOINTENSIVE" METHOD

The following elements, properly combined in the Grow Biointensive approach, can achieve these effective and synergistic results:

1. *Deep soil preparation* develops *good soil structure* to a depth of 60 cm (24 inches). The soil is alive with a combination of macro- and microorganisms, humus, minerals and water and air. The microorganisms need air to breathe. With this approach the soil thrives to a greater depth which gives the plant roots a more optimal feeding area. Once a good soil structure is established, only a surface cultivation of 5 cm (2 inches) may be required. In soils with good structure, double-digging is not needed to maintain significant yields and may even deplete the quality of the structure.

2. The soil is fed with appropriate amounts of *compost*–the major source of food for microbes. An amount of cured compost the size of a teaspoon can contain up to 6 billion microbial life forms. This is more life forms than there are people on the Earth. In one raised growing bed there are unimaginably more life forms than this. Many of these microbes have the capacity to fix nitrogen in the soil, and others produce

antibiotics in the soil which help keep plants healthy. The humus in compost also "traps three to five times more nutrients, water, and air than other soil matter does" (Brown et al., State of the World, 1998, p. 102).

3. *Organic fertilizers* on the approved list of the California Certified Organic Farmers, such as alfalfa meal, oyster shell flour, kelp meal and zinc chelate, are used if needed.

4. *Close spacing* is utilized for the plants in the growing area. The plants are placed in offset, or hexagonal, spacing so their leaves touch, or barely touch, when they are mature. Nature has a desire to grow plants close together rather than in rows. That is why so many weeds grow in between the rows in conventional agricultural practices. Nature abhors a void or desert and as much as possible fills it with living plants. For the greater part of history, much of humankind has grown plants close together. In this way the plants provide a *living mulch* which preserves precious moisture in the soil. The plants also like the stimulation of growing together. The umbrella provided by the plants creates a *carbon dioxide envelope* underneath the leaves as well as a *humidity envelope*. The crops breathe in this extra carbon dioxide which increases their productivity, and the humidity provides a more optimal environment for the soil microbes. All these factors produce healthier plants.

5. *Companion planting/plant symbiosis* relationships are used to advantage. Different crops have special affinities for each other. Some prefer to be close–others distant–just as in human relationships. Green beans and strawberries are reported to do better when they are grown together rather than separately. For the best-tasting bibb lettuce, Alan Chadwick suggested growing one spinach plant with each four bibb lettuce plants. Wheat may benefit by a ratio of one chamomile plant to 200 wheat plants. Grain crops have key rotation relationships as well (Companion Planting Citations, 1936-1985).

6. The use of *open-pollinated seeds*. With Grow Biointensive techniques, Green Revolution-type yields can be obtained with normal open-pollinated seeds which have been selected over the decades and centuries because of their advantage. Special hybrids are not needed for excellent results. In this way a wide spectrum of varieties can be grown with success while more of the world's genetic diversity is preserved actively in the field.

7. *Carbon farming–Soil fertility* is facilitated when approximately 60% of the growing area is planted in *dual-purpose* seed and grain crops. These key crops produce a large amount of carbonaceous material per unit of area, which is used to build compost for improving and

maintaining the soil ecosystem's microbial life. These crops also produce a significant amount of calories. Corn, wheat, amaranth, millet, sorghum and oats are some of the crops that make this possible. Growing compost materials on the farm will be important in the future, since large amounts of organic matter and nutrients are currently being "mined" from other soils and sent away to improve other farms. Instead we need to be producing more organic matter and retaining more nutrients on a "closed-system" basis. One survey asked organic farmers, "'Approximately what percentage of your soil fertility inputs come from on-farm and off-farm sources?' (This question, of course, allows for tremendous leniency in the perception of the farmer.) The 945 respondents, as a group, generated 58% of their soil fertility inputs on-farm, and 38% came from off-farm. Two additional follow-up questions asked whether on-farm livestock were part of the fertility regime (43% said yes; 47% keep no livestock), and what off-farm soil fertility inputs were most important to them: manures came in first at 331 responses, composts came in second at 179 responses" (Organic Farming Research Foundation, 1995). In the future the "mining" of other soil in order to improve a farm will need to be kept to a minimum if worldwide sustainable soil fertility is to be maintained.

8. *Calorie farming*–The production of sufficient calories efficiently in a small area is facilitated when special root crops are planted in 30% of the growing area. These crops include potatoes, sweet potatoes, salsify, burdock, garlic and parsnips and produce a large amount of calories for the human diet per unit of area.

9. Grow Biointensive farming involves a *whole system*. It is important to use all of its elements together or the soil may be depleted rather than improved. For example, the production of high yields without replenishing the soil with nutrients and organic matter will ultimately result in lower yields and a depleted soil. Also, close spacing does not generally work well with shallow soil preparation unless good soil structure 60 centimeters (24 inches) deep has already been established.

The Questions

The questions are: Given the perspective, principles, techniques and history of Grow Biointensive Sustainable Mini-Farming, what has been its performance under different conditions, what is its future potential and what research needs to occur?

REFERENCES

Biodynamic Farming Citations:

Kafka, S. 1972. Lecture. September, Palo Alto, CA.

Koepf, H., et al. 1976. Biodynamic Agriculture. Anthroposophic Press, New York, 429pp.

Pfeiffer, E. 1938. Biodynamic Farming and Gardening–Soil Fertility Renewal and Preservation. Anthroposophic Press, New York, 240pp.

Pfeiffer, E. 1942-1962. Biodynamic Farming–Articles 1942-1962.

Biodynamic Farming and Gardening Association, Wyoming, RI, 150pp.

Podolinsky, A. 1988. Bio-Dynamic Agriculture Introductory Lectures, Vol. 1. Gavemer Publishing, Sydney, 190pp.

Biointensive Citations:

Bonnefons, N. de. 1658. The French Gardner: Instructing How to Cultivate All Sorts of Fruit Trees, and Herbs for the Garden: Together with Directions to Dry and Conserve Them in Their Natural. John Crooke, St. Paul's Church-Yard, England, 1658, 294pp.

Courtois-Gerard, M. 1845. Manuel Pratique de Culture Maraichere. J. Hetzel et al. Cie, Paris, 336pp.

Kafka, S. 1972. Lecture. September, Palo Alto, CA.

Macself, A.J. 1932. French Intensive Gardening. W.H. and L. Collingridge, London, 128pp.

Smith, T. 1909. French Gardening. Utopia Press, London, 128pp.

Weathers, J. 1909. French Market Gardening. John Murray Co., London, 225pp.

Weathers, J. 1913. Commercial Gardening, Vols. I-IV. Gresham Publishing Co.

Bronson, W. 1970-1971. The lesson of a garden. Cry California, Winter, pp. 4-16.

Brown, L.R., et al. 1998. State of the World–1998. W.W. Norton.

Buchanan, K. 1970. Transformation of the Chinese Earth. Praeger, 335pp.

Companion Planting Citations:

Carr, A. 1985. Good Neighbors: Companion Planting for Gardeners. Rodale Press, 379pp.

Pfeiffer, E. 1936. Sensitive Crystallization Processes. Anthroposophic Press, 59pp.

Pfeiffer, E. 1984. Chromatography Applied to Quality Testing. Biodynamic Literature, 44pp.

Philbrick, H. and Gregg, R.B. 1966. Companion Plants and How to Use Them. Devin-Adair, 113pp.

Cuthbertson, T. 1978. Alan Chadwick's Enchanted Garden. Dutton, 199pp.

Diet Citations:

Cox, C. 1991. Learning to grow all your own food: one-bed model for compost, diet and income crops. Ecology Action, 25pp.

Duhon, D., et al. 1984. One Circle–How to Grow a Complete Diet on Less Than 1,000 Square Feet. Ecology Action, 200pp.

Griffin, J.M. 1987. One basic Mexican diet. Ecology Action, 32pp. plus 4pp. supplement.

Jeavons, J. 1986. The complete 21-bed Biointensive mini-farm. Ecology Action, 39pp.

