International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2020; 8(2): 330-339

Received: 18-01-2020
Accepted: 22-02-2020

Sanjay Swami
Professor, Department of Soil Science and Agricultural Chemistry, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Umiam Barapani, Meghalaya, India

Corresponding Author:
Sanjay Swami
Professor, Department of Soil Science and Agricultural Chemistry, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Umiam Barapani, Meghalaya, India

Soil health management under organic production system

Sanjay Swami

DOI: https://doi.org/10.22271/chemi.2020.v8.i2e.8789

Abstract
Indian traditional farming system prior to the 20th century was generally organic in nature with low production potential. The chemo-centric technological advancement during green revolution period boosted the production potential and provided food security to the nation. However, over a period of time, this production system has started exhibiting its carrying capacity as reflected by production plateau in green revolution belt like Punjab, Haryana, Western UP, etc. The success of industrial agriculture and the green revolution in recent decades has often masked significant externalities, affecting natural resources and human health as well as agriculture itself. Further, increasing consciousness about conservation of environment as well as health hazards associated with agrochemicals and consumers' preference to safe and hazard-free food shifted interest in alternate forms of agriculture in the world. The major challenge in organic farming is the availability of huge quantity of organic inputs. Use of animal excreta based manure is not sufficient for meeting the nutrients demand of crops. The present paper deals with the various options/resources available for effective nutrient management or soil health management under organic production system.

Keywords: Soil health, organic farming, cultural practices, organic sources, green manuring, bio-fertilizers

Introduction
Organic farming system in India is not new and is being followed from ancient time. In *Ramayana*, it is mentioned that all dead things returned to earth are transformed into wholesome things that nourish life. In *Mahabharatha*, there is a mention of celestial cow *Kamadhenu* and its role on soil fertility. Several manures like oil cake, excreta of animals are mentioned in Kautilya's *Arthashastra*. The methods of manuring were described in *Brihad-Sanhita*. *Rig Veda* mentioned organic manures. *Holy Quran* says that at least one third of what you take out from soils must be returned to it implying recycling.

Even, our traditional farming system prior to the 20th century was generally organic in nature with low production potential. At the time of Indian independence, the challenge was to feed our growing population. The chemo-centric technological advancement during green revolution period boosted the production potential and provided food security to the nation. However, over a period of time, this production system has started exhibiting its carrying capacity as reflected by production plateau in green revolution belt like Punjab, Haryana, Western UP, etc (Sanjay-Swami, 2017) [1]. The success of industrial agriculture and the green revolution in recent decades has often masked significant externalities, affecting natural resources and human health as well as agriculture itself. Further, increasing consciousness about conservation of environment as well as health hazards associated with agrochemicals, and consumers' preference to safe and hazard-free food shifted interest in alternate forms of agriculture in the world.

Organic agriculture is one among the broad spectrum of production systems that are supportive of the environment. It has come to be the viable alternative to address the issues thrown as the after effects of chemo-centric agriculture practiced since 1960. Organic agriculture, without doubt, is one of the fastest growing sectors of agriculture production. It is a method of farming system which primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes (crop, animal and farm wastes, aquatic wastes) and other biological materials along with beneficial microbes (bio-fertilizers) to release nutrients to crops for increased sustainable production in an eco friendly pollution free environment (Prasad and Gill, 2009) [2].

The United States Department of Agriculture (USDA) study team on organic farming defined that “organic farming is a system which avoids or largely excludes the use of synthetic inputs (such as fertilizers, pesticides, hormones, feed additives etc.) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection.” FAO suggested that “Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs.” In September 2005 in Adelaide, Australia, the General Assembly of IFOAM - Organics International passed a motion to establish a succinct definition of organic agriculture. After almost three years of work by a designated task force, a definition reflecting the four principles of organic agriculture in a succinct way was adopted in Vignola, Italy as follows:

"Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."
(https://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture) [3]

The concept of organic farming builds on the idea of efficient use of locally available resources as well as the usage of adapted technologies e.g. soil fertility management, closing of nutrient cycles as far as possible, control of pests and diseases through management and natural antagonists (Sanjay-Swami, 2017) [4]. There may be different management approaches for organic cultivation under different climates, locations and cropping systems. Unlike western developed countries where specialized farming is common, farms in India are mostly diversified in terms of crops grown, species and breeds of livestock raised. On-farm diversity is considered good for the organic farming. The North East Region (NER) of India is a hub of organic cultivation by virtue of its soil being organic by default (Sanjay-Swami, 2017) [5]. Approximately 18 lakhs ha of land in NER can be classified as “Organic by default.” In the hills even today, agriculture remains predominately in the form of shifting cultivation locally known as ‘*Jhum*’ (Sanjay-Swami, 2018) [6]. This practice has an in-built mechanism of sustenance, conservation and renewable system of resource management (MBDA, 2015) [7]. Most of the farmers of this region are generally small and marginal in nature and cannot afford to buy the adequate amount of fertilizers and chemicals necessary for the crop production (Bujarbaruah, 2004) [8]. Therefore, the NER with its unique characteristics and agricultural practices can be exploited as potential area for the introduction of organic farming.

