

Outcomes of applied weed and micro-organism technology for bio-remediation and sustained fertility on an intensive micro-horticulture unit

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Abstract

The intent of the work at the Organic Research unit at Kakanui was to follow the methods and philosophies of researchers such as Steiner (1958), Balfour (1943) and Boserup (1965), to investigate bio-remediation methods of recovering damaged agricultural soils, using local resources coupled with microorganism technology, to assist farmers the world over. The bio-remediation method developed was a modified “Bio-Intensive” (Jeavons 1995) method of cultivation. Inputs were restricted to weeds and bio mass generated on the property, community green waste, seaweeds, fish offal and chicken manure. Water was from a rural water scheme, at 1000ℓ per day, for the 0.57 ha property. A lead crop of potatoes was planted to initiate bed formation. Post lead cropping, a layer of compost was incorporated into beds prior to the next, and each subsequent, crop. The study product chosen was garlic [var. ‘Printanor’], a primary crop grown for the Koanga Institute’s ‘Heritage Seed’ programme. Lettuce was planted and cropped prior to garlic, spinach was planted coincidentally with, and beetroot was planted as a side crop post the harvesting of the spinach. Microorganism innoculum was applied twice per garlic crop cycle, once as a soil drench at planting and again just prior to bulb formation. Standard soil and microorganism tests were done prior to initial innoculum application. Results were measured by observation of changes in soil structure, changes in soil analysis results and increases in the percentage of marketable quality garlic. Marketable yield increased from 40 to 80% in one cycle. Average bulb weight increased from 70 to 100g when dried. In addition the soil maintained under-storey crops, which equated to an approximate yield of \$45/m².

Introduction

In 1996 the property in Kakanui was purchased to establish a School of Environmental Recovery in association with Assoc Prof Tatsuka Toda of Soka University, Japan. In order to create the most benefit to the target farming community it was decided to remove inputs that would not be available to farmers in less resourced countries. As a result, hand tools were used. The water supply was a restricted allocation from a rural water scheme, to 1000ℓ per day [in a drought prone area average rainfall 650mm per annum]. Resource gathering was restricted to that which was retrieved by hand or green waste donated by the community. After researching various organic 'how to' texts, Jeavons 'How to Grow More Vegetables' (1995) double dig method, and Smillie and Gershuny's 'The Soul of Soil' (1999) were chosen as primary references. It was reasoned that if organic systems are to be credible in their production methods, anyone would be able to read and apply the information with a certainty of success. Seed stocks were developed from locally sourced heritage seeds where possible (The garden is now dedicated to heritage seed production for the Koanga Institute). Development capital was limited to that which could be produced from the land.

LAND STATE

The soil type was Loess over clay on limestone bedrock. The land had previously been in intensive horticulture for two generations and had been cropped almost continuously for more than thirty years, firstly in brassica and finally in narcissi. Standard fertilizer (eg Nitrophosca Blue) and chemical applications, (including DDT and the Triazine family of herbicide, especially Symazine), had been used (prior to purchase) for disease and pest control. Neighbors report that prior to narcissi harvest, the land was "sprayed to bare brown dead". A stream of brown was said to flow out the gate whenever it rained. The topsoil at the top of the property was less than 2cm deep, while that at the bottom was 60cm and more in places. Soil cover was successional weeds; predominantly California thistle. Herbal ley had been oversown five years previously, and vetch, chicory, plantain and mustard were evident amongst otherwise rank grasses, predominantly couch and cocksfoot. The sward in places was over two metres tall. Samples were taken for chemical residue analysis. Results are shown in (Table 1, Appendix A).

OBSERVED STATE

The initial impression was that the land was very dry, the soil lacked stable humus and was packed and hard. A field test revealed no worms in evidence and water took more than 24 hours to drain away in test holes. A machinery-created hard pan was evident at approximately 15 to 20 cm depth throughout the property.

Hypothesis

A degraded piece of horticultural land can be rehabilitated into a viable self-sustaining organic production unit within ten years using micro-biological husbandry and effective weed management.

Methods

The method chosen was a modified double dig (Jeavons 1995). Rather than the wider beds, it was decided to create beds shoulder-width to suit the tools. The lead crop chosen was potatoes which because of the need to “shore” or mould them up and break the soil in. Initially the bulk of the green matter was scythed and removed for composting. The soil was worked and the remaining weed burden chipped off just below ground level with the large chipping hoe. The weed and grass ball was then turned or “turved”, forming a basic bed shape. When the grasses resprouted, the beds were turved again and potatoes planted. Subsequent weed control was provided by shade from the potatoes. The double dig process began after the lead crop potatoes were harvested.

TOOLS

Conventional tools such as forks, spades and shovels, were discarded in favour of the “Turver”, various sizes of chipping hoes and a sharpened bricklayer’s trowel. The intent was to create a series of tools that could be effective in most soil types, which would be able to be made from locally sourced and recycled materials. Decisions for tool design were influenced by the need to keep weeding time minimized.