Omondi, E.C. 1997. The smallest possible area to grow food and feed. Ecology Action, 45pp.
Wasike, P. 1991. One basic Kenyan diet: with diet, income and compost crop designs in a three-growing-bed learning model. Ecology Action, 28pp.
Ecology Action, 1996. 'Circle of plenty' nutrition and health global initiative–personal Biointensive experiences from around the world.
Economic Mini-Farming Citations:
Cox, C. 1991. Learning to grow all your own food: one-bed model for compost, diet & income crops. Ecology Action, p. 14.
Devault, G. 1990. City farm grosses $238,000 on 1/2 acre. The New Farm, July/August, pp. 12-15.
Gibson, E. 1988. Big bucks from small acres. Income Opportunities, July/August, pp. 54-56.
Jeavons, J., et al. 1983. Backyard Homestead, Mini-Farm & Garden Log Book. Ecology Action, chapter 2.
Kona Kai Farms. 1988. Spring Newsletter. March, 4pp.
Lenz, L. 1990. Dried, cut, and edible flowers for pleasure, food and income. Ecology Action, 60pp. Preliminary evaluation of flowers as income crops included.
Berkeley Ecology Center. 1986. Salad fresh from 4th street. Newsletter, March, p. 2.
King, F.H. 1972. Farmers of Forty Centuries. Rodale Press, 441pp. Dust jacket, front flap.
Maher, D.E. 1983. Changes in carbon content in a soil under intense cultivation with organic amendments. Master of Science thesis, Soil Science Department, University of California–Berkeley, 228pp.
Marino, B.D.V. 1998. The agricultural mesocosm of Biosphere 2: an overview of the system and production. From: Bassam, N. El, et al., eds. 1998. In: Sustainable Agriculture for Food, Energy and Industry. James and James, London.
Organic Research Foundation. 1996. Final results of the 1995 national organic farmers' survey. June 1, 40pp.
United Nations. 1997 and other relevant volumes. UN-FAO Yearbook–Production.
USDA. 1998. USDA Yearbook–1998. U.S. Government Printing Office.
Watt, K.E.F. 1974. The Titanic Effect. Sinauer Associates, p. 41.
World Monitor. 1993. Running dry. May. p.10. Based on: Brown, L.R. et al. 1993. State of the World–1993. W.W. Norton.

RECEIVED: 06/20/00
REVISED: 01/08/01
ACCEPTED: 01/28/01

Biointensive Sustainable Mini-Farming: III. System Performance–Initial Trials

John C. Jeavons

ABSTRACT. The purpose of this paper is to: briefly describe the system performance of the "Grow Biointensive" method of agriculture in the initial trials at Palo Alto, California in a C-horizon molisol material including water use; first year yields; and a second year comparative experiment with broccoli. The data collected at this site, Ecology Action's newer site in northern California near Willits and at the related projects in India and Russia described in this series of articles have not been developed and analyzed on a statistical basis. The results in the different soils, climates and geographic regions involved appear to be significant enough over an almost three decade period to merit statistical evaluation by academic institutions. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com> © 2001 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. Biointensive, small-scale, high-yielding, resource-conserving, organic

SYSTEM PERFORMANCE–RESULTS AND DISCUSSION

The Biointensive sustainable mini-farm data collected by Ecology Action and individuals, projects and programs associated with it have

---

John C. Jeavons is Executive Director, Ecology Action, 5798 Ridgewood Road, Willits, CA 95490. He has a BA from Yale University and is the recipient of the following awards: Boise Peace Quilt Award–1988, Giraffe Award for Public Service–1989, Santa Fe Living Treasure Award–1989, Steward of Sustainable Agriculture–2000. Nominated for World Food Prize–1993 and 1995.

not to date been statistically developed or analyzed. It has been the goal to demonstrate the potential of the Biointensive system and to leave to others at universities and institutes with larger budgets the complete development of this potential with full academic vigor and statistical analysis including the proper controls. Our results have been uneven over the years as we have been redeveloping the understanding of biologically intensive food raising; changing research sites, soils, climates and water sources; working with an ever-changing group of staff, volunteers, interns and apprentices of different national and educational backgrounds, talents and abilities; and proceeding with limited and uneven funding. *The results of our tests* have varied from crop failures to very significant yields and, all things considered, *have been promising overall.* Some highlights are described below.

Early Work in Palo Alto

In 1972 Ecology Action's non-profit Biointensive self-help food-raising program began in the Stanford University Industrial Park on Syntex Corporation land in Palo Alto, California. Essentially all the topsoil and subsoil had been removed from the mini-farm site during an earlier construction process. The material farmed was a *molisol C-horizon material with a gravelly, sandy clay loam with more soil fertility potential than the soil at the later Willits, California, location.* In addition, the climate was more favorable and the water better. Ecology Action's experience at the Palo Alto site demonstrated the Biointensive method's capacity to build soil, not just to rebuild and maintain soil fertility. Increased productivity with reduced resource consumption per kilogram (pound) of food produced occurred. The level of these increases and reductions is significant and is touched upon by the results noted below.

Water

At Ecology Action's first mini-farming site in Palo Alto, water usage tests were performed. In Santa Clara County as a whole, the *year-round (including both hot and cold growing periods)* water consumption average per day per 9.3 square meters (100 square feet) was about 75.7 litres (20 gallons). At the beginning, Biointensive water consumption was similar at the *hottest time of the year.* As the soil's quality was improved by Biointensive techniques, water consumption at the hottest time of the year dropped five years later, in 1977, to 37.8 liters (10 gallons) per day per 9.3 square meters (100 square feet). This test, using a water meter

The potential could mean that, if similar water-conserving practices had been used on a statewide level, California might not have experienced a drought during the 1990 through 1996 period, as "one year's worth" of normal agricultural water use could have been sufficient for more than one year.

After much evaluation it appears that the factors which make Biointensive food-raising water-efficient include the following:

- Research by others has shown that soil which has organic matter as 2 percent of its volume in the upper 11 inches of soil can *reduce* the rainfall or irrigation required for poor soils by *as much as 75 percent* (Poor soils contain about 1/2 of 1 percent organic matter in their upper soil area. Biointensive practices encourage maintaining an even higher amount of organic matter than this 2 percent amount) (Wilson, 1968).
- Even under arid conditions, soil which is shaded may *reduce evaporation up to 62 percent,* depending on soil type. The *mini-climate* from closely spaced plants provides good shading (Widtsoe, 1919, pp. 150-151).
- *Transpiration* of water by the plant can be *reduced as much as 75 percent* in soils which contain good quantities of nutrients in the soil water. The Biointensive method prepares the soil in a manner which provides for a high level of fertility (Widtsoe, 1919, pp. 174-192; Tisdale, 1993).

One of the most important themes in the future is going to be how to increase yields with a reduction in resource consumption. If resources are utilized wisely, people can live well with fewer resources. "Grow Biointensive" practices are based upon a natural efficiency of resource use, utilizing the same elements as other forms of agriculture–soil, water, nutrients, seeds, and the energy from the sun–combined in a synergistic manner, with the result being that there can be sufficient resources for the world's population for years to come. The need for good programs of family planning in the future cannot be overemphasized, however. In many situations *Biointensive practices can transform a situation of relative scarcity into one of comparative abundance.* For agricultural water consumption (due to the combined effectiveness of the three principles noted above), this means that, once soil fertility has been established, as little as 151 kilograms (333 pounds) of water may be needed to grow 0.4 kilogram (1 pound) of grain with Biointensive practices in a bioregion where 453.6 kilograms (1000 pounds) of water is required to grow 0.4 kilogram (1 pound) of grain with conventional practices.

Yields–1972 Preliminary Research Report (Ecology Action, 1973)

Grow Biointensive Sustainable Mini-Farming is not a panacea. Like any tool, these practices can be used well or poorly. When used properly, Grow Biointensive techniques can build the soil up to 60 times faster than in nature (Ecology Action, 1996, Worldwide). If not used properly, these techniques can deplete the soil base where they are used as much as 2 to 6 times more rapidly than other techniques, because of their high level of productivity. The difference is in *how* Grow Biointensive practices are used. When used properly with all its techniques, this approach can, over time, create a fertile, lush soil and micro-climate capable of fostering and building a healthy agricultural system with genetic diversity.

The previously uncultivated C-horizon molisol material at our site in Santa Clara County, California, produced some of the following results with vegetables during the first year. The test areas were 1.8 meters by 5.8 meters or 10.6 square meters (6 feet by 19 feet or 114 square feet). Simple hand tools, such as D-handled spades and spading forks, bow rakes, watering hoses with watering fans, wheelbarrows and 5-gallon buckets, were used. Some of these yields are shown in Table 2 (Note: the "U.S. Good Farmer Average" is two times the "U.S. Average").

For example, in 1972 the yield for bush green beans per unit of area was: 2.4 times the U.S. good farmer yield average; 3.9 times the U.S. average; 1.5 times the California average; and 1.6 times the Santa Clara county, California average–the county the project was in.

Sampling and experimentation with other crops in 1972 indicated that the following yields might occur on a sustained basis after more research was performed. See Table 3.