Soil health management

Deteriorating soil health is often quoted by farmers as a major reason for adopting organic management but they are not sure whether all the nutrients with the required quantities can be made available by the organic materials. Knowledge about the availability and usefulness of supplementary nutrient sources to enrich the soil plays a vital role in successful adoption of organic farming. The major components of soil health management under organic production system are crop rotation, maintenance and enhancement of soil fertility through biological nitrogen fixation, addition of organic manure and use of soil micro-organisms, crop residues, biogas slurry, waste etc (Sanjay-Swami, 2017) [9]. Vermiculture has become a major component in biological farming, which is found to be effective in enhancing the soil fertility and producing large numbers of horticultural crops in a sustainable manner (Sanjay-Swami, 2017) [10].

Plate 1: Components of soil health management under organic production system

The various options for nutrient management/soil health management under organic production system are being discussed here under in detail:

1. Crop rotation

It is a systematic arrangement for the growing of different crops in a more or loss regular sequence on the same land covering a period of two years or more. The selection of optimal crop rotation is important for successful sustainable agriculture. Crop rotation is very important. Soil fertility management, weed, insect and disease control. Legumes are essential in any rotation and should 30 to 50 percent of the land. A mixed cropping, pasture and livestock system is desirable or even essential for the success of sustainable agriculture.

2. Crop residue

In India there is a great potential for utilization of crop residues/ straw of some of the major cereals and pulses. About 50% of the crop residues are utilized as animal fed, the rest could be very well utilized for recycling of nutrients. Adequate care is required to use the residues after proper composting with efficient microbial inoculants. While the incorporation of crop residues like wheat and rice straw as such or inoculated with fungal species had beneficial effects on crop yields and important in physico-chemical properties of soil.

3. Organic manure

The organic manure is derived from biological sources like plant, animal and human residues. Organic manure act in many ways in augmenting crop growth and soil productivity. The direct effect of organic manure relates to the uptake of humic substances or its decomposition products affecting favourably the growth and yield of plants. Indirectly, it augments the beneficial soil microorganisms and their activities and thus increases the availability of major and minor plant nutrients.

(a) Bulky organic manure: It generally contains lesser amounts of plant nutrients as compared to concentrated organic manure. It includes FYM, Compost and Green manure.

- **FYM:** It refers to the well-decomposed mixture of dung, urine, farm litter and left over or used up materials from roughages or fodder fed to the cattle. The waste material of cattle shed consisting of dung and urine soaked in the refuse is collected and placed in trenches about 6 m long, 2 m wide and 1 m deep. Each trench is filled up to a height of about 0.5 m above the ground level and plastered over with slurry cow-dung and earth. The material is allowed to decompose undisturbed 3-4 months for anaerobic microorganism for completion of fermentation. FYM becomes ready to apply after 3-4 months. Well-rotted FYM contains 0.5% N, 0.2% P_2O_5 and 0.5% K_2O.
- **Compost:** Large quantities of waste material are available as vegetable refuse, farm litter, such as weeds, stubble, bhusa, sugarcane trash, sewage sludge and animal waste in houses and in areas like human and industrial refuse; therefore, excreta can be converted into useful compost manure by conserving and subjecting these to a controlled process of anaerobic decomposition. Compost is used in the same way as FYM and is good for application to all soils and all crops. Hill farmers generally pile the compost in small heaps several weeks before ploughing or crop planting; then spread the compost across the field several days before incorporation into soil. Reports suggest that this practice results in nitrogen losses up to 30-40% due to volatilization. Studies indicate that nutrient losses were greater when the compost was spread in the field several days (one week or more) before incorporation, than when simply heaping it in the field. Therefore, if the compost has to remain in the field for a while, it is better to make only one or two larger heaps in the field rather than many small ones. If possible, cover the heaps with straw or dry soil so that volatilization losses of plant nutrients can be minimized.