THE DOUBLE DIG PROCESS

Standing to one side or astride the bed, first the topsoil was broken open, with minimum turning,

and pulled aside to expose the subsoil, which was then broken open in-situ. The next section of topsoil was then broken open and dragged over the top of the open subsoil, repeating the process and forming a shoulder-width bed. This increased the aeration of the soil and broke through the hard pan, increasing the amount of soil available to crop roots and formed paths between the beds to prevent bed compaction. The beds, thus formed, were covered with mature compost at a rate of 100ℓ per 10metres (one large wheelbarrow-full, approx 1cm layer).

The sides of the bed were drawn up, to mix the compost into the top few centimetres of soil. The beds were then planted out in the second season beginning the lettuce-spinach-garlic-beetroot intercropping cycle. Planting was done in a quincunx pattern at distances to suit the crop. Crops were left to grow with a weed burden until an optimum time to weed (crop dependent).

The beds continued to be cropped throughout the first season, using rotations of light feeders such as lettuce and spinach and adding compost between each crop. Nutrient and biological soil tests were taken in 2003, prior to planting of the first garlic crop, and continued through 2006. Soil test results are shown in Tables 2, 3, 4, 5a and 5b (Appendix A). From June through August 2004 garlic was planted amongst lettuces and spinach in the previous season's potato beds.

Post lettuce and spinach cropping, beetroot was planted on the sides of the beds, to overwhelm the weeds in the pathways between the garlic beds, for the garlic's last trimester. The garlic and beetroot were cropped and the beds planted in carrots (with the intent of helping control carrot fly). Beds were planted in peas the following year 2005 then grown again in the garlic cycle. Soil tests were taken and compared with previous tests (Tables 2 and 3, Appendix A).

WEEDING

Weeding was undertaken with a variety of tools depending on the weed, the crop and the desired outcome. For example, lettuces were weeded using a sharp edged bricklaying trowel. This method can effectively weed 200 lettuces in 30 minutes. It reduced weeding to a once-per-crop routine and captured weed tops and roots to help develop the soil by providing mulch and decaying roots to feed the soil life. Carrots and onions were weeded using the smaller chipping hoe to define the rows then hand weeded to ensure a clear crop. Again, the weeds were left on the paths between the beds as mulch.

Results

TURNOVER

Production from 8 beds 20 metres long

Lettuce 7 per metre @ \$1ea; Spinach 5 bunches per metre @ \$2 ea; 17 garlic per metre @ \$1.5 ea; Beetroot @ \$4 per metre; Carrots @ \$10 per metre.

Rate taken at 80% of output = \$45.2 per metre.

SOIL STRUCTURE

The soil depth changed from its initial 15 -20cm to 50-60cm. The micro biological activity had increased dramatically (Tables 5a and 5b, Appendix A). There were now mychorrizal strands evident. Water retention properties had improved. Less watering was needed to produce the crops. Soil crumb structure had improved. The soil was now open and friable. Beds that took 6 to 9 hours to create initially now took 2 hours and weeds such as dock and couch simply lift out. Worms spilled from each breaking of the soil. Nutrient tests show that those elements which were previously out of balance, were now coming into equilibrium and, moreover, comparative soil tests suggest that this method could increase CEC (Table 2, Appendix A).

CROP RESULTS

Garlic average weight changed from 70gm in the 2004/05 season to 100gm (largest bulb 314gm), in 2006 to 2007. First grade Garlic seed quality has increased from 42% (2005/06) to 82% of the crop. This was in a year (2006/07) that was generally considered to be a poor year for garlic. On a number of occasions from the second season onwards, beds of lettuce cropped at 100%. ie all of the lettuces in that bed were of saleable quality. (2005, 2006, 2007). Tomatoes had been grown in beds that were straight clay when started, for the four years from 2003 through 2006. The use of biological inoculum has apparently increased crop resistance to pests and diseases. Addition of woody material in compost and added to beds with compost aids in the growth of micro organisms in the soil. Mycelium strands are now evident in the beds (2006/2007).

Conclusion

The combination of soil and weed management, compost and stable humus applications and micro organism inoculums appear to have beneficial effects on degraded horticultural soils such that fertility can be maintained and soil structure can be improved while cropping intensively. The application of buried “woody “ material appears to create a “nursery” in that it provides a substrate for beneficial microorganisms.

This demonstrates Boserup’s concept that when the population increases to a certain point, humans will find creative new ways to sustain themselves and reinforces Balfour and Steiners’ focus on micro organisms as the basis for establishing and maintaining healthy soils.

Use of weeds as a basis for composting materials appears to be successful. There is enough evidence from these results to encourage continued observation and analysis and to refine the process over time. However, further research needs to be conducted, on the various aspects of weed management, as weed types change during cultivation.

Future

Continue to refine the process

Test the hypothesis over diverse conditions and soil types

Mechanise the system.

Offer scholarships for post graduates.

