Sustainable high soil fertility without chemical fertilizers, a challenge for agriculture scientists

OP Rupela et al.*

Background:

- This farm is in village Bajwada, district Dewas, Madhya Pradesh; owned by Malpaani Trust and managed by Mr Dipak Suchde, CEO of the trust (deepaksuchde@gmail.com, mobile: 9329570960). As I understand, Mr Suchde is also an important member of 'Prayog Parivar' – a non-institutional network of knowledge communication initiated by Prof. Shripad A. Dabholkar. The network involves several practicing farmers. More information on the network should be available at www.prayogpariwar.net. A book "Plenty for All" written by Prof. Dabholkar, published in 1998 (Mehta Publishing House, 1216, Sadashiv Peth, Pune; mehpubl@vsnl.com) tells us of a different outlook to farming and should be read by all students of agriculture.
- I know the group from April 2005 when I participated in a workshop by the group, organized to commemorate first death anniversary of Prof. Dabholkar. Surprisingly, quite a few farmers associated with the group were awarded by some states/organizations for harvesting highest yields for different crops, including sugarcane and grapes. Some of their views/concepts (in the book and/or on the website) may appear unscientific, but the fact that their farmers were harvesting high yields forced me to spend more time/interest in this direction.
- The group has developed several innovative protocols of crop production. The most fascinating for a microbiologist like me was 'the method of composting' which they called process of making 'Masala Matti' – Mr Dipak Suchde now calls it "Amrit Matti". Some samples of this compost had up to 100 million plant-growth promoting bacteria (siderophore producers) in every gram of the compost - highest ever measured in any compost in our lab.
- Mr Suchde believes that about 10 Gunta (one hectare = 2.42 acres, one acre = 40 Gunta) land is enough for not only feeding a family of four, but also providing other items of livelihood through selling the excess produce.
- Visit to crops at the Yusuf Meherally Centre (YMC) Tara, Panvel district of Maharashtra, where Mr Suchde used to work when I met him first, was an eye opener. The small area of 10 Gunta had over 100 crop species (mix of annuals like Papaya and perennials) and reminded me of several publications of Miguel A. Altieri (Professor of Entomology, University of Florida, 215 Mulford Hall Berkeley, California 94720; agroeco3@nature. berkeley.edu) where he argues in favor of designing agroecosystems mimicking the structure and function of natural ecosystems if we have to have sustainable high yields. Here at the YMC I was witnessing a working model of what perhaps Altieri was theorizing in his publications. The Alfisol soil at YMC did not seem fertile and had lot of pebbles. I was told that the crop was only 3-months plus. Still there were all signs of high productivity per unit area. It seemed much was happening in the heaps of "Amrit Matti" and needed explorations.

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* Co-authers will soon be contacted because of their intellectual contributions in educating me on aspects relevant to 'soil chemistry' and several sessions of discussions in the past one decade on interactions between microorganisms and soil chemistry. All the soil samples were analysed in the Soil Chemistry Laboratory at ICRISAT, headed by Dr KL Sahrawat, for NPK and OC%.

The key characteristics of this technology of growing crops, which the group calls 'Natueco Farming', were (a) plants growing on small 'heaps of Amrit Matti' covered with mulch, (b) the heaps were always kept moist (watering with rose cans at the rate of 1000L water per day per 10 Gunta), (c) spacing was wide, (d) not only the heaps, even the rest of the area was covered with grass mulch, (e) weeds were allowed to grow until flowering and were seen as a resource (again this reminded me of the work by Altieri), (f) need-based sowing and harvesting of crops – overall it looked a constructed forest.

- In Sept 2007, I visited at the Krushi Teerth, this time to spend five days. This was a new place of work for Mr Suchde. I was told that the Malpani Trust acquired these lands only recently and the 10-Gunta experiment was started only in June 2007 and thus the crops I was looking at were only about 3 months old. And again there were signs of high productivity per unit area as noted at the YMC. When dug out, most plants (including upland rice) had abundant roots and were white ie. highly active, as was true at the YMC. **Note:** *Yield data from the Krushi Teerth*.

On Studies/Data:
The signs of high productivity and other factors indicated above made me to take detailed soil sampling and we analyzed all possible parameters for which facility was available at ICRISAT. Results of the analyses along with comments are in the attached four data tables. The data indicate a system of crop husbandry that uses locally available natural resource, knowledge and labor to convert a soil with 'low' to 'high' available form of crop nutrients.