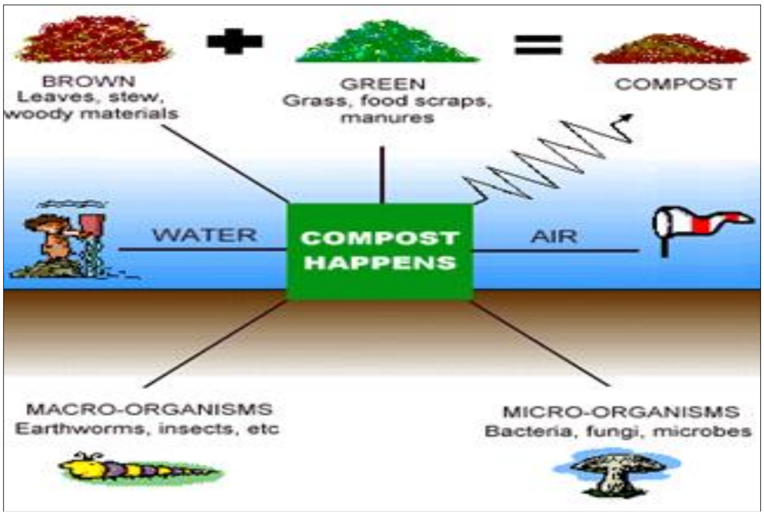

Plate 2: Component of composting

- **Green manuring:** It is a practice of ploughing or turning into the soil under-composed green plant tissues for the purpose of improving physical structure as well as fertility of the soil. From the time immemorial the turning in a green crop for improvement of the conditions of the soil has been a popular farming practice. Green manuring, wherever feasible, is the principal supplementary means of adding organic matter to the soil. It consists of the growing of quick growing crop and ploughing it under to incorporate it into the soil. The green manure crop supplies organic matter as well as additional nitrogen, particularly if it is a legume crop, which has the ability to fix nitrogen from the air with the help of its root-nodule bacteria. A leguminous crop producing 25 tones of green matter per hectare will add about 60 to 90 kg of nitrogen when ploughed under. This amount would equal an application of 3 to 10 tones of FYM on the basis of organic matter and its nitrogen contribution. The green manure crops also exercise a protective action against erosion and leaching. The most commonly used green manuring crops are: Sunhemp (*Crotalaria juncea*), Dhaincha (*Sesbania aculeata*), Cluster bean (*Cyamopsis tetragonoloba*), Senji (*Melilotus parviflora*), Cowpea (*Vigna catjang, Vigna sinensis*), Berseem (*Trifolium alexandrium*).


Plate 3, 4: Green manure crop and it incorporation in soil

(b) Concentrated organic manure: Concentrated organic manures are those materials that are organic in nature and contain higher percentage of essential plant nutrients such as nitrogen, phosphorous and potash, as compared to bulky organic manures. These concentrated manures are made from raw materials of animal or plant origin. The concentrated organic manures commonly used are oilcakes, blood meal, fishmeal, meat meal and horn and hoof meal.

4. Waste

1. **Industrial waste:** Among the industrial by products, spent wash from distilleries and molasses and press-mud from sugar industry have good manurial value. It is important to use only well decomposed press-mud at 10 tones/ha. Addition of press-mud improves the soil fertility and enhances the activity of microbes. Coir waste is the by-product from coir industry and can be used as manure after proper decomposition.
2. **Municipal and sewage waste:** It also forms an important component of organic waste. In India, the total municipal refuse is about 12 mt/annum containing about 0.5% N, 0.3% P_2O_5 and 0.3% K_2O. Sewage sludge is available to an extent of 4 million tones per annum containing 3% N, 2% P and 0.3% K. Sewage sludge particularly from industrialized cities is contaminated with heavy metals and these pose hazards to plants, animals and human beings. Separation of the toxic waste at the source will minimize the concentration of such elements in the sludge.

5. Bio-fertilizers

It has been observed that there is decline in crop yield due to continuous apply of inorganic fertilizers. Therefore, increasing need is being felt to integrate nutrient supply with organic sources to restore the health of soil. Bio-fertilizer offers an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of internal sources. Bio-fertilizer is microorganism's culture capable of fixing atmospheric nitrogen when suitable crops are inoculated with them. The main inputs are microorganisms, which are capable of mobilizing nutritive elements from non-usable form to usable form through biological process. These are less expensive, eco-friendly and sustainable. The beneficial microorganisms in the soil that are greater significance to horticultural situations are biological nitrogen fixers, phosphate solubilizers and mycorrhizal fungi.

The bio-fertilizers containing biological nitrogen fixing organism are of utmost important in agriculture in view of the following advantages:

- They help in establishment and growth of crop plants and trees.
- They enhance biomass production and grain yields by 10-20%.
- They are useful in sustainable agriculture.
- They are suitable organic farming.
- They play an important role in agro-forestry / silvi-pastoral systems.

Types of bio-fertilizers: There are two types of bio-fertilizers.

1. Symbiotic N-fixation: These are *Rhizobium* culture of various strains which multiply in roots of suitable legumes and fix nitrogen symbiotically. Almost 50% demands of N are met by these microorganisms in legumes.

- **Rhizobium:** It is the most widely used bio-fertilizers, which colonizes the roots of specific legumes to form tumours like growths called rot nodules. It is these nodules that act as factories of ammonia production. The *Rhizobium* legume association can fix up to 100-300 kg N/ha in one crop season.

2. Asymbiotic N-fixation: This includes *Azotobacter*, *Azospirillium*, *BGA*, *Azolla* and *Mycorrhizae*, which also fixes atmospheric N in suitable soil medium. They grow on decomposing soil organic matter and produce nitrogen compounds for their own growth and development, besides that they leave behind a significant amount of N in surroundings.

