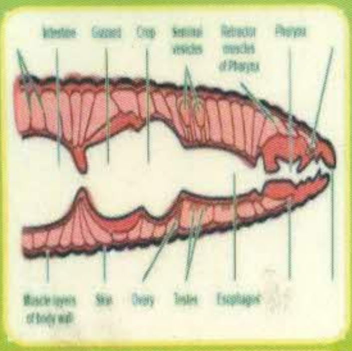
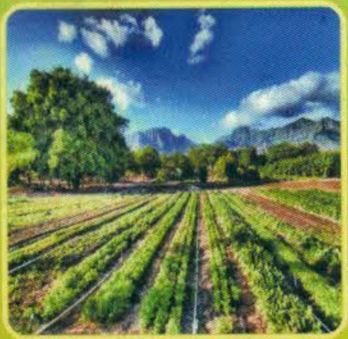




A Practical Manual on Organic Farming

Ram Narayan Meena
Ram Kumar Singh

A Practical Manual on Organic Farming

Ram Narayan Meena
Assistant Professor (Stage-2)

Ram Kumar Singh
Professor

Department of Agronomy
Institute of Agricultural Sciences
Banaras Hindu University
Varanasi – 221005, INDIA

A Practical Manual on Organic Farming

ISBN : 978-93-83583-38-6

First Edition : 2015

Published by
Srijan Samiti Publication
H.No. 498, Kakarmatta (South), Post-D.L.W., Varanasi-221004
Cell : 09415388337
E-mail : srijansamiti@rediffmail.com, srijansamiti@sify.com

Printed by
Mushtaque Ahmad
Lanka, B.H.U., Varanasi

PREFACE

*Sustainability of self-sufficiency in foodgrains, human welfare and nutrition, preservation of resources for prosperity, management of natural resources, environment, ecology, precision farming, organic farming etc. are some of the top priority areas of work of the ICAR for the well being of one and all. Intense necessity was felt to bring out this practical manual "**A Practical Manual on Organic Farming**", to keep pace with the rapid strides happening in the field of organic crop management. Therefore, effort was made to modify and elaborate the version to suit the requirements of students as per new syllabus of ICAR Dean's committee recommendation as well. This practical manual will be a vital tool for all those involved in the organic crop production/agrochemical industry, agricultural scientists, botanists and besides those studying and teaching crop production along with organic farming.*

I thank Prof. Ravi Pratap Singh, Director, Institute of Agricultural Sciences for boosting up my morale and support to publish this practical manual. I gratefully acknowledge the sincere effort of Prof. Avijit Sen, Head of department in preparation of this manuscript.

I am glad to record my thanks to my colleagues and friends for their continued interest.

March, 2015

Ram Narayan Meena

Ram Kumar Singh

CONTENTS

1 | Organic Manures and Biofertilisers

Organic Manures and Related Materials

These are a very important class of nutrient sources for crops and a key component of integrated crop nutrition. All organics are not alike and differences between them are as large as those between fertilisers and manures.

Green Manures: These are green plants, mostly N-fixing legumes which are buried in the soil before sowing the main crop to add organic matter and nutrients present in the green manures. Such manures can be grown right in the main field (example *Dhaincha*, Sunnhemp, short-duration legumes) or green leaves from plants grown elsewhere can be brought in and buried (example Subabul). It is thus not always essential to grow green manure right where it is needed. A good 60-day crop of *Dhainclua* can add 60-80 Kg N plus other nutrients. Nutrient wise and from ease of decomposition, it is the best of organic manures. The problem is most farmers these days do not practice green manuring due to land. labour and cost involved and also due to relatively cheaper urea fertiliser.

Farmyard Manure (FYM): This is the common name for well rotten animal dung mixed with urine, shed litter, left over fodder etc. It is available wherever animals are kept but amount available for manure is much less than the dung produced because most of the dung is used for fuel in the rural houses. If it is used in biogas plant. a farmer can have both fuel and manure. FYM is very widely recommended but mostly farmers are seen to apply it for growing vegetables, potato, sugarcane. maize etc. Its composition can vary by 100% from lot to lot.

Composts: These arc obtained from systematically decomposed organic material through several processes. Composts produced in the villages are called rural composts and those from urban/city refuse, garbage or wastes are called urban composts. These are richer than FYM in nutrient content but still come under bulky organic manures. These can be enriched to a certain extent by fortification with fertilisers and minerals such as urea, rock phosphate etc. Vermicompost is produced with the help of earthworms who have the ability to digest and discharge a variety of organic wastes.

Crop Residues: These include products such as straw, stover, sticks etc. after the grain is, removed, or leaf trash of sugarcane, air of coconuts, peels of fruits and vegetables, shells of groundnut, husk of coconut and rice etc. Essentially any plant parts remaining after the main produce is taken away is a residue. Crop residues are particularly rich source of potash because most of the potash absorbed by the crop is left behind and as soil mulches for conserving soil moisture and lowering soil temperature.

Oil Cakes: These are a special category of organic manures and are residues after the oil has been extracted from seeds. These are more concentrated than most plant-based organic manures because these are derived from nutrient-rich seeds and not nutrient depleted straw. Due to their high price, cakes of edible oils are used mostly for cattle feed and export while cakes of non-edible oil (castor, neem, etc.) can be used for manure. *Neem* and *Karanj* seed cake have a special role in improving the efficiency of urea fertiliser. The same amount of urea produces higher yield when it is mixed/blended with powdered neem cake.

Manures Derived from Animal Body: These include' products derived from the blood, hoof, flesh etc. of dead animals and are generally called animal meals. Other products include bone meal (both raw and steamed).

Biogas slurry, Sewage and Sludge: The biogas slurry is the thick liquid discharged by biogas (gobar) plants. It has whatever was present in the dung used to make biogas and is a good manure. From convenience point of view it can be spread to fields near the biogas plant. Sewage and sludge are obtained from human wastes. Sewage is the mixture of these wastes with water as it arrives in sewage treatment plants. It has lot of water and can be used for irrigation after different degrees of treatment according to the crop for which it is to be used. Too heavy irrigation with these waters can lead to soil sickness and does not serve the purpose. Sludge is the semi-solid material left at the bottom of treatment tanks. Before using these, it is essential to find out their composition and correct application (loading) rates. Some suggestions given by Dr. Jawarkar of NEERI, Nagpur are given below:

Waste water	**Suggested crops in order of preference**	
Primary treated	Cash crops	- Cotton, jute, sugarcane, tobacco
	Essential crops	- Citronella, menthe, lemon grass
	Cerals and pulses	- Wheat, rice, greengram, blackgram, sorghum, pearl millet
	Oilseeds	- Linseed, sesame, castor, sunflower, soyabean and groundnut

	Fruit crops	- Coconut, banana, citrus, sapota, guava, grapes, papaya, mango
	Vegetables	- Brinals, beans, lady finger etc. These should be exclusively cooked before eating
Secondary treated		All crops listed above
		All crops including vegetables borne near the soil surface, but consumed after cooking only
Secondary treated and disinfected		All crops without restrictions

Considerable amount of background information on organic manures and wastes is provided in the FDCO publication on "Recycling of Crop, Animal, Human and Industrial Wastes in Agriculture".

Biofertilisers

These are not traditional fertilisers in that they do contain plant nutrients. Most biofertilisers are bacteria which fix atmospheric N into ammoniacal form so that it can he used by plants. Such biofertilisers are *Rhizobium*, *Azotbactor*, *Azospirillum*. and cyanobacteria (BGA). *Azolla* is a fern in the cavities of which the cyanobacteria fix N. Two other important biofertilisers are the phosphate-solubilising microorganisms and the mycorrhizae which help the plant roots to gather more nutrients from a bigger soil volume.

***Rhizobium**:* Among the biofertilisers the most important is the *Rhizobium*. It works specifically (symbiotically) with leguminous plants. It is thus an important contributor of N to the nutrition of pulses, legume forages, oil crops such as groundnut and soybean. Blue-green algae and azolla can serve as biofertilisers for wetland/fl ooded rice. Their role is not much in upland rice or at unfavourable temperature regimes. Mycorrhizae is (least used at the practical level, partly due to the difficulty of multiplying it on a large scale.

Any strain of *Rhizobium* cannot be used to inoculate any legume seed. These are specific well-worked out matches and only the appropriate strain (culture.)., should be used. Normally the biofertiliser packet indicates the crop for which that product is meant. For example, the *Rhizobium* species which develop symbiotic (mutually-beneficial) relationship with particular legumes are:

Crop	Matching *Rhizobium*
Soybean	*Rhizobium japonicum*
Groundnut, horsegram Greengram, cowpea, pigeonpea	*Rhizobium sp.* (cowpea miscellary)
Chickpea	*Rhizobium species*
Bean	*Rhizobium phaseoli*
Lentil, Pea	*Rhizobium leguminosarum*
Lueerne	*Rhizobium meliloti*
Berseem	*Rhizobium trifolii*

Blue Green Algae (BGA): The actual number of BGA species is very large but a very few of these are actually N-fixing. Among the important N-fixers are most species of the *Anabaena, Nostoc* and *Cylindrospermum* genera. These ideally function at temperatures upto 38°C and can fix 20-30 kg/ha for the paddy

Azospirillum: It has 4 species of which *A. lipoferum* and *A. brasilense* are the most important. These are recommended (not everywhere) for a large number of upland crops and can fix 15-25 Kg/ha in a season).

Azotobacter: Like *Azospirilum*, it does not need to live with a plant (like *Rhizobium* does with legumes) in order to fix N. That is why these are called free-living. Out of 7 species of *Azotobacter*, *A. chroococcum*, *A. vinelandii* and *A. beijerinkia* are more important. Its use as recommended in general as in case of *Azospirillum* and N contribution is also similar in general.

Azolla: It has seven species of which the most common is *A. pinnata*. It fixes N symbiotically with *Anabaena azollae* (BGA), It works best in submerged rice fields within 38°C and ideally under adequate supply of phosphorus in the soil medium. *Azolla* can be grown both as a traditional green manure and alongwith rice plants in the main field.

Phosphorus Solubilising Biofertilisers: These can be bacteria or fungi. Among bacteria, the important ones are *Bacillus megatherium, B. polymyxa, Pseudomonas striata, P. liquifaciens* etc. Among fungi, these are *Aspergillus awamori, A. fumigatus, Penicilium digitatum, P. lilacinum* etc.

The Mycorrhizae belong to the genera such as, *Glomus*, *Gigaspora*, *Acaulospora*, *Scleocystis* and *Endogone*. They do not fix nutrients but enhance the ability of roots to gather more of them.

The technical aspects of biofertilisers are discussed in greater detail in the following FDCO publications:

1. Biofertiliser Technology, Marketing and Usage
2. Fertilisers, Organic Manures. Recyclable Wastes and Biofertilisers.

The above discussion briefly presents an account of plant nutrients and their carriers. These differ greatly in their physical and chemical properties, bulk, local availability, material and application costs. It thus very important to know the advantages and disadvantages of each at the field level and then develop the most suitable integrated packages.

2 Phylum-Annelida (Armelids or Segmented Worms)

Kingdom – Animalia

Phylum - Annelida

Super phylum – Lophotrochozoa

Scientific Name: *Eisenia foetida* (red wiggler worm)

Superclass : Clitellata

Class : Chaetopoda

Subclass : Oligochaeta

Order : Opisthopora/Haplotaxida

Suborder : Lumbricina

Superfamily : Lumbricoideae

Family : Lumbricidae

(1) Polychaeta (Polychaetes or bristle worm) –
Arenicola (*lugworm*), *Neris* (*ragworm*)

(2) Oligochaeta (Oligochaetes or Earthworm)

(3) *Hirudinea* (leeches)

Etymology : From the Latin *Annellus* a little ring.

Characteristics of Annelida

(1) Bilaterally symmetrical and vermiform.

(2) Body has more than two cell layers, tissues and organs.

(3) Body cavity is a true coelom, often divided by internal septa.

(4) Body possesses a through gut with mouth and anus.

(5) Body possesses 3 separate sections, a prosomium, a trunk and a pygidium.

(6) Has a nervous system with an anterior nerve ring, ganglia and a ventral nerve chord.

(7) Has a true closed circulatory system.

(8) Has no true respiratory organs.

(9) Reproduction normally sexual and gonochoristic or hermaphoditic.

(10) Feed a wide range of material.

(11) Live in most environments.

Phylum Annelida.

Earthworms

Fig.-1

Earthworms are enormously important in the construction and fertility maintenance of the soil and were described by Aristotle as 'the intestines of the earth'. Numerous soil scientists have been equally fascinated by the amount of work done by them, Charles Darwin said of them "It may be doubted whether there many other animals which have played so important a part in the history of the world as these lovely organised creatures".

Earthworms are miniature top soil factories, earthworms make soil, all other living things eventually pass through an earthworm on the way to becoming soil, and it is likely that nearly every atom in your body has been in an earthworm's stomach before it was part of you, (some salts and ions, and some water are the exceptions). Earthworm castings are rich in all the minerals necessary for plant growth in a water soluble form so that they are immediately available for plant use. All the soil you have ever seen, at least in temperate climes, has passed through the stomachs of numerous earthworms to become what it is. The best way to deal with those unwanted earthworm casts on your lawn is to collect them and use them as potting compost, no manufacturer can make anything better suited to the growth of seedlings.

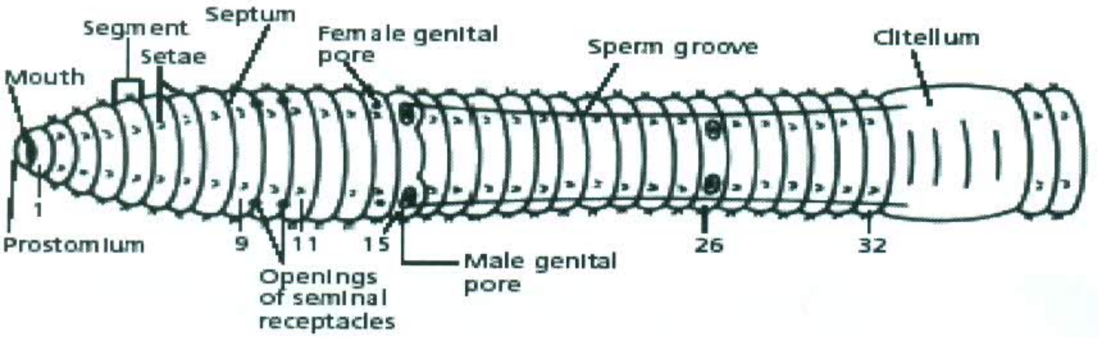


Fig.-2

It has been scientifically proven that earthworms increase the productivity of many soils, in some cases doubling or tripling crop yields. They do this by improving the structure of the soil, by bring nutrients up to the surface layers of the soil from deeper down and assisting in the break down of organic matter in, or on the surface of the soil.

This has resulted in a huge market in worms springing up in the second half of the 20[th] century in Western Europe and USA. In many cases this has been good, but in others, ignorance has resulted in the efforts and money spent being wasted. Soil have a definite worm carrying capacity which relates directly to the amount of organic matter in, and regularly added to, them (yearly in natural environment). Adding more worms than the soil can carry, or adding worms to soils poor or deficient in organic matter will result in only a small temporary increase in fertility resulting from the nutrients released from the dead worms and not from the work they have done. Further more not all worms are suitable for all soils and not all worms are active in soil creation, in particular *Eisenia foetida*, a commonly sold species which is very useful in composts and dung recycling is useless in, and will not survive in, ordinary field soils.

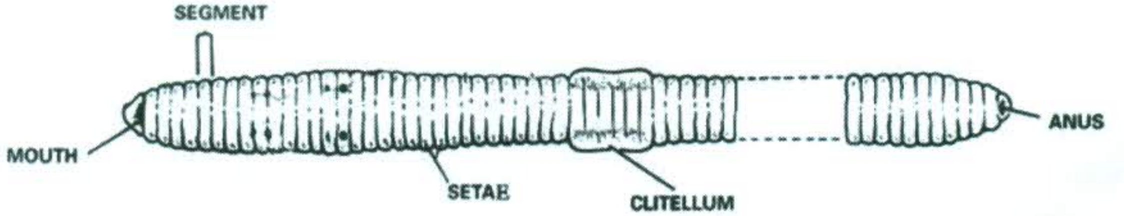


Fig.-3

Benefit(s): Are often seen as beneficial to soil processes, particularly in pastoral and agricultural settings. Earthworms increase the rates of plant litter decomposition. They are also important for decreasing the time for nutrients to be transformed into a usable form.

They also increase plant nutrient utake. Soil aggregation and porosity are improved. Infiltration of water is also improved when earthworms are present.

Vermiculture

Vermiculture biotechnology invoking the use of earthworms as versatile natural bioveactors for effective recycling of non-toxic organic wastes to the soil, resulting in soil improvement and sustainable agriculture. They effectively harness the beneficial soil microflora, destroy soil pathogens and converts organic wastes into valuable products such as biofertilizers, vitamins, enzymes, antibiotics growth hormones and proteinous worm biomas. Hence, we can call the earthworms as 'Nature fertilizer factories'.

- Earthworm's gut is an effective tubular bioreactor, with raw materials (feed) entering from one end and the product (castings) coming out through the other end.

- They maintain a stable temperature through normal temperature regulation mechanisms, thus accelerating the rates of bioprocesses and preventing enzyme inactivation caused by high temperatures.

- Gizzard is a novel colloidal mill in which the feed is ground into particles smaller than 2 microns, giving thereby an enhanced surface area for microbial processing.

- They have an in house supply of enzymes such as protease, lipase, amylase, cellulose and chitinase, which bio-degrade complex triomolecules, into simple compound utilizable by the symbiotic gut microflora.

- Earthworms have a butt in O_2 plant which can separate aerial O_2 by chemical absorption into blood haemoglobin.

- Castings contain nutrients in a balanced proportion and are rich in vitamins, enzymes, antibiotics and growth hormones.

Vermiculture biotechnology can be fruitfully utilized to gain several benefits:

To Farmers

(i) Less reliance on purchased inputs leading to low cast of production.

(ii) Enhancement of soil productivity.

(iii) Recycling of organic wastes is achieved.

To Industries

(i) There is a cost effective pollution abatement technology.

To Environment

(i) Wastes create no pollution, as they become valuable raw materials for the soil biotechnology processes.

(ii) There is more ground H_2O recharge and less ground water depletion.

(iii) Soil salinization is reduced with low soil erosion and runoff.

To National Economy

(i) Lesser import of agrochemicals, saving valuable foreign exchange.

(ii) Savings on subsidies.

(iii) Boost to rural economy.

(iv) More export of agricultural produces with lower pesticide residues.

(v) Reduced wasteland formation.

Vermiculture process/steps involved in vermicomposting : vermicomposting involves the steps like:

1. Selection of site and construction of tank.
2. Selection of suitable species.
3. Collection and half decomposition of substrates.
4. Preparation of vermi-bed and watering.
5. Release of earthworms.
6. Putting the different layers of substrates.
7. Covering with gunny bags/cloths.
8. Control of insect pests.
9. Turning upside down at one month interval.
10. Harvesting followed by separation of worms and cocoons.
11. Drying under shade.
12. Winnowing and separation of undecomposed materials and packing and marketing.

1. Selection of Site and Construction of tank – raised, under shade, there should a shed and which having the watering source, sun and rain avoided.

Vermicomposting can be done in pots, bins, trays, barrels, temporary or permanent tanks, pits and heaps but in all the cases there should be a cover to protect the unit from sun and rain. Direct sunlight not only reduces the activities of the worms but increase gaseous loss of nitrogen ($NH_3\uparrow$) while rainfall causes leaching loss of nutrients and growth promoting substances. Excess of H_2O due to rain can create anaerobic condition and kill the worms. However, there should be a drainage hole at the bottom of the unit and water should be applied after proper examination so that there is minimum drainage of water. Beginners can start with a temporary unit of 2m×1m×0.6m dimention which can be constructed simply by putting bricks in layers over a cemented floor or a sheet of polythene. The innermost side of the unit should also be covered with polythene sheets before tilling it with bedding materials or substrates. Such a unit can be dismantled with less cost at the time of harvesting and assembled again for the next cycle.

2. Selection of suitable species – The species of earthworm should have qualities like –

(a) Preference for eating concentrated half decomposed animal dung and wide range of organic waste.

(b) Utilizing only around 5% of the foods eaten for its own maintenance and excreting the rest as cast.

(c) High consumption, digestion and assimilation rate and.

(d) High multiplication rate.

(e) Worm species should be tolerant to disease.

(f) The culturing techniques should be simple enough to adopt.

(g) Worm should be efficient convertor of plant or animal biomass to body proteins, so that its growth rates are high.

(h) The worm should have wide adoptability (tolerance) to environmental factors (capability to live in varying temperature conditions).

(i) The worm should produce large numbers of cocoons that should not have long hatching time, so that multiplication and organic matter conversion is fast.

(j) Growth rate, maturity from young one to adult stage should be fast.

(k) Worm should have compatibility or tolerance with other worms as would add to productivity of bio-mass (worms) and conversion rate at different strata (layers) of organic matter, i.e. faster composting.

(l) Worms on introduction in substrate, should have least inactivity period (= vermistabilization period).

(m) The worms should feed near the surface of organic matter.

(n) They should have ability to bear transportation shock at their cocoon stage (resting phase).

Important species for vermicomposting

Esemia foelida, *Lumbricus rubellus*, *L. terrestris*, *Endrillus* spp., *Lampito mauriti*, *Octochaetona striata*, *Dravida willsi*, D. *surrentis* and D. *thurton*

3. Collection and half decomposition of substrates and vermicomposting materials

The biologically degradable and decomposable organic waste are used in vermiculture and vermicomposting. Commonly used composting materials are as follows–

Animal dung, Agriculture waste, Forestry waste, city leaf litter, waste paper and cotton cloths, city refuge, Biogas slurry, Industrial wastes.

All types of biologically decomposable non-poisonous wastes like animal dungs, agricultural wastes, orchard leaf litter, processed food wastes, waste paper, cotton cloths, city refuge and biogas slurry can be used for vercomposting. However the pH should be around neutrality or some time or egg cells may be added and use of acidic substances, pet excreta, excess of cruciferous leaves should be avoided. Dung or urine and poultry litters being acidic in nature should be used after considerable lapse of time. The substrates should be mixed with 20-50% dung around 10% of leguminous materials and rest of cereal and other straws. RP may be added @2.5% P_2O_5 to increase the phosphorus content in the vermicompost. However, use of paddy straw has been found to increase only the K_2O content. Use of greasy, coloured and glazy papers should be avoided. Rice husk being full of Silica takes more than 6 months to decompose and its residue in the final product reduces consumer acceptance. It is also to be kept in mind that the materials fed, to the animal from whom the dung is collected and the area where the plants required for substrates were grown, should not have contained more of heavy metals mentioned earlier.

Collection of agricultural waste should follow the practices like –

(a) breaking of large lumps.

(b) cutting of bigger plant parts into smaller ones.

(c) exposing to sun to reduce excess moisture content.

(d) application of 4% aqueous solution of neem pesticides to kill insects if any and

(e) treatment with lime dust to increase pH.

Half decomposition of the materials is done by heaping the above mixture with sufficient moisture content for 21 days during which its temperature increases to 65°F and falls down to ambient temperature at the end.

4. Preparation of vermibed and watering – Vermibed is prepared by putting pebbles, sand and loamy soil one above the other having 2 inches of thickness each, at the bottom of the unit. Alternatively coir or any plant refuge which does not decompose easily can also be used. This should be watered followed by putting well decompose FYM of 4 inches thickness over it.

5. Release of earthworms – Earthworms are to be released over the top of animal dung. For the above mentioned size of 2m × 1m × 0.6m 2kg worms (which may be 2000 to 2500 depending upon the size of the worms) are to be released. However the number of worms could be doubled when they are available in more quantities and compost is necessary to be prepared within a month instead of the normal time of two months.

6. Putting the different layers of substrates – Above the layer of FYM the half decomposed materials are to be kept to fill up the pit. When there are more number of pits half decomposition can be done in some of there in which different materials can be put in layers till the pit is filled up and worms are to be released after the thermophilic stage of half decomposition is over.

7. Covering with gunny cloths – After filling up of the unit it is to be covered preferably with an old wet gunny cloth to reduce loss of moisture and encourage the activities of the worms at the surface. Even if the worms are epigeic in nature they may not like to come to the top if the upper portion is exposed to light. When worms come to the upper surface they eat away the weed seeds present there which is very much essential for maintaining weed free condition in the final product. If the unit is not covered, one can find some weed seeds to germinate; while other remain viable – an undesirable character for a good quality vermicompost. Intermittently the unit is to be watered to maintain moisture content of 40 to 50%.

8. Control of insect pests – Care should be taken to control ants and other insects by applying turmeric powder alone or mixing with neem cake, over and around the unit. Dried leaves of *Lantana camara* could be used around the tank as an alternative, chemicals should not be used as that would make the product unfit to be used under organic farming.

9. Turning upside down at one month internal – It is very much necessary to maintain aerobic condition inside the heap for production of quality vermicompost. It helps in growth of beneficial microorganisms. Therefore, the heap should be thoroughly mixed at an interval of 30 days. However, when more of dung is used, mixing becomes necessary at an internal of 15 days.

10. Harvesting followed by separation of worms and cocoons – Harvesting of vermicompost is done when the compost looks dark brown and soft. The vermicompost is piled under sun for 3 to 4 hours so that the verms go down and forma ball which can be separated for further use. But in small units when the top portion of the unit is fund to be covered with few inches of casts these could be collected for selling at a premium price.

11. Drying under shade – After separation of the worm ball as narrated earlier, the compost should be dried under shade for reducing its moisture content to around 30%. This helps to preserve all the nutrients and growth factors present in the compost.

12. Winnowing and separation of undecomposed materials – The compost is passed through a sieve of 2-3 mm diameter so that the cocoons and the undecompposed materials could be separated for further use.

13. Packing – Packing can be done in beautifully labelled polythene for attracting the consumers. Its date of packing, amount of nutrients present, the dose of application and the date before which it should be used for getting the maximum benefit should also be written for specific type of consumers. Chemical analysis for every batch may be done separately which should be done in recognized laboratories. Home scale gardens require as small as 1kg packets and may require packets of 5kg or larger.

14. Use of vermicompost – Farmers prefer to use vermicompost for the garden crops or crops having an aesthetic or high value when the quantity is limited. In flowering pots it is applied at the rate of 200g/pot having a single plant. This dose is applicable once in three months.

Organic Manures

Organic manures have been used to improve and sustain soil productivity. These manures are classified into –

(i) Bulky organic manures.

(ii) Concentrated organic manures.

(iii) Bio-fertilizers.

Depending upon their nature and quality.

(i) Bulk Organic Manures

These are farmyard manure (FYM), Compost VM and green manure (GM) added in a large quantity because of their bulk, mainly to improve physical condition of the soil, replenish and keep its humus status, maintain the optimum conditions for the activities of soil microorganisms and make good a small part of the plant nutrients removed by the crops or otherwise lost through leaching and soil erosion. The thus supply practically all the elements of soil fertility, that the crop require, though not in adequate amounts and in right proportions. The plant food elements contained in manures are released in an available form upon decomposition by soil microorganisms. The main role of these manures is to add organic matter and humus content. The properties and the roles of organic matter and humus in soil are as follows –

1. Coarse organic matter on the surface reduces the impact of the falling rain drops and thus reduces surface runoff and erosion. ………………

2. Easily decomposable organic residues lead to synthesis of complex organic substances that bind soil particles into structural units called aggregates, which help maintain a favourable condition of aeration and permeability. (Pedology)

3. Organic matter increases water-holding capacity.

4. Organic matter adds and serves as a reservoir of essential nutrients which are released in harmony with the needs of the plants.

5. It produces organic acids (H_2Co_3), that help in dissolving ….. available K, P, micronutrients etc. forms in soil.

In a summary the effect of bulky organic manures on soils is three fold –

(i) Bulky organic manures contain nutrients in small quantities, therefore large quantities of them need to be applied per ha. Besides the major nutrients, bulky organic manures also contain traces of micro/minor/trace nutrients.

(ii) Bulky organic manures increase organic matter content and hence improve the physical properties of soils. This effect is very important in case of most of our arable land such manures increase the humus content of soils at least temporarily, and consequently the H_2O holding capacity of soils is increased and the drainage of clayey soils is improved, $CO_2+H_2O \rightarrow H_2\ CO_3$ (carbonic acid) $\rightarrow$ Acidity.