Engage with students in assistance and aid programmes overseas via Internet

Extend the seed bank for cool temperate crops

Create a demonstration Eco-village

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Appendix A

Table 1: Chemical contaminants of two properties in Kakanui as indicated by Agri-Quality New Zealand, final laboratory report. *Job number 118589*

	Endosulphan I mg/kg	Lindane	ppDDT	Endosulphan II mg/kg	ppDDD	DDE	opDDT	Pesticides - others	Benzene hexachlorine	HCB	Aldrin	Heptachler
O'Gorman	<0.01	<0.01	0.04	<0.01	<0.01	0.03	<0.01	0	<0.01	<0.01	<0.01	<0.01
Shields	<0.01	<0.01	0.27	<0.01	<0.01	0.27	0.04	0	<0.01	<0.01	<0.01	<0.01

Table 2: Soil Chemical Characteristics for “A Place to Be” transcribed from Massey University Laboratory Report 29/09/03 and Hill Laboratories’ Laboratory Report 10/07/06

Date	Soil Sample	pH	Olsen P $\mu\text{gP.g}^{-1}$	SO ₄ $\mu\text{gS.g}^{-1}$	K me.100g ⁻¹	Ca me.100g ⁻¹	Mg me.100g ⁻¹	Na me.100g ⁻¹	CEC me.100g ⁻¹	Base Saturation %	Soil Volume g.mL ⁻¹
29/09/03	Carrot	6.9	126.5	7.6	3.22	15.9	3.67	0.29	23	100*	1.09
	Garlic	6.8	165	67.2	4.5	16.9	4.73	1.26	27	100*	1.09
	Potatoes	6.5	103.8	11.3	3.23	12.1	3.73	0.2	21	92*	1.06
	Average	6.733	131.7667	28.7	3.65	14.9667	4.0433	0.5833	23.667	97	1.08
10/07/06	Garlic	7	159	NR	3.25	14.2	3.99	0.35	23	93	0.93
Medium Range		5.6-7.0	45-90	-	0.7-1.1	5- 12	1-3	0-0.5	12-25	50-80	0.6-1.00

*Not indicated by original tests - Calculated as: $[\text{Total Bases (K, Ca, Mg, Na)} / \text{CEC}] \times 100$

Table 3: Soil N, C, and Organic Matter Characteristics for “A Place to Be” transcribed from Hill Laboratories’ Laboratory Report 10/07/06

Date	Available N 15 cm depth kg.Ha ⁻¹	Organic Matter %	Total C %	Total N %	C/N ratio %	Anaerobically mineralisable N µg.g ⁻¹	AMN/TN ratio %
10/7/06	124	7.8	4.5	0.46	9.8	89	1.9
Medium range	100-150	7.0-17.0	-	0.3-0.6	-	-	-

Table 4: MAF quick test values for “A Place to Be” transcribed from Massey University Laboratory Report 29/09/03 and Hill Laboratories’ Laboratory Report 10/07/06

MAF quick test values							
Date	Soil Sample	P µgP.g ⁻¹	SO ₄ µgS.g ⁻¹	K	Ca	Mg	Na
29/09/03	Carrot	138	8	55	20	91	-
	Garlic	180	67	77	21	118	-
	Potatoes	110	11	54	15	91	-
	Average	142.667	28.667	62	18.667	100	-
10/07/06	Garlic	-	-	62	16	83	15

Table 5a: Soil Biological Characteristics as indicated by Soil Food Web Institute laboratory reports for 15/01/04, 6/04/05, 26/07/07

Date	Sample #	Treatment	Dry weight of 1g of fresh material (g)	Active bacterial biomass (µg)	Total bacterial biomass (µg)	Active fungal Biomass (µg)	Total fungal biomass (µg)	Hyphal diameter (µm)	% Mycorrhizal colonisation of Root	Total Fungal : Total Bacteria l Biomass	Active : total Fungal Biomass	Active : total Bacterial Biomass	Active fungal : active bacteria l biomass
15/01/04	233	A	0.82	24	459	21.7	139	3	NR	0.3	0.16	0.05	0.9
6/04/05	925	A	0.78	41.7	646	29.7	221	2.5	NR	0.34	0.13	0.06	0.71
26/07/07	2360	A	0.77	NR	NR	0.00	815	2.5	NR	NR	0.00	NR	NR
Desired range			0.45-0.85	5 - 15.0	100 - 300	3 - 10	150-200+	2 – 3+	40%-80%	0.2-1.2	0.05-.95	1	

Table 5b: Soil Biological Characteristics as indicated by Soil Food Web Institute laboratory reports for 15/01/04, 6/04/05, 26/07/07

Date	Sample #	Treatment	flagellates	amoebae	Ciliates	Total Nematodes (#/g)	Plant Available N Supply from predators (kg/ha)	Root-feeding nematode presence
15/01/04	233	A	5635	5635	683	NR	100-110	NR
6/04/05	925	A	35658	17829	592	NR	100-150	NR
26/07/07	2360	A	NR	NR	NR	NR	NR	NR
Desired range			10000+	10000+	50-100	10 - 20		