- ***Azotobacter*:** Application of *Azotobactor* has been found to increase the yields of wheat, rice, maize, pearl millet and sorghum by 0-30% over control. The beneficial effect of *Azotobactor* bio-fertilizers on cereals, millets, vegetables, cotton and sugarcane under both irrigated and rainfed field conditions have been substantiated and documented. Apart from nitrogen this organism is also capable of producing antibacterial and anti-fungal compounds, hormones and siderophores.
- ***Azospirillium*:** It is an important bacterium, which colonize the root zones and fix nitrogen in loose association with plants. The crops which response to *Azospirillum* is maize, barley, oats, sorghum, pearl millet and forage crop. *Azospirillum* applications increase gain productivity of cereals by 5-20%, of millets by 30% and of fodder by over 50%.
- ***Blue green algae*:** The utilization of blue-green algae as bio-fertilizers for rice is very promising. Recent researches have shown that algae also help to reduce soil alkalinity and this opens up possibilities for bio-reclamation of such inhospitable environments.
- ***Azolla*:** Azolla is a free-floating water fern that floats in the water and fix atmospheric nitrogen because of its association with the nitrogen fixing cyanobacterium, *Anabaena* (Sanjay-Swami and Singh, 2020) [11]. The *Azolla*-*Anabaena* association is a live floating nitrogen factory using energy from photosynthesis to fix atmospheric nitrogen amounting to 100-150 kg N/ha/year from about 40-64 tones of biomass. The average N, P and K content in *Azolla* on dry weight basis are 4.0-7.0, 0.6-0.8 and 2.0-4.0 per cent, respectively. With a doubling of biomass within two days, *Azolla* ranks amongst the fastest-growing plants on our planet and thus can provide large bio-mass (Sanjay-Swami and Singh, 2019) [12].

Plate 5, 6: *Azolla* harvesting and its application in paddy field

- **Mycorrhizae:** Mycorrhizae are the symbiotic association of fungi with roots of Vascular plants. The main advantage of Mycorrhizae to the host plants lies in the extension of the penetration zone of the root fungus system in the soil, facilitating an increased phosphorous uptake. In many cases the Mycorrhizae have been shown to markedly improve the growth of plants. In India, the beneficial effects of Vascular-arbuscular Mycorrhizae (VAM) have been observed in fruit crops like citrus, papaya and litchi. Recent studies showed the possibility of domesticating Mycorrhizae in agricultural system.

6. Vermicompost

Vermicompost is produced as the vermi-cast by earth worms feeding on biological waste material and plant residues. It is a method of making compost with the use of earthworms that generally live in soil, eat biomass and excrete it in digested form. It is generally estimated that 1800 worms which is an ideal population for one sq. meter can feed on 80 tones of humus per year. These are rich in macro and micronutrients, vitamins, growth hormones and immobilized micro-flora. The average nutrient content of vermicompost is much higher than that of FYM. It contains 1.60% N, 5.04% P_2O_5 and 0.80% K_2O with small quantities of micronutrients. Application of vermicompost facilitates easy availability of essential plant nutrients to crop. It has been emerging as an important source in supplementing/substituting chemical fertilizers in agriculture (Sanjay-Swami, 2019) [13]. Besides higher concentration of available nutrients (macro, secondary and micro) than the ordinary FYM, it has also been reported to enhance plants ability to fight against insect pests and diseases (Sanjay-Swami, 2012) [14].

Vermicompost also improves soil structure due to presence of soil binding chemicals and improves physical properties of the soil like soil air, soil temperature, soil water retention and soil mechanical impedance (Sanjay-Swami and Bazaya, 2010) [15]. Due to non-presence of toxic enzymes it is also eco-friendly and it also has beneficial effect on the bio chemical activities of the soil (Sanjay-Swami and Bazaya, 2011) [16]. There is a growing realization that vermicomposting provides the nutrients and growth enhancing hormones necessary for plant growth (Sanjay-Swami, 2019) [17]. The fruits, flowers and vegetables and other plant products grown using vermicompost are reported to have better keeping quality (Sanjay-Swami, 2018) [18]. A growing number of individuals and institutions are taking interest in the production of compost utilizing earthworm activity.

Table 1: Nutrient status of vermicompost and farm yard manure* (Sanjay-Swami, 2019) [19]

Nutrient	Farm Yard Manure	Vermicompost
N (%)	0.40-0.75	1.0-1.6
P_2O_5 (%)	0.17-0.30	0.50-5.04
K_2O (%)	0.20-0.55	0.80-1.50
Ca (%)	0.91	0.44
Mg (%)	0.19	0.15
Fe (mg/kg)	146.5	175.2
Mn (mg/kg)	69.0	96.91
Zn (mg/kg)	14.5	24.43
Cu (mg/kg)	2.8	4.89
C:N ratio	31.28	15.5

* The values may vary depending upon the type of organic waste

Compost pit of any convenient dimension can be dug in the backyard or garden or in a field. The most convenient pit of easily manageable size is 2m x 1m x 0.75m. A tank may be constructed with brick and mortar with proper water outlets, or a plastic crate (600 mm x 300 mm x 300 mm) with holes drilled at the bottom or empty wooden crates (deal wood boxes/apple cases) or well rings made of cement or clay of 750 mm diameter and 300 to 450 mm height can also be used with slight modifications in the thickness of layers used. If nothing is available then four worn out car-tyres are placed one above the other and composting can be started in it. To make it simpler it can also be done in a 25-litre bucket. Vermi-bed (vermes= earthworms; bed= bedding) is the actual layer of good moist loamy soil placed at the bottom, about 150 to 200 mm thick above a thin layer (50 mm) of broken bricks and coarse sand. Earthworms are introduced into the loamy soil, which the worms will inhabit as their home. About 100 earthworms (a combination of *epigeics* and *anecics*) may be introduced into a compost pit of about 2m x 1m x 0.75m, with a vermin-bed of about 15 to 20 cm thick. The vermi-bed should always be kept moist, but should never be flooded.