TABLE 2. 1972 Biointensive Tests Produced Yields Times Greater Than:

	U.S. Good Avg.	U.S. Avg.	Calif. Avg.	Santa Clara County Avg.
Zucchini	3.1	---	---	5.5
Bush Green Beans	2.4	3.9	1.5	1.6
Romaine Lettuce	---	---	1.4	---
Bibb Lettuce	---	---	---	2.3

TABLE 3. 1972 Biointensive Tests Producted Yields Times Greater Than:

	U.S. Good Avg.	U.S. Avg.	Calif. Avg.	Santa Clara County Avg.
Celery	2.5	4.7	4.0	5.0
Cauliflower	1.6	3.6	3.4	4.9
Head Lettuce	1.6	2.0	1.7	2.5
Cabbage	2.3	2.5	2.6	3.4
Beets	2.7	4.2	---	---
Carrots	2.1	2.5	1.8	---
Onions	6.3	7.4	6.5	5.7

For example, the yield for celery per unit of area was: 2.5 times the U.S. good farmer average; 4.7 times the U.S. average; 4.0 times the California average; and 5.0 times the Santa Clara county average.

In 1973, the first test on Utah *hard red spring wheat* produced a low yield of 0.75 times the U.S. average for this crop. In 1979, after seven years of selecting better crop spacings and improving skills and the soil, the test on 12.5-centimeter (5-inch) centers produced a yield *4.5 times* the U.S. average for the grain at the rate of 10,266 kilograms per hectare (9,147 pounds per acre) and *9 times* the U.S. average for the straw and refuse at the rate of 30,801 kilograms per hectare (27,442 pounds per acre) (see also: Revelle, 1976). The latter yield was especially important, because the production of sufficient carbon on a "closed-system" basis is necessary so that enough humus-containing compost can be made to ensure truly sustainable soil fertility. The wheat seedlings for this test were transplanted. Millennia ago the Chinese discovered that transplanted grains produce higher yields, and this Ecology Action grain test produced 25% to 35% more grain than parallel tests which mimicked the broadcasting of seed.

In several different plant spacing/seed depth tests, *potato yields* by 1979 had also reached *four times* the U.S. average or 113.4 kilograms (250 pounds) per 9.3 square meters (100 square feet) in multiple simultaneous tests.

1973 Comparative Experiment with Broccoli

The following broccoli head average yields were obtained in tests performed in 1973 in previously uncultivated, predominantly C-horizon soil material using comparative chemical, organic and Biointensive

TABLE 4. Comparative Tests with Broccoli

	Approx. Avg. Yield/Head	Approx. Lbs. Yield per 100 Sq. Ft.	Approx. Total Yield Times U.S. Avg.
Chemical	0.08 ounce each	0.4	0.02×
Organic	4.0 ounces each	21.2	0.83×
Biointensive	10.0 ounces each (with 3 times the plants per unit of area due to intensive spacing)	53.1	6.25× (7.5 times greater than organic)

agriculture approaches. The test with duplicate test areas for each of the three approaches was performed by a volunteer, Wayne Miller, who was a professional researcher employed by Zoecon. Miller possessed a Master's degree in Biochemistry and training in statistical analysis. Note the 7.5 times greater yield between the organic and Biointensive approaches (Ecology Action, 1996, Broccoli). See Table 4.

The Question

The question is: How will the Grow Biointensive agricultural system perform under a more difficult environmental situation?

REFERENCES

Ecology Action. 1973. 1972 preliminary research report. 1973. 22pp.
Ecology Action. 1996. Broccoli: chemical agriculture vs. organic agriculture vs. Biointensive agriculture. 1p.
Ecology Action. 1996. Worldwide loss of soil and a possible solution. 1pp. Based on the statistics given in: Summary Report 1992 National Resources Inventory. 1994.
Tisdale, S.L., et al. 1993. Soil Fertility and Fertilizers. Prentice Hall, pp. 55, 513, 515, 516, 525, and 526.
Widtsoe, J.A. 1919. Dry Farming–A System of Agriculture for Countries Under a Low Rainfall. Macmillan.
Wilson, C.M. 1968. Roots: Miracles Below. Doubleday, pp. 173-174.

RECEIVED: 06/20/00
REVISED: 01/08/01
ACCEPTED: 01/28/01

Biointensive Sustainable Mini-Farming: IV. System Performance–Continuing Trials in a More Difficult Environment and Soil

John C. Jeavons

ABSTRACT. The purpose of this paper is to: Briefly describe the system performance of the "Grow Biointensive" method in continuing trials at Willits, California in a serpantine soil–a type noted for its low productivity; the research challenges and environment involved; the state of the soil at the commencement of testing and in the sixteenth growing season in 1997; yield results experienced with relatively low inputs of cured compost relative to those expected to be developed and utilized over time; and the beginning of significant grain and biomass yield increases in 1998.

KEYWORDS. Biointensive, small-scale, high-yielding, resource-conserving, organic

SYSTEM PERFORMANCE–RESULTS AND DISCUSSION

Research Challenges in Willits

In 1979 Ecology Action lost its research and development site in Palo Alto when the area was needed for a construction project. During 1980

John C. Jeavons is Executive Director, Ecology Action, 5798 Ridgewood Road, Willits, CA 95490. He has a BA from Yale University and is the recipient of the following awards: Boise Peace Quilt Award–1988, Giraffe Award for Public Service–1989, Santa Fe Living Treasure Award–1989, Steward of Sustainable Agriculture–2000. Nominated for World Food Prize–1993 and 1995.

and 1981 the work to date was evaluated, and a Self-Teaching Mini-Series of "how-to" booklets on specific topics was initiated. In 1982 a new site about three hours north of San Francisco was obtained.

Ecology Action's very small headquarters at Willits, California, is on a hillside overlooking the Little Lake Valley. Ecology Action's research goal is complete economic, nutritional, environmental and soil sustainability. Achieving sustainable soil fertility requires working with the natural system. Crop failures and other problems are experienced as the search seeks the best solutions. Usually, discovering the answers is part of a "shotgun" testing process that tests many strategies, crops and varieties to discover the best approach for the goal desired. Once discovered, the answers are often simple, based on sophisticated principles, and can be learned easily. Generally, most test beds are 9.3 square meters (100 square feet) though some test beds and test areas are smaller or larger. The quantities of organic fertilizers applied are generally the amounts prescribed by the ComSpec Soil Testing Service (ComSpec).

The Research Environment

The *constraints* that have kept our research and soil improvement at Willits proceeding at a slow rate are similar to those in many developing countries. Higher yields with even greater resource efficiencies are possible in better soil and climatic situations. The challenges have been:

- *Climate*–Both the Alaskan and the Hawaiian jet streams pass over the Willits property. This creates dramatic temperature fluctuations for the garden. During the growing season, there is often a forty- to fifty-degree *daily* temperature fluctuation. A nightly air temperature of at least 15.5°C (60°F) appears to be desirable for the microbial life in the soil to flourish. That level is only reached at the Willits site a few times a year. It is also desirable to have daytime temperatures under 35°C (95°F) because pollination is reduced when the temperature goes above 35°C (95°F). A significant number of over-35°C (95°F) daytime temperatures occur during the most-active four- to five-month growing season. This growing season is also an arid period with no rain, and the porous soil does not naturally retain water well. However, *significant* improvements in the quality of the soil have been made through the use of "Grow Biointensive" practices.
- *Soil*–The loam serpentine soil (approximately 49% sand, 36% silt and 15% clay) was rated as only fair for grazing at the point when

cultivation began. Serpantine soils are known for their normally low productivity (Jenny, 1980). Initially, the soil contained some sodium and high levels of magnesium, challenging levels of other soil nutrients and low levels of many more-beneficial nutrients including potassium, calcium, iron, sulfur and boron. The first crop of alfalfa grew only a few inches tall with only two harvests. Now that the soil nutrient balance is being restored, alfalfa test yields as high as three times the U.S. average have been obtained, or at a rate of 17.4 metric tonnes per hectare (17.1 tons per acre) dry weight (it is interesting to note that, because of the poor soil conditions at both our Palo Alto, California, and Willits, California, test sites, people at locations around the world often obtain higher yields than Ecology Action's).

- *Water*–The wellspring water we use contains some sodium and magnesium. The water is also cold, which tends to contribute to the retardation of microbial life activity in the soil, and therefore plant growth, when we water the mini-farm with it during the main growing season which is arid.

Research

- *Organic Matter*–Crops are grown with the goal of producing a large amount of carbonaceous compost materials per unit of area on a *"closed-system" basis.* This is a way of working towards "100%" sustainability. For most of the time to date, due to many tests that by their very nature do not produce sufficient organic matter to ensure sustainable soil fertility, there often has been much less compost produced than is optimal for the test area as a whole. This situation has produced an overall lower biomass yield than expected. Current key research experiments have brought an understanding of how the system can best produce the optimal compost quantities necessary for the best crop growth and sustainable soil fertility. It is hoped to significantly increase the amount of cured compost added to a given area per unit of time in the near future.