(iii) Bulky organic manures provide food for soil microorganisms. This increase activity of microbes which in turn help convert unavailable plant nutrients into available forms.

Farmyard manure (FYM)

The term farmyard refers to the decomposed mixture of dung and urine of farm animals alongwith the litter (bedding material) and left over material from roughages or fodder fed to the cattle. Farmyard manure collected daily from the cattle shed consists mainly dung and part of the urine soaked in the refuse. Newly collected and stored FYM is fresh as against well decomposed FYM which has been stored for a sufficient period of time to allow its decomposition to completion. On an average, well-rotted Farmyard manure contains 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 per cent K_2O.

Trench method of manure preparation

Trenches of 6m long, 2m wide and 1m deep are dug. The material consisting of dung and urine soaked in it is collected daily and placed in these trenches. Additions are normally applied in suctions of one metre length. When each section is filled upto a height of about 0.5m above the ground level, the top of the heap is rounded off to the shape of a dome and plastered with shiny of cow dung and earth. Before plastering it is important to apply 4-5 buckets of H_2O in the pit. Plastering conserves moisture and nitrogen and also prevents housefly nuisance. The manure pit should be protected from sun and rain. The manure becomes ready for use in about 4-5 months after plastering. Normally 10-25 cartloads of manure are applied per ha. A cartload of manure measuring 9 cubic metres weighs about 0.5 tonnes. It is possible to obtain 5-6 tonnes of good quality manure per year per head of cattle.

Precaution

1. The manure trench/pit should for away from the residencial house to avoid the fly population and diseases.
2. The cowshed floor should be cemented with concrete.
3. Out grazing of animal should be avoided.
4. The plastering should be done completely.
5. The trench should be sheltered by shed.
6. The trench or pit should be cemented.
7. Bioactivator/preservator should be added.
8. Caking of cowdung should be avoided.
9. The well rotted farmyard manure should be applied to the field and mixed with soil immediately.
10. Volatilization losses of N in the form of NH_3 should be avoided by not heaping the manure into field before saving of the crop.
11. The raw FYM should not be applied to field otherwise weed and termite problems damage the crop.
12. The gobar gas slurry should be applied to the kitchen garden specially for vegetable crops.
13. The dung, urine and litter should be removed from shed daily.
14. The litter used for animal should be a good quality for soaking the urine and comfortable to animal.
15. Handling of manuring should be proper.
16. The cattle in the shed should be kept in a proper manure.

Heading/Outlines for Study FYM

1. Chemical composition of fresh excreta of animals.
2. Quality of excreta produced per year by different types of animals.
3. Factors influencing the composition of manure.
    - (i) Source of manure.
    - (ii) Food of the animals.
    - (iii) Age and condition of the animal.
    - (iv) Function of the animal.
    - (v) Manner of storage.
    - (vi) Nature of litter.
4. Losses during handling and storage of farmyard manure.
    - (A) Losses during handling.
        - (i) Loss of liquid portion or urine.
        - (ii) Loss of solid portion or dung.
    - (B) Losses during storage.
        - (i) By leaching.
        - (ii) By volatilization.
5. Improved methods of handling farmyard manure.
    - (i) Trench method of preparing farmyard manure.
    - (ii) Use of gobar gas – compost plant.
    - (iii) Proper field management of farmyard manure.
    - (iv) Use of chemical preservatives.
6. Supply of plant nutrients through farmyard manure.
7. Crop which respond to farmyard manure.
    - (i) Crops which show profitable response to application of farmyard manure.
    - (ii) Crops less responsive to application of FYM.
8. Potential supplies of farmyard manure and the quantities at present.

9. It serves as a source of energy for the growth of microorganisms as well as food for such life as earthworms, ants and rodents.

10. Organic mulches reduce evaporation losses.

11. Optimum temperature can also be maintained by organic mulches.

Principal Green Manure Crops Suitable for Growing in sit

Both Legumes and non-legumes are used as green manure crops in India. Legumes due to their additional advantages of adding atmospheric nitrogen to the soil, are mostly used as green manure crops, while non-legumes are used to a limited extent. List of common leguminous green-manuring crops are –

Botanical Name	Common Name	Growing Season
Crotalaria juncea	Sunnhemp	*Kharif*
Sesbania aculeata	Dhaincha	*Kharif*
Phaseolus trilobus	Pillipesara	*Kharif*
Vigna radiate		
Vigna sinensis		
Cyamopsis tetragonoloba	Guar	*Kharif*
Melilotus alba	Senji	*Rabi*
Lathyrus sativus	Khesari	*Rabi*
Trifolium alexandrinum	Berseem	*Rabi*

The most commonly used non-leguminous GM crops are –

Cannabis sativa, Vernonia cinerea, Sorghum biolor, Zea mays, Helianthus annus.

Important GM Crops

(i) *Sunnhemp* – This is the most outstanding green manure crop. It is well suited to almost all parts of the country, provided the field is not swampy and the area receives sufficient rainfall or has an assured irrigation. It is extensively used with sugarcane, potatoes garden peas;

(ii) *Dhaincha* – It occupies the second place next to sunnhemp for green manuring. It has the advantage of growing under adverse conditions of drought, waterlogging, salimity and acidity.

(iii) *Sesbania rostrata* – It is aquatic leguminous crop which have nodules both on the stem and roots. It was introduced in India in the1980's from the IRRI, philippines. It is a tropical legume which thrives well under flooded and waterlogged conditions, producing aerial nodules on the stem. Due to its profuse stem nodulation, it gives ten times more nodules than most of the legumes.

Technique of green manuring (*in situ*) – The maximum benefit from green manuring cannot be obtained without knowing – (i) when the green manure crops should be grown, (ii) when they should be buried in the soil and (iii) how much time should be given between the burying of a green manure crop and the sowing of the next crop.

Time of sowing green manure crops (*in situ*) – The normal practice usually adopted is to begin sowings immediately after the first monsoon rains.

The stage of green manure crop at burying – It can be generalized that a green manure crop may be turned in at the flowering stage. The majority of the green manure crops take about site to eight weeks from the time of sowing to attain the flowering stage.

Green leaf manuring – *Glyricidia maculate, Sesbania speciosa, Tephrosia purpurea, Indigofera tesmania (Shrubs). Trees – Pongamia pinnata, Terminalia arjuna, Cassia tora.*

Regions not suitable for GM – Dryland farming (arid and semi-and) receiving < 62.5 cm of annual rainfall, on very fertile soil in good physical condition. In areas where *rabi* crops raised on conserved soil moisture.

Green Manuring

Green manuring can be defined as a practice of ploughing or turning into the soil undecomposed green plant tissues for the purpose of improving physical structure as well as fertility of the soil. There are two types of green manuring –

(i) **Green manuring *in situ*** – In this practice, green manure crops are grown and buried in the same field which is to be green manured either as a pure crop or as intercrop with the main crop. The most common green manure crops grown under this system are – sunhemp, dhaincha pillipesara (*Phaseolus trilobulus*) and guar (*Cyamopsis tetragonoloba*) etc. (Northern India).

(ii) **Green-Leaf Manuring** – Green-leaf manuring refers to turning into the soil green leaves and tender green twigs collected from shrubs and trees grown on bunds, wastelands and nearby forest areas. The common shrubs and trees used are – *Glyricidia* (*Glyricidia maculata*), *Sesbania speciosa,* Karanj (*Pongamia pinnata*) etc. (Eastern and central India).

Advantages of Green Manuring

1. It adds the organic matter to the soil. This stimulates the activity of soil micro-organisms.

2. The green manure crops return to the upper top soil, plant nutrient taken up by the crop from deeper layers.

3. It improves the physical condition (structure) of the soil.

4. It facilitates the penetration of rain water, thus decreasing run off and erosion.

5. The green manure crops hold plant nutrients that would otherwise be lost by leaching.

6. When leguminous plants, like-sunnhemp and daincha are used as green manure crops, they add N to the soil for the succeeding crop.

Brown Manuring

Brown manuring is a technique to grow *Sesbania* in standing rice crop and then on its flowering (25-30 DAS) with the help of herbicide (2, 4-D @ 1.5 kg ha^{-1}) for manuring. After killing the colour of *Sesbania* residue become brown so it called brown manuring. Brown manuring practice introduced where sesbania crop @ 20 kg seed ha^{-1} is broadcasted three days after rice sowing and allow to grow for 30 days and dried by spraying 2, 4-D ethyle easter which supplied upto 35 kg ha^{-1} N, dry matter. It also control broad leaf weeds, higher yield by 4-5 qha^{-1} due to addition of organic matter in low fertile soils. There is potential of up-scaling of rice + *Sesbania* irrigated system including salanity affected canal irrigated area.

(7) It increases the availability of certain plant nutrients, like phosphorus (P_2O_5), Ca^{+2}, K^+, Mg^{2+} and $Fe^{+2/+3}$.

Disadvantages of GM

(i) under rainfed conditions, it is feared that proper decomposition of the green manure crop and satisfactory germination of the succeeding crop may not take place if sufficient rainfall is not received after burying the green manure crop.

(ii) Since green manuring for wheat means loss of *kharif* crop, the practice of green manuring may not be always economical. This applies to regions where irrigation facilities are available for raising *kharif* alongwith easy availability of fertilizers.

(iii) The cost of growing green manure crops may be more than the cost of commercial nitrogenous fertilizers.

(iv) An increase of diseases, insects and nematodes is possible.

(v) A risk is involved in obtaining a satisfactory stand and growth of the green manure crops, if sufficient rainfall is not available.

Desirable Characteristics of GM crop (*In Situ*)

(1) It should be a legume with good nodular growth habit indicative of rapid nitrogen fixation under even unfavourable soil conditions.

(2) It should have little water requirements for its own growth and should be capable of making a good stand on poor and exhausted soils.

(3) It should have a deep root system which can open the subsoil and tap lower regions for plant nutrients.

(4) The plant should be of a leafy habit capable of producing heavy tender growth early in its life cycle.

(5) It should contain large qualities of non-fibrous tissues of rapid decomposability containing fair percentage of moisture and nitrogen.

Unfortunately however, nearly 50% of the cattle dung production in India today is utilized as fuel and is thus lost to agriculture.

Input Requirements

(1) Rice – Tablepea – Onion – cropping sequence.

Prof. (1) A research scholar of Agronomy weats to give an organic treatment in his research trial. He has to carryout his experiment under RBD with following –

Treatment – T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9 and T_{10}

T_1 – 100 % RND as FYM.

T_2 – 125 % RND as FYM.

T_3 – 150 % RND as FYM.

T_4 – 100 % RND as VM.

T_5 – 125 % RND as VM.

T_6 – 150 % RND as VM.

T_7 – 100 % RND as PM.

T_8 – 125 % RND as PM.

T_9 – 150 % RND as PM.

T_{10} – 100 % through urea.

Calculate the needed amount of Nitrogen for the cropping sequence

Rice – Tablepea – onion if the plot size is 4×2 fm^2 and % N of FYM = 0.5%, VM = 2% and PM = 3%.

(A) Needed Amt of FYM

$T_1 \rightarrow 0.5 - 100/0.5$

1 –

126 – 100/0.5 × 120

= 24,000 Kg ha^{-1} or 24.96 Kg plot.

So on 24,000 Kg ha^{-1} or 24.96 Kg plot.

(B) T_4 – 11 – 100/1 × 8 = 1200 Kg ha^{-1} 1200/1000 × 10.4 = 12.186 plot.

So on 100/1 × 8 = 1200 Kg ha^{-1} 1200/1000 × 10.4 = 12.186 plot.

(C) T_7 = 3 – 100/3 × 4 = 4000/10000 × 10.4 = 3.48 Kg plot.

Rest – so on 100/1 × 8 = 1200 Kg ha^{-1} 1200/1000 × 10.4 = 12.186 plot.

(D) T_{10} = 100/46 × 126 => 60.86 Kg ha^{-1} or 260.86/10000 × 10.4 = 0.271 Kg plot.

for three Replication it will be = 0.271×3 = 0.8138 Kg.

Chemical composition of different organic Manures –

	OM	N%		P_2O_5		K_2O %	
1.	FYM	0.5%	0.5	0.8	0.2	0.5	0.5
2.	VM	2.3	3.0	0.75	1.0	1.23	1.5
3.	PM	2-4	3.03	2.2	2.63	1.3	1.40

(2) Calculated the needed amount of Farmyard Manure in respect to N, P, K in groundnut crop of a ha.

Chemical composition of FYM = N 0.5%, P_2O_5 0.2, K_2O 0.5

(1) 0.5 – 100 FYM

1 – 100/0.5

120 – 1000 ×5 or 24 = 5000 Kg ha^{-1}.

How much P_2O_5/K_2O has been supplied - ?

P_2O_5 = 10 Kg ha, 1000 – 2/1 × 24

48 Kg ha^{-1} P_2O_5 and 120 Kg ha^{-1} Nitrogen or 120 Kg K_2O_5 ha^{-1}.

or ratio – 4 : 10 : 10   5 : 2 :5 or 5: 2 :5

5 + 2 + 5 = 12

12 – N – 5 × 2000 = 10000 Kg ha^{-1}.

12 – 2 × 2000 = 2000 Kg ha^{-1}.

12 – 5/12 × 24000 = 10000 Kg ha^{-1}.

Or

0.5 – 100/0.5 × 120 = 24000 Kg ha^{-1}.

0.2 – 100/0.2 × 12

0.5 –

Prof. (2) Calculate the needed amount of nutrients from the following particulers groundnut cultivation –

(1) Recommended dose of NPK – 25 – 35 – 70 Kg ha^{-1}.

(2) Chemical composition of FYM = 0.5% 0.2% 0.5%

(3) Other chemical fertilizers are – SSP and Kcl.

(4) Ca (Mo_3), - 15% N.

Calculate different organic or inorganic nutrients or fertilizer or manure for groundnut crop –

(1) 0.5 – 100

1 – 100/0.5

25 - 100×10/5 × 5 = 5000 Kg FYM or

Supplied Nitrogen = 5 × 5 × 1/1 = 25 Kg N ha^{-1} N.

(2) 0.2 P_2O_5 – 100/0.2

1 – 100/0.2

35 – 100/2 × 5 × 35 = 17500 Kg FYM P_2O_5

(3) 0.5 – 100/0.5

or – 100/5 × 2 ×70 = 14000 Kg ha^{-1}.

3 Biological Properties

CLASSIFICATION OF MICROORGANISMS

BACTERIA	FUNGI	ACTINOMYCETES	ALGAE
I. Autotrophic Bacteria	1. Parasitic	Streptomycin	Green
A. Nitrifying Bacteria	2. Saprophytic	Potato scab	Blue green
B. Sulphur Bacteria	3. Symbiotic	disease etc.	Yellow Green
C. Iron Bacteria		*Mycorrhiza*	Diatoms
D. Manganese Bacteria	a. Ectotrophic		
E. Hydrogen Bacteria	b. Endotrophic		
F. CO Bacteria		*Phoma*	
G. Methane Bacteria		*Pythium*	
II. Heterotophic Bacteria			
A. N-fixing Bacteria			
1. Symbiotic e.g. *Rhizobium*			
2. Non-Symbiotic			
a. Aerobic e.g. *Azotobacter*			
b. Anaerobic e.g. *Clostridium*			
B. Non N-fixing Bact.			
1. Aerobic e.g. ammonifiers			
2. Anaerobic e.g. Denitrifiers			

Autotrophic Bacteria

Obtain carbon from the CO_2 of atmosphere and energy from the oxidation of simple carbon compounds or from inorganic substances. These organisms are self-sustaining i.e. they can built complex compounds required for their living processes by using very simple inorganic substances. Specific groups of autotrophs are capable of oxidizing ammonia, nitrate, sulphur, iron, manganese, hydrogen, CO, or CH_4 (Methane). The most important groups of autotrophs are those that oxidize ammonia to nitrite to nitrate known as nitrifying bacteria.

Heterotrophic Bacteria

1. Comprise of majority of soil bacteria.
2. Consume organic substances for their energy and carbon source.
3. Primarily decompose cellulose and other carbohydrates, proteins, fats and waxes.
4. Functionally they bring about mineralization of organic matter through hydrolysis and oxidation and release nitrogen, phosphorus and other nutrients in form of available to plants.
5. N-fixing bacteria are another example of heterotrophs. These can work under aerobic conditions or under anaerobic conditions.

Fungi

Fungi may be parasitic, saprophytic or symbiotic. Parasitic fungi produce plant diseases like cotton root, rot, many kinds of wilts, rusts, blights and smuts.

Saprophytic fungi obtain their energy from the decomposition of organic matter.

Symbiotic fungi live on the roots of certain plants and both fungus and plant are mutually benefited.

Fungus are specially useful in soils as they break down the somewhat resistant cellulose, lignins and gums, as well as more readily decomposed sugars, starches and proteins. A large part of the slowly decomposing soil humus consists of the dead remains of fungal hyphae.

Mycorrhiza:- Meaning fungus root.

A symbiotic association of fungal mycelium and roots of certain trees and shrubs. It is presumed that mycorrhiza aid the host plant in the absorption of certain nutrients.

Forest nurseries that have been established to raise tree seedlings that are not native to the area usually need an artificial inoculation of the suitable mycorrhiza the reasoning behind this practice is that in a new region the compatible mycorrhiza are usually not present in the soil. There are two types of mycorrhizae based upon their manner of growth.

A. Ectotrophic – Formed by members of *Agaricales* including mostly mushroom type fruiting fungi. They grow as thread like filaments into small roots between the root cells, but not into the cell. They increase the absorbing surface of the tree roots, ectotrophic *mycorrhiza* is exhibited by pines, spruces, oak, elms, beech, hickories, chestnut and birches.

B. Endotrophic – Formed by species of *Phoma* and *Pythium.* The fungal hyphae penetrate the root cells upon dying mycorrhizal tissues are absorbed and utilized by the growing trees. e.g. sweet gums, poplars, maples, laurels, azaleas, rhododendrons and orchids.

Actinomycetes

1. Taonomically and morphologically related to both fungi and bacteria, but have recently been classified as bacteria.

2. Characterized by branched mycelia similar to fungi and when the mycelia break into fragments they resemble to bacteria.

3. Common examples are- Streptomycin, Aureomycin, Tetramycin and Neomycin.

4. They thrive best when there is ample fresh organic matter, when the soil is neutral to slightly acidic and when soil moisture is fairly abundant. However when the soil is fairly dry the grow better than fungi.

5. Their primary function is in decomposing organic matter, especially cellulose and other resistant forms.

6. Potato scab diseases an actenomyces can be readily controlled by keeping the pH of the soil below 5.0

Algae

Soil algae are microscopic chlorophyll bearing organisms. The main groups are-

1. Green   2. Blue green   3. Yellow green   4. Diatoms

Algae grow best in most fertile soils. The green colour of the soil surface following the application of commercial fertilizers is due to an increase in their number.

The affect of algae on plant growth is-

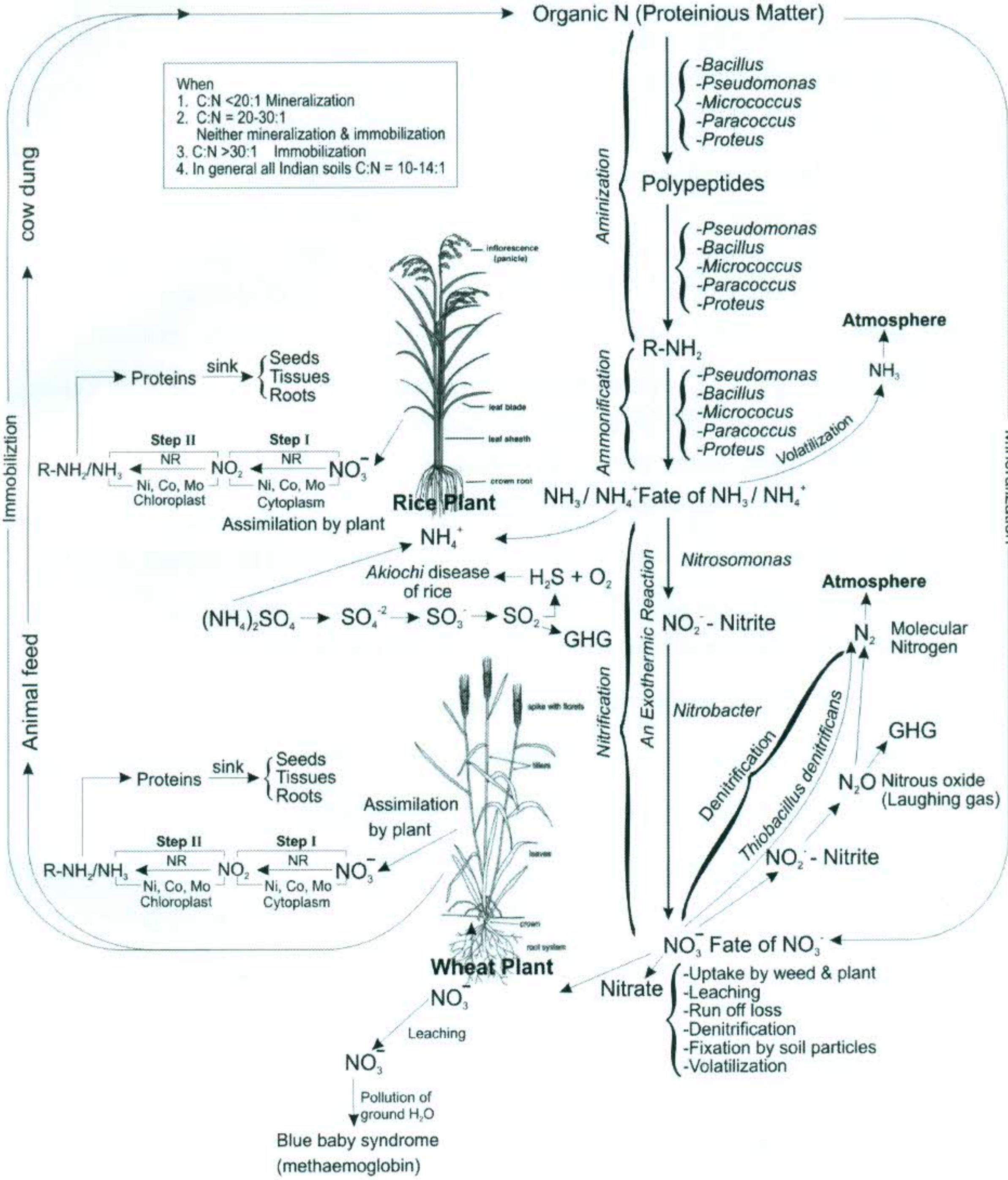
a. Add organic matter to the soil as they are self sustaining organisms.

b. Improve soil aeration – especially in rice fields by excretion oxygen.

c. Fix atmospheric nitrogen –Blue green algae is capable of fixing atmospheric nitrogen. The best pH range for working of blue green algae is 7 to 8.5. In rice fields they contribute significant amount of N from the atmosphere. Even in desert soil the blue green algae are and high N content of many surface soils.

MICROBIAL TRANSFORMATIONS

N-Cycle



Nitrogen

The transformation of nitrogen in the soil can be grouped into two :-

1. GAINS:-

A. Mineralisation :- 1. Ammonification 2. Nitrification

B. Atmospheric Nitrogen fixation :-

1. Fertilizers
2. Rain water
3. Microbial

2. LOSSES :-

A. Immobilization

B. Denitrification

C. Crop removal, word removal

1. Ammonification :-

The transformation of organic nitrogenous compounds into ammonia is called Ammonification. Heterotrophic organisms which form the bulk of soil population break down organic matter into simple substances available for plant nutrition or for further oxidation by Autotrophic organisms.

The process involes a gradual simplification of compounds. The process is of two types – A. Aerobic B. Anaerobic

In aerobic process heterotrophs consume oxygen and release CO_2. The steps are-

Amminization

Proteolytic enzyme Peptidase

Proteins → Polypeptides → Amino acids

Proteases

Peptones

↓ Ammonification → $(NH_4)_2SO_4$ → H_2S

NH_3, NH_4^+ Mercaptans

H_2O, CO_2

Anaerobic process (Putrefaction)

Proteolytic enzyme

Proteins → Polypeptides → NH_3, Amines, CO_2, Organic acids, Indole,

Organisms

Aerobic bacteria, fungi, Actinomycetes and certain facultative and strict anaerobes

For highly proteinaceous material – species of *Pseudumonas, Bacillus, Clostridium, Serratia, Micrococcus* readily decompose pure proteins. Under neutral to alkaline environment- Bacteria under acid conditions proteins are broken down chiefly by fungi.

Ammonification occurs as a result of action of enzymes product by microorganisms. The action is chiefly hydrolytic and oxidative. For best result well drained aerated soils are best suited for rapid ammonification.

Part of the ammonia or amino acids so product are utilized by the microorganisms for their own body building proteins. They are organic compounds as their N – source. But if the organic matter as a very wide C : N ratio then the microorganisms utilize the NO_3 or NH_3. If it is available in the soil (Immobilization). Thus the immediate effect of addition of quantities of easily oxidisable carbohydrates like molasses or straw would be immobilization of NO_3 or NH_3, if no nitrogen from external source is not added with such materials. The ideal C : N ratio of accomplish mineralization is 10:1.

Nitrification

The oxidative sequence involved in the conversion of ammonia to nitrate is termed nitrification.

Nitrification is an aerobic process carried out by Autotrophic bacteria. It occurs in two steps-

$$\text{Organic nitrogen} \rightarrow NH_3 \xrightarrow{\textit{Nitrosomonas}} NO_2 \xrightarrow{\textit{Nitrobacter}} NO_3 + \text{energy}$$

Energy

Ammonification — Nitrification

The detailed steps and mechanism are :-

Nitrosomonas:-

$$NH_3 \xrightarrow{\frac{1}{2}O_2} NH_2OH \xrightarrow{-2H} \tfrac{1}{2}\,HON = NOH \xrightarrow{\frac{1}{2}O_2} HNO_2 + 79 \text{ cal.}$$

Hyponitrite Hydroxyl amine

(Its presence is not definitely established)

Nitrobacter:-

H_2O -2H

$HNO_2 \longrightarrow HON(OH)_2 \longrightarrow HNO_3 + 43$ cal.

Conversion of NO_2 to NO_3 is faster as compared to that of NH_3 to NO_2, accumulation of NO_2 is toxic to plants.

The source of carbon of these organisms is CO_2 of atmosphere or HCO_3^-

Ion in soil :-

Nitrosomonas oxidize 35-70 moles of NH_3 and *Nitrobacter* 70 – 100 moles of NO_2 per mole of carbon assimilated.

The overall reactions can be summarized as:-

$2 NH_3 + 3O_2 \rightarrow 2 HNO_2 + 2H_2O + 79$ cal. – *Nitrosomonas*

$2 HNO_2 + O_2 \rightarrow 2NHO_3 + 43$ cal. – *Nitrobacter*

Factors affecting nitrification

1. Soluble organic matter – Depresses nitrification but the presence of heterotrophic organisms keeps the soluble organic matter at a low level. Thus heterotrophs and autotroph works for their mutual benefit.

2. Soil reaction – Slow in acid and alkali soils but favoured by neutral pH.

3. Phosphorus supply – Phosphorus addition favours the process. The efficiency of super-compost (compost + SSP) is explained by this.

4. Oxygen supply – The nitrifying organisms are aerobic and have a high requirement of O_2, therefore favoured by well drained, aerated soils.

5. Soil texture – Nitrification occurs at the colloidal surface where abundant NH_4^+ is absorbed and where bacteria adhere. Favored by loamy or clayloam soils and slow in sandy soil.

6. Moisture – 50% WHC suitable for the reaction.

7. Temperature – Greatest at 37ºC, stops below 5ºC and above 55ºC.

Nitorgen Fixation

N-fixation is one of the three most important processes, the other two are photosynthesis and respiration. Biological N-fixation in one of the chief sources of nitrogen for soils. Plant growth leaching and activities of denitrifying organisms all tend to remove the soil nitrogen reserve though plant residues returned to soil for decomposition add to the soil status. Still considerable quantity of soil N is build up by biological N-fixation.

There are two main classes of organisms that fix atmospheric nitrogen-

A. Non symbiotic

B. Symbiotic

(A) Non-symbiotic N-fixing organisms :-

The free living organisms capable of utilizing molecular nitrogen include. *Azotobacter*, *Clostridium* as the main genera of bacterial population besides a wide range of heterotophic bacteria, autotrophic organisms, blue green algae are capable of fixing atmospheric nitrogen nitrogen non symbiotically.