Handful lumps of fresh cattle dung are then placed at random over the vermi-bed. The compost pit is then layered to about 50 mm with dry leaves or preferably chopped hay/straw. For the next 30 days the pit is kept moist by watering it whenever necessary. The bed should neither be dry nor soggy. The pit may then be covered with an old jute (gunny) bag to discourage birds. Plastic sheets on the bed are to be avoided as they trap heat. After the first 30 days, as above, wet organic waste of animal and/or plant origin from the farm or kitchen or hostel or hotel that has been pre-digested is spread over it to a thickness of about 50 mm. This can be repeated twice a week. All these organic wastes can be turned over or mixed periodically with a pick axe or a spade. Care should be taken not to disturb the vermi-bed in which the worms live. Keep adding garbage till the compost pit is nearly full. Continue to keep the pit moist for another 30 to 45 days, turning over the material in the pit with care avoiding injury to the worms. Turning over can be done on every fifth or seventh day with the help of a forked spade. Regular watering should be done to keep the right amount of moisture in the pits. In 60 to 90 days the compost should be ready as indicated by the presence of earthworm castings (vermi-compost) on the top of the bed. The compost should be turned occasionally since this allows for aeration. If the weather is very dry it should be dampened periodically. The pile should be moist not wet and soggy. Vermi-compost can now be harvested from the bin/pit. The material should be placed in a heap in the sun so that most of the worms move down to the cool base of the heap. The compost is then sieved before being packed. The earthworms and the thicker material, which remains on top of the sieve, go back in the bin and the process starts again. Compost works best with a mixture of coarse and fine materials, layered together. The extra worms that are produced can be used as feed for poultry and fish

Plate 7, 8, 9: Vermicomposting unit, earth worms in action and final product

7. Vermiwash

Foliar sprays are a part of organic production practices. Worm worked soils have burrows formed by the earthworms. Bacteria richly inhabit these burrows, also called as the drilospheres. Water passing through these passages washes the nutrients from these burrows to the roots and being absorbed by the plants. This principle is applied in the preparation of vermiwash. Vermiwash is a very good foliar spray.

Setting up of vermiwash unit

Vermiwash units can be set up either in barrels or in buckets or even in small earthen pots. It is the principle that is important. The procedure explained here is for setting up of a 250 litre barrel. An empty barrel with one side open is taken. On the other side, a hole is made to accommodate the vertical limb of a 'T' jointed tube in a way that about half to one inch of the tube projects into the barrel. To one end of the horizontal limb is attached a tap. The other end is kept closed. This serves as an emergency opening to clean the 'T' jointed tube if it gets clogged. The entire unit is set up on a short pedestal made of few bricks to facilitate easy collection of vermiwash (Sanjay-Swami, 2017) [20].

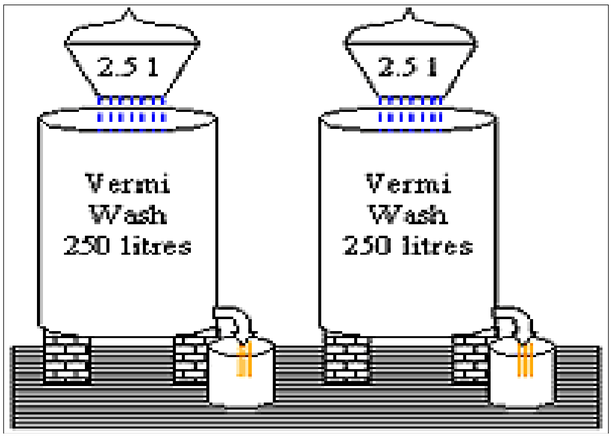

Plate 10, 11: Vermiwash unit: Interior and external looks

Keeping the tap open, a 25 cm layer of broken bricks or pebbles is placed. A 25 cm layer of coarse sand then follows the layer of bricks. Water is then made to flow through these layers to enable the setting up of the basic filter unit. On top of this layer is placed a 30 to 45 cm layer of loamy soil. It is moistened and into this, about 50 numbers each of the surface (*epigeic*) and sub-surface (*anecic*) earthworms are introduced. Cattle dung pats and hay is placed on top of the soil layer and gently moistened. The tap is kept open for the next 15 days. Water is added every day to keep the unit moist. On the 16th day, the tap is closed and on top of the unit a metal container or mud pot perforated at the base as a sprinkler is suspended. 5 litres of water (the volume of water taken in this container is one fiftieth of the size of the main container) is poured into this container and allowed to gradually sprinkle on the barrel overnight. This water percolates through the compost, the burrows of the earthworms and gets collected at the base. The tap of the unit is opened the next day morning and the vermiwash is collected. The tap is then closed and the suspended pot is refilled with 5 litres of water that evening to be collected again the following morning. Dung pats and hay may be replaced periodically based on need. The entire set up may be emptied and reset between 10 and 12 months of use. Vermiwash is diluted with water (10%) before spraying. This has been found to be very effective on several plants. If need be vermiwash may be mixed with cow's urine and diluted (1 litre of vermiwash, 1 litre of cow's urine and 8 litres of water) and sprayed on plants to function as an effecting foliar spray and pesticide (Sanjay-Swami, 2012) [21].