Soil

Background Soil Test

The Background Soil Test in Table 1 shows the initial state of this *loam (almost sandy loam) soil with less soil fertility potential than the*

TABLE 1. 1986 Background Soil Test Results

Timberleaf

SOIL AUDIT REPORT

Box 1000 • Camden, West Virginia 26338 • 304/269-7632

AUDIT NO.: 05107-2

Grower John Jeavons–Common Ground Mini-Farm	Date Sampled: 12/9/86
Address 5798 Ridgewood Road	
City Willits	County Mendocino
State CA Zip 95490	Phone (707) 459-5958
Sample No.: 1	Field No.: Background

LABORATORY RESULTS		DESIRED LEVEL
Organic Matter	2.0%	4-6%
Cation Exchange Capacity	16.2	
Soil pH	6.7	
Ca - Mg - K Ratio	36:58:1	70:15:5
CATIONS		
Calcium	1180 ppm @ 36.4%	60-75%
Magnesium	1130 ppm @ 58.1%	12-15%
Potassium	68 ppm @ 1.1%	4-7%
Sodium	109 ppm @ 2.8%	.5-3%
Hydrogen	4.5%	10-15%
ANIONS		
Nitrogen (Ann. Release)	84 PPA	
Phosphorus-1	4 ppm	25
Phosphorus-2	8 ppm	50
Sulfur	6 ppm	30
TRACE MINERALS		
Zinc	1.6 ppm	6-8
Manganese	7.0 ppm	25
Iron	41.0 ppm	20-50
Copper	2.5 ppm	2-3
Boron	0.4 ppm	2.5-3

former Palo Alto, California, site. The background soil sample exhibited a poor calcium/magnesium/potash ratio, was especially high in magnesium, and was low in organic matter, calcium, potassium, phosphorus-1 and -2, sulfur, zinc, manganese and boron. Due to financial constraints and location considerations, this was the land that was chosen. It was less than ideal for soil improvement, yield increases and reduced resource consumption. The mountainside situation, however, is similar to the farming conditions many people in the world experience.

The University of California-Davis Sustainable Agriculture Research and Education Program Soil Tests

The University of California-Davis Sustainable Agriculture Research and Education Program Soil Tests performed at the Willits site in 1997 show the improvement of the soil in several locations over time in comparison with the Background Soil Test taken earlier by Ecology Action. As can be seen in the tables, all test areas have similar soil texture. Therefore, the resulting soil transformation has been simple and positive: the percentage of carbon and nitrogen has increased. This is in great part attributable to the increase in organic matter. The balance of nutrients is much better. With the increase in organic matter, the water-holding capacity of the soil is improved. The exception to this is the newer three-year-old Bed 100, and even it is on its way to improvement. Most of the other test beds were 16 years old at the time of the soil test. Compared with the background test: the pH is lower in three of the eight samples, similar in two and higher in three in spite of a water source containing an excess of both sodium and magnesium. The cation exchange capacity and levels of zinc, manganese, iron, copper, potassium, calcium and magnesium (now lower) are improved. The total carbon and total nitrogen are higher. The ammonium, nitrate and sodium levels are low. (An interesting fact not apparent from the data is the fact that a significant increase in soil and plant health seemed to occur in the test beds beginning in the fourteenth growing season in 1995.) See Table 2.

Yields

Alfalfa Test Results

During the first years at the Willits site, many grains, compost crops and vegetables were evaluated using a broad "shotgun" testing approach. Different spacings, timing, fertilization levels and compost amounts were tried. The results all demonstrated a potential generally consistent with the Economies of Small-Scale (noted in Part 2 of this series) once the soil's fertility and farmer's skill levels had been improved. There were and still are crop failures as part of this process. "Destructive" testing has also been performed using "insufficient" amounts of compost. Often only about 25% of the ultimate 4 to 8 cubic feet (6 to 12 five gallon buckets) of cured compost (including approximately 50% soil) has been used per 100 square feet. The results of this have been mixed, but sometimes the yields have been surprisingly good

TABLE 2. SAREP Soil Test of Willits Site

DANR ANALYTICAL LABORATORY
UNIVERSITY OF CALIFORNIA
COOPERATIVE EXTENSION

SUBMITTED BY: LIEBHARDT, WILLIAM
DANR SECTION: SP: SARPET, UCD
COPY TO:
COMMODITY: Vegetables
DRY MATTER: As Received
Jeavons–Willits 4/24

WORK REQ #: 67S0560
OF SAMPLES: 8
DATE RECEIVED: 4/24/97
DATE REPORTED: 6/9/97
DANR CLIENT #: LIEW2C
TURN AROUND TIME IN WORKING DAYS: 32

SAMPLE #	DESC	pH	Zn ppm	Mn ppm	Fe ppm	Cu ppm	CEC meq/100 g	OM %	N-Total %	C-Tot %	TKN %	P-Olsen ppm	X-K meq/100 g	X-Ca meq/100 g	X-Mg meq/100 g
1	Bed85	6.5	1.0	69	481	7.5	27.0	2.70	0.139	1.5	0.166	23	0.4	11.1	6.4
2	Bed46	6.9	2.3	39	296	4.7	28.5	2.68	0.144	1.6	0.105	49	0.6	16.0	4.9
3	Bed30	7.1	3.4	81	315	4.4	23.0	2.51	0.130	1.4	0.067	41	0.5	14.4	4.9
4	Bed10	6.3	1.8	37	291	5.1	25.0	2.65	0.163	1.9	0.106	38	0.4	10.6	5.7
5	Bed54	6.8	1.0	15	146	2.5	30.0	2.81	0.130	1.6	0.126	37	0.5	16.1	7.6
6	Bed19	7.1	1.6	35	139	2.5	23.0	2.25	0.161	1.8	0.150	60	0.6	14.2	3.2
7	Be100	7.1	3.8	32	123	2.2	21.5	1.95	0.115	1.1	0.097	36	0.6	12.6	5.9
8	Amana	6.3	1.4	13	112	2.5	21.5	1.80	0.117	1.1	0.083	9	0.3	7.7	8.5
Blank Concentration:		-	0	0	0	0	-	0	-	-	0	0	0	0	0
% RPD:		0.1%	0.1%	0.1%	2.7%	3.9%	0.1%	5.5%	4.4%	5.6%	1.2%	0.1%	0.1%	2.6%	3.5%
Duplicate sample # 8:		6.3	1.4	13	109	2.6	21.5	1.69	0.112	1.04	0.084	9	0.3	7.9	8.8
Standard Reference (Est.):		8	8.6	52	54	2.2	31.54	2.5	1.115	1.2	0.149	39	2.8	20.6	9
Standard Reference (Actual):		8.0 ± 0.2	8.5 ± 1	58 ± 7	53 ± 8	2.0 ± 0.3	31.0 ± 1.0	2.47 ± 0.1	0.113 ± .002	1.16 ± 0.05	0.153 ± .015	39.1 ± 4.0	2.7 ± 0.1	21.8 ± 1.0	9.1 ± 0.4
Standard Reference ID's:		UCD 001	NORD	NORD	NORD	NORD	NORD	NORD	GRIDLEY	GRIDLEY	NORD	NORD	NORD	NORD	NORD

SAMPLE #	DESC	X-Na meq/100 g	NH_4-N ppm	NO_3-N ppm	SO_4-S ppm	Sand %	Silt %	Clay %	.3 ATM %	15 ATM %
1	Bed85	0.1	4.7	0.6	4.9	48	36	16	19.1	12.6
2	Bed46	0.1	6.0	1.5	25.9	43	42	15	20.4	13.7
3	Bed30	0.1	4.3	1.1	< 0.1	52	35	13	17.7	11.8
4	Bed10	0.1	5.3	1.8	3.4	50	35	15	17.7	12.3
5	Bed54	0.1	4.0	1.4	4.2	42	41	17	19.6	13.7
6	Bed19	0.1	4.2	2.9	5.0	55	32	13	17.2	11.6
7	Be100	0.1	4.2	3.1	5.3	53	32	15	16.9	11.4
8	Amana	0.1	4.7	0.3	3.4	50	37	13	15.8	11.4
Blank Concentration:		0	0	0	0	-	-	-	-	-
% RPD:		0.1%	0.1%	0.1%	6.1%	2.0%	2.7%	0.1%	6.7%	0.1%
Duplicate sample # 8:		0.1	4.7	0.3	3.2	51	36	13	16.9	11.4
Standard Reference (Est.):		0.1	5.4	69.6	7	12	49	39	31.2	16.6
Standard Reference (Actual):		0.1 ± 0.1	5.1 ± 1.0	68 ± 3	7.2 ± 0.3	15 ± 5	45 ± 5	40 ± 5	32.6 ± 2	17.1 ± 2
Standard Reference ID's:		NORD	NORD	NORD	UCD 001	FARWELL	FARWELL	FARWELL	NORD	NORD

as the elusive proper amounts of compost to be used for true sustainability in this situation are sought.