Azotobacter

It is a most important N-fixing organisms responsible for non symbiotic nitrogen fixation. It is a strongly aerobic and oxidizes carbohydrates and other such sources of carbon completely to CO_2 to H_2O The efficiency of *Azotobacter* to fix atom N does not exceed 15-20 mg N/g of carbohydrate oxidized. *Beijerinkia* spp. Are more tolerant of acidic soils.

Condition (Habitat)

Azotobacter is favoured by a neutral reaction, ample phosphorus, aerobic conditions and moist well drained soils. *Azotobacter* is susceptible to PO_4 deficiency. The properties is utilized in detecting the P-deficiency of soils in *Azotobacter* plaque tech. Other nutritional requirement of *Azatobacter* are :-

1. vitamin-B
2. Nucleic acids
3. Ca
4. Mo
5. Mn- (Mn compound accelerate N-fixation by *Azatobacter*).

Clostridium

Clostridium pasteurianum etc. works in anaerobic conditions. This organism is less efficient than *Azatobacter*. Fixation capacity of nitrogen by this organisms is 2-3 mg/g of carbohydrate fermented. The low efficiency of *Clostridium* can be attributed to the fact that while anaerobic fermentation releases only a small amount of energy, aerobic oxidation produced tremendously large amount of energy which help to fix more atmospheric N.

Non-symbiotic N-fixation occurs on the roots of corn, wheat, millet, sorghum, rice and species of earthen higher plants.

Mechanism of Non Symbiotic Nitrogen Fixation

The partial pressure of nitrogen at which N fixation take place non symbiotically at half the maximum velocity is-

For	*Azatobacter*	-	0.02 atm.
	Rhodospirrillum	-	0.02 atm.
	Nostoc	-	0.02 atm.
	Clostridium	-	0.03 atm.
	Redclovers	-	0.05 atm.

Higher the concentration of N in the soil higher will be fixation rate. Practically no fixation takes place below 0.02 atm. and above 0.05 atm. of N.

$$N_2 + 6H \xrightarrow{\text{Nitrogenase}} 2\,NH_3$$ The sequence is :-

$$N = N \xrightarrow{\text{Nitrogenase (Enz.)}} N = NH \xrightarrow{\text{Enz.}} NH - NH_2 \xrightarrow{\text{(Enz.)}} 2NH_3$$

or

$$N = N \xrightarrow{\text{Enz.}} \underset{\text{Diamide}}{NH = NH} \xrightarrow{\text{Enz.}} NH_2 - NH_2 \xrightarrow{\text{Enz} + H_2} 2NH_3$$

The enzyme nitrogenase contains Mo and hence the need of Mo for non-symbiotic N-fixation.

Symbiotic Nitrogen Fixation

The classical example is the symbiosis between bacteria of genus *Rhizobium* and plant of leguminceae. The association is sited in root of the host plant in the form of nodules. Most legumes differ from other plants in that they use, in addition to the soluble N to the soil, the atmospheric N, made available to them by the bacteria living in the nodules of their roots.

NODULE :- These are rounded outgrowths on the roots and root hairs of the legume plants.

Mature nodule consists of a central core containing non dividing cells of the bacterial tissues (which is the site of N-Fixation) surrounded by the host tissue having double the usual chromosome number. This tissue of the host plants is called disomatic.

The nodules are of two types-

1. Effective **2.**Non-effective

1. **Effective Nodules :-** The effective nodules are capable of a successful host guest symbiosis and result into atmospheric nitrogen fixation. The effective nodules are pink, large sized and less bunched then the ineffective nodules. The pink colour is due to the presence of leghaemoglobin. The concentration of leghaemoglobins directly linked with amount of N-fixed by the bacteria. This also suggests the need of iron and oxygen for larger proportion of N-fixation. The leghaemoglobin plays a molar role in the nitrogen metabolism of the *Rhizobium* species in the plant.

2. **Non effective nodules :-** More branched, brown coloured no leghaemoglobin in them. Incapable of fixing N_2.

   Usually a certain strains of *Rhizobia* species can form nodules on limited groups host plants. These group host plant is called the cross inoculation group.

Process of nodule formation :-

The first step involves release into root zone of the plant excretory product like tryptophan, which are stimulatory to the bacteria. The *Rhizobia* then aggregate at distinct sites adjacent to roots. The *Rhizobia* product B indole acetic acid. B-IAA which causes root hair deformation.

The infection starts at the root hairs. The *Rhizobium* synthesizes and excretes one or more product provoking deformation of legume root hair. These compounds include a nucleic acid, polysaccharide and/or proteins. The root hair wall at this site of synthesis of the above compounds gets irritated, softened and invaginates. This invagination then continues to develop into tube like structure called infection thread. This tube contains the *Rhizobia* bacteria. Finally the nodule and the bacteria are ultimately released into symbiont's cytoplasm to multiply further. Immediately following the release of these bacteria in the host cell a period of rapid cell division of the host cells surrounding the infection are take place giving rise to a swollen round structure of nodule. The final structure is a central core, containing the *Rhizobia* and surrounding cortical containing plant vascular system.

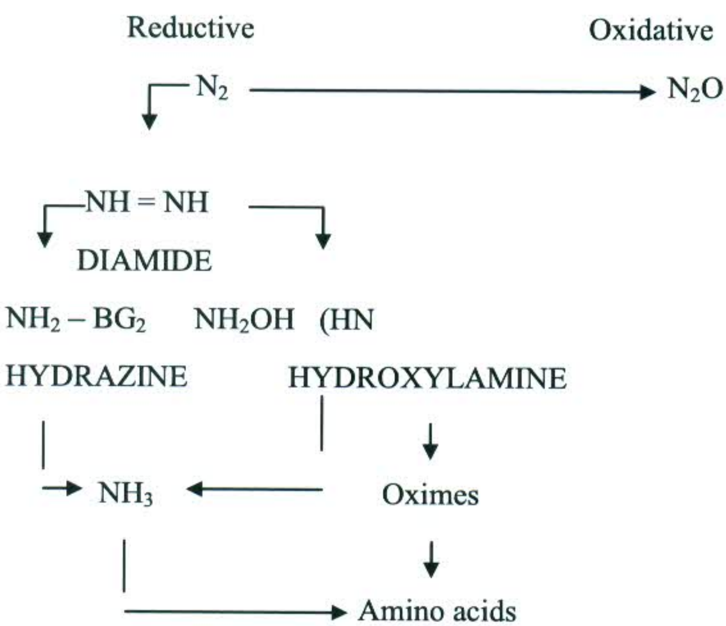
The host cells of the central portion of the legume contains double the chromosome number characteristic of the host.

The central core containing the *Rhizobia* contains them in the form of non-dividing resting cells of *Rhizobium* called bacteroids. This central core is the site of fixation of atmospheric nitrogen. Bacteroids are non-motile, non-viable derivative cells original infecting *Rhizobia.* Bacteroids have a complete nitrogen system capable of fixing N_2. In addition to the nitrogenase complex, bacteroid have pigment called leghaemoglobin which reversibly combines with oxygen in a manner similar to that of animal haemoglobin. The oxygenated leghaemoglobin then transports the oxygen under low free oxygen tension to the sites of the bacteroid oxidative phosphorylation to be used for generation of ATP.

Fixation of N by Non legumes :-

The symbiotic fixation of N_2 is not confined to the plants of the legume family only eight genera of the angiosperms comprising some 190 spp of widely distributed trees and shrubs also produce nodules. These plants do fix significant quantities of atmospheric nitrogen and this fixation is confined to the nodules. The responsible organisms have not been isolated.

Mechanism of symbiotic N-fixation :



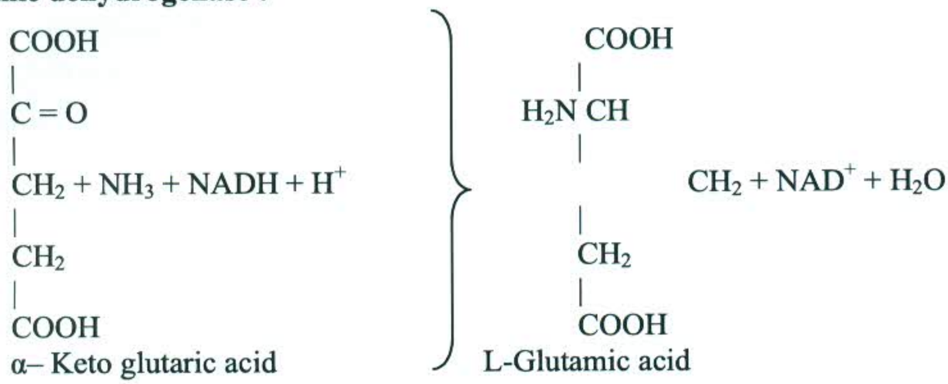
The fixation of inert N_2 is accomplished by the enzyme nitrogenase. This enzyme lowers the activation energy (The energy needed to cause the reaction to occur). The fixation process for both symbiotic and non-symbiotic nitrogen fixation are almost similar. The first step is adsorption of molecular nitrogen (N_2) by the enzyme nitrogenase

N=N bond is broken to form NH=NH and $NH_2 - NH_2$ to form $2NH_3$.

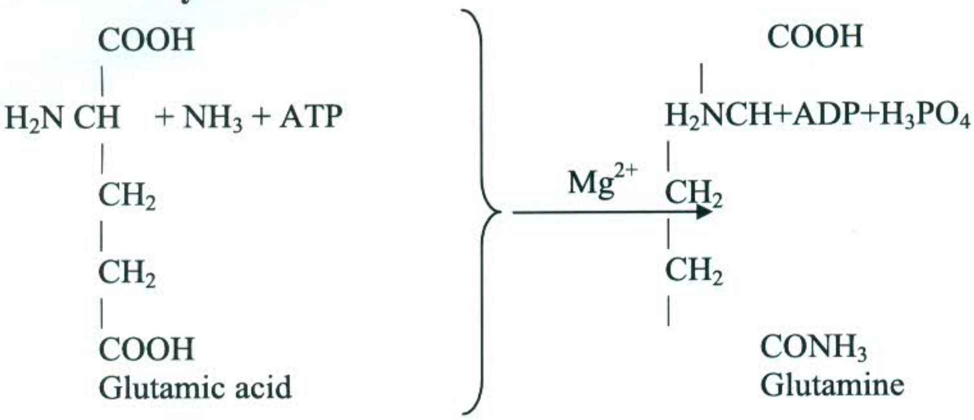
Fate of ammonia

All the above take place the nitrogen is bonded to the enzyme. The NH_3 combines with some decomposition products of carbohydrates, organic acids to form amino acids which ultimately condense to form peptide linkages and them proteins. One such example is formation of glutamine from α-keto glutaric acid. The reaction involves enzymes like glutamic dehydrogenase, glutamine synthetase and one more is carbamyl kinase to produce carbonyl phosphate. The reactions are:-

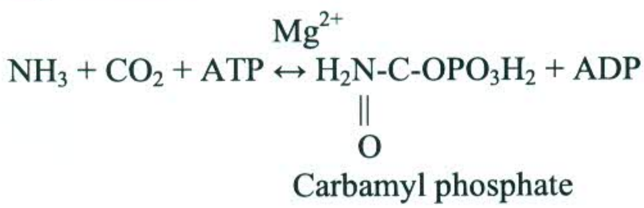
Glutamic dehydrogenase :



Glutamine synthetase:



Carbamyl kinase:-



Denitrification

It is microbial process whereby NO_3^- is reduced to gaseous products. It is one of the major factors of losses of nitrogen from soil.

The process under which nitrates are utilized by microorganisms fall into two general classes:- 1

(a) Nitrate Assimilation :

Denotes biological reduction of NO_3 to NH_3 or NH_2 level, with the products being used for biosynthesis of N-containing cellular constituents of microorganisms.

(b) NO_3-Respiration :

In this nitrate is used as the terminal electron acceptor in place of oxygen by a variety of microorganisms, under anaerobic conditions. These organisms obtain their oxygen from NO_3 or NO_2 with accompanying release of N_2 or N_2O, e.g. when soil become logged water.

Organisms involved :

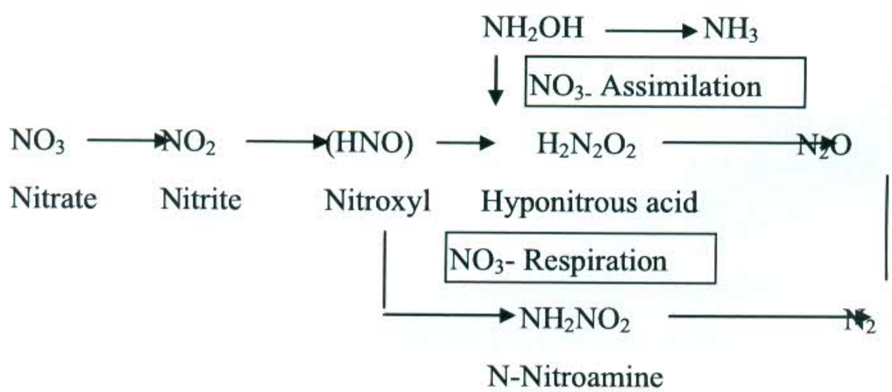
Two distinct group of micro-organisms have been noted-

1. Those organisms which reduce NO_3 to NO_2 and allow the product to accumulate.
2. These are true denitrifiers and completely reduce NO_3 to N_2 or NO or N_2O.

The capacity for denitrification is limited to bacterial population only and so far no fungi or actinomycetes have been reported to carry out this loss.

Since common examples are : sp. of *Pseudomonas, Micrococcus* (sp.-*Denitrificans*) *chromobacter, Bacillus* etc. *Autotrophs* like *Thiobacillus denitrificans, Thiobacillus thioparus* etc.

Mechanism



Factors

1. Denitrification occurs only when the supply of oxygen is restricted for the bacteria thus in well drained aerated soil no denitrification will take place but if the moisture level is above 60% of water holding capacity the rate of denitrification increases.
2. Adequate supply of organic substrate is required as the energy source for bacteria.
3. Presence or absence of growing crops as they compete for NO_3 with each other. Losses of N through denitrification can be minimized by keeping adequate drainage and pH level 5.5 to 7.0.

Transformation of Sulphur

The total sulphur content of tropical soil is generally lower than that of temperate soil because of lower organic matter and greater leaching. Sulphur occurs in soil are :

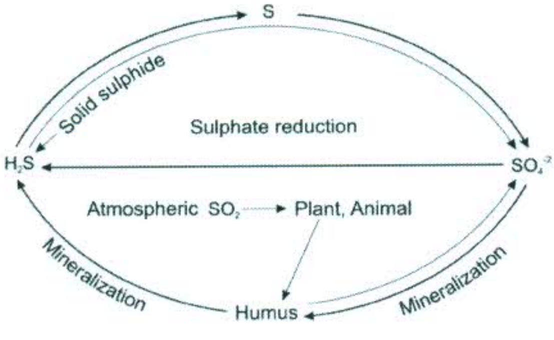
Inorganic forms – Sulphate of Mg, Ca and Na, Sulphide (S), Sulphite (SO_3), H_2S.

Organic forms – S – amino acids like cystine, cysteine and methionine, the others are peptide glutathione, glucosides, alkaloids, thiamine, biotin, thioctic acid, thiocynate, mercaptans, taurine, thiourea, ethereal, sulphate, thiosulphates, thiosulphides, organic sulphates etc.

Sulphur compounds undergo many transformation as a result of activities of plants animal and microorganisms, and to a lesser extent non biological actions.

Plants assimilate sulphur as SO_4^- form soil and smaller amount at S-amino acids and direct assimilation of atmospheric SO_2. Animals utilize this plant assimilated sulphur converting reduced sulphur compound to SO_4^- or simple organic forms. Plant and animal remains are decomposed by micro-organisms in the soil with liberation of inorganic sulphur.

Sulphur Cycle



The major microbial process are-

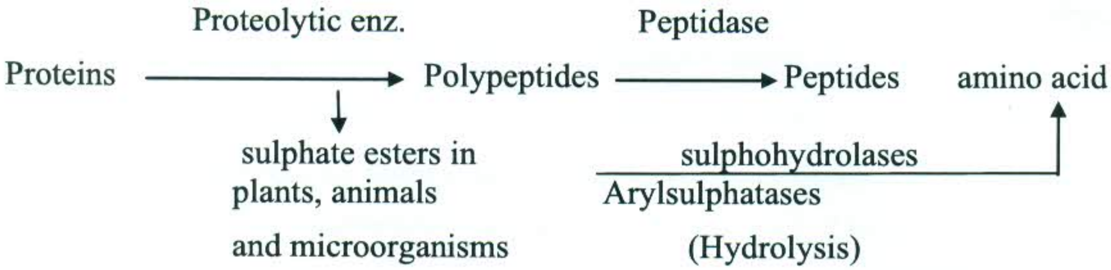
1. Mineralisation :- Break down of organic sulphur molecules to inorganic sulphate.
2. Immobilisation :- Conversion of inorganic sulphur to organic sulphur compound.
3. Oxidation :- Conversion of reduced inorganic sulphur compounds to sulphate.
4. Reduction :- The dissimilatory reduction of sulphate and intermediate compounds to sulphide (S).

Mineralisation

Plant and animals residues containing sulphur compound act substrate for microbial activity. Prominent among these are S- containing proteins, amino acids – cystine, cysteine, and methionine. The peptide glutathione, glucosides, alkaloids, thiamine, biotin, thioctic acid, thiocynater, mercaptans, taurine, ethereal sulphate, sulphates, thiosulphates and sulphides etc.

Mechanism

Soil microorganism produce a variety of proteolytic enzymes which can hydrolyse peptide and ester bond. The proteinaceous compound are eventually broken down to amino acids.



Under aerobic condition to end products are SO_4^{-2} and elemental sulphur.

Under anaerobic condition end products are mercaptans, H_2S.

Immobilisation

Such organic matter which is low in sulphur but is energy rich is added to soil then the soil microorganism make use of the inorganic S for their own body building. Thus the inorganic sulphur is converted into organic forms. To avoid it sulphur fertilization is necessary. (Like that of N)

Mechanism

The process is assimilatory sulphur reduction involving enzymatic reaction of

SO_4^{-2} SO_3^- to S^- compound and elemental sulphur.

The high energy low sulphur organic matter can immobilize added sulphur from 38.06 to 45% as it has been recovered from the falvic acid fraction of the humus.

Organisms Involved In Mineralisation And Immobilisation

Mostly heterotrophic organisms, strict and facultative anaerobes, and all those organisms involved in the mineralization and immobilization of N are capable doing so for sulphur also.

Factors

Soil properties, temperature, moisture, S content of organic matter, rhizospheric activities, plant roots etc.

Sulphur Oxidation

Formation of sulphate and other sulphur compound from more reduced form sulphur both organic and inorganic in soil is sulphur oxidation.

S-oxidation is carried out by 4 groups of organisms.

1. chemoautotrophic bacteria of genus *Thiobacillus*.
2. Poorly defined group of heterotrophic bacteria, fungi and actinomycetes.
3. Colour has filamentous bacteria of genera *Baggiatoa*, *Thiotrix* and *Thioplaca*.
4. Photosynthetic sulphur bacteria belonging to families Thiorhodaceae and Chlorobacteriaceae.

Only the first two groups are found in soils. *Thiobacillia* obtain all the energy required for their growth from the oxidation of inorganic sulphur compound to sulphates. All of the organisms of the genus are obligate autotrophs with exception of *T. novellus* which is facultative autotroph capable of developing on organic substrates.

T-denitrificans is capable of utilizing NO_3 anaeorobically in place of oxygen.

T-ferroxidans oxidize Fe^{++} iron in addition to sulphur for its energy.

Other differences between members of thiobacilli include the degree of acid tolerance and range of organic sulphur compound which they can oxidiise.

Most of the Thiobacilli are capable of oxidizing sulphide, elemental sulphur, thiosulphate, tetrathiovate and in some cases sulphide to sulphate.

Some typical reaction are-

***Thiobacillus thioxidans* :**

$$S + \frac{1}{2} O_2 + H_2O \rightarrow 2\ NaHSO_4$$

Sod. Thiosulphate

***T. thioparus* –**

$$Na_2S_4O_6 + Na_2CO_3 + \frac{1}{2}O_2 \rightarrow Na_2SO_4 + CO_2$$

Sodium

tetrathionate

***T. denitrificans* (anaeorobically)**

$$5S + 6\ KNO_3 + H_2O \rightarrow 2K_2SO_4 + 2\ H_2SO_4 + 3N_2$$

Other species of *Thiobacillus* carry out this oxidation as :-

$H_2S + 2O_2 \rightarrow H_2SO_4$

$2H_2S + 2O_2 \rightarrow 2S + 2H_2O + 2H_2O$

$2S + 3\ O_2 \longrightarrow 2H_2SO_4$

$2KSCN + 4\ O_2 + 4H_2O \rightarrow (NH_4)_2SO_4 + K_2SO_4 + 2CO_2$

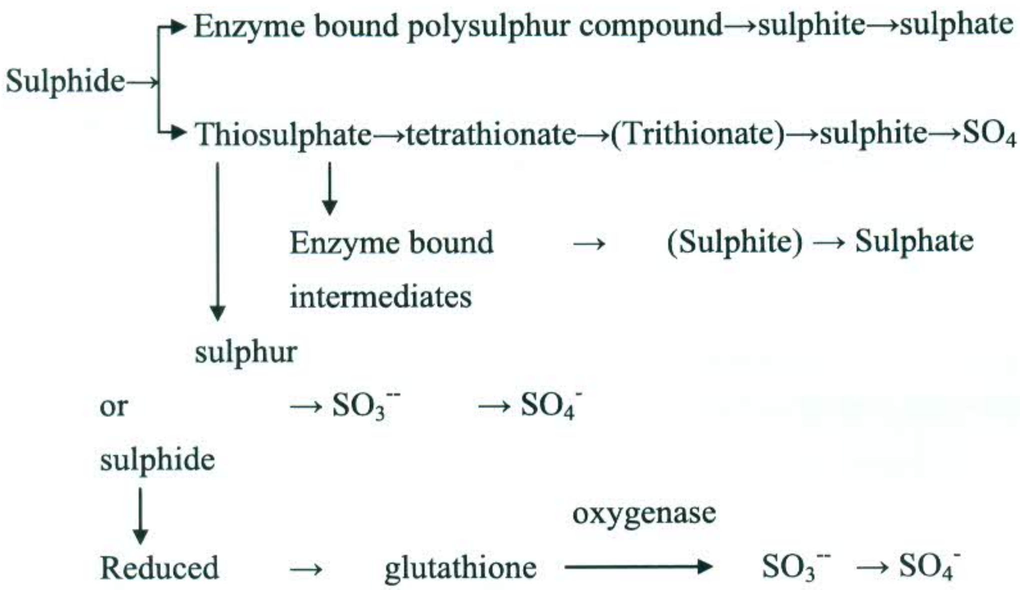
Thiobacillus ferrooxidans derive energy from the oxidation of ferrous iron as follows.

(Pyrite) $2FeS_2 + 2H_2O + 7O_2 \rightarrow 2FeSO_4 + 2H_2SO_4$ (Mostly chemical)

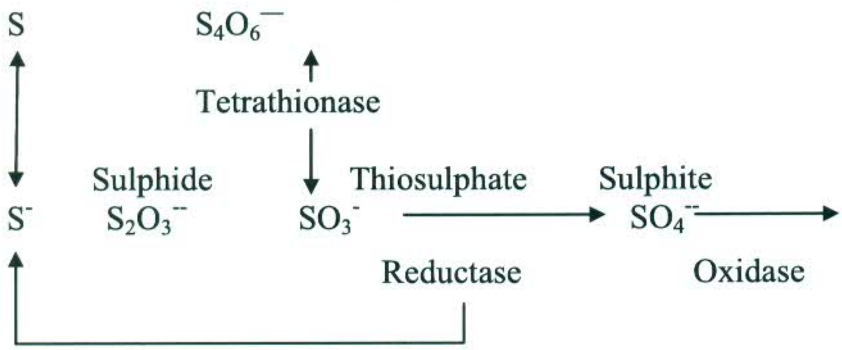
$4FeSO_4 + O_2 + H_2SO_4 \rightarrow 2\ Fe(SO_4)_3 + 2\ H_2O$ T-*ferroxidans*

$2S + 3O_2 + 2H_2O \rightarrow 2\ H_2SO_4$ T-*thiooxidans*

The mechanisms can be summarized as under



The biochemical α Pathway can be summarized as:-



Adavantages of S-oxidation

Microbial sulphur oxidation is beneficial to soil fertility.

1. Formation of SO_4^{-2} as plants available nutrient.
2. Acidity is produced in the form of H_2SO_4 which solubilises many and reduces solicity and salinity.

Factors affecting S-oxidation

Temperature, soil pH, moisture, soil structure etc.

The oxidation of S is also carried out by many heterotrophic microorganisms aeorobic bacteria, actinomycetes and filamentous fungi. These organisms fall into two categories.

1. Oxidising elemental S and thiosulphate to polythionates.
2. Converting polythionates to sulphate.

Sulphate Reduction

SO_4^{-2} reduction takes place particularly in waterlogged, flooded rice soil. Under well aerated conditions this process is of insignificant amount.

Organisms

Dissimilatory sulphate reduction is the proper of a few anaerobic bacteria and many heterotrophic organisms where by sulphides and elemental sulphur (S) or inorganic S compounds are produced H_2S accumulates at the expense organisms and the oxidation of organic compounds they carry out are :-

1. *Desulfovibrio desulfuricans* (most common and important bacteria for this process)

   → Lactate → Acetate + CO_2

2. *Desulfotomaculum*
3. *Desulfomonas* → pyruvate → Acetate + CO_2
4. *Clostridium*
5. *Desulfococcus* → fatty acids → CO_2
6. *Desulfosarcina* → fatty acids → CO_2
7. *Desulfonema* → fatty acids CO_2
8. *Desulfobacter* → Acetate → CO_2

9. *Desulfobulbus* → Propionate or lactate → Acetate + CO_2

In the SO_4^{-2} reduction the SO_4^{-2} acts as the terminal acceptor of electrons in the reduction of these bacteria. Bacteria like No.1 make use of sulphite, sulphate, thiosulphate, tetrathionate as e^- acceptors, but not oxygen nor organic sulphur compounds.

Biochemistry of Sulphate Reduction

During the reduction of SO_4^{-2} there is simultaneous oxidation of many organic compounds like carbohydrates, organic acids, amino acids acetate, pyruvate, lactate, fatty acids etc.

Two typical reaction for *D. desulfuricans* are given below :-

(Acetate is a common product)

$4CH_3.CO.COOH + Na_2SO_4 \rightarrow 4\ CH_3\ COOH + 4CO_2 + Na_2S$

Pyruvate Acetate

$2CH_3CHOH\ COOH + Na_2SO_4 \rightarrow 2CH_3COOH + 2CO_2 + Na_2S + 2H_2O$

Hydrogen and are therefore capable of autotrophic growth.

$4\ H_2 + CaSO_4 \rightarrow H_2S + Ca(OH)_2 + 2H_2O$

The first step in the reduction process is activation of sulphate by esterification to an aderyl group by the anzyme ATP sulfurylase to form adenosyl phosphosulphate (APS) and pyrophosphate. The APS is reductively cleaved to yield AMP and bisulphate which is sequentially reduced to trithionite, thiosulphate & sulphide.

The enzyme bisulphate reductase is present in all sulphate reducting bacteria, catalyzing reduction of bisulphate to trithionite.

The pathway can be summarized as :-

$SO_4^{--}ATP \leftrightarrow$ Adenosyl Phosphosulfate (APS) + PP → 2P

HSO_3^- (bisulphate) + AMP

↓ $2e^-$

$S_3O_6^{--}$ (Trithionate)

↓ 2e--

$S_2O_3^{--}$ (Thiosulphate)

↓ 2e

S^{--} (sulphide) (H_2S etc.)

Condition for SO_4 Reduction

1. Anaeorobic condition are the primary requirement for SO_4 reduction. Soon after flooding oxygen disappears in the following –

   $NO_3^- - NO_2^- - Mn^{+++}$ Compounds → Fe^{+++} - SO_4^{--}

   (Manganic) (Ferric)

   Sulphate is not reduced to S^{--} if oxygen and NO_3 are present.

2. The SO_4^{-2} reducing bacteria are very salt tolerant and function in pH range of 5.5 – 9.0

3. Heavy textured soil, submerged soil etc.

4. Addition of organic matter with wide C : S ratio.

   Accumulation of H_2S is toxic to the plants and activities of *Desulfovibrio* also cause tremendous economic losses to the industry.