Table 2: Vermiwash analysis report

Parameter	Value
pH	7.48 ± 0.03
Electro conductivity (dS/m)	0.25 ± 0.03
Organic Carbon (%)	0.008 ± 0.001
Total Kjeldhal Nitrogen %	0.01±0.005
Available Phosphate %	1.69 ± 0.05
Potassium (mg/kg)	25 ± 2
Sodium (mg/kg)	8 ± 1
Calcium (mg/kg)	3 ± 1
Copper (mg/kg)	0.01 ± 0.001
Ferrous (mg/kg)	0.06 ± 0.001
Magnesium (mg/kg)	158.44 ± 23.42
Manganese (mg/kg)	0.58 ± 0.040
Zinc (mg/kg)	0.02 ± 0.001
Total Heterotrophs (CFU/ml)	1.79 x 103
Nitrosomonas (CFU/ml)	1.01 x 103
Nitrobacter (CFU/ml)	1.12 x 103
Total Fungi (CFU/ml)	1.46 x 103

Bio-char as nutrient source and managing soil acidity

Approximately, 84 per cent of the soils in the North Eastern Hill (NEH) region of India are acidic in reaction, having low available phosphorus (P) and zinc whereas toxicity of iron and aluminium (Lyngdoh and Sanjay-Swami, 2018) [22]. To overcome the problem of soil acidity, farmers adopt variety of soil amendments like manures, lime, compost and bio-sorbents. Although, liming is good practice to overcome the soil acidity problem, yet the latest, cheap and good organic source is bio-char as the availability of biomass is much more in NEH region (Chan *et al.*, 2008; Yadav and Sanjay-Swami, 2018) [23, 24]. The usefulness of bio-char increases when it is applied in combination with organic manures like FYM, vermicompost, poultry manure, pig manure, etc.

Bio-char is a solid carbonaceous rich material obtained from thermally degrading of crop and agro-forestry residues in the presence of little or no oxygen. Almost any form of organic resources can be pyrolyzed into bio-char including various types of forest residues (sawdust), agricultural residues like corn cob, corn stalk, wheat straw, rice straw, stalk of pearl millet, cotton, mustard, soybean, and sugar beet tailing and agro-industrial wastes. There are many ways to produce bio-char but all of them involve heating biomass with little or no oxygen to drive off volatile gasses, leaving carbon behind. This simple process is called thermal decomposition usually achieved from pyrolysis. Pyrolysis can be of four types: slow pyrolysis, fast pyrolysis, flash pyrolysis, and gasification. Slow pyrolysis performed under lower temperature (<400-500°C) and with long contact times often results in a high yield of bio-char (35%). Faster pyrolysis or gasification operates at higher temperatures (<800°C) and gives a high yield of combustible gases in relation to the solid bio-char (12%) (Sanjay-Swami *et al.*, 2018) [25]. The most commonly employed method is slow pyrolysis. This process involves direct thermo-chemical decomposition (exothermic reaction) to transform low-density residue matrix into a bio-char at a temperature range of 450-500˚C under low-oxic or anoxic conditions in a closed reactor.