After the soil nutrients began to be increased and balanced, the regular testing of the compost crop, alfalfa, began. Some of the alfalfa test results over a number of years are given in Table 3.

One-Bed Unit Test

In 1992 we decided to begin a 9.3-square-meter (100-square-foot) One-Bed Unit test in an Upper Knoll test area which had been farmed since 1983 [in 1996 this area was expanded to 15.8 square meters (170 square feet)]. This area is a demonstration of the compost, diet and income crops which could be grown in such a way that, if these crop proportions were extended to a 371-square-meter (4,000-square-foot) area, a person might eventually grow all the compost materials, complete diet crops and crops for a modest income from one-twentieth of a hectare (one-eighth of an acre) of planted surface including paths.

The One-Bed Unit Test results for several years are shown in Table 4. Notice the relative Biointensive yield averages compared with U.S. commercial averages in the table and the overall seven-year average given below. The One-Bed Unit is located in an area which receives less sunlight than most of the test areas, and this is reflected in the mangel, onion, winter squash and compost crop yields. The compost crops seemed to be particularly affected by the resulting decrease in photosynthesis. Also, the fact that less than the optimal amount of organic matter was added to this test area each year probably had an effect on the yields.

However, 1999 harvested biomass tests with both oats and cereal rye in other unshaded test beds have produced dry matter yields at *four* times and grain yields at *two* times the U.S. average level. Seventeen years of soil improvement, often with a conservative annual application of cured compost, appears to be producing a difference in some test areas at this point. If this improvement turns out to be a trend, it will have been a rapid soil buildup when compared with much longer-term natural soil-building processes. What might be the source of such an improvement? The percentage of organic matter in most of the test beds has not changed dramatically recently. Perhaps a change in the relative percentage of the "active," "slow" and "passive" soil organic matter levels is involved. This is being looked at currently. (Note: A more broad-based increase in winter grain biomass and grain yield was experienced in year 2000 harvested tests.)

TABLE 3. Alfalfa Yields–Long Term Stands*

(AIR-Dry Weight)

YEAR ->			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
U.S. YIELD/100 sq ft ->			15.2	15.7	15.2	11.9	13.7	15.1	15.0	15.1	14.9	15.4	15.8	15.0	15.4	15.0
BED	SQ FT															
11	100	EA	NP	17.68	23.12	14.43	Repl.	12.53	22.82	49.70	26.68	36.64	24.18	17.52	Repl.	15.47
		X	–	1.13	1.52	1.21	–	0.83	1.52	3.29	1.79	2.38	1.53	1.17	–	1.03
12	100	EA	Planted	20.21	24.48	41.16	27.13	26.08	27.74	38.01	23.36	30.45	24.40	15.99	Repl.	10.74
		X	–	1.29	1.61	3.46	1.98	1.73	1.85	2.52	1.57	1.98	1.54	1.07	–	0.72
23	30	EA	NP	NP	NP	NP	NP	NP	Planted	11.13	DM	12.45	18.25	DM	11.11	8.82
		X	–	–	–	–	–	–	–	2.46	–	2.69	3.85	–	2.40	1.96
35	50	EA	NP	Planted	23.10	18.31	14.32	11.57	16.29	24.34	24.15	22.49	16.98	20.37	24.04	17.62
		X	–	–	3.04	3.08	2.09	1.53	2.17	3.22	3.24	2.92	2.15	2.72	3.12	2.35
44	100	EA	NP	Planted	12.20	43.59	0.85	38.79	34.31	52.79	41.59	38.02	33.52	31.80	41.45	33.66
		X	–	–	0.80	3.66	0.06	2.57	2.29	3.50	2.79	2.47	2.12	2.12	2.69	2.24
50B	73	EA	NP	8.18	16.40	1.71	12.21	19.51	22.37	24.84	16.38	18.51	18.01	15.60	21.75	Removed
		X	–	0.71	1.48	0.20	1.22	1.77	2.04	2.25	1.51	1.65	1.56	1.42	1.93	–
50C	35	EA	NP	NP	NP	Planted	10.34	11.81	12.25	19.05	7.86	11.22	12.86	9.33	12.13	7.13
		X	–	–	–	–	2.16	2.23	2.33	3.60	1.51	2.08	2.33	1.78	2.25	1.36
67	125	EA	27.98	56.01	60.98	50.79	35.18	16.84	Repl.	20.14	28.77	34.94	26.63	27.20	DM	11.72
		X	1.47	2.85	3.21	3.41	2.05	0.89	–	1.07	1.54	1.82	1.35	1.45	–	0.63
83D	22	EA	NP	NP	NP	NP	NP	NP	NP	NP	Planted	9.60	9.29	1.69	Removed	–
		X	–	–	–	–	–	–	–	–	–	2.83	2.67	0.51	–	–

* Currently, most commercial stands of alfalfa in California are replanted every 2 to 3 years.
Note: Dry matter is assumed to be 25% for all harvests through 1991; beginning in 1992, dry samples were taken for each harvest.
EA = Ecology Action actual yield
X = Ecology Action yield adjusted to 100 sq. ft. and compared to U.S. average
DM = Data missing
NP = Not planted
Repl. = Replanted

Overall X average for all test areas: 2.00

TABLE 4. Common Ground Mini-Farm One Bed Unit (1998) with Comparative Indices for 1992-97 (Bed Located in a Cooler Area of the Garden on a W/NW Slope)

CROPS	SQ FT	SOWN (TP) (mo/day)	HVST DATE (mo/day)	EDIBLE YIELD (lb)	BIOMASS YIELD (lb)	CLEAN GRAIN (lb)	ED. YIELD/ 100 sq ft (lb)	U.S. Avg.* (lb)	Willits Yield** 1998	Willits Yield** 1997	Willits Yield** 1996	Willits Yield** 1995	Willits Yield** 1994	Willits Yield** 1993	Willits Yield** 1992	COMMENTS
INCOME CROPS																
Lettuce Bronze Arrow 9°C	10	5/19 (a) 10/1 (b)	7/20-23 (a) 10/1 (b)	9.12 (a) 0.87 (b)			99.9 Total	[51.0]	[2.0×]	[3.1×]	[2.1×]	[3.0×]	[1.9×]	[2.6×]	[2.7×]	(a) First planting (b) Second planting
Mangels Yellow Intermed. 7°C	10	5/19	9/9	5.00 Roots	6.62 Leaves, wet		50.0 Roots	[68.0] Roots	[0.7×]	[0.8×]	[1.0×]	[0.7×]	[1.2×]	[0.4×]	[2.5×]	Reemay helped w/ leafminer probs.
Onions, Bunching Ishikura 3°C	10	5/19 (a) 7/29 (b)	7/29 (a) 10/1 (b)	3.62 (a) 2.00 (b)			56.2 Total	[29.5]	[1.9×]	[3.4×]	[6.0×]	[3.2×]	[2.7×]	[3.8×]	[3.1×]	
DIET CROPS																
Potatoes Désiree 9°C	10	4/30	9/16	7.37 Potatoes	2.25 Plants, wet		73.7 Potatoes	69.7	1.1×	1.4×	1.3×	1.4×	1.5×	1.3×	3.1×	10-15% gopher damage
Onions Early Yel. Globe 4°C	5	4/30	9/2	2.37 at harvest			27.4 Cured @	86.8	0.3×	1.0×	0.5×	0.8×	–	–	–	@ Actual yield cured 1.37 lb
Rutabaga Swede Purple Top 6°C	5	4/30	8/27-9/14	4.06 Roots	6.62 Leaves, wet		81.2 Roots	[68.0] Roots	[1.2×]	[3.2×]	[1.5×]	–	–	–	–	
Dry Beans Pinto, Agate 6°C	10	6/8	–	Beans, wet	Crop failure Plants, wet	Dry		4.0	0×	2.8×	0×	1.5×	2.5×	2.2×	2.8×	
Squash, Winter Butterbush 18°C	9	6/18	9/21	2.75 4 squash	0.62 Plants, wet		30.6 Squash	[50]	[0.6×]	[0.4×]	0×	0×	[0.6×]	[0.3×]	[2.4×]	2 borage plants at each end of row.
Compost addeded/ 100 sq ft									9 5gB@@(#)	6 5gB	9 5gB	3 5gB	3 5gB	3 5gB	6 5gB	(#) except 6 5gB for Potatoes,
% of Compost Application Recommended by Soil Test Analysis									100%	100%	100%	33.3%	25%	50%	100%	Onions, Rutabaga and Oats