Overall:
Unfortunately, in the absence of any comparative treatment we cannot say that the yield with the Natueco Farming was or will be higher than conventional system of agriculture. But there were no signs of nutrient deficiency, diseases and insect-pests worth worrying. The fact that this method does not need agrochemicals, make it environment and farmers friendly, another 'low-cost biological option' that can help farmers. The method is worth exploring further and seems to have surprises for we scientists (plant pathologists, entomologists, soil fertility experts, agronomists, soil physics, crop physiologists, environmental economists, and ---?).

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Note : items highlighted yellow need confirmation

Table 1. Available P, total P, kjhel N, exchanglable K (ppm) and % organic carbon in the soil samples collected from Krishi Tirth, Bajwada, Dewas (MP).

Treatment	Available P (ppm)	Total P (ppm)	Kjehldahl (organic form) N (ppm)	Exchangable (available) K (ppm)	%OC (ppm)	pH
Original Soil	17.1	392	174	284	0.66	7.75
Between Heaps	20.5	362	198	315	0.74	7.59
Planted Heap	33.1	410	194	424	0.72	7.91
Below heap	247.7	500	798	770	2.61	7.89
Mean	79.6	416	341	448.25	1.1825	7.79
SE$\pm$	17.7***	58.4^{NS}	77.8**	87.0*	0.264***	0.036***

*= Differences across treatments are statistically significant at probability level (*P*) 0.05 **=Differences across treatments are statistically significant at *P* 0. 01; ***= Differences across treatments are statistically significant at *P* 0.001, NS= Differences across treatments are statistically non significant

Soil sampled on 19.09.07.
Original soil = soil sample from unplanted area on the farm
Between Heaps = Planting concept on the farm is grow horticultural crops on heaps and heaps are widely apart, soil sampling in this treatment was done between heaps.
Planted Heap = Sampling in this treatment was done at the heap, besides a growing plant on top of a heap
Below Heap = Sampling in this treatment was done after removing all the soil and plant roots from soil surface. Sampling was done from area just below the soil surface but below the heap.
Replications: each of the four treatments had three replications, and there were about three spots within a given replications.

On the different parameters that were measured:

A plant needs over 30 different elements for its growth/formation of leaves, stem fruits etc. all body parts. But we generally measure only selected few and largely **nitrogen (N), phosphorus (P) and potash (K)**. All the 30 about elements occur in a soil largely in two forms – **'available' and 'non-available' form**. Wherever it is stated as 'Total' it means it is total of available plus non-available form. The available form of a nutrient can be readily taken-up by a plant through its roots while the other form has to be processed by microorganisms, which are in maximum numbers on surface of roots and convert them into available form, through enzyme activities or production of organic acids. The process of conversion will generally be slow and would depend on type and numbers of different microorganisms. An element provided as a 'fertilizer' is essentially in available form and therefore when applied to soil, we generally notice a rapid response of plants, in terms of increased green color of foliage and/or growth/yield. pH tells us whether a soil is close to normal or a problematic soil. For a very good soil, pH should be around 7, and values more than 8 (salinity/alkalinity) and less than 6 (acidity) indicate problem. ***Note:*** *All these elements come from mother rock from which a soil has formed. Formation of soil is very long process. Few centimeters layer of soil might have taken thousands of years to get formed.*

Organic carbon (OC) is a biological and not a chemical parameter. Unlike the other biological parameters, this can be measured readily by a chemistry laboratory and is therefore generally lumped with the chemical parameters. **OC%** is like a bank of nutrients in soil and may contain all the nutrients needed for plant growth. More the value, bigger will be the bank balance. But like other elements in soil, much of these elements are also in unavailable form for a plant, but relatively easily degradable to become available for use by plants. These can be made available to plants by microbial activity and carbon in this component serves as food for the microorganisms.

Comments on data table 1: (a) fertility of the original soil was lower than the area under cultivation; (b) fertility was maximum below (15 cm) the heap indicating that roots from plants sown on heaps will tend to go deep in the soil to explore/take-up the nutrients; (c) organic carbon percent (OC%) below heap was at least 3 times more than that in the heap itself, indicating that smaller carbonaceous molecules of degrading biomass move down from heaps with water (rain or irrigation).

Table 2. Total B, S, Fe, Zn (ppm), and Available B, S, Fe, Zn and Mo (ppm), in the soil samples collected from Bajwada (MP), sampled on 19.09.07.