Microbial Transformation of Phosphorus

Micro organisms brings about a number of transformations of the elements – viz:

1. Solubilising inorganic compound of phosphorus.
2. Immobilisation of available P.
3. Mineralisation of organic P.
4. Oxidation or reduction of inorganic P compound.

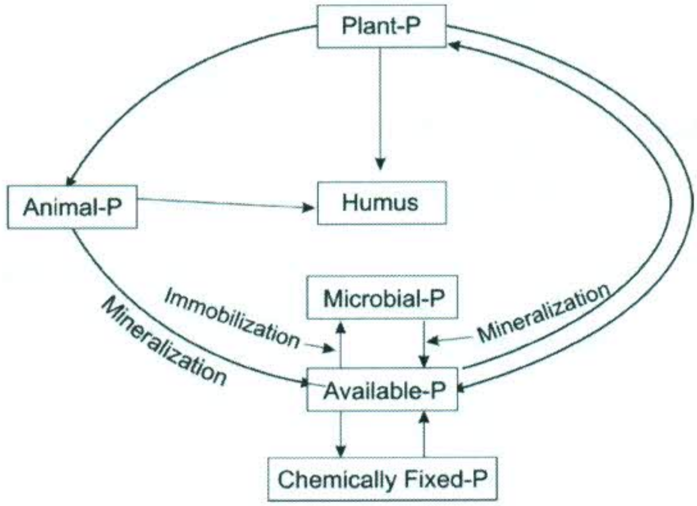
Source of P in soil :-

Organic P :- Agricultural crops contain about 0.05-0.50% P in their tissues, the compounds containing pure phytin, phospholipids, nucleic acids, phosphorylated sugars, coenzymes and related compounds.

Inorganic P :- Mineral forms $H_2PO_4^-$, HPO_4^{-2}, apatities Fe and Al phosphates.

P-CYCLE :-

The transformation can be illustrated in a cyclic form as:-



Living forms of P

Unlike NO_3^- sulphate which are assimilated by the plants only in their reduced forms [- NH_2 (amino) and –SH (sulphydryl)]. Plants do not reduce phosphate as is evident from the structure of phytic acid and lecithin (Phospholipid)

$H_2 - C - O - R$

|

$H - C - O - R$

O

||

$H_2 - C - O - P - O - CH_2 - N - (CH_3)_3$

|

O^-

Lecithin – (R = Fatty acids)

In soil of the total P 15-85% is in organic forms.

SOLUBILIZATION OF INORGANIC – P

Insoluble inorganic P forms like $Ca_3(PO_4)_2$ etc. are converted by solubilisation action of many species of:

Pseudomonas, Mycobacterium, Micrococcus, Bacillus, Flavobacterium, Penicillium, Selerotium, Fusarium, Aspergillus etc.

1. No only Ca by Fe, Al, Mg, Mn and other forms of P are also solubilised.

   The solubilisation is brought about by the release of organic acids. The NH_4^+ and sulphur oxidizing chemoautotrph release HNO_3 and H_2SO_4 solubilising Ca, Fe, Al etc. phosphates.

2. In flooded conditions iron in insoluble ferric phosphates is converted (reduced) to Fe^{++} ferrous and concomitantly release phosphate in the solution.

3. Anaeorobic product H_2S react with Fe_3PO_4 to yield Fe_2S and H_2PO_4.

4. The organic acid produced by the metabolic activity of microorganisms are lactic acid, glycolic, citric, formic and acetic acids.

5. 2-Ketogluconic acid and similar acid are very effective chelating agent capable of complexing with Ca, Cu, Ni, Mn, Fe, and Al salts of phosphates with resultant solubilisation of phosphates.

Mineralisation of Organic Phosphorus

Conversion of organic forms of P into available inorganic forms is called mineralization.

Organisms

All microorganisms requiring P for their life cycle specially the heterotrophs make the bound element in the remains of the vegetation and in soil organic matter available to the succeeding plants.

Species of *Aspergillus, Penicillium, Rhizopus, Cunnighamella, Arthrobacter, Streptomyces, Pseudomonas* and *Bacillus* can mineralize the organic P. All these organisms possess phosphates and Phytase enzymes. Many types of fungi specially mycorrhizal fungi and actinomycetes also carry out mineralization.

Condition

1. More rapid in virgin soil.

2. Decomposition favoured by warm temperature thermophilic range (30° C to 50°C) more favourable than mesophilic range (<20°C)

3. The rate increases with rise in pH (acidity to neutrality increases phosphatase activity).

4. quantity and type of substrate, soil rich in organic P will result in more mineralization of P.

5. Bacterial cell P is mineralized quickly and its acid soluble organic P, phospholipids and DNA are dephosphorylated in short period.

6. P in microbial RNA is released more slowly.

7. All condition favouring ammonification favours P mineralization.

8. A C : P ratio of <200 : 1 will result in net P mineralization while if it is 300 : 1 there will be immobilization.

Mechanism

Highly significant correlation exists between mineralization of N and P. The amount of N mineralized is 8-15 times more than that of P mineralized.

There are many enzymes that cleave P form organic substrates. They are collectively called phosphatases. A general reaction is:-

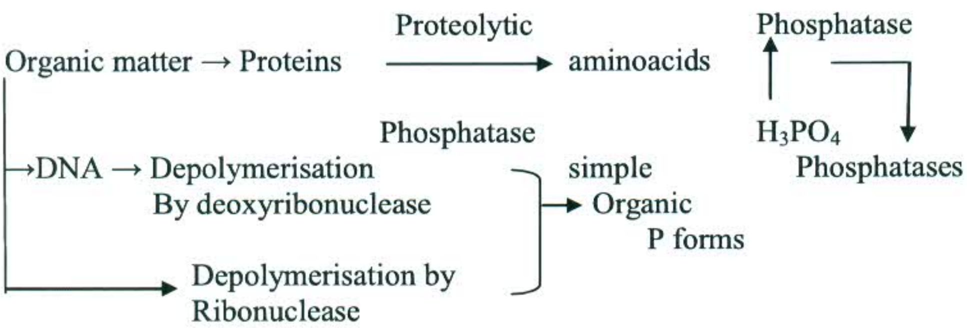
$$R-O-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle OH}{|}}{P}}-O-H + H_2O \rightarrow ROH + HO-\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle OH}{|}}{P}}-OH$$

R – May have numerous structure.

Phosphatase catalyze cleavage of ethyl phosphate, glyceroph-osphate, phenyl phosphate. The substrates with two –R groups. Diesters will have different enzymes in contrast to single R groups (monoesters).

In soil presence of inositol phosphates with 5 or 6 or less P atoms per molecule suggests that a breakdown of the inositol hexaphosphate takes place. The enzyme phytase 1 : berate P form phytic acid or its Ca or salt (phytin) with resultant accumulation of inositol.

In general phytin derivatives are more resistant to mineralization hence phytase is more stronger then phosphatases.



Immobilisation

Conversion of available forms of phosphorus into organic form by microbial activity is called immobilization of phosphorus.

Almost all kinds of microbes assimilate P in nucleic acid, phospholipids, other protoplasmic substances.

Organisms

1. The aerobic organisms possess great capacity to immobilize P as compared to anaeorobic population.
2. The capacity of P immobilization of various organisms is in the order fungi > bacteria > astinormycetes.
3. *Aspergillus niger, Azatobacter* etc. are very sensitive for adequate P supply.

Conditions

1. Incorporation of organic residues with a wide C : P ratio (> 300 : 1)
2. Well aerated normally moistened soil.
3. Medium textured soil.
4. Incorporation of animal residues possess less susceptibility of P immobilization.

   Usually immobilization of N entails immobilization of P as well.

   The organic P : organic N ratio generally remains 10 : 1 hence the C : N : P ratio 100 : 10 : 1.

Oxidation -Reduction Reaction

Oxidation

P like N exist in a number of oxidation states ranging form -3 of phosphene (PH_3) to oxidized state +5 of orthophosphate. Many of these redox transformation of P are biologically carried out.

e.g. $HPO_3^{-2} + \frac{1}{2}O_2 \rightarrow HPO_4^{--}$

Phosphite (reduced form of P)

This conversion is brought about microbiologically as is evident that on addition of a biological inhibitor such as toluene this reaction is eliminated. The process is carried out by unspecified microbes only.

A number of heterotrophic bacteria fungi and actinomycetes utilize phosphate as their P source in culture media.

Reduction

When there is an anaeorobic condition and there is no supply of NO_3^- or SO_4^- then phosphate acts as the terminal e^- acceptor.

$$\underset{(+5)}{H_3PO_4} \xrightarrow{2H} \underset{\substack{(+3)\\ \text{Phosphite}}}{H_3PO_3} \xrightarrow{2H} \underset{\substack{+1\\ \text{Hypophosphite}}}{H_3PO_2} \xrightarrow{4H} \underset{-3}{PH_3\ (\text{phosphen})}$$

oxidation State

The quantitative significance of such biological reduction of P even in logged water soil is of practical value only.

Organisms like *Clostridium butyricum* and *Echerichia* coli are known to bring about this reduction.

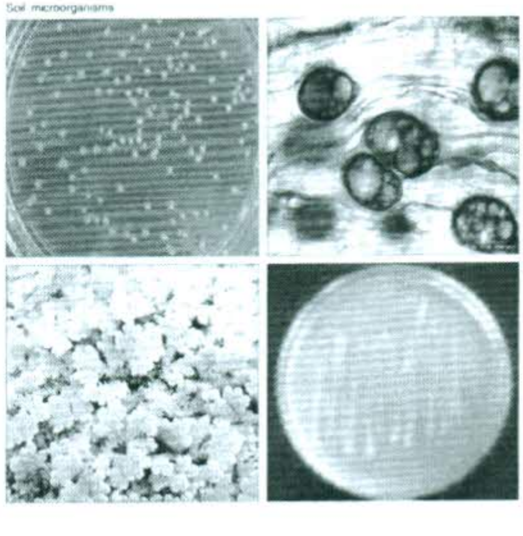
4 | Soil Biota and Organic Farming

Significance of soil biota in Organic farming

The ill effects of long usage of chemical fertilizers and pesticides have resulted in rendering the soil less fertile leading to the depletion of vital nutrients which is a serious threat to ecology and environment. The only option left with us is, ecofriendly natural farming or ecofriendly organic fanning where the proper exploitation and utilization of naturally available resources is possible. Among many natural resources for ecofriendly organic farming, soil forms the important medium for the survival, growth, multiplication of wide variety of soil invertebrates most of which are directly or indirectly involved in enhancing soil fertility and growth of the plant The ecofriendly inputs for organic farming include the use of compost, FYM, green manure, biofertilizers, vermicompost, biopesticides, biocontrol agents etc. Therefore, the organic resource management is the backbone of organic farming and sustainable agriculture.

Soil is a living heterogeneous system with characteristics of physical, chemical and biological properties. Soil is inhabiting a vast group of soil biota including most of the vertebrates by which they make significant contributions to the soil fertility and crop production. The awareness on the existence of life process in the soil was aroused with the publication of Charles Darwin's classical book "The formation of vegetable mould through the action of worms" in 1881. During the same period, Muller (1879) recognized the importance of soil invertebrates in the establishment of different humus forms. These soil invertebrates can be manipulated to improve the soil physical, chemical and biological properties and regulate the decomposition processes to release the vital nutrients for plant growth. These are broadly categorized into soil microorganisms, nematodes, earthworms, soil micro and macro arthropods which directly or indirectly are contributing to the soil ecosystem.

Soil microorganisms

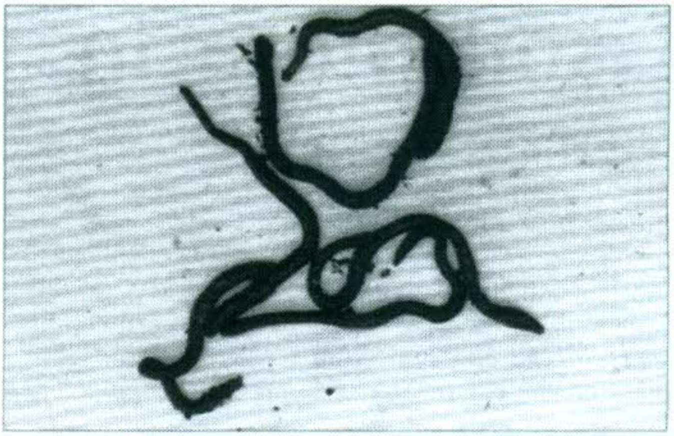


Soil Microorganisms

The fundamental characteristic of soil is that it has its capacity to produce green plants. Plant and their products after being utilized by man and animal are thrown away as waste material to the soil. Fortunately microorganisms act upon and convert them into useful or harmful substances. In the words of noble laureate Waksman "Without microbes the life on this planet would come to a standstill". The different kinds of microbes such as bacteria, fungi, actinomycetes, algae, protozoa and viruses present in soil bring about several changes.

Bacteria

These are the most dominant group of soil biota, their population ranges from hundred thousand to several hundred million per gram of soil depending upon physical, chemical and biological conditions of soil. They live in soil as cocci, bacilli or spirilli. Some of the bacilli persist in unfavourable conditions and great resistance to prolonged desiccations and also to high temperature as endospores.



Earthworms for vermiculture

Most of the soil bacteria are heterotrophs and saprophvtic in nature. They help in decomposing organic matter and involve in weathering and decomposition of rocks and minerals which help in soil formation processes. Most of the bacteria secrete extra polymeric substances which help in binding soil particles, improve soil structure and texture for improved soil porosity for better exchange and infiltration of gases. Bacteria present in soil also involves various Geo- bio-chemical cycles like nitrogen, sulphur and carbon cycle etc.

Many beneficial bacteria present in soil has the capacity to use atmospheric nitrogen as biological nitrogen fixers. *Rhizobium*, *Azotobactor*, *Beijerinchia*, *Azospirillum* are the common bacteria present in this category Some of the bacteria like Bacillus ., Pseudomonas sp., and fungi like *Aspergillus*, *Penicillium*, *Fusarium* present in soil help in solubalization of unavailable or fixed form of phosphorous present in soil. Of late *Pseudomonas fluorescens* has been receiving greater attention all over the world for the biocontrol of different crop diseases. The ability to grow in the absence of oxygen is an important biochemical trait which helps in the recognition of two broad categories of bacteria as aerobes and anaerobes. Under anaerobic conditions bacteria dominate the scene and carry out the microbiological activities in the soil since other organisms usually do not grow well in the absence of oxygen.

Actinomycetes

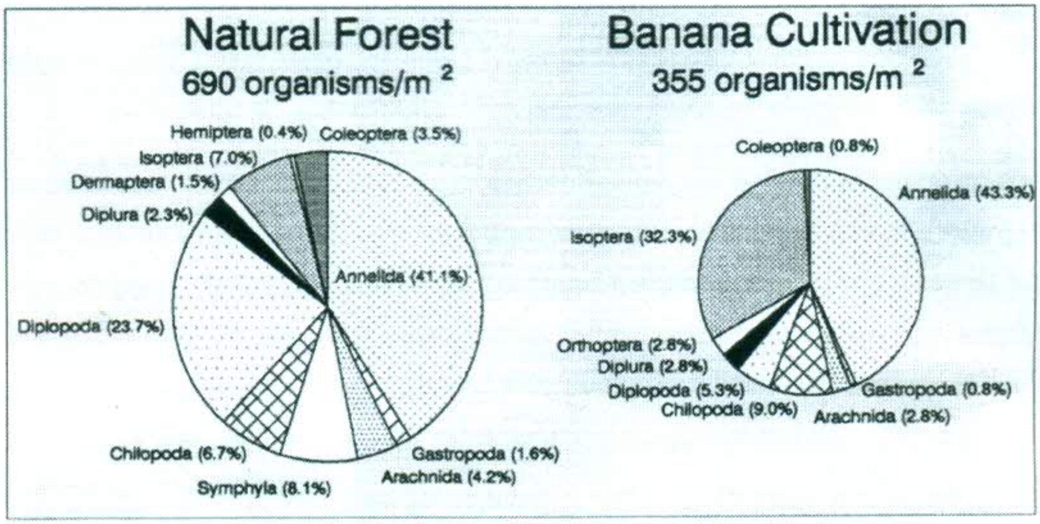
These are numerous and widely distributed in soil. They are usually regarded as intermediate group between bacteria and fungi and produce hyphae or conidia or sporangia like fungi, but the width of the mycelium is almost similar to the width of the bacterial cell. They differ from fungi in the composition of their cell wall. They do not have ehitin and cellulose, which are commonly found in the cell wall of fungi.

Actinomycetes are usually second to bacteria in abundance. They are estimated to be ranging from 10^4 to 10^8 per gram of soil. The population of actinomycetes increased in the presence of decomposing organic matter. They are intolerant to acidity and their numbers decline at pH5.

The most conducive range of pH is between 6.5 and 80. Water logging soil is unfavourable for the growth of actinomycetes whereas desertic soils of arid and semi-arid zones sustain sizeable population, probably due to resistance of spores to desiccation. The percentage of actinomycetes in the total microbial population increases with the depth of the soil and these can be isolated in sufficient number even from soil samples obtained from the C horizon of soil profile. Temperatures between 25°C and 30°C are conducive for the growth of aetinomycetes although thermophillic species growing at 55°C and 65°C are common in compost heaps where they are numerically extensive and mostly belong to genera Thermoactinomyces and Streptomyces. Many species of Streptomyces are known to produce antibiotics. Actinomycetes also play a role in the decomposition of resistance components of organic matter and in the formation of humus. Thermophillic actinomycetes dominate and actively participate in the transformations taking place in the compost pits, manure pits and hay.

Fungi

These are present in soil as mycelial hits or rhizomorphs or various types of spore forms. Their number in the soil varies from few thousand to few million per gram. A wide range of soils under various vegetation types and geographical areas have been examined for the occurrence of fungi. *Aspergillus*, *Mucor*, *Penicillium*, *Trichoderma*, *Cladosporium*, *Verticillium*, *Rhizopus*, *Fusarium*, *Cephaloporium*, *Botrytis* etc. are the most commonly encountered genera of fungi in the soil.



Comparison of density and diversity of soil macro-arthropond between natural forest and banana cultivated soils

Fungi being aerobic are more numerous in surface layers of well aerated cultivated soil. The quality and quantity of organic matter present in soil has direct hearing on fungal population, since majority of fungi are heterotrophic in nutrition. Fungi are dominant in acid soils compared to neutral and alkaline soils.

Filamentous fungi play an important role in the degradation of cellulose, hemicellulose, starch, pectin and lignin which arc present in organic matter added to soil. It is implicated that some fungi like *Trichoderma* sp., *Aspergillus* sp., *Penicillium* sp. and *Pleurotus* sp acts as most efficient organic matter degraders. The genus *Trichoderma* is a source of promising biocontrol agent against many plant pathogens. They grow rapidly on substrates and a wide range of fungal pathogens. *Trichoderma harzianum*, *T. viride*, *T. koinigii* and *T. virens* have been reported to control many soil borne diseases such as wilt, root rot, collar rot etc in many field crops. In addition TT *viride* is known to produce toxic chemical as viridian which prevents egg hatching and kills the larvae of root knot nematodes by rupturing their cuticle. Besides they are very good plant growth promoters, *p solubalizers* and organic matter decomposers. These species have been practically tested under field conditions and formulated and recommended for integrated disease management including seed treatment to many field crops, especially in organic farming. Many organizations have taken up the large scale production of *Trichoderma sp*. and thus they have become commercially important as biocontrol agents.

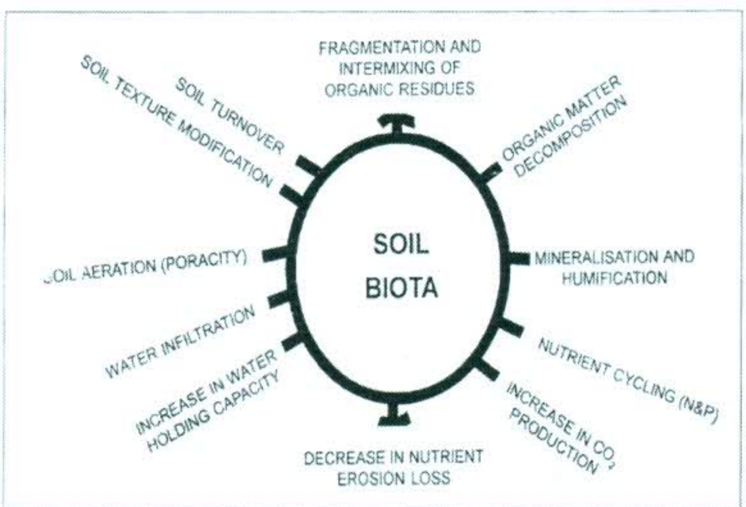
The utilization of proteinacious substances is another characteristic and as a consequence, the fungi are active in the formation of ammonium and simple nitrogen compounds. Fungi also help in formation of humus from raw organic residues. Some of the fungi are predacious on protozoans. Some like *Arthrobotrys conoides* are known to trap nematodes, thus they may participate in the maintenance of microbiological balance in soil.

Some fungi form symbiotic association with plant roots and help in plant growth. The classical example of arhuscular mycorrhizal fungi which is known to help in transformation of available soil phosphorous and micro nutrients like zinc, copper, iron, molybdenum etc. for the benefit of plant growth is well documented.

Algae

These are found in different soils. They are abundant in places with enough moisture and sunlight. Their number, usually ranges from 100 to 10,000 per gram of soil. They form a scum on the surface of the soil visible to the naked eye. They are unicellular or filamentous or colonial. Green algae, blue green algae and diatoms are numerous in soil. By virtue of the presence of photosynthetic pigments of their cells, algae are phototrophic and use carbon dioxide from atmosphere and give out oxygen. Green algae are dominant algal flora in acid soils hut still numerous in neutral and alkaline soils. *Chlorella*, *Chlamydomonas, Chrocococcum, Oedogonium* are the most common green algae found in the soil. Blue green algae are pigmented having phycocyanin in addition to chlorophyll. They do not posses flagella and do not produce sexually. Some of the blue green algae produce specialized cells known as heterocyst which are implicated in nitrogen fixation. The waterlogged rice soils provide an ideal environment for the growth and multiphcation of blue green algae. Blue green algae also add lots of organic matter to soils and improve soil aggregation.

They also grow on eroded and abandoned soils and also volcanic deposits when the required moisture is available. The mucilage of these algae has the properties of absorbing water quickly and retaining it for long time. Thus the growth of these algae provides a substratum for the growth of spores, grass seeds etc and thus help in building soil fertility The thick growth of such algae on the surface of such soil acts as surface binders and prevents soil erosion.



Integrated activity of soil biota as reflected on physico-chemical characteristics of the soil

Protozoans

These are also common in soil where, the population ranges from 10,000 to 100,000 per gram of soil. They are characterized by a cyst stage in their lifecycle which can help the species to withstand adverse soil conditions. Most of the soils contain protozoans like flagellates, amoebae or ciliates. Flagellated protozoan are predominated as compared to Amoebae and Ciliata. They are abundant in upper layer of soil. Application of organic manures increases the population of protozoans which is a reflection on the corresponding increase in the bacterial flora due to the addition of organic mater. Soil moisture level is another important factor affecting soil protozoa hut they could survive even during the absence of moisture by forming cysts especially in dry condition.

Viruses

These are sub microscopic and obligated on other soil microorganisms like bacteria, fungi, actinomycetes and viruses. Some of the plant viruses are said to be soilborne, they do not multiply in soil hut persist for some time as obligate parasites. There is no strong evidence to conclude that they have any relationship to enhance the crop yields or their overall influence of soil on agricultural productivity.

The beneficial microorganisms present in soil will generally be low in numbers and hence desired results cannot be reaped from these microorganisms. Hence there is a dire necessity to produce these beneficial microorganisms in large quantities for application to the field crops, which not only help in saving the application of chemical fertilizers. Currently efficient rhizobium strains have been isolated and used in the production of biofertilizers. *Rhizobium* is extensively used in dicoryledonous crops like pulses and oilseeds where *Azotobacter* and *Azospirillum* is extensively used in cereals, vegetables, fruits, ornamentals, plantation and commercial crops. Azolla and blue green algae are commonly used as biofertilizers in paddy cultivation. Phosphorus solubalizers are being generally applied to all crops irrespective of monocot or dicot. Similarly, mycorrhizal fungi were also isolated and used for phosphorous nutrition in different crops.

Arbuscular mycorrhizal fungi application is most suited to nursery crops. But the quality of the produce was improved due to secretion of growth promoting hormones like Indole acetic acid, Gibberlic acid, Cytokinins and vitamins that help in deterring root borne pathogens.

These beneficial microbial inoculants are mass multiplicated in large quantities on appropriate medium on large scale fermentors and will be mixed in pre sterilizes carrier material like lignite, wood charcoal, talk exfoliated vermiculate, peat etc and are packed in materiel like low density standard polythene bags. Arbuscular mycorrhizal is an obligate parasite and can be mass multiplicated in the presence of hosts like blue panic or guinea grass. In recent years big commercial organizations like KRIBI-ICO, MFL, and IFECO etc have ventured into this business for large scale production and marketing. These microorganisms will survive for long time, are ecofriendly in nature and help for soil fertility sustenance for long time. Thus their contribution is immense in the field of organic farming.

Nematodes

Incredible nematodes live in soil and participate in the food webs at several trophic levels. Soil inhabiting nematodes are classified as free living bacterial feeders, fungal feeders and predators. One entomopathogenic nematode, *Steinernema carpocapsae* has been identified as an effective biocontrol for wide range of pests including soil pests like rootgrubs. A bacterium, *Xenorhabdus sp.* is symbiotically associated with this nematode which actually kills the pests. This nematode is commercially available for field application. Predacious nematodes such as *Seinura sp.* and *Strongylids sp.* are known to predate on root feeding nematodes, *Meloidogyne sp.* soil protozoa, bacteria etc. Free living nematodes are saprophytic in nature and feed on organic matter which helps in decomposition and indirectly participating in soil fertility but not so significant like other soil invertebrates such as earthworms, microorganisms and microarthropods.

Earthworms

Earthworms are the important soil invertebrates have an widespread distribution and show a high degree of adoptability to the prevailing soil conditions. Their involvement in the soil ecological process contributing to the soil fertility was first recognized by Charles Darwin (1809-1884) and called the "Earthworms as farmers friend" and also stated that "these lowly organized creatures are so important as they played an important role in the history of the world. This statement is so relevant in the present scenario of organic farming and sustainable agriculture.

Globally more than 7000 species of earthworms has been distributed in all the habitats except cold and desert regions. Ecologically they are classified as 1) Epigeic earthworms confining to the topsoil feeding on the organic matter at surface feeding zones. 2) Endogeic earthworms are completely soil dwelling feeding on the organic matter at subterranean feeding zone. 3) Anecic earthworms are deep soil inhabitants making horizontal and vertical tunnels for feeding activities. The Epigcic earthworm species are most important as surface feeders on organic matter include *Eudrilus eugeniae, Perionyx excavatus, P. sansibaricus, Eisenia foetida* and *Pheretima* sp. And they can also be used for vermicomposting.

Vermiculture is the art of maintaining and multiplication of earthworms in semi-arid conditions for the purpose of vermicomposting. The most preferred and generally used species of earthworms include the African night crawlers, *Eudrilus eugeniae*, the banded or tiger worm, *Eisenia foetida* and *Perionyx excavatus*. It is always good to use all these earthworm species in combination so as to get enhanced microbial density and reflect on the quality of vermicompost.

Biology

The body of earthworm is longitudinal and segmented. The colour is more intense on the upper surface because of the presence of pigments usually reddish brown or red in the cells of skin but much of the colour is due to haemoglobin in the earthworm. They have no special breathing organs, oxygen is absorbed and waste gases are eliminated by diffusion through the skin from a network of fine blood vessels just beneath the skin surface. Gland cells in the skin secrete mucus to keep the surface moist and lubricate the body as it moves through the soil that is how the earthworms are moist and slippery to touch and because they must constantly replace water lost by evaporation from the surface and they cannot live in very dry soils.

Earthworms have both male and female reproductive organs in the same individual as hermophrodites with two pairs of testis and one pair of ovaries. During mating two earthworms align themselves in head to tail attitude with their lower surface touching each other over a length of about 35 anterior segments. A thick layer of mucus is produced covering each worm from near the front end to a few segments behind the clitellum. Sperm celis are discharged by both worms, the sperms from each worm find their way to the sperniathecae of each other. Sperm cells are released to fertilize the eggs and forms the oval egg case or cocoon. The cocoons are deposited in the soil and fertilized eggs develop and grow into small worms taking 2-4 weeks to hatch depending on temperature. The number of eggs/cocoon is variable, but usually only one or two worms succeed in developing and emerging from a cocoon.