CROPS	SQ FT	SOWN (TP)	HVST DATE	ACTUAL GRAIN	GRAIN/ 100 sq ft	U.S. Av. Grain	Grain Index	ACTUAL BIOMASS	DRY BIOMASS/ 100 sq ft	U.S. Av. Dry Bm	B'mass Index	COMMENTS
Bkt 14 Comp Crop (Barley, Rye, FB, V)	25	10/16/97 Broadcast	4/20	None	–	–	–	9.31 At hv 2.94 Dry	11.76	[6]	2.0	Removed for Rutabaga, Onions and Potatoes.
Bkt 14 Comp Crop (Barley, Rye, FB, V)	100	10/16/97 Broadcast	5/18	None	–	–	–	64.56 At hv 12.29 Dry	12.29	[6]	2.0	Removed for warm- and hot-weather crops.
Fava Beans Banner 8°C	15	10/16/97	7/27	1.81 Beans, dry	12.07 Beans, dry	[4?]	3.0	9.56 At hv 4.46 Dry	29.74	[12?]	2.5	
Barley, Hull-less Mid-Mountain 5°C	30	2/18-24	7/16	0.91 Dry	3.03 Dry	6.1	0.5	3.62 At hv 1.12 Dry	3.73	9.2	0.4	
Corn Isleta 12°C	32.5	6/2	10/1	0.43 Dry	1.23 Dry	14.0	0.1	29.50 At hv 10.32 Dry (est.)	31.77	[21]	1.5	Biomass includes roots.
Amaranth, Grain Golden Giant 12°C	25	6/11	8/26	0.68 Dry, cleaned	2.72 Dry, cleaned	[4]	0.7	16.00 At hvst 1.81 Dry	7.24	[6]	1.2	
Sorghum Dale 12°C	15	8/4	10/1	None	–	–	–	3.50 At hv 0.98 Dry	6.56	[?]	–	Catch crop. Biomass includes roots. Planted after Fava Beans.
Quinoa Multi-Hued 12°C	30	7/22	10/1	None	–	–	–	6.75 At hv 2.11 Dry	7.03	[6]	1.2	Catch crop. Biomass includes roots. Planted after Barley

@@ 5gB = 5-gallon buckets

* U.S. Average (1991 data) from Column G in How To Grow More Vegetables, 5th ed. Brackets = U.S. Avg. estimated because official data not available.
** Compared with U.S. Average in HTGMV, 5th ed. **TOTAL BIOMASS PRODUCED (ACTUAL, DRY WEIGHT): 33.91 lbs/170 sq ft** = 19.94 lbs/100 sq ft

The One-Bed Unit seven-year averages are:

Beans, Dry–1.9×
Lettuce–2.48×
Mangels–1.21× (Mangels, and especially beets, have done less well at the Willits site)
Onions, Early Bunching–3.44×
Onions, Regular–0.65× (4-year average)
Potatoes, Irish–1.58×
Rutabagas–1.96× (3-year average)
Squash, Winter–0.61×

Overall Compost Crop Dry Biomass Production in 1998–1.35× from wheat, cereal rye, fava beans, vetch, hull-less barley, corn, grain amaranth, sorghum and quinoa. See Table 4 for detailed data.

New Test in an Area with Unimproved Soil

Then, in 1994, we decided to begin a new test in an area with unimproved soil. This test bed was designated Bed 100. In this way we could take the knowledge gained during 23 years, apply it, see how long it would take to build up the soil for good results, and determine if the improvement could be maintained. Often in such a process the yields drop during the second year as nutrients accumulated in the formerly unused area are used up in the first year. This did not occur. The soil test results for this test bed are given in Table 5.

Note the initial drop in the organic matter percentage and its re-establishment and slight improvement by the end of the fourth year in 1998; an improvement in the cation exchange capacity; a disappointing significant increase in pH (possibly due to the hot, windy conditions in the test area oxidizing soil organic matter plus a correspondingly increased amount of slightly saline wellspring water used to maintain the water level of a soil with less organic matter); a significant increase in the calcium, potassium, phosphorus-1 and -2, sulfur, zinc, manganese, iron and boron levels; and a significant decrease in the magnesium level.

Bed 100 Yields

Note that Bed 100 yields have remained more or less consistent during the first five years for the lettuce and mangel crops (Table 6). It is interesting that the grain amaranth crop yields were high in the second year (the

TABLE 5. Bed 100 Soil Test Results

Ecology Action–Common Ground Mini-Farm
SOIL TEST RESULTS (Cumulative)

Bed 100

	Background (1988)	1994	1996	1997	1998
Compost Ap. (5gB)	– – –	12	12	3	12
INDEXES					
O. M. %	3.0	1.9	3.2	2.8	3.3
C.E.C.	16.1	15.9	19.8	15.9	18.6
pH	6.4	6.2	7.2	7.6	7.6
BASE SATURATION %					
Calcium Sat.	36.9	36.7	58.6	62.6	66.4
	70	70	75	70	70
Magnesium Sat.	51.6	49.1	37.8	33.8	29.5
Potassium Sat.	1.2	1.0	2.4	2.6	3.3
Sodium Sat.	1.3	1.1	1.2	1.0	0.8
Hydrogen Sat.	9.0	12.0	0.0	0.0	0.0
CATIONS					
Calcium	1190	1170	2320	1990	2470
	2226	2226	2970	2226	2604
Magnesium	1000	940	897	644	658
	256	286	356	286	335
Potassium	75	64	184	162	239
	210	210	240	210	240
Sodium	49	42	55	36	34
Hydrogen	Not given	1.9	0.0	0.0	0.0
ANIONS					
Nitrogen	101	64	90	83	92
Phosphorus 1	5	5	43	37	52
Phosphorus 2	13	10	126	117	194
Sulfur	7	4	12	11	11
TRACE MINERALS					
Zinc	1.4	1.7	12.0	7.4	9.9
Manganese	15	7	44	43	61
Iron	65	50	37	39	46
Copper	2.5	2.1	1.7	1.9	2.5
Boron	0.2	0.2	1.7	1.6	1.6
Soluble Salts	Not given	1.0	0.4	0.3	0.3

TABLE 6. Bed 100 Test Results

YEAR	CROP	VARIETY	SQ FT	CNT *	FLAT SOWN	TRNSPLTED	HARVEST	QUANTITY	QTY/100	(DRY) WT	WEIGHT/100	INDEX	COMMENTS
1998	FAVA BEANS	Banner	34	8							0.00		
	AMARANTH	Golden Giant	14	3	4/14	5/19	7/30	–	–	0.81	5.79		Cleaned seed 0.45 lb actual; 3.2 lb/100
	MANGELS	Yellow Intermediate	10	7	4/27	5/19	9/7	25	250	7.37	73.70	1.08	
	LETTUCE	Bronze Arrow	10	9	4/16	5/19	7/7-29	18	180	9.37	93.70	1.84	
	LETTUCE	BA (2nd crop)	10	9	6/24	7/29	9/28-10/12	21	210	8.68	86.80	1.70	
1997	FAVA BEANS	Banner	34	8	Not rec.	1/16	5/16			23.31	68.56		Wet wt. B14CC BC Oct failed.
	AMARANTH	Golden Giant	14	3	4/8	5/22	7/25			0.87	6.21		Cleaned seed 0.26 lb actual; 1.9 lb/100
	MANGELS	Yellow Intermediate	10	7	4/21	5/22	9/16	Not rec.	–	5.56	55.60	0.82	
	LETTUCE	Bronze Arrow	10	9	4/15	5/22	7/22	14	140	10.25	102.50	2.01	
	LETTUCE	BA (2nd crop)	24	9	6/20	7/30	9/27-10/13	37	154	10.5	43.75	0.86	2nd crop included Amaranth area.
1996	FAVA BEANS	Banner	34	8		10/3	5/13			5.88	17.29		
	AMARANTH	Golden Giant	12	3	4/8	5/13	7/31			1.12	9.33		Cleaned seed 0.48 lb actual; 4.0 lb/100
	MANGELS	Yellow Intermediate	10	7	4/22	5/13	10/14	23	230	6.00	60.00	0.88	
	LETTUCE	Bronze Arrow	12	9	4/16	5/13	7/12-23	19	158	8.87	73.92	1.45	At fence end of bed: hotter, more stress
	LETTUCE	BA (2nd crop)	12	9	6/27	7/24	10/8	19	158	3.18	26.50	0.52	
1995	AMARANTH	Golden Giant	12	3	5/18	6/9	9/11			3.12	26.00		Cleaned seed 0.98 lb actual; 8.2 lb/100
	MANGELS	Yellow Intermediate	12	7	5/15	6/9	9/8-10/1	24	200	9.18	76.50	1.12	
	LETTUCE	Bronze Arrow	10	9	5/3	6/9	7/25-31	14	140	7.87	78.70	1.54	
	LETTUCE	BA (2nd crop)	10	9	6/26	7/31	9/16-10/2	20	200	3.87	38.70	0.76	
1994	AMARANTH	Golden Giant	12	12	6/22	7/12	9/23			Data missing			Cleaned seed 0:60 lb actual; 5.0 lb/100
	MANGELS	Yellow Intermediate	10	7	7/12	7/26	10/8-15	29	290	6.68	66.80	0.98	
	LETTUCE	Bronze Arrow	12	9		7/13	8/29-9/9	19	158	9.43	78.58	1.54	