Treatment	Total B (ppm)	Available B (ppm)	Total S (ppm)	Available S (ppm)	Total Fe (ppm)	Available Fe (ppm)	Total Zn (ppm)	Available Zn (DTPA-Zn)	Available Mo (ppm)
Original Soil	29.7	0.27	93	7.17	40442	15.6	133	0.83	0.019
Between Heap	26.0	0.29	103	7.00	33550	11.7	108	1.08	0.009
Planted Heap	27.0	0.32	94	7.60	34625	9.1	77	0.97	0.012
Below heap	26.7	2.29	420	18.93	33300	21.0	97	6.10	0.020
Mean	27.3	0.79	178	10.18	35479	14.4	104	2.25	0.015
SE$\pm$	1.11^{NS}	0.215***	21.0***	1.054***	1641.1$^{NS(0.06)}$	2.48*	21.7^{NS}	0.293***	0.0031^{NS}
CV%	7	47	21	18	8	30	36	23	37

* = Statistically significant at 0.05, *** = Statistically significant at 0.001, NS= Statistically non-significant

NS (0.06) = Statistically nonsignificant at p=0.05 but the values are statistically significantly different at p=0.06.

On the different parameters that were measured:

As stated above, a plant needs over 30 different elements for its growth and good yield and these should be in balanced form. The three elements nitrogen (N), phosphorus (P) and potash (K) are called major elements because these are required in relatively large quantities compared to the others. Ten other elements [**B (boron), Ca (calcium), Mg (magnesium), S (sulphur), Fe (iron), Mn (manganese) , Mo (molybdenum), Cu (copper), Zn (zinc) and Cl (chloride)**] are regarded as vital elements for plant growth along with the P and K. These ten are widely known as micro-elements because these are needed in micro quantities - parts per million (ppm). Like the major elements these also occur in **'available' and 'non-available'** form. As stated above, an agricultural field would highly likely have all the over 30 elements needed for crop growth, but they would largely be in 'unavailable' form. But interestingly, much of the soil analyses done by scientific community is only for the 'available' form and not for the total amount of any given element in the soil. Also, it is worth noting that all the recommendations of a given fertilizer by the extension agencies or by fertilizer dealers is based on the available quantity of an element.

Note: For good crop growth, other 18 elements are also needed, but in very miniscule quantities and these are regarded as 'Trace Elements'.

Comments on data table 2: Only five of the ten micro-nutrients, widely noted as deficient in farmers' fields in semi-arid tropics [see paper by Sahrawat et al. 2007; Current Science 93(10):1428-1432], were analyzed. Salient comments follow: (a) quantities of available form of nutrients (B, S, Fe, Mo and Zn) were invariably significantly more below the heap than that at other sampling spots of the same field; (b) total concentration of all these elements was similar across sampling spots except for 'total S' indicating addition of 'S' with the items such as 'Amrit pani etc. being applied, and this needs to be studied; (c) the noted small differences across sampling spots in the total concentration of three elements -- B, Fe and Z were statistically non-significant. It was apparent that the heap method of cultivation has ability to continuously converting insoluble form of nutrients to soluble form (note: heap remains moist due to continuous application of water) and therefore potentially obviates the need of dependence on market purchased elements. Discussion with soil scientists indicated that most soils would have total form of most elements.

Table 3. Biomass carbon, biomass nitrogen and dehydrogenase activity in the soil samples collected from Krishi Tirth, Bajwada, Dewas (MP)

Treatment	Microbial Biomass C	Microbial Biomass N	Dehydrogenase activity
Original Soil	376	37	58
Between Heap	274	33	38
Planted Heap	208	34	63
Below heap	426	66	98
Mean	321	42	64
SE$\pm$	79.8^{NS}	19.3^{NS}	26.9^{NS}

NS= Differences across treatments are statistically non-significant

On the different parameters measured:

Microbial biomass carbon: this parameter tells us about the carbon held in body of microorganisms, and is an indirect measure of total population of microorganisms, irrespective of their culturability. ***Note:*** *microbiologists can only culture (in laboratory conditions) about 10% of microbial life in a given niche – a generalization. But this does not mean that the un-culture-able microorganisms are not functioning in nature. It only means that we do not fully understand their importance/value*.