Decomposition of organic matter

They prefer to live in a light, loamy soil and structure of heavy' clay soils should be modified for release of earthworm population. Horizontal and vertical burrows of earthworms provide channels for root, water and air penetration deep into the soil and also increase the volume of the soil from which plant roots can extract nutrients and water. The crumbs or aggregates of soil formed from worm casts are usually more stable than the hulk of the soil. Earthworms eat large quantities of soil as well as organic materials. Everyday they eat about half of their own weight of soil.

Species that excrete their faeces as casts on the surface of soil have been shown to bury the original surface to a depth of 4-5 cm. the common earthworms in any garden soil tend to excrete their faeces underground.

Earthworms breakup, eat and mix the large amount of organic material in to the soil. Individual earthworm can eat as much as 40 gram div matter per year. This works out at 80 tonnes/ha/year for a typical population of 200 worms/sq. m. This number may be reduced due to longer dry period when earthworms are inactive.

Earthworms eat to live but an important benefit for soil and plants is that organic materials are broken up and mixed with soil. In the process, the nutrients in them become much more readily available to soil microorganisms and to plants. The increased microbial activity further aids organic matter decomposition and hence nutrient available to plants. Studies elsewhere have shown that about 6% of the nitrogen in organic matter previously unavailable to plants becomes available after passing through digestive tracts of earthworms. Calcium, Magnesium, Potassium, Phosphorus and Molybdenum are many times readily available in worm casts than in the surrounding soil and casts are also nearly neutral pH than the soil. Increased availability of nutrients is one reason why crop yields are generally increased by earthworms.

Observations have indicated char some soils have 20% greater water holding capacity since the introduction of some species of earthworms. This means that more water is available for plant growth. Field experiment conducted elsewhere to determine the introduction of earthworm *Pontoscolex coretyhrurus* at the rate of 360 kg/ha for soil fertility and crop production by cultivating 4 crops; i.e. maize followed by rice, cowpea and rice. Nitrogen and carbon contents were recorded 18 and 7% higher in earthworm treated crop fields. The establishment of earthworm population had seen in all the subsequent crops also.

Culture methods

The Vermiculture units could be as simple as eras cardboard boxes or even cement or stone slabs tanks. Any container with 25 to 30 cm deep similar to bath tubs like troughs or drums can be used for small scale vermicompost production. Permanent beds with cement concrete tanks also with the higher dimension of 4 m length × 1.5 m width × 0.75 m height. Such tanks are recommended to use in organic farming villages for vermicomposting. The temperature and moisture requirements of earthworms need to be kept in mind while selecting the sites for vermicomposting tanks. Earthen pits with still longer dimensions are also used in most of the sugar factories where sugarcane trash is being utilized for making vermicomposting. The worms are best added to the medium from which they are collected. The best should be kept moist her not saturated with water. Placing the wet gunny bags on the surface reduce evaporation losses and provide darkness to earthworms. Frequent monitoring is required to make sure that the bed is moist enough so that the worms are healthy with continuous breeding activity.

The decomposed organic leafs' materials along with cattle dung and moisture of about 40-60 % is essential for Vermiculrure. The units can be mulched with gunny bags or leafy materials. One kg of earthworms containing about 1000- 1200 numbers can yield 2000 cocoons/week and 4000 young ones emerge and from this 7000 to 8000 earthworms can be produced in about 3 months. Thus the culturing of earthworms is more profitable and a kg of earthworms cost around rupees 450 to 600.

The availability of earthworm is the most critical factor to go for vermicompost production which is universally known as vermicomposting. It is very simple and now it has become popular technology among the farming community in India.

Vermicomposeing can be taken up by anybody including farm men, women, urbanites, terrace gardeners etc. The main principle behind that any biodegradable organic waste including agro based or city solid waste or biodegradable industrial waste (excluding plastic material) can be used for vermicomposting. The agro based waste need to be decomposed by mixing with one part of cattle dung with three parts of biodegradable wastes. The decomposition process will continue depending on the C: N ratio of organic materials used and essential moisture between 40 and 60% during which frequent turning or mixing has to be done to hasten the decomposition process and may need about 20 to 30 days for decomposition.

The size of tank is individual choice depending on the amount of waste available and only height of the tank is constant, i.e. 1 m for all different dimensional units, the right time to release the earthworms into these tanks when the decomposition of organic material is completed atleast 70-80%. About one kg of earthworms (1000-1200 worms) are required for the tank size of one sq. m. The earthworms consume the decomposed organic waste and convert in to vermicasts to form vermicompost which can be harvested periodically once in 3-4 days. The composting process will be completed in 50-60 days and one can produce the vermicompost in 3 months period. The shelf-life of vermicompost is 10 to 12 months if it is preserved in cool and shady place. The vermicompost thus producef is a value added product since it has all the required major and minor nutrients and growth enhancers in addition to being 100% organic manure (Table. 1). They should be taken to protect the units from sunlight and rainfall and also from common predators like ants, ground beetles, lizards, birds, rodents etc.

Advantages of vermicomposting

The Vermiculture and vermicompost technology offers many advantages to end users:

- Earthworms are the biological tools for healthy and productive soils and are decomposers of complex organic matter.
- Vermicompost can be used as effective fertilizer to almost all crops including vegetables, ornamentals and plantation crops.
- Vermicompost is an aerobically degraded organic manure which undergoes chemical changes by the enzymatic activity of earthworms and also associated microbial population.
- Vermicompost is a value addition product which is economically a viable venture.
- Vermicompost is the hot spot for multiplication of soil fungi and bacteria.
- Vermicompost technology is effective in urban solid waste management to reduce environmental pollution.
- The production of vermicompost is a highly lucrative business and income generating activity by way of marketing earthworms and vermicompost.
- Vermimeal is a dried extract of earthworms that can be used as feed for poultry birds, fishes and cattle.
- Vermiwash, the coelomic fluid extract of earthworms has medical properties such as antibacterial, antifungal and also pharmaceutical in medical field. It has also anti plant pathogen property which can be used as foliar spray to control the plant diseases.
- Vermicompost technology is a morale booster for farmers in organic farming and also farmers can avail loans from the nationalized banks to start commercial production of vermicompost.

Table 1: The nutrient status of the vermicompost

Parameters	% or ppm
Organic carbon	9.15-17.98
Total nitrogen	0.5-1.5
Available phosphorous	0.1-0.3
Available potassium	0.15-9.56
Calcium and magnesium (meq/100g)	22.67-47.6
Copper	2.0-9.5
Iron	2.0-9.5
Zinc	5.7-11.5
Sulphur	128-548

Recommendations have been made on the use of vermicompost based on the feed back from the farmers who had higher yields in different crops. Application of vermicompost at 2 tonnes per acre in case of cereals, pulses and oilseeds, 4-6 tonnes per acre in case of vegetables, ornamentals and spices and in case of fruit crops, plantation crops like coconut and arecanut 2-5 kgs/tree depending on the size of the trees were recommended to the cultivators.

Earthworms play an important role in comminuting organic matter resources to produce value added vermicompost which can be used in organic farming. Hence, the earthworms are very optly referred as "Cindrella of organic farming" for self sustained, ecologically safer and economically viable future.

Limitations

Earthworms are rich in natural rain forests where the temperature is optimum between 20° C to 30° C. Temperatures above 35° C under Indian conditions are usually fatal for earthworms and death is more rapid during drier periods. Some species remain dormant in cocoon stage to overcome the adverse conditions. Similarly earthworms do not tolerate too much alkalinity with more than 8 pH and too much acidic with less than 5 pH and the most optimum is 6 to 8 pH as neutral for better survival of earthworms in nature.

Earthworm's populations are reduced due to mechanical damage by agriculture implements like ploughs, spades, forks, power tillers and other implements. Experimental evidence is available to prove that man chemical pesticide sprays likc chlorinated hydrocarbons, Organophosphorus and carbamates are lethal to the earthworm populations. Application of fumigants such as chloropicrin, methyl bromide and DD for the control of soil inhabiting insect pests and nematodes wili reduce the earthworms populations. Similarly, the application of Arsenic and Copper compounds to control many plant diseases are also known to reduce the earthworm population.

Soil Microarthropods

The microarthropods generally found in soil measuring less than 10 mm in length can be considered as microarthropods including proturans, diplurans, collembolans, mites, isopods, pauropods, symphylans etc. they are distributed in all kinds of soil including organically rich grasslands, pasture lands, garden land, cultivated, uncultivated, barren land etc. The population of these microarthropods varies from place to place depending upon many factors such as soil moisture, organic matter content, cultivation practices etc. Prolonged inundation adversely affect the soil microarthropods population and the population increases with precipitation of organically rich soils. A total density of 16-20 thousands per sq m. has been reported from the soil containing higher organic mater content especially in the fhrest litter of Western Chats and Himalayas.

Among the soil microarthropods collembolan and mites are abundant and found to he predominant group of soil fauna that accounted for 78- 90 % of total arthropods fbund in soil. Collembalans are commonly called spring tails primitively wingless group and are found as abundant soil fauna. Soil mites including Crvptostigmata (orbatei) Mesostigmata and Astigmata surpass other soil arthropod group in density and species diversity Collembalans and soil mites are important detrivorous and fungivorous saprophagous etc. Proturans and Collembalans are very small, less than 2 mm in length primitively wingless, white, fragile insects. These are found to occur in organically rich soils mostly common during rainy season.

Similar to proturans and diplurans Pauropoda and Sympla are small, fragile, delicate, miniature group of Myriopoda that prefer to live in leaf litter of surface soils 'and they prefer to feed on decaying organic matter. Isopods are terrestrial crustaceans popularly known as woodlice associated with litter, logs, bark stones etc. They are known to live mostly in dark and damp places. They have ability to conserve moisture due to the presence of their water proof cuticle. Isopods mainly feed on dead and decomposing organic mater including faecal pellets of soil animals. Based on the field experiments conducted in different parts of India, soil faunal diversity are quite active under organic farming system in soybean, cowpea, ragi etc. during rainy season.

Higher abundance of oribatid mites, collembolans, mesostigmatids have been found to occur regularly in the plots applied with minimum of 15 tonnes per ha farm yard manure. These plots also recorded significantly higher organic carbon, available phosphorus, calcium and also enhanced physical properties such as pore space, bulk density, water holding capacity etc.

Application of 15 tonnes per ha of FYM helped to establish significantly higher population of invertebrates compared to chemical fertilizers alone. Similarly, partially decomposed FYM application helped to establish significantly higher population of soil invertebrates as compared to fertilizer application alone. Higher abundance of soil invertebrates such as oribatid mites, collembolans etc. had positive correlation with increased physico-chemical properties of the soil. Agricultural management practices such as indiscriminate use of fertilizers, pesticides, use of heavy implements, deforestation have adverse effect on the activity of soil microarthropods and their useful role in organic matter decomposition.

Soil Macroarthropods

The soil arthropods measuring more than 10 mm in length can be considered as macroarthropods including centipedes, millipedes, termites, ants, large number of ground dwelling beetles etc.

Millipedes and centipedes

Millipedes and centipedes are important soil macroarthropods found in arable and garden soil and are quite abundant during rainy season. Millipedes are generally recognized as feeders on dead and disintegrating plant material. They are also acting as agents for decomposition and enrich the soil fertility. They are comparatively longer in size (5-6 cm) and can be easily recognized by the presence of well developed dorsolateral expansions on all body segments. Millipedes are active burrowers in forest litter, compost pits and farm yard manure. Millipedes ingest the detritus along with soil and thereby mix the organic and inorganic components. Centipedes are distributed in moist habitats of tropical soils. They are often found under leaf litter, bark, rocks, cracks and crevices etc. They are carnivorous feeding on smaller insects which are associated in the leaf litter and smaller plants.

Termites

Termites are primarily cellulose feeders and are pests of many dry land crops and wood work of the buildings. Large population will be involved in burrowing the soil by moving in subterranean galleries to more than 100 m in search of food. Termites affect the soil properties through construction of mounds, nests, galleries and earthen runways on the ground. Termites wherever present play a significant role in soil modification and organic matter break down and their effects may be positive or negative for crop production. Termites activity may drastically influence the fertility process in natural ecosystems to the extent that the physical and chemical properties of soils may be largely determined by the digestive activities of the animals and modifications of the environment caused by them. According to Drummand (1886) that the termites are true analogues of earth worms and play vital role in turning over soil cover by mixing organic matter with the soil facilitating its decomposition. Since the termites are removing the soil from various depths and they arc more selective in clay, silt and fine sand particles to build their nests and earthen runways.

Termites build variety of mounds/nests either above ground or below ground with unilocular and multilocular arrangement of fungus gardens, these fungus gardens are sponge like structures and are built out of their faecal matter over which mycelium and conidospores grow for food and depositing the eggs and nursing the young ones. The excreta is also used in the construction of nest and lining the subterranean galleries and earthen sheeting's on the food surface. Fungus garden contains cellulose, lignin, carbon, nitrogen, mineral matter, fat in addition to smaller quantities of calcium, magnesium, sodium, zinc, iron, manganese and copper.

The mound soils are characterized by higher proportions of finer soil particles such as clay, silt and fine sand as well as organic matter, phosphorus, the exchangeable cations like Ca, Mg, K, and Na are recorded higher in the mound soils. Mound soils affect the vegetation by adding certain modified properties of the soil that influence the growth of plants as this was verified in many crops such as cowpea, ragi, sorghum, soybean, cotton, sugarcane, chilly etc. The growth of the plant was luxuriant, vigorous with larger pods and earheads and also higher yields on the mound soils compared to surrounding soil.

Ants

Ants are found everywhere on the earth marching in large numbers on the ground. Soil inhabiting ants exhibit wide variety of feeding habits such as omnivorous, carnivorous, fungivorous, grenivorous, detrivorous etc. Ants exhibit territoriality, good communication system, alarm and assembly, polymorphism, division of labour etc.

They build crater like nests on the ground by excavating the soils from deeper regions and as a result water percolation to the plants is found to be faster. Excavation of nests and deposition of heaps of soil ants hasten the decomposition of organic matter and also act as scavengers in removing dead insects from their habitats. These ants are closely associated with homopteran insects for feeding on honeydew, nectar of plants. They are predators to attack many harmful insects such as termites, cutworms, aphids etc. They are also house hold pests causing nuisance in the human habitations.

Beetles

Many beetles such as ground beetles, darkling beetles, tiger beetles and dung beetles are known to live in the soil during their immature stages. Among these ground beetles and tiger beetles are predators, darkling and dung beetles are nature's scavengers. Dung beetles mainly carry large quantity of dung under the ground and this precious organic manure is being preserved by these beetles naturally to enrich the soil. The larvae and adults are making tunnels by burrowing the soil and organically enrich the soil by improving the soil fertility in many cultivated crops.

Observations recorded on the development of soil macrofaunal communities and the corresponding effect on the soil physical and chemical properties as well as quantifying the role of these soil fauna in sustaining the soil productivity The diversity, density and biomass of soil faunal communities in the natural tropical forest are compared to those in plots of banana where the abundance of different macrofauna are, continued to exist under cultivation of banana.

Summary

The soil biota including microorganism, earthworms, micro and macro arthropods are playing very important and significant role in organic matter decomposition, mineralization by biochemical transformation to enhance the rapid recycling of nutrient and consistently make them available for plant growth. The natural resource management with recommended quantity of all the organic inputs is very much necessary to conserve the agro-ecosystem. There is a possibility of manipulating the soil biota to optimize its influence on soil fertility and plant growth. Therefore, soil biota is an important component for organic farming system and sustainable agriculture.

Good agricultural practices, such as conservation agriculture, can reduce the carbon footprint and the adverse environmental impacts of biofuel production-just as they can for extensive agricultural production in general.

Source: Food and Agriculture Organization of the

In the last century, chemical fertilizers were used in agriculture. Farmers were happy of getting increased yield in agriculture in the beginning.

But slowly chemical fertilizers started displaying their ill-effects such as:

- ❖ Leaching out
- ❖ Polluting water bodies
- ❖ Destroying micro-organisms and friendly insects
- ❖ Making the crop more susceptible to the attack of diseases
- ❖ Reducing the soil fertility and thus causing irreparable damage to the overall system

- Biofertilizers are groups of live and latent cell of microbes or micro-organism which are used to inoculate seed, plant surface and soil or all three which increase the production or productivity without impairing soil fertility.
- The term bio fertilizer refers to preparation containing live or latent cells of efficient strains of microbes which helps in enhancing the soil fertility by
    - fixing atmospheric nitrogen,
    - solublization of phosphorus or
    - decomposing organic wastes or
    - augmenting plant growth by producing growth hormones with their biological activities.

Benefits from using biofertilizers

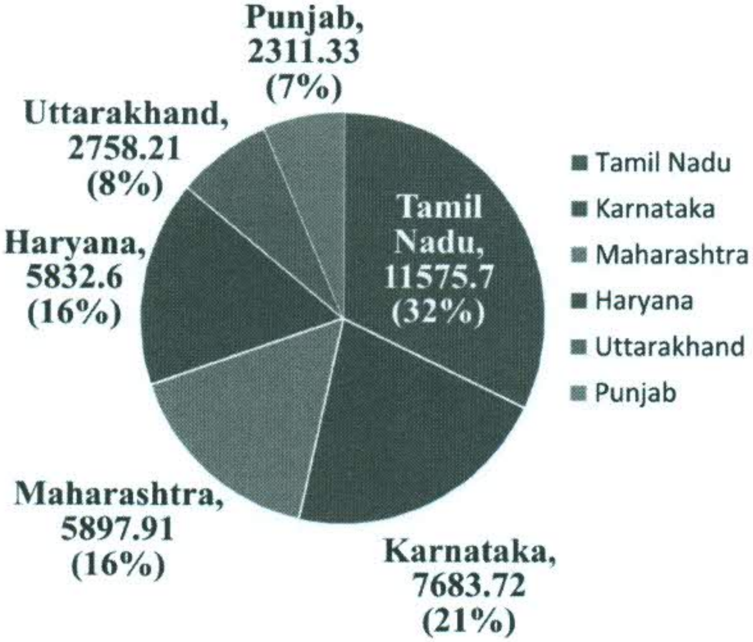
- Stimulate plant growth.
- Activate the soil biologically.
- Restore natural soil fertility.
- Provide protection against drought and some soil borne diseases.
- Increase crop yield by 20-30%. Cost effective.
- Supplements to fertilizers.
- Eco-friendly (Friendly with nature).
- Reduces the costs towards fertilizers use, especially regarding nitrogen and phosphorus

Role of biofertilizers for sustainable agriculture

- Renewable source of nutrients.
- Sustain soil health.
- Supplement chemical fertilizers.
- Replace 25-30% chemical fertilizers.
- Increase the grain yields upto 10-40%.
- Decompose plant residues and stabilize C:N ratio of soil.

- Improve structure and water holding capacity of soil.

Production of Biofertilizers in different states of India in tonnes (2012-13)

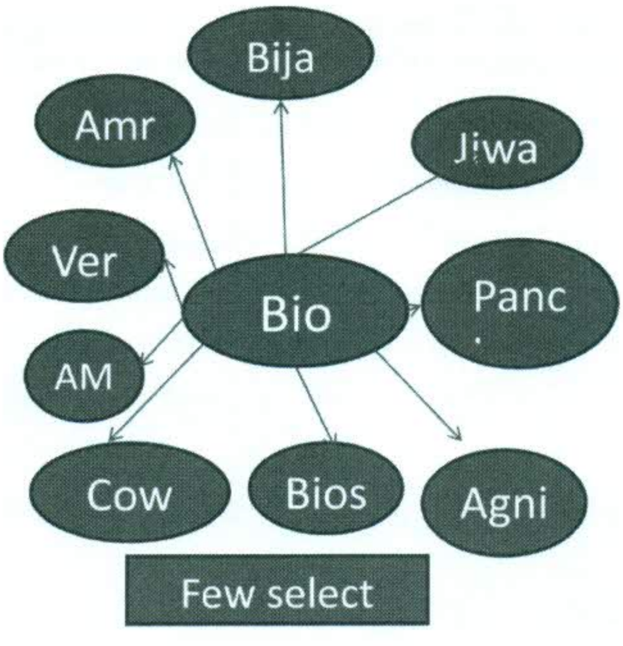


5 Bio- Enhancers: A Potential Tool To Enhance Soil Fertitity & Crop Productivity

Bio Fertilizer

- Bio fertilizers are special preparations with living microbes;
- These are used for seed/seedling treatment and improving soil fertility;
- They are useful in minimizing 20-30 % requirement of fertilizers;
- But for N,P and K different bio fertilizers has to be used;
- Being living utmost care is required in their transport, storage and application;
- With lot of promotional activity, its use did not picked by farming community;
- We are trying to popularize a new product known as Bio enhancers – a potent product in agriculture

Bio enhancer



Concentrated manures, bio products in powder or in liquid form, henceforth termed as Bio-enhancers are organic preparations, obtained by active fermentation of animal & plant residues over specific duration. In fact as on today, each established organic farming systems have developed their own products and are using as per need for different crop activities. We are trying to provide these scientific acceptability through intensive research, validation and extension.

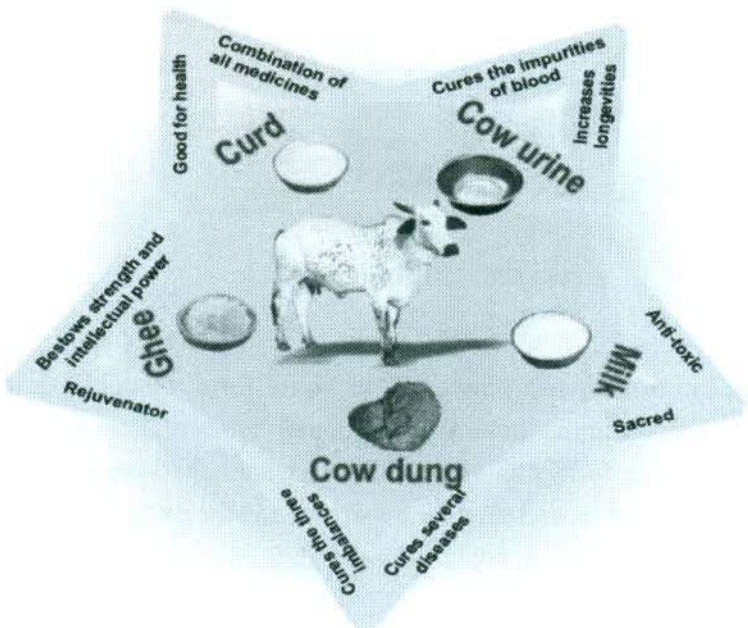
Characteristics of bio enhancer

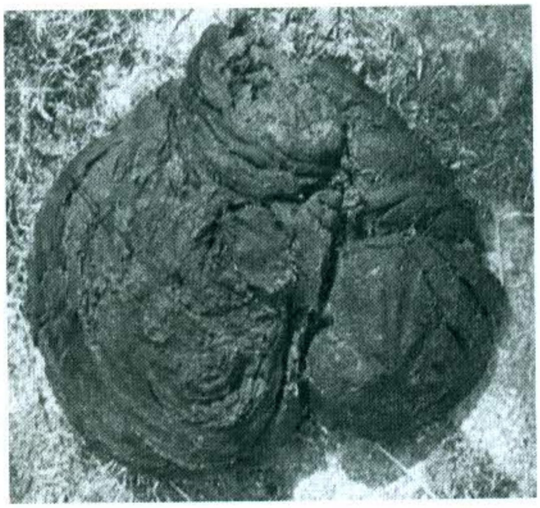
- Potent source for all macro and micro nutrients;
- Presence of Plant Growth Promoting factors;
- Immunity enhancer;
- Pesticide & fungicidal property;
- Efficacy is influenced by inputs used and method of preparation.
- Used for seed/seedling treatment, enhancing decomposition, improving soil fertility and productivity.
- An effective and potent tool for drip irrigation and fertigation!

Cow

- Since ancient times cow has been identified as kamdhenu (wish fulfilling) and considered mainstay symbol of purification, health, wealth and prosperity;
- She lives on the leftover materials from human being i.e straw, grasses, cakes, husk etc and converts to valuable products for agriculture and human health.
- Indigenous breed of cow with hump have capacity of absorbing solar and cosmic energy;
- Presence of *Surya ketu nadi* is another good feature of Indian cow;
- Impact of bio enhancers have changed mind set of policy makers of GOI;
- But for bringing glory of cow more systematic research by all of you is required.

Importance of Cow Products





One cow dung dropping is sufficient to supply microbial inoculants for one ha – Jayant Barve

Cow Dung

- Digestive system of cow is a veritable cosmos in nature, most refined on earth
- There are more than 60 species of bacteria & 100 species of protozoa encountered in rumen of cow;
- Dung that comes after passing through intestine of cow has up to 25% microbes;
- Consists of crude fiber, crude protein, cellulose, lignin, hemi cellulose & pentose's;
- Contains plenty of Menthol, Ammonia, Phenol, Indol and Formalin, especially its bacteriophages eradicate pathogens;
- At CISH identified an *Actinomycete* identified as *Streptosporangium psedovulgare* and four potential strains of *Bacillus subtalis;*
- Shown anti pathogenic potential against anthracnose, gummosis, stem end rot and dieback pathogens;
- Cow dung is best soil conditioner;
- Dung a well recognized disinfectant;
- Keeps environment free from pollution & does not allow any radiation effect.
- Used in preparation of enriched compost, bio enhancers, bio pesticides and tree pastes.
- Dung is basic component in Cow Pat Pit (CPP) and BD-500;
- Dung cake and ghee are basic components in Homa farming;

Cow Urine

- Cow urine is most effective secretion of animal origin with innumerable therapeutic values;
- Contains 95 % water, 2.5 % urea, mineral salts , hormones and enzymes;
- Contains iron, calcium, phosphorus, carbonic acid, potash and lactase;
- It is antibacterial, antifungal, antiviral;
- It is disinfectant, prophylactic, improves fertility of land.
- It has 24 types of salts and medicines made from cow urine are used to cure several diseases;
- Contains amino acids, cytokinins, lactones which play important role in immune enhancement of plants & human;
- In organic farming, cow urine is used for preparation of number of bio -enhancers and bio-pesticides;
- Cow urine diluted with water 1:10-20 is used as seed/ seedling treatment and foliar spray;
- Effective in management of pathogens & insects and also acts as effective growth promoter;
- Cow gives dung and urine till end of her life, hence utmost care is needed to get these valuable materials?

Cow's Milk

- Milk sprays induced systematically acquired resistance in chili against leaf curl (a viral disease);
- Milk also has been used for controlling powdery mildews;
- High amounts of endogenous proline increase contents of Cytokinin and Auxins;
- Cow milk is applied to a seedling, enhances overall growth of plant;
- Microbes like *Lacto bacillus* present in it, produce organic acids that promote crop growth and resists pathogens;
- Above statement requires our attention and gives us an opportunity to rediscover its beneficial effects in agriculture.

Butter milk

- Butter milk is byproduct obtained in preparation of butter /ghee;

- It has lot of therapeutic value in human health and agriculture;
- Two-three weeks fermented butter milk had been in use for management of pests and diseases since ancient times;
- In a study, 35 bacterial and 21 yeasts isolates have been isolated at HPKVV, Palampur;
- In *vitro* tests, 11 bacterial isolates and 8 yeast isolates exhibited pro biotic activity;
- Four sp of *Lacto coccus*, 6 from *Lacto bacillus* and 1 from *Bacillus* were found effective against antibiotic resistant human bacterial pathogens;
- Bacterial pro biotic were effective against selected plant pathogens with or without combination of cow urine.

Cow Ghee

- Ghee is richest source of energy among all organic compounds;
- Special medicinal substance acts as carrier of subtle energies;
- Helps in quick combustion of dung patties in Homas;
- On combustion and oxidation these form hydrocarbon, aldehides and formaldehydes;
- It also gives glycerol, acetone bodies, pyruvic aldehyde and glyoxol, methyl and ethyl alcohol, acetaldehyde, formic acid and acetic acid;
- Ghee is powerful vehicle for energies which sustain life;

Energies coming from sun are captured through Ghee which nourishes and strengthen every living being.