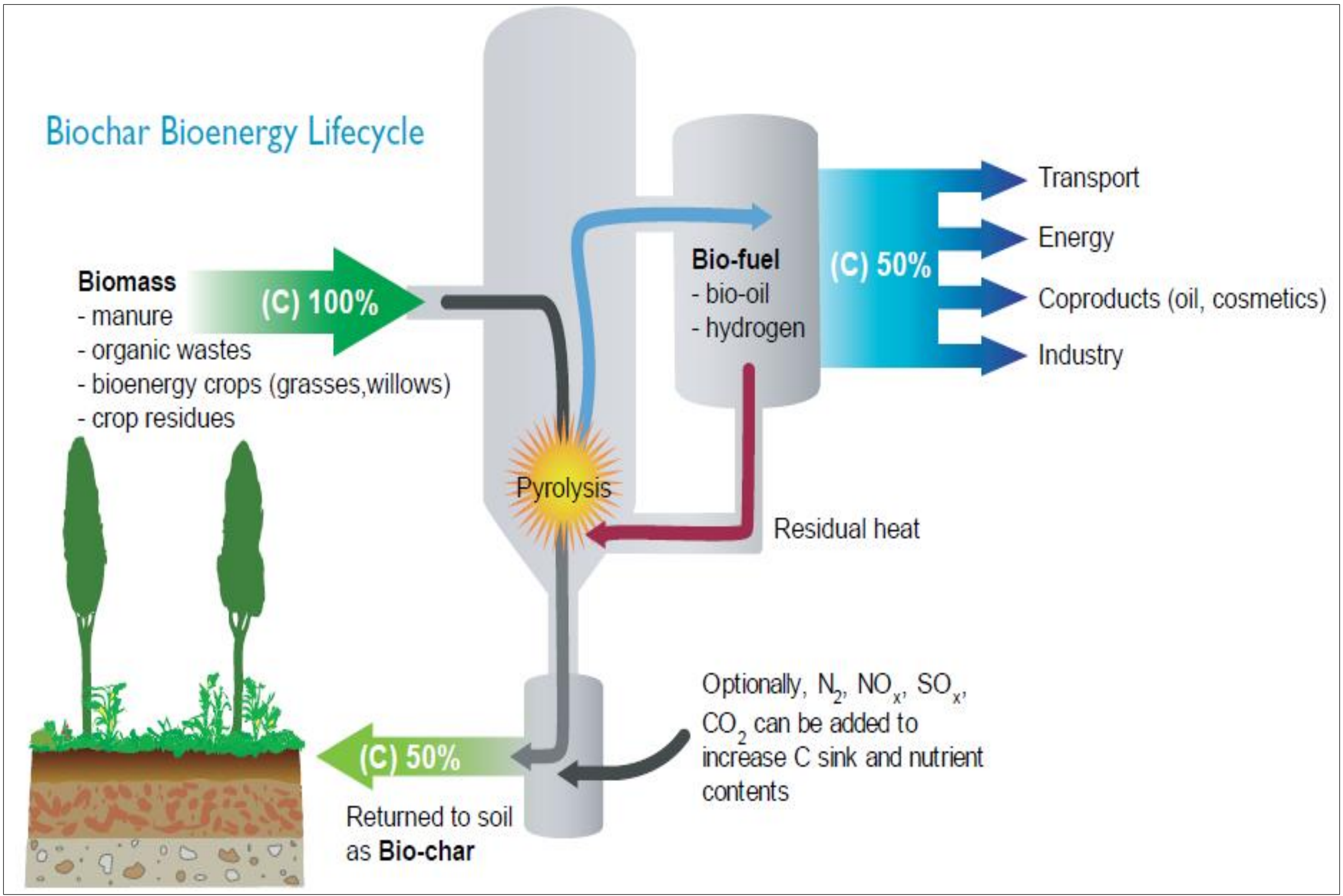

Plate 12: Concept diagram of low-temperature pyrolysis

Plate 13, 14, 15: Bio-char, its application and mixing in soil for managing acidity problem

For optimization of bio-char dose to maximize the yield of tomato in acid soil, a field experiment was conducted at School of Natural Resource Management, CPGS-AS, Umiam, Meghalaya during *rabi* season of 2017. Tomato cv. Megha tomato-2 was used as test crop with three doses of biochar (B) @ 2, 3 and 4 t/ha, vermicompost (VC) @ 2.5 t/ha and two graded recommended doses of NPK fertilizers (RDF) @ 75 and 100% in sixteen treatment combinations. The results indicated that plant height, number of fruits/plant, fruit size and fruit yield of tomato was higher with the application of biochar @ 4 t/ha with vermicompost @ 2.5 t/ha and 100% RDF and the soil pH showed improvement over control. Hence, the combined application of biochar @ 4 t/ha with vermicompost @ 2.5 t/ha and 100% RDF may be recommended for Meghalaya farmers to enhance tomato productivity coupled with managing their acidic soils (Yadav and Sanjay-Swami, 2019; Sanjay-Swami, 2019) [26, 27].

Plate 16, 17: Experimental plots with different treatments and tomato crop at fruiting stage

Conclusion

Organic farming can be a viable alternative production system for farmers, but there are many challenges. One key to success is in ensuring the easy and on time availability of organic inputs. Recyclable nutrients (N, P, K, S, Zn, Mn, Fe and Cu) from plant and animal waste in large quantity can overcome the synthetic fertilizer usage. Developing local organic manure suppliers by adopting additional entrepreneurs like animal husbandry and collecting biomass from fields and domestic waste may help in this direction. The technology for converting waste into compost needs advancement and potential verification. Inoculation by improved *Azotobacter* strains can enhance the productivity significantly. Use of PSB helps in increased availability of phosphorous. These steps would help farmers to adopt organic farming, improving the soil health and reducing the cost of cultivation as compared to conventional farming practices.