Microbial biomass nitrogen: this parameter tells us about the nitrogen held in the body of microorganisms, an indirect parameter of total population of microorganisms, irrespective of their culturability.

Dehydrogenase activity: like the above two parameters, this also reflects all microbial life in a given niche, irrespective of culturability limitations. This reflection is recorded through activity of this enzyme having over 10 sub-types by oxidizing several different substrates of the several biochemical processes operating inside a living microorganism.

Comments on data table 3: (a) as indicated by microbial biomass carbon and nitrogen, the soil below heaps had most microbial activity/population followed by that in the original soil while the activity in the decomposing biomass in heaps was next highest, (b) activity of microorganisms as indicated by 'dehydrogenase' enzyme was also maximum in the sample collected below the heaps, followed by that in the heap itself, and lowest activity was noted in unplanted area between heaps which was covered with dry biomass, the noted high activity in the original soil is perhaps due to good growth of grass that would have allowed a good level of microbial activity in its root rhizosphere and needs further consideration.

Table 4: Population (log_{10} g^{-1} dry soil) and diversity (no. of colonies of different types) of different microorganisms in the soil samples collected from Krishi Tirth, Bajwada, Dewas (MP)

Treatment	Total bacteria pop.	Total bacteria diversity	Actinomycetes pop.	Actinomycetes diversity	Fungal pop.	Fungal diversity	Plant growth promoters (Ab)	Pseudomonas pop.,suppress diseases (Ab)	P-solubilizers pop. (Ab)	Org. Acid producers pop. (Ab)	N_2-fixers, AZO like pop (Ab).
Original	6.64	5	5.67	8	4.02	6	4.94	<4.0	<3.0	3.33	4.33
Between heaps	6.80	7	5.30	6	4.34	6	4.77	<4.0	<3.0	3.67	4.09
Planted heap	7.20	7	5.67	5	4.51	3	5.57	<4.0	<3.0	5.33	4.28
Below heap	6.86	11	5.58	7	4.18	6	3.85	<4.0	<3.0	4.00	4.16
Mean	6.87	8	5.55	6	4.26	5	4.79	<4.0	<3.0	4.08	4.22
SE±	0.099*	0.6***	0.103[NS]	0.9[NS]	0.152[NS]	1.4[NS]	0.482[NS]	<4.0[a]	<3.0[a]	1.244[NS]	0.135[NS]

a=Population of *Pseudomonas* spp. and P-solubilizers could not be assessed due to presence of large numbers of other bacteria.
*= Differences across treatments are statistically significant at probability level (*P*) 0.05 **=Differences across treatments are statistically significant at *P* 0. 01
***= Differences across treatments are statistically significant at *P* 0.001 NS= Differences across treatments are statistically non significant

On the different parameters measured:

Total population of bacteria, actinomycetes and fungi: this parameter tells us about the population of these types of microorganisms that can grow on selected recipes (different for different microorganisms) where microbiologists believe that majority microorganisms will grow. It may, however, be noted that microbiologists can culture about 10% of total population of microorganisms in any niche, due to limitations of methods of culturing. ***Note:*** *all populations are log numbers and have to be taken accordingly. For example, log 3 means 1000 and log 6 means 10 lakh.*

Diversity of bacteria, actinomycetes, and fungi : this tells us the different types (due to size, color, texture etc. of the microbial colony) of microorganisms noted on the growth medium (recipes) used for population count (above parameter). Thus it does not account for the total microbial diversity in a given niche.

Agriculturally beneficial bacteria (Ab): All the five parameters (last five columns) indicated by (Ab) [the last five columns of this table] are the five different functional group of bacteria with functions as indicated with their names.

Comments on data table 4: (a) Population of bacteria inside heaps and below heaps was significantly more than the other treatments (range from 6.64 to 6.80 log_{10} per g of soil); (b) population of actinomycetes and fungi was similar across the four treatments and ranged from 5.30 to 5.67 (log_{10} per g of soil) in case of actinomycetes and from 4.00 to 4.51 (log_{10} per g of soil) in case of fungi; (c) maximum population of the plant growth promoters and organic acid producers was inside heaps where lot of roots were noted during sampling and lowest in the soil below the heaps where chemical fertility was the highest; (d) population of *Psuedomonas* (indicators of ability of soil to manage diseases) and P-solubilizers could not be counted due to methodology problems; (e) N_2-fixing bacteria (colonies that were looking like *Azotobacter*) was similar across the four treatments.