BED 100–FERTILIZATION

YEAR	AMENDMENTS AND COMPOST (Actual amounts used)
1998	ALF 1-12.24, GYP 0-12.24, KS 0-2.72, BOR 0-0.17; 4 5gB** Compost.
1997	ALF 1-4.74, OYS 1-5.76, KS 0-3.4, BOR 0-0.04, COP 0-0.14; 1 5gB Compost (should have been 4).
1996	ALF 0-9.8, GYP 0-6.4, OYS 0-5.4, KS 0-3, BOR 0-0.1; 4 5gB Compost.
1995	ALF 1-12.9, BO 0-8.16, GYP 1-3.04, OYS 1-0.32, RockPh 1-11.2, KS 0-8.84, SUL 0-0.57, ZS 0-0.44, BOR 0-0.29, MnSul 0-2.72; 4 5gB Compost. NB: Bone 1/2 amt added '94.
1994	ALF 1-12.9, BO 1-0.32, GYP 1-3.04, OYS 1-0.32, RockPh 1-11.2, KS 0-8.84, SUL 0-0.57, ZS 0-0.44, BOR 0-0.29, MnSul 0-2.72; 4 5gB Compost.
	As per Soil Test Analysis recommendations, June 1994

* CNT = Centers = Distance between plants

** 5gB = five-gallon buckets

data was lost for the first year), and then decreased the third and fourth years and had still not recovered by the fifth year. The fact that, due to a student error, only one-quarter of the scheduled cured compost was added to the test area in 1997 may have had an effect on this crop's yield, but then why not the lettuce and mangel yields as well? We hope to discover the answer in the next years of the multiple-year testing plan for this area. See Table 6 for detailed data (bed 100 appears to be doing well in 1999).

The Question

The question is: What are the future potential, some representative world applications, future challenges and research opportunities for the Grow Biointensive method of agriculture?

REFERENCES

ComSpec Soil Testing Service, 5569 State St., Albany, OH 45710.
Jenny, H. 1980. The Soil Resource: Origin and Behavior. Springer-Verlag.

RECEIVED: 06/20/00
REVISED: 01/08/01
ACCEPTED: 01/28/01

Biointensive Sustainable Mini-Farming: V. Future Potential, Some Representative World Applications, Future Challenges and Research Opportunities

John C. Jeavons

ABSTRACT. The purpose of this paper is to: Look at the future potential of "Grow Biointensive" sustainable mini-farming in terms of the production of calories and carbon per unit of water; discuss world applications by briefly looking at the overall preliminary results of two experiences in India and Russia; and review the future challenges and research opportunities for the "Grow Biointensive" method of agriculture and the need for corroboration through comparison with independent research projects and programs with data collected on a rigorous statistical basis and subjected to statistical analysis. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com> © 2001 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. Biointensive, small-scale, high-yielding, resource-conserving, organic

FUTURE POTENTIAL

Caloric Production per Unit of Water

The apparent potential of "Grow Biointensive" practices for producing increased yields per unit of area offers a hope of growing complete

John C. Jeavons is Executive Director, Ecology Action, 5798 Ridgewood Road, Willits, CA 95490. He has a BA from Yale University and is the recipient of the following awards: Boise Peace Quilt Award–1988, Giraffe Award for Public Service–1989, Santa Fe Living Treasure Award–1989, Steward of Sustainable Agriculture–2000. Nominated for World Food Prize–1993 and 1995.

diets in one-half, or less, the area currently required. In addition, key root crops, such as potatoes, sweet potatoes, salsify, garlic, burdock and parsnips, by this approach are both very water-efficient in the amount of calories produced per unit of water used *and* possess *caloric area efficiency* when compared with grain, seed and bean crops. For example, all the calories for one person for all year might be grown with the Grow Biointensive method with potatoes in as little as 55 square meters (600 square feet) while the same caloric productivity may take approximately eight to twenty times the area, or 440 to 1,100 square meters (4,800 to 12,000 square feet), with likely soybean yields.

Grow Biointensive practices have significant potential to produce more calories per unit of water. This potential can be observed from the generally increased yields per unit of area at both Ecology Action test sites and the significantly decreased water consumption per unit of area experienced at the Palo Alto, California, test site. A higher clay content in the Palo Alto test area soil enabled Biointensive practices to be more water-efficient in terms of the amount of calories and carbon produced per unit of water there. *Assuming only a doubling of yield and a halving of water used per unit of area, as little as one-quarter the water per pound of food and/or per calorie produced can result.*

Therefore, the levels of caloric and carbon production per unit of water shown in Table 1 have been developed to demonstrate only conservative estimates of the overall potential for the efficient use of water by Grow Biointensive practices. This table assumes only one-half the water consumption per pound of food and/or calorie produced. Some key yields at the Willits location, however, have been significantly higher than the ones shown in this five-part series, indicating the potential for higher yields over time as the soil continues to improve and as the environmental constraints of the site are minimized.

Biomass Energy

Grow Biointensive manual farming practices also appears to have the capacity both to produce food with one-half or fewer the kilocalories of energy–in all forms–through its manual farming practices *and* to produce high levels of "energy" in the form of the carbonaceous food needed for the soil microbes in order to maintain sustainable soil fertility. This can be seen in Table 2 when the carbon produced by Biointensive techniques per unit of water is compared with the carbon produced by the conventional approach.

TABLE 1. Use of Water in Agriculture (estimated)

APPROXIMATE. Based on U.S. Average Yield figures and Weeks to Maturity data in *How To Grow More Vegetables*, 1991 ed. (Columns G and M). Assumes water use of 20 gal/100 sq ft/day for vegetables and 12 gal/100 sq ft/day for grains.

					CALORIES		
TO PRODUCE 1 LB (0.45 KG) **OF**	**WATER NEEDED**** gal	lit	lb	kg	**CALORIES/ LB** (0.45 KG) **OF CROP**	**CONVENTIONAL CROP CALORIES/ LB** (0.45 KG) **OF WATER**	**CONSERVATIVE COMPARISON– BIOINTENSIVE CROP CALORIES/ LB** (0.45 KG) **OF WATER*****
Japanese Millet (grain) (?)* (45 days)	79	299	619	280	1,483	2.40	4.8
Corn, Fodder (grain) (112 days)	118	449	927	420	1,579	1.70	3.4
Proso Millet (grain) (?)* (90 days)	158	599	1,238	561	1,483	1.20	2.4
Carrots (70 days)	23	87	185	83	156	0.84	1.68
Potatoes (120 days)	45	170	355	161	279	0.78	1.56
Soya (120 days)	399	1,512	3,120	1,414	1,828	0.59	1.18
HRS Wheat (grain) (120 days)	388	1,525	3,035	1,376	1,497	0.49	0.98
Hamburger	3,205-6,410	12,132-24,264	25,000-50,000	11,340-22,680	1,216	0.048 -0.024	0.096-0.048

* Estimate: full data not available. Crop worthy of investigation. Assumes millets require half the water compared to wheat and other grains, ~6 gallons/100 sq ft/day (22.5 liters/9.3 sq m).

** Assumes growing-season average water use of 20 gallons/100 sq ft/day (75 liters/9.3 sq m) for grains and 12 gallons/100 sq ft/day (45 liters/9.3 sq m) for vegetables.

*** The Biointensive example assumes two times the yield per unit of area (conservative estimate of Biointensive production efficiency) and the same input of water per unit of area compared with commercial agriculture. This means double the production of carbon and calories per pound of water used.

SOME REPRESENTATIVE WORLD APPLICATIONS

Biointensive sustainable mini-farming has been disseminated around the world primarily through Ecology Action's many self-help publications. This process has been amplified through volunteer, intern and apprentice positions, introductory-level Three-Day Workshops, *basic-level* Five-Day Workshops, *intermediate-level* Seven-Day Workshops and *advanced-level* Six-Week and Ten-Week Workshops.