References

1. Sanjay-Swami. Organic farming: A way towards maintaining soil health, improving crop productivity and livelihood security of tribals in NE India. In: Enhancing Socio-economic Status and Livelihood Security of Tribal Farmers of Meghalaya, CPGS-AS, CAU, Barapani, 2017, pp. 33-40.
2. Prasad K, Gill MS. Developments and strategies perspective for organic farming in India. Indian J Agron. 2009; 54(2):186-192.
3. https://www.ifoam.bio/en/organic-landmarks/definition-organic-agriculture
4. Sanjay-Swami. Organic farming: An eco-friendly approach for sustainable agriculture. In: CAU Farm Magazine. 2017; 7(2):30-37. ISSN: 2279-0454.
5. Sanjay-Swami. Organic farming: A way towards maintaining soil health, improving crop productivity and livelihood security of tribals in NE India. In: Enhancing Socio-economic Status and Livelihood Security of Tribal Farmers of Meghalaya, CPGS-AS, CAU, Barapani, 2017, pp. 33-40.
6. Sanjay-Swami. Shifting cultivation: A tribal way of life in North East India and alternative approaches for increasing productivity. The Pharma Innovation Journal. 2018a; 7(3):380-385.
7. MBDA. Mission Organic: In Conversation with People of Meghalaya. Meghalaya Basin Development Authority, Shillong, Meghalaya, 2015, pp. 9(1).
8. Bujarbaruah KM. Organic farming: Opportunities and challenges in North Eastern region of India. *In*: Souvenir, International Conference on Organic Food, 14-17 February, 2004. ICAR Research Complex for NEH Region, Umiam, Meghalaya, 2004, pp. 7-13.
9. Sanjay-Swami. Organic farming: A way towards maintaining soil health, improving crop productivity and livelihood security of tribals in NE India. In: Enhancing Socio-economic Status and Livelihood Security of Tribal Farmers of Meghalaya, CPGS-AS, CAU, Barapani, 2017, pp. 33-40.
10. Sanjay-Swami. Composting technology for organic crop production. In: Organic Crop Production: Principles and Practices, Vol. I: Principles and General Aspects, (ed.) Jag Paul Sharma, Kalyani Publishers, Ludhiana, 2017, pp. 219-245. ISBN: 978-93-272-7466-0.
11. Sanjay-Swami, Singh S. Effect of nitrogen application through urea and *Azolla* on yield, nutrient uptake of rice and soil acidity indices in acidic soil of Meghalaya. Journal of Environmental Biology. 2020; 41(1):139-146.
12. Sanjay-Swami, Singh S. Harnessing production potential of acidic soils: Impacts of Azolla (*Azolla pinnata*) bio-fertilizer and urea on rice (*Oryza sativa* L.) performance, temporal soil P availability and acidity indices. South Asian Research Journal of Agriculture and Fisheries. 2019; 01(1):01-07.
13. Sanjay-Swami. Vermicomposting: Transforming garbage into gold. CPGS-AS Extension Bulletin No. 2018-19/05, School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Umiam-793 103, Meghalaya, 2019.
14. Sanjay-Swami. Vermicomposting: Transforming Garbage into Gold, 2012, 17-06-2012, Online at www.krishisewa.com
15. Sanjay-Swami, Bazaya BR. Vermicompost technology. In: Quality Seed Production of Vegetable Crops: Technological Interventions, ed. Sharma, JP, Kalyani Publishers, Ludhiana, Punjab, 2010, pp. 344-356.
16. Sanjay-Swami, Bazaya BR. Techniques of vermicompost and its application to crops In: Advanced production technologies for kharif cereal crops in Jammu division, ed. Lekh Chand, State Agriculture Management Extension and Training Institute, SKUAST-Jammu, 2011, pp. 37-52.
17. Sanjay-Swami. Vermicomposting: Transforming garbage into gold. CPGS-AS Extension Bulletin No. 2018-19/05, School of Natural Resource Management, College of

Post Graduate Studies in Agricultural Sciences, Umiam-793 103, Meghalaya, 2019.

18. Sanjay-Swami. Protecting soil health through organic recycling by Gujjar and Bakarwal women in North-West Himalaya, India. Int. J Curr. Microbiol. App. Sci. 2018; 7(5):1075-1083.
19. Sanjay-Swami. Women in hill agriculture: Protecting soil health through organic recycling. In: Women in Agriculture (The Invisible Partners in Development), eds. Rathore, S. and Sharma, P, Jaya Publishing House, New Delhi, 2019c, pp. 153-168. ISBN: 978-93-87 590-98-4.
20. Sanjay-Swami. Organic farming: A way towards maintaining soil health, improving crop productivity and livelihood security of tribals in NE India. In: Enhancing Socio-economic Status and Livelihood Security of Tribal Farmers of Meghalaya, CPGS-AS, CAU, Barapani, 2017, pp. 33-40.
21. Sanjay-Swami. Sustainable Agriculture through Organic Composts: Recent Advances in Composting Methodologies, LAP Lambert Academic Publishing, Saarbrucken, Germany, 2012, pp. 137.
22. Lyngdoh EAS, Sanjay-Swami. Phytoremediation effect on heavy metal polluted soils of Jaintia Hills in North Eastern Hill Region. Int. J Curr. Microbiol. App. Sci. 2018; 7(11):1734-1743. doi.org/10.20546/ijcmas.2018.711.199.
23. Chan KY, Van Zwieten L, Meszaros I, Downie A, Joseph S. Using poultry litter bio-chars as soil amendments. Aust. J Soil Res. 2008; 46(5):437-444.
24. Yadav OS, Sanjay-Swami. Utilizing bio-char potential for acid soil management. In: Soil and Water Conser. Today. 2018; 13(4):05-06. ISSN: 0975-4059.
25. Sanjay-Swami, Yadav OS, Gurjar GN. Use of biochar for increasing carbon sequestration in soil. In: Souvenir, 27th National Conference of SCSI on Sustainable Management of Soil and Water Resources for Doubling Farmers Income (eds.) Bipul Deka *et al.*, October 25-27, 2018, Assam Chapter of SCSI, AAU, Jorhat, Assam, 2018, 75-77.
26. Yadav OS, Sanjay-Swami. Performance of tomato (*Solanum lycopersicum* L.) in acid soil under integrated nutrient management with biochar as a component. Int. J Curr. Microbiol. App. Sci. 2019; 8(05):793-803.
27. Sanjay-Swami. Ecosystem approach to make agriculture more efficient, more sustainable in Meghalaya. In: Souvenir, CAU Regional Agri-Fair 2019-20, November, 2019, 11-13, 2019: 52-57.