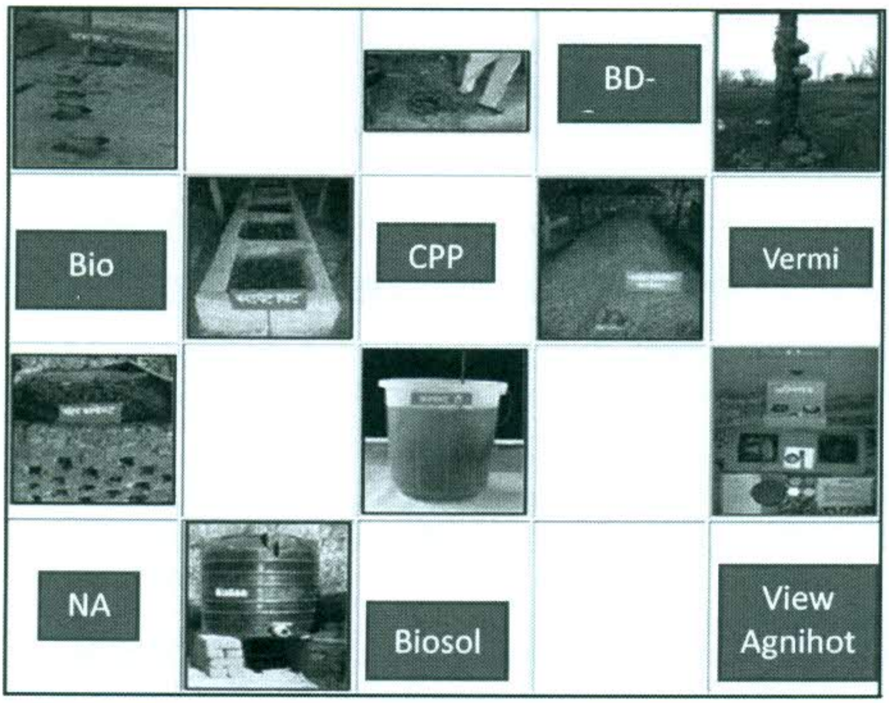
Cow and Aura Energy

- Pests and fungal diseases attack plants, when their Aura energy is depleted;
- Such plants show negative energy which can be quantified by using Universal Scanner;
- In such cases cow urine and dung works as good remedy to supplement positive energy;
- Dr. Murthy, a nuclear scientist developed an electro gadget named as Universal Thermo Scanner which instantly measures bio energy of animate and inanimate objects;
- Instruments work with principle of Aura i.e. light energy emitted from the objects as depicted: -

Aura Energy of Cow Products

Cow products	Aura energy-m	Impact
Milk	12-13m’	Cow milk has been used for seed treatment in ancient India. Has unique blending of 101substances, 19 amino acids. Microbes like *Lacto bacillus* produces organic acids which promote crop growth and resist pathogens.
Cow curd	6.5-7m’	An important component in Panchagavya and good for human health
Cow ghee	14m’	Richest source of energy, helps in quick combustion of dung, by burning it cleanses air pollution. Power full vehicle for capturing solar energies and its transmission in larger area through Agnihotra.
Cow dung	6m’	Rich source of beneficial microbes, used for seed coating and preparation of composts and bio enhancers.
Cow urine	8-9 m’	It is disinfectant, prophylactic, antibacterial, antifungal, anti viral, contains amino acids, cytokinins, and lactone which play role in immunity enhancement and soil fertility

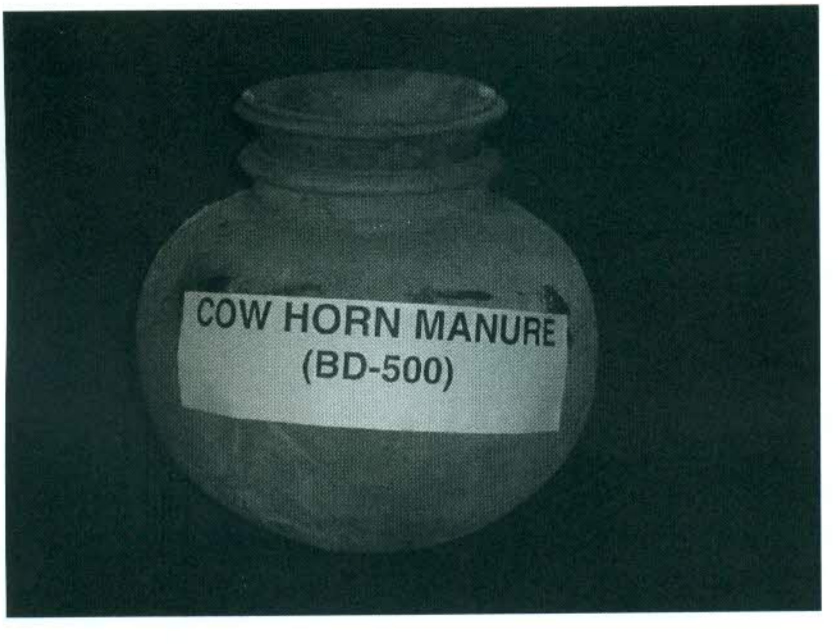
Organic input- A View



Soil Bioenhancer- Bd-500

Preparation

- Fresh cow dung paste is filled in horn and *placed in ground*
- *Descending* phase of Sep-Oct.
- Taken out in March-April
- 25 g is dissolved in 13.5 L water
- Sprayed on 1 acre with broom



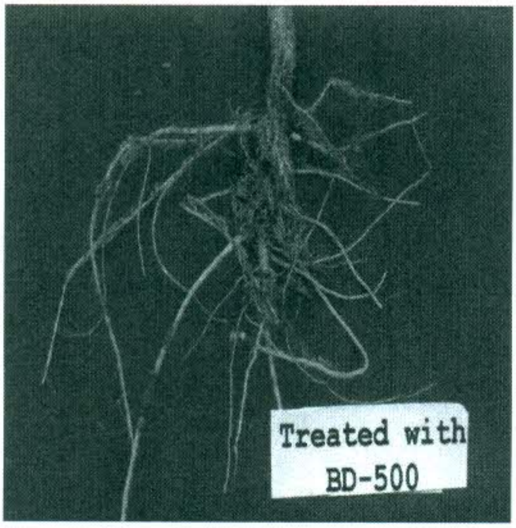
Impact

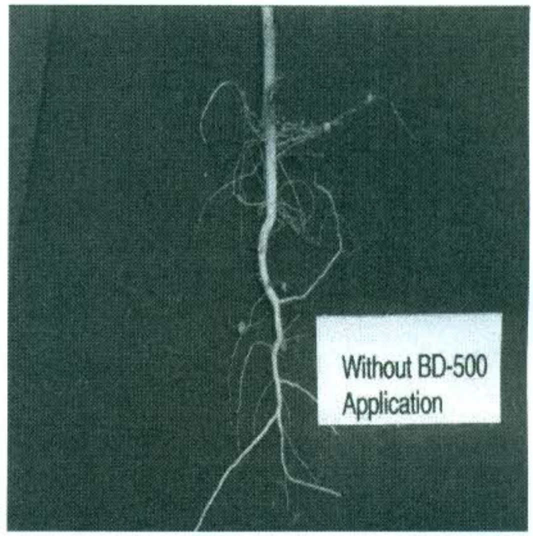
- Promotes root activity

- Stimulates/increases soil micro-life
- Regulates lime and nitrogen
- Helps to release trace elements
- Increases germination

Yeast & mould count during stirring of BD 500

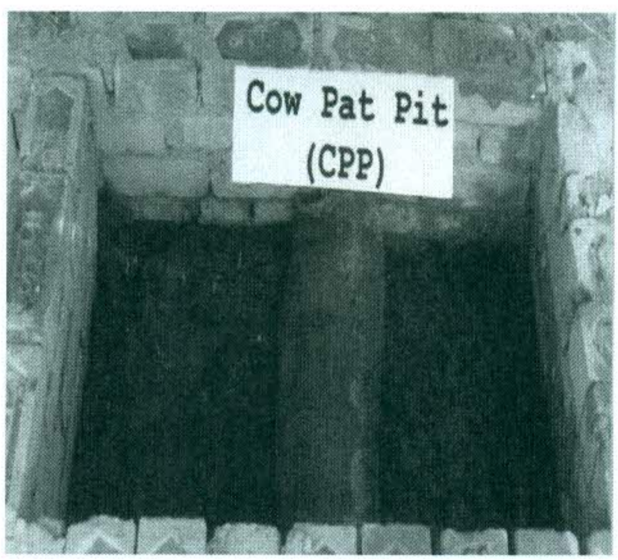
Root growth in *Vigna unguiculata* sown in field sprayed with BD 500 & control





Materials Required

COW PAT PIT, CISH-LUCKNOW



- Pits lined with brick stones and cow dung paste 3x2x1.5
- Cow dung – 60 kg

- Egg shell powder-250g
- Basalt rock/bore well soil 250 g
- BD -502-507-2 sets
- Incorporate BD 502-06 in five holes
- Mix 20 ml of BD 506 with 20 l water stir for 10m by deep vortex and incorporate in hole/spray

Cow Pat Pit (CPP)

CPP contained highest bacterial load (4.5 x 10^6) & beneficial bacteria such as

Rhizobium sp. (1.9 x 10^6),

Azospirillium sp. (0.2 x 10^6), and

Azotobacter sp. (0.8 x 10^6).

Presence of various antagonisms reported by Rupela

Trichoderma

Beverhia

Bacillus sps

Cow Pat Pit (CPP)

Cow Pat Pit contained three plant growth hormones such as

Indole Acetic Acid IAA (28.6 mg/kg),

Kinetin (7.6 mg/kg) and

Gibbrerllic Acid (23.6 mg/kg)

CPP provides nutrient and stimulate plant growth by enhancing microbial population and protecting against fungal disease.

CPP which can be produced at farmer field costs nearly @ Rs. 20/- per kg is cheapest and most effective replacement of synthetic high cost growth hormones which also are sporadic in nature.

Application

- 5 kg CPP/ha is enough for 1 hectare of area;
- Soak in 40-50 liters of water over night ;
- Stir for 20 minutes, dilute to 200 liters and spray over 1 ha.

- It should be sprayed in droplets;
- It can also be coupled with BD-500 spray;
- It can also be used in improving nutrient content of compost;
- One kg CPP is mixed in water thoroughly sprayed over FYM/Compost 4-5X1X1 M and covered with plastic for incubation;

Seeds and seedlings can be dipped before sowing/planting

Panchagvaya

It is a special bio-enhancer prepared from five products obtained from cow, i.e. dung, urine, milk, curd and ghee. When suitably mixed, incubated and used, these have miraculous effects. Preparation is rich in nutrients, Auxins, gibberellins, and microbial fauna and acts as tonic to enrich soil, induce plant vigour with quality production. Its remarkable effects have been demonstrated in fruits like mango, guava, acid lime, banana, spice turmeric, flower-jasmine and vegetables such as cucumber spinach etc by many institutes and individuals.

Ingredients

- Fresh cow dung 5 kg
- Cow's urine 3 L
- Cow's milk 2L
- Cow's curd 2L
- Cow's ghee ½ kg
- Sugar cane juice 3 L
- Tender coconut juice 3L
- Toddy/ grape juice 2 L
- Ripe banana 12
- Container – wide mouth mud/plastic/concrete pot

Steps in preparation of *Panchagvaya*

- Put fresh cow dung and ghee in container
- Mix these thoroughly by stirring twice for 3 days
- On 4th day add rest of ingredients,
- Ripe banana are macerated before mixing
- Stir twice for 15days,
- Stock solution will be ready after 18th day

Precautions: It should be kept in shade and covered with wire mesh, mosquito net to avoid egg laying

- If sugarcane juice is not available –add 500 g jaggary dissolved in 3 l of water,
- If toddy is not available, add 100 g yeast powder and 100g of jaggary in 2 l of warm water and after 30 minutes add it or

Physico-chemical constituents in *Panchagvaya-TNAU*

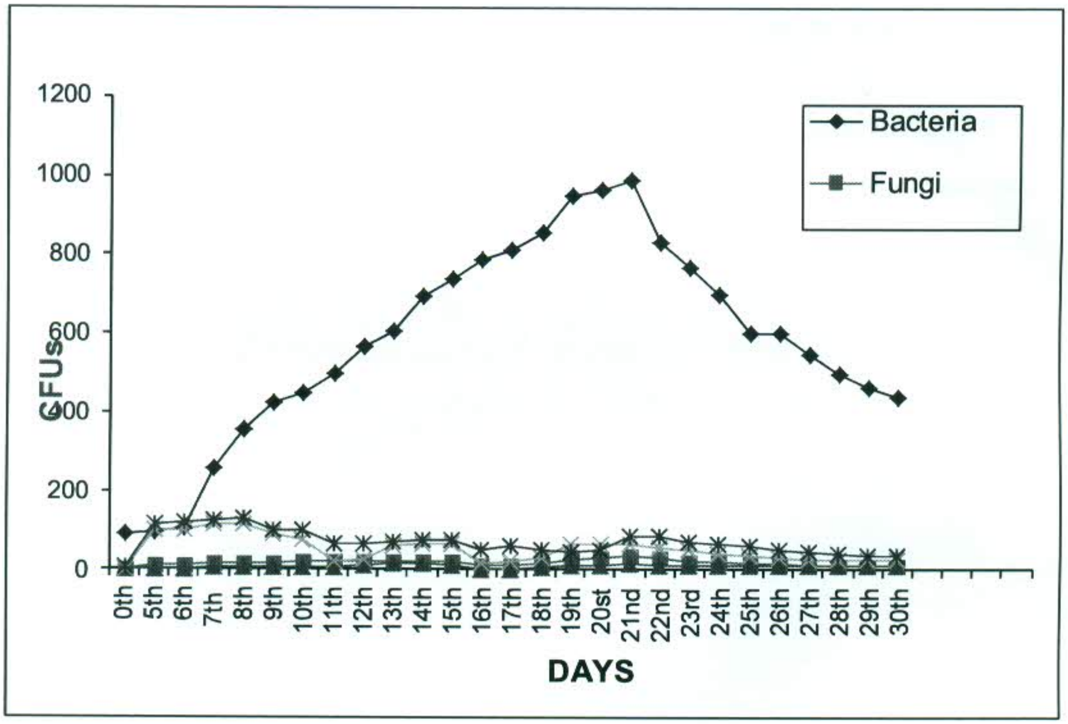
PropertiesF	7^{th} day	10^{th} day	15^{th} day
pH	3.92	4.69	5.12
EC (dsm-1)	11.20	10.4	8.2
Available N/ppm	298	376	492
Available P/ppm	645	760	912
Available K/ppm	940	1540	1635
Organic carbon (%)	0.49	0.53	0.60
IAA ppm	10.8	11.8	13.50
GA ppm	4.9	5.8	5.6
Total sugars ppm	345	386	575
Bacteria ($X10^6$)	5.2	6.4	$92X\ 10^4$
Fungi	$4.5X\ 10^4$	$46X10^4$	$48X10^4$
Actinomycetes	$20X10^1$	$20X10^1$	$21X10^1$

Biological properties of *Panchagvaya*

Presence of microorganisms per gram of *Panchagvaya SGS Laboratory-Chennai*

- Nitrogen fixing *Azosprillium* 10 X 10
- Nitrogen fixing *Azotobacter* 10 X 9
- Phosphorus solublizing phospho bacteria 10X 7
- Immunity enhancer-*Pseudomonas* 10X6

Microbial studies of Panchagavya –Deo Kumar-UAS



Microbial population of panchagavya at different days after preparation

Periodicity of application of *Panchagvaya*

- Three % i.e. 3kg/ 100 L have been found ideal
- Used for seed storage, seed/seedling dip
- Pre flowering phase two sprays @ 15 days, depending upon crop duration;
- Flowering & pod setting two sprays @ 10 days intervals;
- Fruit/ pod maturation One during pod maturation

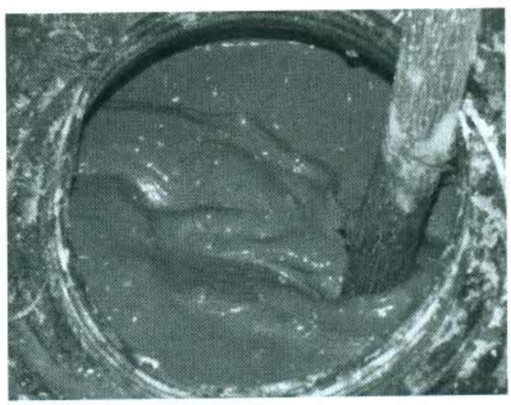
Mode of Action in Animals

- Stimulates the immune system
- Produces lot of antibodies against the ingested microorganisms
- It acts like a vaccine
- Increases immunity of animals
- Helps prevent illness and cure diseases
- Slows down ageing process
- Improves appetite, digestion, assimilation & elimination of toxins in body
- Cures constipation totally

- Increases blood circulation
- Balances endocrine secretions
- Cures sterility
- Animals become hale and healthy with shining hair and skin
- Weight gains are impressive

Effect of Panchagavya on yield of field bean- Deo Kumar-UAS

Sl No	Pachagavya Concentration (%)	Yield (Q/ha)	% increase
1	0	6.35	-
2	3	7.41	16.73
3	6	7.51	18.34
4	9	8.05	26.77
5	12	8.00	25.97



Crops experimented with ***Panchagvaya***

- Fruits-mango, guava, acid lime, lemon, sapota, banana, aonla etc;
- Cereals-rice, wheat, ragi
- Commercial crops-cotton, sugarcane, coconut
- Vegetables-okra, tomato, brinjal, onion, pumpkin, bottle gourd, snake gourd,
- Spices-Ginger, Turmeric

- Flower-Jasmines
- Animals-cows, goat, sheep, poultry, pigs etc;

Jiwamrita

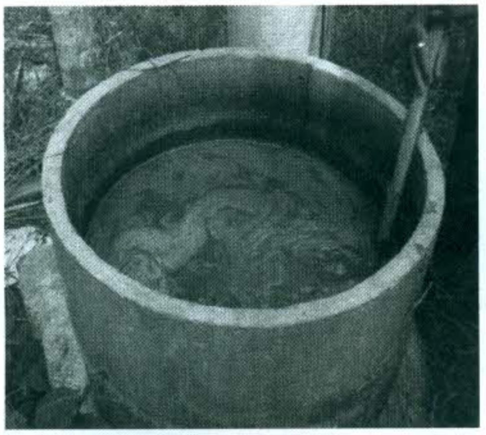
Jiwamrita is is prepared by fermenting cow dung, urine, jaggery, pulse flour, virgin soil by simple facilities created in the village with minimum expenditure. Credit for development of ingredients for Jiwamrita and its extensive use goes to Shree Palekar (2006), a strong promoter of Natural Farming. *Jiwamrita* is a rich bio-formulation contains consortia of microbes. This formulation is used within 4-7 days of preparation.

Analysis of Jiwamrita 5th day sample

Tested Organism	Media used	Viable Cells	Colony Morphology	Pigmentation	Staining
Azospirillum	Bromothymol Blue	$2x10^6$	Regular, entire raised	Blue	Gram-ve
PSM	Pikovisky's	$2x10^6$	Irregular smooth	Cream	Gram+ve
Pseudomonas	Cetrimide Agar Base	$2x10^2$	Raised entire smooth	Cream	Gram-ve
Trichoderma	Potato Dextrose agar	$2x10^6$	Rhyzoidal Filamentous	Green	-
Yeasts and Moulds	Rose bengal Agar	$2x10^7$	Filamentous	White	-

Effect of jeevamrutha on yield of field bean- Deo Kumar-UAS

Sl No	Jeevamrutha Concentration (%)	Yield (Q/ha)	% increase
1	0	4.27	-
2	200	4.92	15.38
3	300	5.08	18.92
4	400	5.43	27.29
5	500	6.00	40.63



Amritpani

- It is a special bio formulation rich in plant nutrients and microbial consortia;
- It is prepared by fermenting cow dung, cow ghee and honey;
- Rich source of microbial consortia and nutrients
- Ingredients for preparation of Amrit Pani and its intensive use was advocated by Deshpandey (2003);
- It has been reported to have Bacteria-5.5X1012, Acticenomytes-2.3X103,PSB-4.7X103,Symbiotic N2 fixer-8.1X105, Pseudomonas flourescence 2.1X103 and P. non pigmented flourescence-2.7X103(Kolambe *et.al.* 2014)
- It are basically used to improve seed germination, soil fertility and plant vigour.

Vermi wash

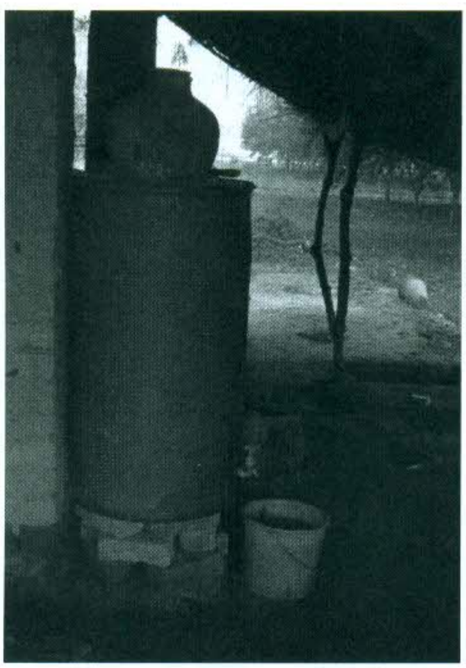
- Vermi wash is prepared from heavy population of earthworms reared in container of suitable size;
- It is a liquid leach ate obtained by excess water to saturate vermi composting substrate.
- It is collection of excretory products and mucus recreations of earthworm along with nutrients from the soil organic molecules.
- Extract contains major, micronutrients, vitamins (such as $B_{12)}$ and hormones (gibberellins, cytokinins) secreted by earthworms ;

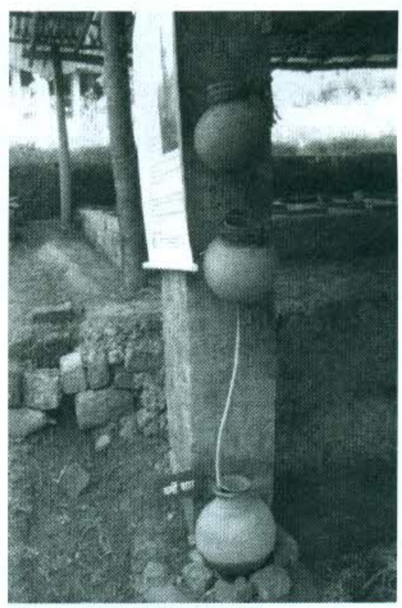
- In fact vermi wash is cock tail of enzymes such as proteases, amylases, urease and phosphatase.

Steps in preparation of vermi wash

- Big earthen pot/ plastic drum with capacity of 200 litres (provided with tap in bottom) is placed in shade.
- Five cm each of concrete and red sand is laid in bottom of pot for effective drainage.
- 30-40 cm layer of soften kitchen waste or one-week-old dung is filled in pot.
- 200-300 red worms are released in organic waste/dung.
- An earthen pot with minute hole in bottom from where water pours drop wise, is hanged over pot/drum after a week of worms inoculation.
- After 2-3 days, extract collected in earthen pots from tap provided in the bottom of pot/drum is called as 'Vermi wash'.
- Extract diluted in the water (1: 5 ratio) can be used as foliar spray.

Vermi wash





Vermi

Microbial load in different bio-enhancers

Source- Institute of Organic Farming, UAS, Dharwar

Table 2 : Nutrient Status of different bio-enhancers

Parameter	Panchagvya	Bijjamrita	Jiwavamrita	Bio-digester slurry
pH	6.82	8.2	7.07	7.29
Soluble salt (EC)	1.88dsm^{-1}	5.5dSm^{-1}	3.40dSm^{-1}	1.09dSm^{-1}
Total Nitrogen	0.10percent	40ppm	770ppm	255ppm
Total Phosphorus	175.4ppm	155.3ppm	166ppm	79ppm
Total Potassium	194.1ppm	252.0ppm	126ppm	42ppm
Total Zinc	1.27ppm	2.96ppm	4.29ppm	0.52ppm
Total Copper	0.38ppm	0.52ppm	1.58ppm	1.24ppm
Total Iron	29.71ppm	15.35ppm	282ppm	9.60ppm
Total Manganese	1.84ppm	3.32ppm	10.7ppm	8.30ppm

Institute of Organic Farming, UAS, Dharwar

Agnihotra Ash - a Powerful Tool

- Agnihotra ash is Secret Weapon of Homa organic farmer;
- Agnihotra ash is extremely medicinal;
- It is a potent medicine for plants, animals and human beings;
- Agnihotra ash is beneficial at all stages of farming operations -- soil treatment, water treatment, seed treatment , seed storage;
- Only ash from sunrise/sunset Agnihotra has this power;
- Ash from other Homas may be used in addition to Agnihotra ash in compost or applied directly onto field.

Some observation at CSK:HP

- Homa environment inhibited growth of i.e. *Fusarium solani, F.oxysporum, Rhizoctonia solani, Sclerotinia sclerotiorum, Sclerotium rolfsii, Phoma medicaginis* and *Alternaria brassicae;*
- Maximum inhibition ranged (29-42%) recorded in agnihotra hut followed by tryambakam hut (8-32 %);

- Homa environment had adverse impact on appearance and population build up of tomato fruit and shoot borer and semi loper;
- Homa ash possessed deterrent capabilities for management of these insects as compared to untreated tomato plants;
- In total of 70 bacterial isolates, 18 isolates selected as phosphate solublizers;
- 18 showed IAA production in range of 0.4-15.6 μg/ mL;
- 7 isolates showed siderophore production in range of 3-14 activity diameters;
- 12 bacterial isolates showed Ammonia production ;
- Isolates isolated during and after the Agnihotra were found to show a variety of PGPR traits;
- These appear attractive towards development of microbial inoculants and enrichment of various organic manures.

Gloria Biosol

- Special organic formulation prepared under anaerobic degradation of organic matters;
- Main ingredients are Fresh Cow dung, urine, Vermi compost, Agnihotra ash and an Yantram;
- A rigid Bio-digester of 100-1,000 l capacity;
- It takes almost 4 weeks for fermentation;
- Biosol is superior to vermi wash and other Bio-enhancers.

Biosol

- Biosol a very potent tool in Homa organic farming;
- Inhibition of mycelial growth of all test pathogens ranged between 85-95 percent;
- It caused 100 % inhibition of *S. sclerotiorum f*ollowed by *Phythophthora* sp. (98.14%), 97.34% of *F.solani* at 10 % concentration;
- It resulted 89.98% inhibition of *R.solani* in poly house causing bacterial wilt.

Fertigation

- Fertigation in different crop is increasing rapidly ;
- Number of macro and micro nutrients are becoming deficient in soil;
- Soluble fertilizers/formulations for most of nutrients are yet to be developed;
- Hence bio enhancer could be a viable tool for fertigation;
- Farmers can prepare and use as per requirement;
- Systematic research and its comparison with chemicals is the need of hour;

- Bio enhancer can be used along with flow/drip/sprinkler irrigation;
- These can be directly placed along the plant root system through gravity drip as shown in next presentation.