India

In 1976, Ecology Action offered free "how-to" information by mail to 160 key farming programs around the world. The Director of the Shri AMM Murugappa Chettiar Research Centre in Tharamani, Madras, In-

TABLE 2. Use of Water in Agriculture (estimated)

APPROXIMATE. Based on U.S. Average Yield figures and Weeks to Maturity data in *How To Grow More Vegetables*, 1991 ed. (Columns G and M). Assumes water use of 20 gal/100 sq ft/day for vegetables and 12 gal/100 sq ft/day for grains.

TO PRODUCE 1 LB (0.45 KG) OF	WATER NEEDED** gal	lit	lb	kg	CARBON CARBON/ LB (0.45 KG) OF STRAW	CONVENTIONAL CROP CARBON/ LB (0.45 KG) OF WATER	CONSERVATIVE COMPARISON–BIOINTENSIVE CROP CARBON/ LB (0.45 KG) OF WATER***
Japanese Millet (grain) (?)* (45 days)	45	169	351	159	0.52	0.00146 (5.5×)	0.00292 (11×)
Proso Millet (grain) (?)* (90 days)	90	340	702	318	0.52	0.00073 (2.7×)	0.00146 (5.4×)
Corn, Fodder (grain) (112 days)	90	342	709	321	0.52	0.00071 (2.6×)	0.00142 (5.2×)
HRS Wheat (grain) (120 days)	240	908	1,872	849	0.50	0.00026 (1×)	0.00052 (2×)

* Estimate: full data not available. Crop worthy of investigation. Assumes millets require half the water compared to wheat and other grains, ~6 gallons/100 sq ft/day (22.5 liters/9.3 sq m).

** Assumes growing-season average water use of 20 gallons/100 sq ft/day (75 liters/9.3 sq m) for grains and 12 gallons/100 sq ft/day (45 liters/9.3 sq m) for vegetables.

*** The Biointensive example assumes two times the yield per unit of area (conservative estimate of Biointensive production efficiency) and the same input of water per unit of area compared with commercial agriculture. This means double the production of carbon and calories per pound of water used.

Note: For the production of a unit of calories or carbon, Biointensive mini-farming uses as little as 1/3 the water per pound of grain and as little as 1/8 the water per pound of vegetable produced. Wtih Biointensive techniques:

8-30 gallons (30-114 liters) per 100 sq ft per day at hottest time of year
4-15 gallons (15-57 liters) per 100 sq ft per day annual average and 2 to 4+ times the yield.

dia, Dr. C.V. Seshadri, requested this free information which included the first 1974 edition of *How to Grow More Vegetables*. . . . He then initiated a Biointensive Project with 22 low-income families who had:

- never really grown food before,
- growing areas in very sandy soil, and
- only fresh manure for fertilizer.

The crops grown were cluster beans, ashgourd, pumpkin, bhendi, tomato, onion, radish, chillis, eggplant, cucumber, luffa and amaranth greens. After two and one-half years, by the end of their third growing season, the yields of the vegetables these families were growing had reached 75% to 100% of the *good farmer yields* in India. The principal conclusions of the project were:

1. this method can be taught to people with no previous experience of vegetable growing,

2. they can produce good yields with locally available resources in poor soils, and
3. they can become self-reliant and self-confident after very little training. This was a result not just of the effectiveness of the Biointensive method, but also of the teaching program of the Indian center (for detailed data see: Shri AMM Murugappa Chettiar Research Centre, 1978).

After other experiments a new project was begun in 1990: ". . . we initiated a project for the Department of Science and Technology, New Delhi, Government of India. The aim of the project was to provide rural women sustainable income by using the . . . [Biointensive] techniques. One hundred women were trained and they started growing vegetables using the . . . gardening techniques in their backyards. As there was no demand locally, a society by the name of 'Shaktha Society for Women' was formed to find a good market for these organically grown vegetables in the city. As the vegetables fetched them better prices, the women got very much interested. We found that with 120 square meters (1,116 square feet), an income of 200-250 rupees can be easily obtained. Most of the women own between 120 and 200 square meters" (Ecology Action, 1993).

Russia

In 1994 Larissa Avrorina of ECODOM in Akademgorodok, Siberia, attended a Three-Day Workshop in Willits and stayed for an additional month of training. In 1995 she began conducting experiments to see how Biointensive methods could be adapted to her harsh climate. The crops were shallots, beets, carrots, onions, radishes, green peas, dill, squash, cucumbers, sweet corn, string beans, potatoes and lettuce. In the first year, vegetable yields were 83% to 230% greater than the control tests. Except for lettuce and potatoes, which require some modification in technique and/or variety for all three agricultural approaches in order to grow most effectively in this situation, the Biointensively grown double-dug growing beds yielded much more highly than the single-dug, unfertilized and the single-dug, fertilized growing areas:

- *Single-dug, unfertilized area* (excluding lettuce and potatoes): *61% to 241%* of the U.S. average, or an overall average of *153%*,
- *Single-dug, fertilized area* (excluding lettuce and potatoes): *82% to 347%* of the U.S. average, or an overall average of *186%*,

- *Double-dug Biointensive area* (excluding lettuce and potatoes): *141% to 802%* of the US. average, or an overall average of *286%* (for detailed data see: Avrorina, 1996).

FUTURE CHALLENGES AND RESEARCH OPPORTUNITIES

Where Do We Go from Here? What Information Is Needed to Understand the System Better So It Can Be Improved?

Grow Biointensive Sustainable Mini-Farming offers hope for the future. In addition to being easily accessible to virtually everyone in all climates and soils where food is grown, its intermediate-level yields may enable people relatively unskilled in farming practices to become as effective as the upper 15% of the farmers in their region–once the quality of the soil and their skill have been moderately developed. Encouraging is the fact that people periodically write that they have obtained yields that exceed Ecology Action's expectations for productivity with a given crop. To make a global difference, these higher yields are not necessary–just a doubling can place the world onto a path of greater self-reliance, the building and maintenance of sustainable soil fertility, and the creation of viable mini-ecosystems thriving with genetic diversity around the globe.

What are some of the major issues for examination and research?

Energy–How much energy is expended in Grow Biointensive production as compared to other management systems?

Productivity–How exactly are high yields achieved in Grow Biointensive? Where (geographically) does using Grow Biointensive result in significant yield increases over other management systems?

Plant nutrition–How does the use of organic amendments affect nutrient availability and plant nutrition? What predictive capacity do we have to estimate "fertilizer" needs?

Effects on soil properties–What effects does Biointensive have on soil physical, chemical, and biological properties and processes?

Composting–What composting scenarios lead to greater carbon and nutrient retention?

Social acceptability–What cultural traits lead to acceptance/rejection of Grow Biointensive? What factors within the system limit its adoption?

Environmental impacts–What are the nutrient leaching rates from compost piles and Biointensive beds? What is the erosion potential?

Comparative potential and replicability–It is important that the Grow Biointensive method be tested in side-by-side research plots with controls at five to ten different soil and climate locations in the United States and around the world, so that the level of its potential can be more firmly established.

Each of these issues is region-specific. Therefore, one of the first things that need to be done is to establish long-term, well-funded, replicated trials in major ecoregions throughout the world. Trials should be located on established experiment stations and managed by individuals with knowledge in agronomy, soil science, and statistics (as well as other appropriate disciplines). How realistic this is, is uncertain. The flow of money has been going away from agricultural research (especially internationally) for over a decade. It is bound to increase, though, given current trends in population growth, and the demand for an agricultural system able to meet the food demands of the future.

It is the hope of the author that this paper will create the increased dialog necessary for a transition and transformation to a more effective and strongly sustainable agriculture. There are some areas in the world where resource-effective approaches, such as Biointensive farming, will be needed more urgently than in other regions. Some countries, such as the U.S., Canada, Australia and New Zealand, may have less need for a rapid transition from current agricultural practices to new ones in the near future. Many countries will benefit by the increased employment opportunities that these practices can be designed to accomplish. Most important, this approach can give people everywhere the techniques for a more positive self-reliance while building the more diverse, thriving mini-ecosystems necessary to a better life and healthier planet. Rather than being increasingly forced to flood into conurbations, this way can provide dignity for people while enabling them to remain and flourish where they live.

It may seem a distant goal, an impractical utopia.
But it is not the least unobtainable,
since it can be worked for here and now.
An individual can adopt the way of the future . . .
and if an individual can do it,
cannot whole groups of individuals? Whole nations?

–Mahatma Gandhi

REFERENCES

Avrorina, L. 1996. Siberian Biointensive research report. Ecology Action, 16pp.

Ecology Action. 1993. Outreach–India. Newsletter, August, p. 6.

Shri AMM Murugappa Chettiar Research Centre. 1978. Monograph series on engineering of photosynthetic systems, Volume 4. 38pp.

RECEIVED: 06/20/00
REVISED: 01/08/01
ACCEPTED: 01/28/01