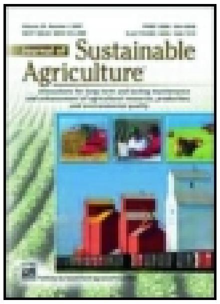

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Biointensive Sustainable Mini-Farming: IV. System Performance-Continuing Trials in a More Difficult Environment and Soil

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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

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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. Serpentine 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 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-l and -2, sul-

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

fur, 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

TABLE 2. SAREP Soil Test of Willits Site

DANR ANALYTICAL LABORATORY
UNIVERSITY OF CALIFORNIA
COOPERATIVE EXTENSION

SUBMITTED BY:	LIEBHARDT, WILLIAM	WORK REQ #:	**67S0560**
DANR SECTION:	SP: SARPET, UCD	# OF SAMPLES:	8
COPY TO:		DATE RECEIVED:	4/24/97
COMMODITY:	Vegetables	DATE REPORTED:	6/9/97
DRY MATTER:	As Received	DANR CLIENT #:	LIEW2C
	Jeavons–Willits 4/24	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

been surprisingly good 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 Désirée 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	–	Crop failure Beans, wet	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
Bklt 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.
Bklt 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 data

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

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?

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