Low pressure drip through gravity

An effective way for fertigation

An effective way for fertigation

Comparative effect of Biosol on Crop Yield

Particulars	Yield (t/ha)	Homa control (HC) Yield (t/ha)	Non homa Control (NHC) Yield (t/ha)	Conventional Control (CC) Yield (t/ha)
Biosol in Soybean (soil & foliar)	9.81	8.37 (+) 17%	7.88 (+) 24%	9.38 (+) 5%
Gloria Biosol on Tomato (Soil & foliar)	36.66	25.90 (+) 41%	25.67 (+) 43%	25.61 (+) 43%
Gloria Biosol in Cabbage (Soil & foliar)	36.84	32.70 (+) 13%	32.06 (+)15%	31.93 (+)15%
Gloria Biosol in okra (Soil & foliar)	15.03	12.32 (+) 22%	11.76 (+) 28%	11.02 (+) 36%

Note - Values in parentheses have been obtained after comparison with Homa control (+) % Increase (-) % Decrease

Effect of Biosol on Soil Dehydrogenase activity

Particulars	Dehydrogenase activity	Homa control	Non homa Control	Conventional Control
Biosol in tomato (Soil & foliar)	5.53	3.63 (+) 52%	3.56 (+) 55%	3.13 (+) 77%
Gloria Biosol in Cabbage (Soil & foliar)	7.40	4.9 (+) 51%	4.8 (+) 54%	4.6 (+) 61%
Gloria Biosol in okra (Soil & foliar)	7.60	5.3 (+) 43%	4.9 (+) 55%	4.8 (+) 58%

Note - Values in parentheses have been obtained after comparison with Dehydrogenase activity (+) % Increase (-) % Decrease

Effect of Bio enhancer on Soil enzyme activities in okra

Particulars	Dehydrogenase	Phosphatase
Agnihotra ash (AH) (Soil application)	5.8 (+) 18% (HC) (+) 21% (CC)	17.01 (+) 2% (HC) (+) 9% (CC)
Biosol (Soil application)	6.0 (+) 22% (HC) (+) 25% (CC)	17.21 (+) 3% (HC) (+) 10% (CC)
Jiwamrita Soil application	5.7 (+) 16% (HC) (+) 19% (CC)	16.98 NS (HC) (+) 9% (CC)
Jiwamrita & AH Soil application)	6.1 (+) 24% (HC) (+) 27% (CC)	17.26 (+) 3% (HC) (+) 11% (CC)
Homa control (HC)	5.3	16.72
Control without homa	4.9	16.03
Conventional control (CC)	4.8	15.60

Effect of Biosol on Soil Phosphatase activity

Particulars	Phosphatasese activity	Homa control	Non homa Control	Conventiona l Control
Tomato (DMT-2) (Soil & foliar)	20.72	15.43 (+) 34%	15.37 (+) 35%	14.50 (+) 43%
Cabbage (var.Saint) (Soil & foliar)	17.40	15.40 (+) 13%	14.70 (+) 18%	14.30 (+) 22%
Biosol on Bhendi (var.Arka Anamika) (Soil & foliar)	17.83	16.72 (+) 7%	16.03 (+) 11%	15.60 (+) 14%

Note - Values in parentheses have been obtained after comparison with Phosphatase activity
(+) % Increase (-) % Decrease

Effect of Biosol on Macronutrients in Cabbage at Harvest

Particulars	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)
Soil & foliar	0.89 (+) 13%	0.33 (+) 18%	0.95 (+) 17%	0.24 (+) 60%
Foliar	.0.85 (+) 8%	.0.30 (+) 7%	0.88 (+) 9%	0.21 (+) 40%
Homa Control (HC)	0.79	0.28	0.81	0.15
Control without Homa	0.78	0.27	0.78	0.14
Conventional control (CC)	0.76	0.25	0.75	0.13

Note - Values in parentheses have been obtained after comparison with control with homa
(+) % Increase (-) % Decrease

Effect of Biosol and Micronutrients in Cabbage at Harvest

Particulars	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Fe (mg/kg)
Gloria Biosol on Cabbage (var. Saint) (soil & foliar)	6.80 (+) 11% (HC) (+) 17% (CC)	19.8 (+) 8% (HC) (+) 10% (CC)	31.0 (+) 8% (HC) (+) 11% (CC)	56.0 (+) 4% (HC) (+) 5% (CC)
Gloria Biosol on Cabbage (var. Saint) (foliar)	6.50 (+) 6% (HC) (+) 12% (CC)	19.0 (+) 3% (HC) (+) 5% (CC)	30.3 (+) 6% (HC) (+) 8% (CC)	54.9 (+) 2% (HC) (+) 3% (CC)
Control with Homa (HC)	6.10	18.4	28.6	53.9
Control without Homa	6.00	18.3	28.3	53.7
Conventional control (CC)	5.80	18.0	28.0	53.5

Note - Values in parentheses have been obtained after comparison with CH and CC (+) % Increase (-) % Decrease

Impact of Biosol and Pest and Diseases in Tomato at Harvest

Particulars	Leaf spot (%)	Fruit borer (%)
Gloria Biosol in Tomato (DMT-2) (Soil & foliar)	11.54 (-) 55%	8.83 (-) 63%
Gloria Biosol in Tomato (DMT-2) (Foliar)	13.82 (-) 85%	10.71 (-) 55%
Homa control (HC)	18.38	14.76
Control without Homa	21.56	21.70
Conventional control (CC)	25.64	23.66

Note - Values in parentheses have been obtained after comparison with Conventional control without homa **(+) % Increase** **(-) % Decrease**

Impact of Biosol on Pest and Diseases in Cabbage at Harvest

Particulars	Black rot incidence (%)	Black spot of leaf (%)	Head borer damage (%)	No. of Dimond back moth larvae / plant	Spodopera larvae / plant
Gloria Biosol on Cabbage (var.Saint) (Soil & foliar)	4.50 (-) 54% (HC) (-) 60% (CC)	4.88 (-) 68% (HC) (-) 75% (CC)	4.58 (-) 69%(HC) (-) 71%(CC)	3.43 (-) 35% (HC) (-) 59% (CC)	3.86 (-) 39% (HC) (-) 48% (CC)
Gloria Biosol on Cabbage (var.Saint) (Foliar)	4.84 (-) 47%(HC) (-) 57%(CC)	5.21 (-) 66% (HC) (-) 73% (CC)	5.69 (-) 61% (HC) (-) 64% (CC)	3.89 (-) 27% (HC) (-) 54% (CC)	3.27 (-) 48% (HC) (-) 67% (CC)
Homa Control Homa (HC)	9.14	15.22	14.72	5.30	6.34
Control without Homa	10.06	17.97	14.59	6.31	7.96
Conventional control (CC)	11.34	19.29	15.95	8.42	9.88

Note - Values in parentheses have been obtained after comparison with Homa control (HC)
(+) % Increase (-) % Decrease

Impact of Biosol on Soil Microorganisms at Harvest

Particulars	**Bacteria (CFU x 10^5 / g)**	**Fungi (CFU x 10^3 / g)**	**Actinomycetes (CFU x 10^3 / g)**
Gloria Biosol in Tomato (DMT-2) (Soil & foliar)	112.67 (+) 18% (HC) (+) 23% (CC)	20.72 (+) 48% (HC) (+) 56% (CC)	35.80 (+) 47% (HC) (+) 63% (CC)
Gloria Biosol in Tomato (DMT-2) (Foliar)	100.68 (+) 6% (HC) (+) 9% (CC)	16.30 (+) 16% (HC) (+) 23% (CC)	27.59 (+) 13% (HC) (+) 25% (CC)
Homa control (HC)	95.35	14.00	24.33
Control without Homa	94.00	12.69	23.67
Conventional control (CC)	91.66	13.28	22.00

Note - Values in parentheses have been obtained after comparison with HC and CC (+) % Increase (-) % Decrease

Strategy for promotion of bio-enhancers

- Bio enhancer can be prepared with little support and skill up gradation trainings by every farmer;
- Delineation of nutrient status (macro & micro nutrients), PGPR & immune enhancer study are required;
- Proper filtration will help in use of these bio-enhancers through drip/sprinkler as fertigation,
- Its impact on soil fertility, crop productivity need to delineated,
- Comparative evaluation of aforesaid bio-enhancers for their nutritive value and impact will help for their use,
- There is need to work out contribution of different bio enhancers in organic production and frequency of their use.
- Looking its ease in preparation and wide range use calls for systematic research and assertive promotion by end users

Now immediate decision is required either persists or perish

Microbes

Role of Biofertilizers in Sustainable Agriculture

6 Role of Biofertilizers in Sustainable Agriculture

In the last decades, synthetic fertilizers were used in modern agriculture. In the beginning farmers gets increased yield in agriculture. But slowly chemical fertilizers started displaying their ill-effects such *viz.* leaching out, polluting water bodies, destroying micro-organisms and friendly insects, making the crop more susceptible to the attack of diseases, reducing the soil fertility and thus causing irreparable damage to the overall system. Bio-fertilizer is a substance which contains live or latent cells of efficient strains of microbes which, when applied to seed, plant surfaces, or soil enhances the soil fertility by fixing atmospheric nitrogen, solublizing of phosphorus or decomposing organic wastes or augmenting plant growth by producing growth hormones with their biological activities.

In India, annual production of biofertilizer is increased up to around 40,000 tonnes (2011-12). The maximum biofertilizer is being produced in Tamil Nadu (11575.7tonnes) which contributes 32% of Indian biofertilizer production (NCOF, 2014)

Biofertilizers have important role in sustainable agriculture as stimulate plant growth, activate the soil biology, restore natural soil fertility, provide protection against drought and some soil borne diseases, increase crop yield by 20-30%, cost effective, supplements to fertilizers. They also play a vital role in sustainable agriculture as renewable source of nutrients, sustain soil health, supplement chemical fertilizers, replace 25-30% chemical fertilizers, increase the grain yields by 10-40%, decompose plant residues and stabilize C:N ratio of soil, improve structure and water holding capacity of soil. Biofertilizers as it replaces part of chemical fertilizer use reduces amount and cost of chemical fertilizers. They are an essential components of organic farming, play vital role in maintaining long term soil fertility and sustainability by fixing atmospheric nitrogen, combined application (N fixing and P solublizing) of biofertilizers increases the performance of both biofertilizers. Application of chemical fertilizers along with biofertilizers found more effective (Patel *et al.,* 2013).

However, there is future need necessary to develop strains of bacteria suitable for different crops in different agro climatic conditions and soil types to fully harness the benefit from the biofertilizers and there is need to put in greater effort in this direction to achieve better quality of inoculants by making necessary arrangements in storage and transport (Bahadur *et al.,*

2013).

Conclusion

Biofertilizers as it replaces part of chemical fertilizer use, reduces amount and cost of chemical fertilizers. These are also essential components of organic farming play vital role in maintaining long term soil fertility and sustainability by fixing atmospheric nitrogen. Combined application (N fixing and P solublizing) of biofertilizers increases the performance of both biofertilizers. Biofertilizers play a key role in productivity and sustainability of soil and also protect the environment as it is eco-friendly and cost effective inputs for the farmers.

Introduction

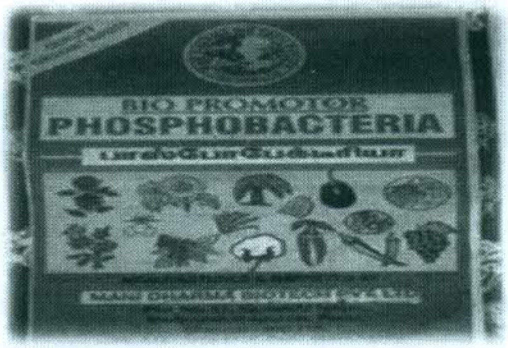
In the last century, chemical fertilizers were used in agriculture. Farmers were happy of getting increased yield in agriculture in the beginning.

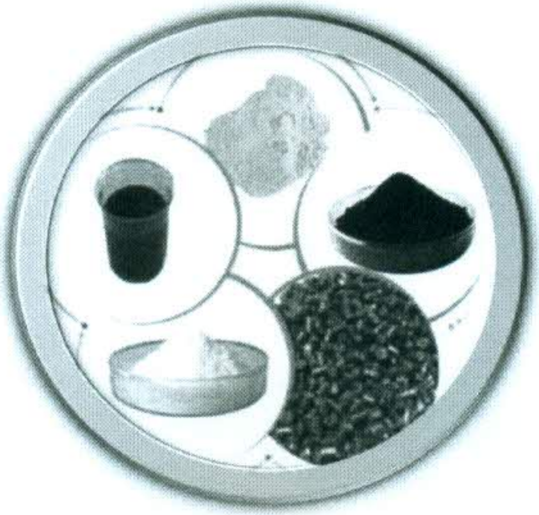
•But slowly chemical fertilizers started displaying their ill-effects such as:

- ❖ Leaching out
- ❖ Polluting water bodies
- ❖ Destroying micro-organisms and friendly insects
- ❖ Making the crop more susceptible to the attack of diseases
- ❖ Reducing the soil fertility and thus causing irreparable damage to the overall system

What is bio-fertilizer ?

Biofertilizers are groups of live and latent cell of microbes or micro-organism which are used to inoculate seed, plant surface and soil or all three which increase the production or productivity without impairing soil fertility.

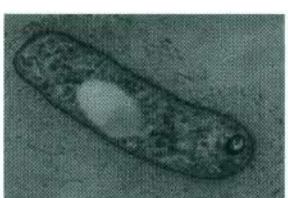




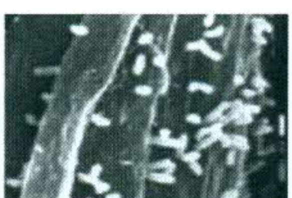
Concept of Biofertilizer

The term bio fertilizer refers to preparation containing live or latent cells of efficient strains of microbes which helps in enhancing the soil fertility by

- fixing atmospheric nitrogen,
- solublization of phosphorus or
- decomposing organic wastes or
- augmenting plant growth by producing growth hormones with their biological activities.



Rhizobium



Bacteria in root

Bacteria in root

Legume

Benefits from using biofertilizers

- Stimulate plant growth.
- Activate the soil biologically.
- Restore natural soil fertility.
- Provide protection against drought and some soil borne diseases.
- Increase crop yield by 20-30%. Cost effective.
- Supplements to fertilizers.
- Eco-friendly (Friendly with nature).
- Reduces the costs towards fertilizers use, especially regarding nitrogen and phosphorus

Role of biofertilizers for sustainable agriculture

Renewable source of nutrients.

Sustain soil health.

Supplement chemical fertilizers.

Replace 25-30% chemical fertilizers.

Increase the grain yields upto 10-40%.

Decompose plant residues and stabilize C:N ratio of soil.

Improve structure and water holding capacity of soil.

No adverse effect on plant growth and soil fertility.

Stimulates plant growth by secreting growth hormones.

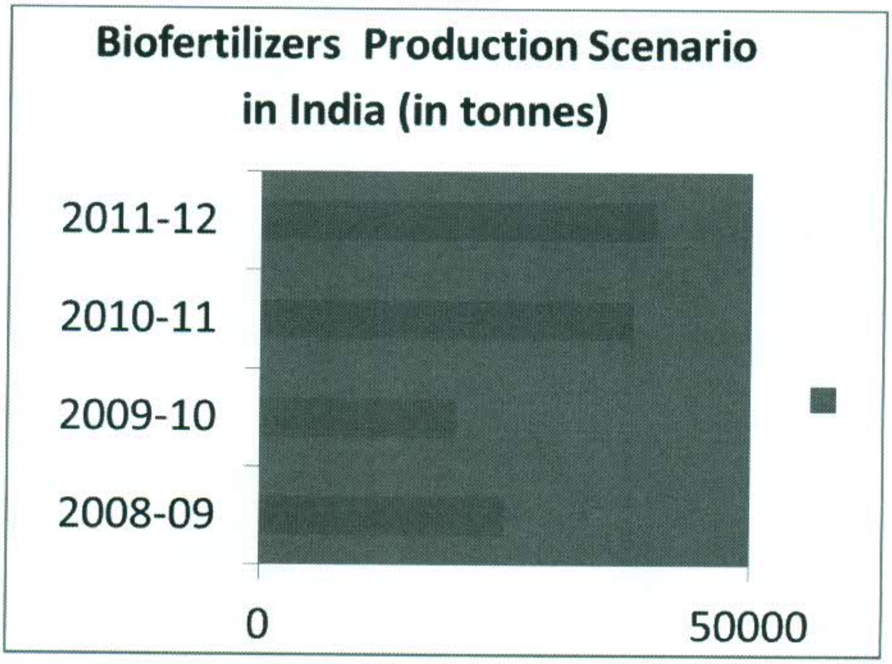
Secrete fungistatic and antibiotic like substances.

Solubilize and mobilize nutrients.

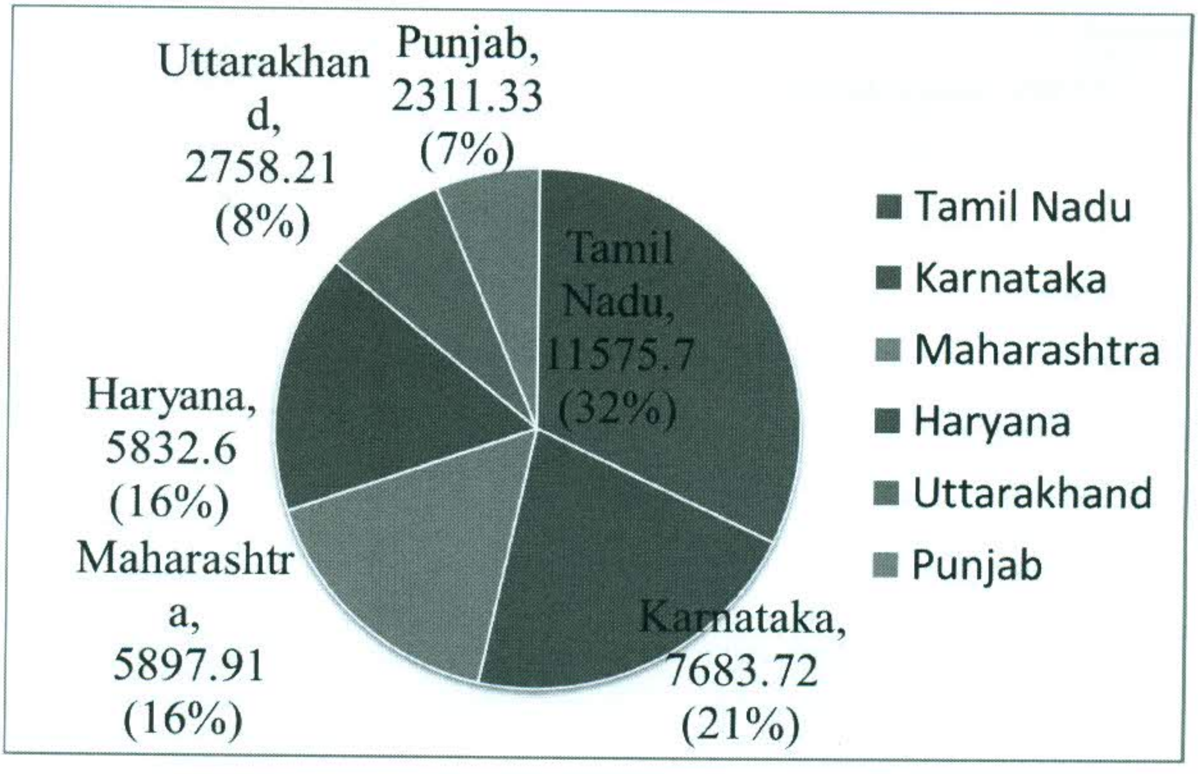
Eco-friendly, non-pollutants and cost effective.

Biofertilizers play a vital role in maintaining long term soil fertility and sustainability.

Biofertilizers Production Scenario in India (in tonnes)



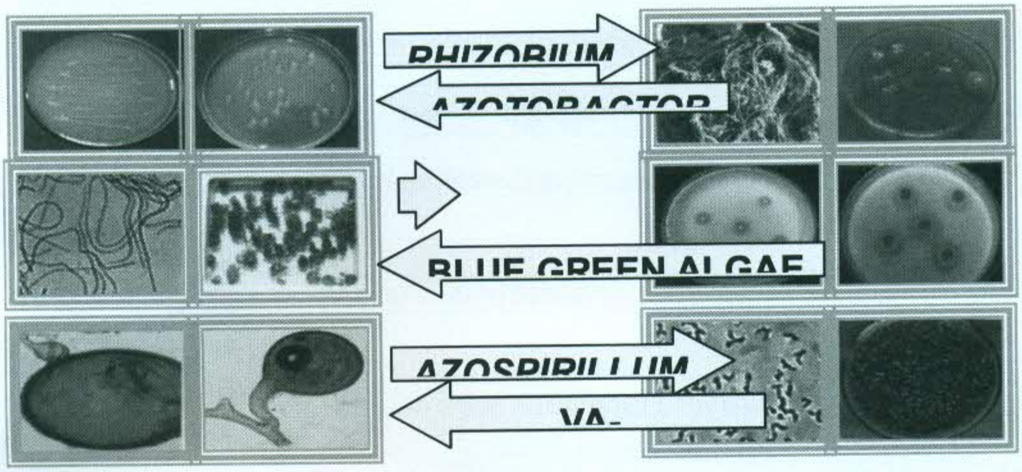
Production of biofertilizers in different states of India in tonnes (2012-13



Source: National Centre of Organic Farming, Department of Agriculture & Cooperation, 2014

Classification of Biofertilizer slide 10

BIOFERTILIZER ORGANISMS



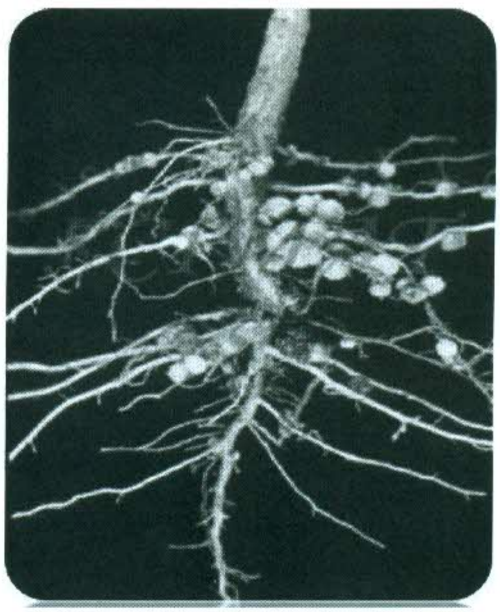
Suitable pH for microorganism

Microorganism	Optimum pH
Aerobic and heterotrophic	
Azotobacter	**6.5 – 8.0**
Beijerenkia	**5.0 – 9.0**
Phosphate solublizing bacteria	**6.5 – 7.7**
Phosphate solublizing fungi	**5.5 – 7.0**
Anaerobic and heterotrophic	
Clostridium	**5.0 - 9.0**
Nodule forming symbiotic	
Rhizobium	**6.5 – 7.5**
Frenkia	**6.5 – 8.5**
Non nodule forming symbiotic	
Azollae	**5.5 – 7.0**

Rhizobium

- That is 'slow growing rhizobia' known as ***Bradyrhizobium*** and the other group is 'fast growing rhizobia' called ***Rhizobium.***
- It is aerobic bacteria fixes atmospheric nitrogen in legumes symbiotically.
- ***Rhizobium*** lives in the root hairs of the legumes by forming nodules.
- *Rhizobium* enters the roots of legumes either through root hairs or at the point of emergence of lateral roots.

- The pink coloured nodules due to the presence of the pigment leghaemoglobin are called as effective nodules.
- This leghaemoglobin limits oxygen supply and helps the nitrogenase enzyme activity.
- **Recommended for**
- **Pulses** : chickpea, pea, lentil, blackgram, greengram, cowpea, pigeon pea.
- **Oil seeds**: soybean, groundnut.
- **Fodders** : berseem, lucern.
- Fixes 50-100 kg atmospheric nitrogen per hectare.
- **Increase in yield : 10-35%**



Genera and *species* of root nodule bacteria in legume

Genera and *Species*	Legume crops
Bradyrhizobium species	
B. japonicum	Soybean.
B. lupini	Lupine
Mesorhizobium species	
M. ciceri	Chickpea,
M. loti	*Trifolium*
Rhizobium species	
R. species	Moong, Redgram, Bengal gram, cowpea
R. leguminosarum	*Pisum* (pea), lentil.
R. phaseoli	Phaseolus (beans)
Sinorhizobium species	
S. meliloti	Alfalfa
S. saheli	*Sesbania*

Dosage of *Rhizobium* Inoculants

Dosage:

(A) 20 g of *Rhizobium* culture is require for 1 kg seed treat.

(B) For small seeded pulses like Moong, lentil, arher, berseem, Lucerne, kulthi, 500 g *Rhizobium* culture is sufficient for seed required to be sown in 1 ha.

(C) For groundnut, 1.5 kg *Rhizobium* culture for 80-100 kg seed for 1 ha.

(D) For soybean and Bengal gram 1 kg *Rhizobium* culture for 1 ha.

Table 1. Effect of biofertilizers on yield attributes, seed yield and harvest index of fieldpea

Treatments	Number of Pods plant^{-1}	No. of seeds pod^{-1}	Test weight (g)	Seed yield (q ha^{-1})	Harvest Index %
T_1= Control	6.78	4.83	177.40	10.81	28.58
T_2= *Rhizobium*	7.75	5.60	183.40	13.87	30.27
T_3= PSB	7.50	5.56	181.42	13.14	30.11
T_4= *Rhizobium* + PSB	9.07	6.30	189.07	15.01	32.62
SEm±	0.09	0.23	0.96	0.29	0.39
CD at 5 %	0.27	0.69	2.80	0.87	1.20

Haryana

Bhat and Gupta (2013)

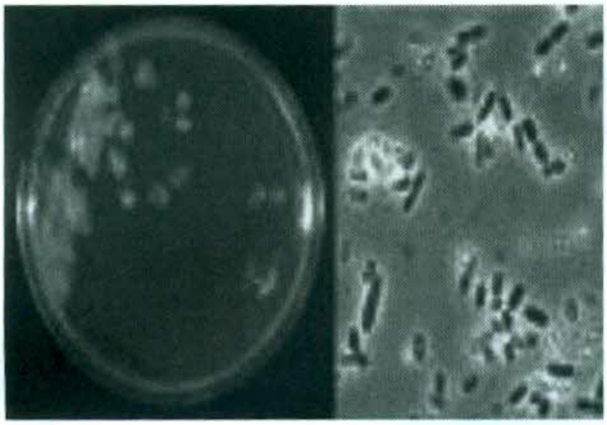
Azotobacter

- ***Azotobacter*** is a heterotrophic free living nitrogen fixing bacteria found in alkaline and neutral soils.
- ***Azotobacter chrococcum*** is the most commonly species occurring in arable soils of India.
- Apart from its ability to fix atmospheric nitrogen in soils, it can also **synthesize growth promoting substances *viz.*** auxins, and gibberellins and also to some extent the vitamins.
- Many strains of ***Azotobacter*** also exhibit fungicidal properties against certain species of fungus.
  - Fixes 10 to 20 kg N/ha.
  - It produces polysaccharides which improve soil aggregation.
  - It improves seed germination and plant growth.

Recommended for

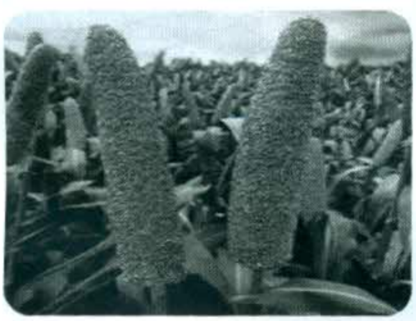
Rice, wheat, millets, other cereals, cotton, vegetable, sunflower, mustard and flowers.

Increase in yield: 15 to 30%



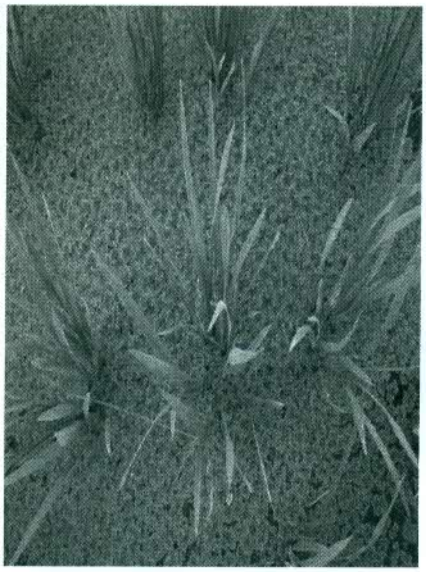
Azospirillum

- ❖ The bacteria have been found to live within the root of sorghum, bajra and ragi plants.
- ❖ They fix atmospheric nitrogen at the rate of 20-40 kg N/ha
- ❖ This bacteria also secretes growth promoting substances like IAA, GA.
- ❖ It is live in associative symbiosis with the host cereals and grasses.
- ❖ There are three common species *A. lipoferrum, A. brazillense, A. amazonese,.*



Azolla

- *Azolla* is a free-floating water fern that floats in water.
- Fixes atmospheric nitrogen in association with blue green algae *Anabaena azollae.*
- *Azolla* is used as biofertilizer for wetland rice
- It contribute 40-60 kg N/ha per rice crop.



Azolla Application

The *Azolla* biofertilizer may be applied in two ways for the wetland paddy.

A. *Azolla* biomass incorporation as green manure for rice crop **(Befor transplanting)**

- Apply fresh *Azolla* biomass (15 tha-^{1}) to the main field and incorporate by using implements or tractor.

B. *Azolla* inoculation as dual crop for rice **(After Transplanting)**

- Broadcast the fresh *Azolla* in the transplanted rice field on 7th day after planting (500 kg / ha).
- Maintain water level at 5-7.5cm.
- A second bloom of *Azolla* will develop 8 weeks after transplanting which may be incorporated again.

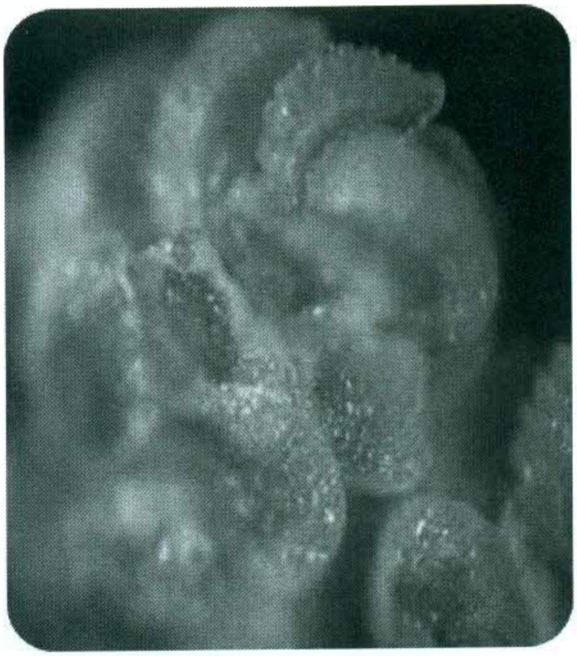
Advantages of *Azolla* application

1. Accommodate P and other nutrients and releases slowly.
2. Can be applied as a dual crop in paddy fields.
3. Suppresses weeds.
4. Use as mulch, compost, fish feed, cattle feed, etc.
5. Edible as vegetable- *Azolla thoran*, *Azolla vada*, etc.- rich in protein.

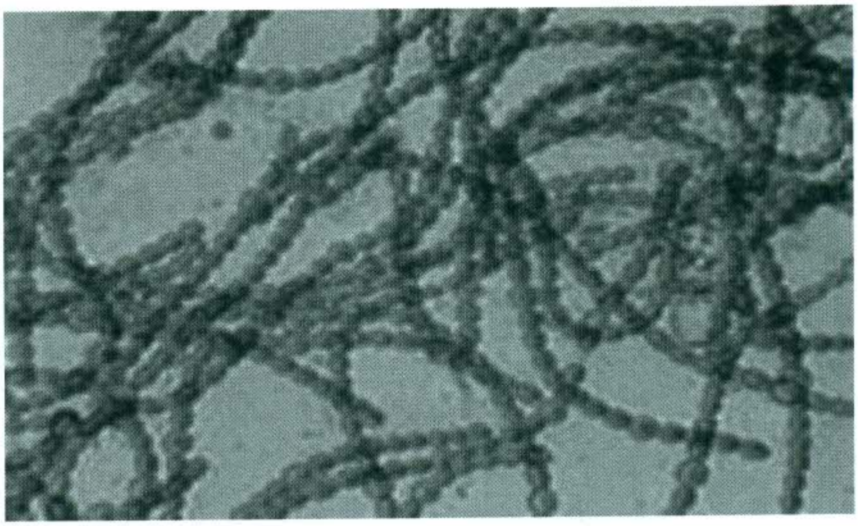
Helps in detoxify heavy metals and many other poll

Blue green algae (Cyanobacteria)

- BGA also called cyanobacteria .
- They having **heterocyst** are capable of fixing atmospheric nitrogen.
- The most important species are *Anabaena* and *Nostoc.*
- These micro-organisms suitable under flooded rice.
- BGA applied at @ 10 kg per ha.
- About 25-30 kg N/ha could added in rice.



Blue green algae (Cyanobacteria)

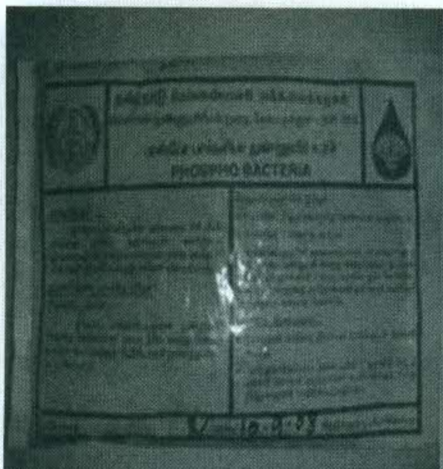


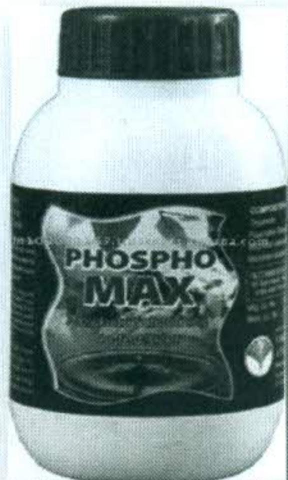
Phosphate Solubilizing Bacteria and Fungi

- A group of heterotrophic microorganism possesses the ability to solubilize organic P from **insoluble form to soluble forms.**
- **Bacteria:** *Bacillus megatherium, B. polymyxa,*
- *subtilis, Pseudomonas striata* etc.
- **Fungi:** *Aspergillus awamori, A. niger, Penicillum digitatum,* etc.
- **Recommended for :** All crops
- **Increase in yield: 10 to 20%**

❖ **Dosage**

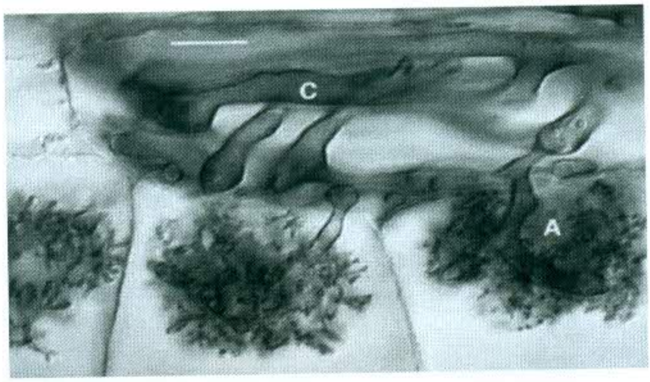
- **Use 5 to 10 g/kg of seed, 1 to 2 kg for soil application, 1 kg for root application(root dipping) of one acre of crop.**

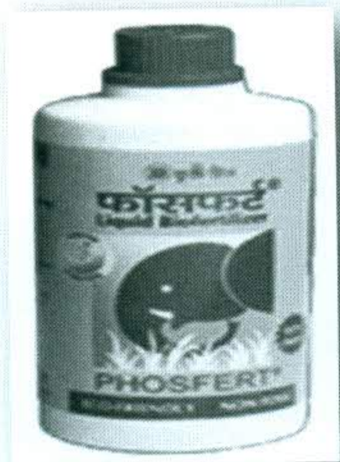




Vesicular Arbuscular Mycorrhiza (VAM)

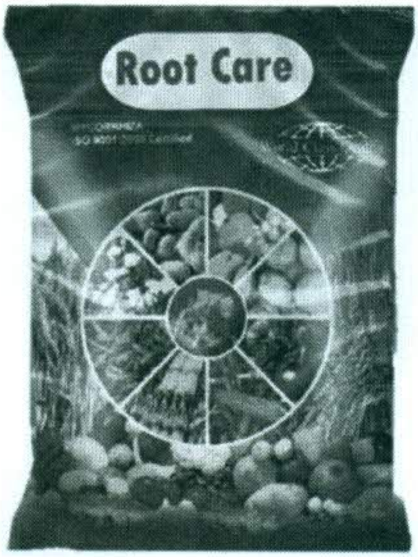
- ➢ The term mycorrhiza was taken from Greek language meaning 'fungus root'.
- ➢ VAM, a fungus colonize the plant root system.
- ➢ As indicated above, the mycorrhiza is a mutualistic association between fungal mycelia and plant roots.
- ➢ VAM help in nutrient transfer mainly of phosphorus, zinc and sulphur.
- ➢ The major genus is *Glomus. spp.*





Actions of Mycorrhiza

- Enhances the feeding areas of the plant root is as the hyphae spreads around the roots.
- Mobilizes the nutrients from distance to root.
- Stores the nutrients (sp. phosphorus).
- Removes the toxic chemicals (example : phenolics)
- Provide protection against other fungi and nematodes.



Plant Growth Promoting Rhizobacteria

- The group of bacteria that colonize roots or rhizosphere soil and beneficial to crops are referred to as plant growth promoting Rzobacteria (PGPR).
- The PGPR inoculants currently commercialized that seem to promote growth through at least one mechanism,
- Suppression of plant disease (termed Bio protectants).
- Improved nutrient acquisition (termed Biofertilizers),
- or phytohormone production (termed Biostimulants).
- These PGPR are referred to as Bio stimulants and the phytohormones they produce indole-acetic acid, cytokinins, gibberellins and inhibitors of ethylene production.

Liquid Biofertilizers

- Liquid bio-fertilizers are special liquid formulation containing not only the desired microorganisms and their nutrients but also special cell protectants that promote formation of resting spores for longer shelf life and tolerance to adverse conditions. (Hegde, 2008).
- Bio-fertilizers manufactured in India are mostly carrier based and in the carrier-based (solid) bio-fertilizers, the microorganisms have a shelf life of only six months. They are not tolerant to UV rays and temperature more than 30 ^{0}C.

Advantages of Liquid Bio-fertilizer over conventional carrier based Bio-fertilizers

- Longer shelf life 12-24 months.
- No contamination.

- No loss of properties due to storage up to 45° C.
- Easy identification by typical fermented smell.
- Better survival on seeds and soil.
- Very much easy to use by the farmer.
- Dosages is 10 time less than carrier based Bio-fertilizers.
- High commercial revenues.
- High export potential.
- Very high enzymatic activity.

Dosage and application of liquid Bio-fertilizers in different crops

Crop	Recommended Bio-fertilizer	Application method	Quantity to be used
Pulses, Chickpea, Pea, Groundnut, Soybean, Beans, Lentil, Lucern, Berseem, Green gram, Black gram, Cowpea and Pigeon pea	*Rhizobium*	Seed treatment	200-500 ml/acre
Wheat, Pearlmillet, other cereals, Mastard, Sesamum Cotton, Castor and Vegetables.	*Azotobzcter/ Azospirillum*	Seed treatment	200-500 ml/acre
Leguminous plants/ trees	*Rhizobium*	Soil treatment	1-2 ml/plant

Biofertilizer application by drip irrigation:

Drip irrigation application, mix about one litre of liquid biofertilizer (Nitrofix) in 100 litres of chemicals free, good quality water. Filter the mixture with a pure cloth, use the filtered solution in drip irrigation for one acre.

Bio-fertilizers application by different methods

Seed treatment

Soil treatment

Root dipping

Drip irrigation application

Table 2. Dry pod weight, and kernel yield of groundnut as influenced by plant growth promoting *Rhizobacteria* under rainfed conditions

Treatments	Dry pod weight (g plant^{-1})	Dry pod yield (kg ha^{-1})	Kernel yield (kg ha^{-1})
T_1 = Control	23.371	2597	1898
T_2 = $PGPR_1$	24.283	2797	2103
T_3 = $PGPR_2$	24.762	2834	2131
T_4 = $PGPR_4$	25.533	2858	2179
T_5 = $PGPR_1$ + $PGPR_2$ + $PGPR_4$	24.972	2914	2195
SEm±	0.460	34.99	27.86
LSD (0.05)	1.321	100	80

Dharwad Lokanath, ***et al.*** **2004**

Table 3: Yield attributes and yield of rice as influenced by different N sources and their integration with *Azolla* and vermicompost.

Treatments	Effective tillers/m^2	Filled grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)
T_1 = Control	49.98	67.39	4.16	4.59
$T_2 = V_{60}$	52.71	73.65	4.63	5.00
$T_3 = U_{40} + V_{20}$	57.28	78.46	5.19	5.58
$T_4 = U_{20} + V_{40}$	55.15	75.55	4.91	5.45
T_5 = Azolla	53.23	73.90	4.61	5.00
$T_6 = V_{60}$ + Azolla	53.35	75.19	4.74	5.18
$T_7 = U_{20} + V_{40}$ + Azolla	55.86	76.65	4.98	5.50
T8 = $U_{40} + V_{20}$ + Azolla	59.35	80.40	5.45	6.01
$T_9 = U_{60}$ + Azolla	**60.50**	**83.98**	**5.70**	**6.24**
CD at 5 %	2.95	4.35	0.38	0.38

U –Urea; V- Vermicompost Imphal, Manipur Singh *et al.* 2005

Table 4. Response of *Azospirillum* inoculation on grain yield pot^{-1} (five hills pot^{-1}) in rice cultivars at two nitrogen levels. Each value is mean of three replicates in pots.

Cultivars	Grain yield pot^{-1}(g)					
	0 Kg N ha^{-1}			50 Kg N ha^{-1}		
	T_1	T_2	T_3	T_1	T_2	T_3
BPT- 5204	65.70 (43.36)	72.00 (47.52)	73.30 (48.37)	80.00 (52.8)	85.30 (56.29)	87.70 (57.88)
Sarjoo- 52	54.70 (36.10)	67.30 (44.41)	68.00 (44.88)	73.30 (48.37)	79.00 (52.14)	81.00 (53.46)
NDR-97	60.00 (39.60)	65.70 (43.36)	67.30 (44.41)	70.30 (46.39)	75.70 (49.96)	77.70 (51.28)
Pusa Basmati	35.00 (23.10)	39.30 (25.93)	41.00 (27.06)	42.30 (27.91)	48.70 (32.14)	50.00 (33.00)
MTU -7029	65.70 (43.36)	76.00 (50.16)	76.30 (50.35)	80.70 (53.26)	86.30 (56.15)	88.00 (58.08)
HUR- 36	50.70 (33.46)	57.00 (37.62)	57.3 (37.81)	59.30 (39.13)	65.70 (43.36)	67.00 (44.22)

CD at P 0.05 = 2.45 g. Value in parenthesis denotes value of grain yield q ha^{-1} (pot size = 0.15 sq.m.)

T_1 = Control (without *Azospirillum* coating) ; T_2 = Seed coating with standard *Azospirillum* Biofertilizer strain (IARI)

T_3 = Seed coating with local isolate strain of *Azospirillum*

BHU- Varanasi Singh, *et.al.*, 2008

Table 5. Effect of seed treatment with biofertilizer on yield, weight and quality of *Arachis hypogea*

Treatment	Pods/plant	Pod yield/ plant (g)	Protein content (%)	Oil content (%)
T_1= Control(NPK)	19.5	44.0	22.1	51.12
T_2 = A+B+ *Azotobacter*	20.0	37.1	22.7	52.08
T_3 = A+B+ BGA	22.4	48.8	23.4	53.28
T_4= A+B+ *Azospirillum*	21.3	53.0	23.2	53.48
T_5= A+B+ *Azospirillum* + *Azotobacter*	21.8	54.5	23.0	52.1
T_6= A+B+ + BGA+ *Azotobacter*	24.0	60.9	24.2	52.64
T_7= A+B+ + BGA+ *Azospirillum.*	27.4	90.5	25.8	56.46
T_8=A+B+BGA+ *Azotobacter+Azospirillum*	**30.5**	**108.7**	**26.3**	**57.2**

Tamil Nadu, A+B= 75% FYM + 25% NPK. Sujanya *et al.* 2011

Table 6: Biofertilizer inoculation effect on seed cotton yield and yield parameters of cotton.

Treatments	Seed cotton Yield ($kg\ ha^{-1}$)		No. of bolls $plant^{-1}$	
kg P ha^{-1}	Un-inoculated	inoculated	Un- inoculated	inoculated
T_1 = 30	1377.7	1489.0	29	34
T_2 = 60	1544.3	1666.7	32	36
T_3 = 90	1611.3	1733.3	32	37
LSD (0.05)	107.25		3.489	

Faisalabad, Qureshi *et al.*(2012)

Table 7: Growth ,Yield and Oil % of sunflower as influenced by biofertilizers. (Pooled data 2 year)

Treatments	Seed yields (kg ha-1)	Biological yield (kg ha-1)	No. of filled seed capitulum	Oil yield (kg ha-1)	Test weight (gm)
T_1 = *Azotobacter*	1969	7512	418.5	622	47.11
T_2 = PSB + *Azotobacter*	2342	8587	471.1	780	49.05
T_3 = VAM + *Azotobacter*	2648	9216	507.3	918	50.13
T_4 = PSB + VAM + *Azotobacter*	3225	10289	567.6	1210	53.84
SEm (±)	**44**	**103**	**4.6**	**14**	**0.40**
CD at 5 %	**127**	**297**	**13.2**	**40**	**1.15**

West Bengal, Pramanik and Bera (2013

Table 8: Effect of bio-fertilizer inoculation on physiochemical parameters of soil (*Vigna mungo)*

Treatment	pH	Available N (kg/ha)	vailable P (kg/ha)	Available K (kg/ha)
Before sowing	7.58	113.5	4.7	99.7
After harvesting				
T_1 = Control	7.60	116.2	5.8	110.3
T_2 = *Rhizobium*	7.34	158.2	8.1	121.2
T_3 = *Phosphobacteria*	7.41	151.1	9.7	123.1
T_4 = *Rhizobium* + *Phosphobacteria*	7.33	159.7	9.02	124.7

Jhansi, U. P, Dixit (2013)

Table 9: Effect of INM on grain and straw yield of rice and wheat

Treatments	Rice yield (t/ha.)		Wheat yield (t/ha.)	
	Grain	Straw	Grain	Straw
T_1 =Control	2.05	2.93	1.74	2.00
T_2 = Farmer practice(N100, P 40, K0)	3.68	5.33	3.00	3,78
T_3=T_3 100 % NPK Zn.	4.73	6.58	3.30	4.28
T_4 = T_3 + FYM 5 t/ha	5.11	7.16	3.48	4.44
T_5 = T_3 + PSB	5.01	7.13	3.37	4.32
T_6 = T_3 + BGA/ *Azotobacter*	5.07	7.24	3.41	4.36
T_7 = T_3 + BGA/ *Azotobacter* + PSB	5.16	7.35	3.46	4.40
T_8 = T_3 + BGA/ *Azotobacter* + PSB + FYM 5 t/ha	5.46	7.87	3.57	4.62
SEm±	0.12	0.18	0.15	0.09
CD at 5 %	0.24	0.36	0.30	0.19

Kanpur . U. P., Bahadur *et al.* (2013)

Table 10: Effect of bio-fertilizers on yield and quality of groundnut

Treatments	Kernel yield (kg/ha)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Biological Yield (kg/ha)	Oil content (%)	Protein Content (%)
T_1 = Control	1897	2923	4787	7709	47.80	24.91
T_2 = *Rhizobium*	2182	3170	5060	8230	48.80	25.56
T_3 = **PSB**	2084	3069	4934	8003	49.07	25.37
CD at 5%	92	80	157	181	0.95	0.31

Jaipur (Rajasthan), Pareek *et al.* (2013)

Table 11: Effect of bio-fertilizer application on growth, yield parameters and quality parameters of greengram

Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Seed yield(kg ha^{-1})	Stalk yield (kg ha^{-1})	Protein content (%)
Biofertilizer Uninoculated	16.34	9.65	1274.68	2000.72	20.12
PSB (Bio.) Inoculated	17.39	10.35	1350.19	2153.29	20.57
S.Em.±	0.336	0.187	26.359	44.318	0.124
CD at 5 %	0.954	0.531	74.917	125.959	0.351

Sardarkrushinagar, Gujarat, Patel *et al.* (2013)

Table 12: Quality and yield parameters of soybean as influenced by levels and sources of P and biofertilizers.

Treatments	Protein content (%)	Oil yield (t/ha)	Seed yield (t/ha)	Harvest Index (%)
T_1= Control	36.29	0.20	1.10	29.42
T_2=PSB + VAM	37.03	0.22	1.21	29.33
T_3=50% P as RP	37.14	0.22	1.23	30.17
T_4=50% P as RP + PSB + VAM	38.76	0.27	1.48	32.47
T_5=50% P as DAP	37.73	0.25	1.38	31.04
T_6=50% P as DAP + PSB + VAM	37.45	**0.28**	1.51	32.00
T_7=100% P as RP	37.72	0.26	1.40	30.46
T_8=100% P as RP + PSB + VAM	**38.89**	**0.28**	1.56	35.33
T9=100% P as DAP + PSB + VAM	38.86	0.28	1.55	34.35
SEm ±	0.18	0.004	0.02	0.41
CD (P=0.05)	0.52	0.01	0.06	1.18

IARI, New Delhi Munda *et. al.* (2013)

Table 13 . The effect of organic manures & biofertilizer combinations on grain , straw yield and protein content of wheat.

Treatment	**Grain yield ($t\ ha^{-1}$)**	**Straw yield ($t\ ha^{-1}$)**	**Protein content (%)**
T_1 = Control	2.4	4.9	6.99
T_2 = Farmyard manure (FYM)	3.4	5.7	8.47
T_3 = Green manure (GM)	3.8	6.0	8.65
T_4 = GM + biofertilizers (B)	4.1	6.3	8.74
T_5 = GM + FYM + B	4.6	6.6	9.26
SEd±	0.19	0.17	0.42
CD at 5 %	0.39	0.34	0.86

Pali (Rajasthan), Davari *et al.* (2014)

Probable reasons for getting poor responses of biofertilizers

- Ineffective microbial strain
- Insufficient microbial population
- High levels of contaminants
- May have been exposed to high temperatures or sun light
- Not following recommended methods and dosage
- Using simultaneously with inorganic fertilizers or pesticides
- Prevailing high soil temperatures and low soil moisture
- Acidity or Alkalinity in soil

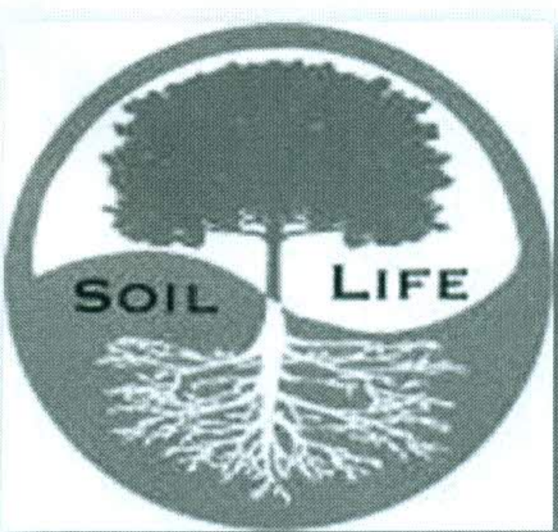
Tips for improving effectiveness of bioferilizers

Biofertilizers should be stored in a cool place or at room temperature (25°C to 28°C for longer shelf life). The simplest method is to store in a pitcher containing wet paddy straw.

- Avoid direct contact with chemical fertilizers, insecticides and pesticides during storage or application
- The storage and use of biofertilizers should be avoided in direct sunlight.
- The inoculant should be used before the expiry date.
- When fungicides and insecticides are to be used, apply fungicides before insecticides application. Apply biofertilizers after all other treatments, give a gap of 24 hrs.
- *Rhizobium* biofertilizer is specific to host crop, hence, only specific inoculant should be used for specific crop.

Conclusion

- Biofertilizers as it replaces part of chemical fertilizer use, reduces amount and cost of chemical fertilizers.
- Bio-fertilizers being essential components of organic farming play vital role in maintaining long term soil fertility and sustainability by fixing atmospheric nitrogen
- Combined application (N fixing and P solublizing) of biofertilizers increases the performance of both biofertilizers.
- Application of chemical fertilizers along with biofertilizers found more effective.
- Biofertilizers would play key role in productivity and sustainability of soil and also protect the environment as it is eco-friendly and cost effective inputs for the farmers.



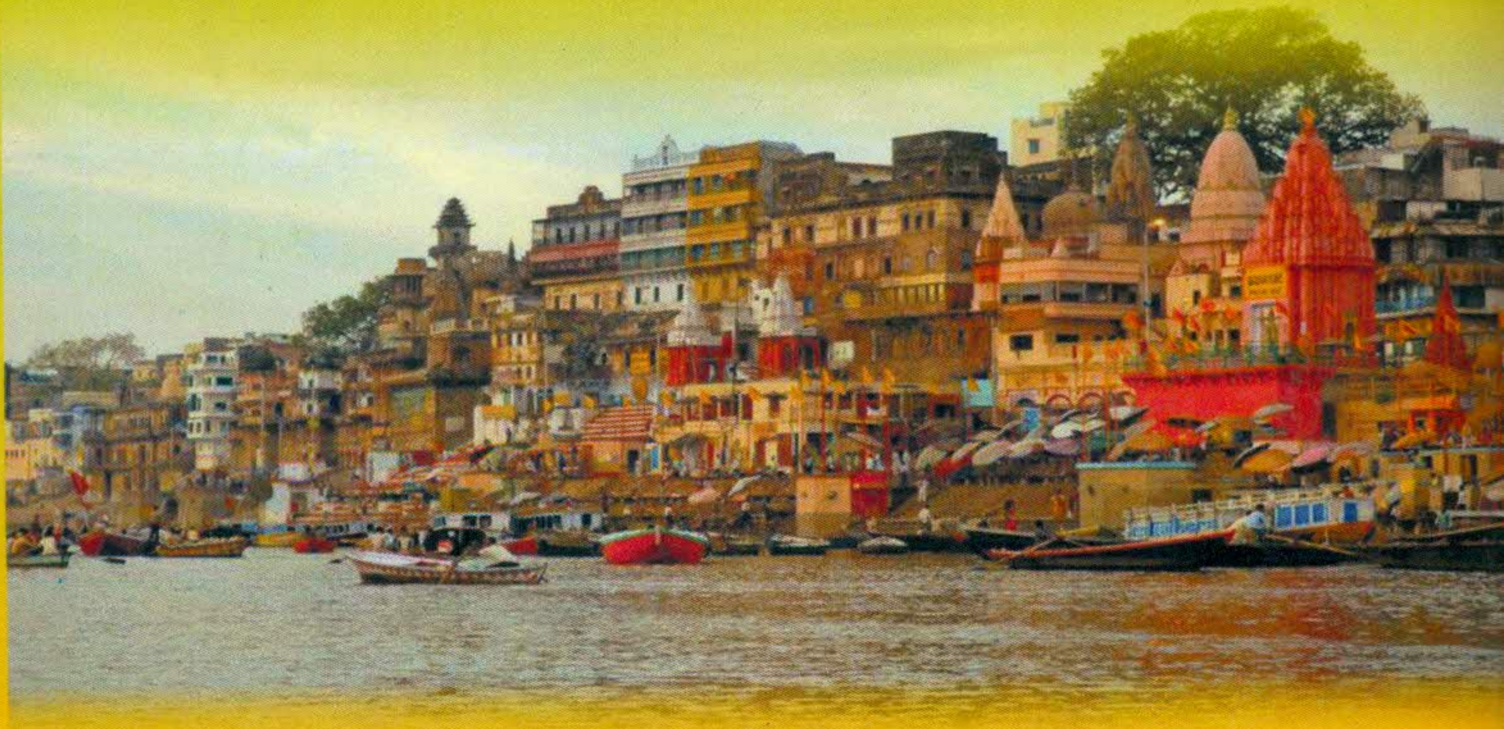
Future needs:

- There is necessary to develop strains of bacteria suitable for different crops in different agro climatic conditions and soil types to fully harness the benefit from the biofertilizers.
- There is need to put in greater effort in this direction to achieve better quality of inoculants by making necessary arrangements in storage and transport.
- The effect of biofertilizers on crop growth and yield is not as striking as that of chemical fertilizers. However on long term sustainability basis, biofertilizers has an important role.

About the first author

Ram Narayan Meena born on August 05, 1977 and permanent resident of Village-Bhaglav, Post-Shyalawas, Via-Paparda, Tehsil-Nangal Rajawataan, Distt.-Dausa (Rajasthan), received his B.Sc. (Ag.) and M.Sc. (Agronomy) from S.K.N. College of Agriculture, Jobner, S.K.R.A. University, Bikaner and Ph.D. in Agronomy from Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (India).

Presently he is at the post of Assistant Professor (Stage-2), Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (India).



Publisher
SRIJAN SAMITI PUBLICATION
H.No. 498, Kakarmatta (South), Post-D.L.W., Varanasi-221004
Cell : 09415388337 / E-mail : srijansamiti@rediffmail.com

ISBN 978-93-83583-38-6