ORGANIC FARMING

Organic farming or organic agriculture is a farming system that makes use of techniques of soil care and cropping which are dependent on biological processes for sustainable food production through the use of local resources.

Organic farming differs from other farming systems in a number of ways. It favours renewable resources and recycling, returning to the soil the nutrients found in waste products. Where livestock is concerned, meat and poultry production is regulated with particular concern for animal welfare and by using natural foodstuffs. Organic farming respects the environment's own systems for controlling pests and disease in raising crops and livestock and avoids the use of synthetic pesticides, herbicides, chemical fertilisers, growth hormones, antibiotics or gene manipulation. Instead, organic farmers use a range of techniques that help sustain ecosystems and reduce pollution. It relies on developing biological diversity in the field to disrupt habitat for pest organisms, and the purposeful maintenance and replenishment of soil fertility.

In developed countries, there are standard organizations that monitor the quality of products. A product has to be verified by independent state or private organizations accredited by the government, and be certified. A certified organic refers to agricultural products that has bee grown ad processed according to uniform standards. Organic foods may not be more nutritious than the conventionally produced foods but they are definitely freer from pesticide residues (13% vs 71%).

BIOLOGICAL TRANSFORMATION OF NITROGEN

- Nitrogen exists in many forms and the transformations of N into these different forms are mostly mediated by microbes.
- Nitrogen in the atmosphere can be fixed into the soil industrially (fertilizer manufacture), through lightning and by microorganisms.

Biological N fixation (BNF)

- Describes the conversion of gaseous N_2 (dinitrogen gas) into organic forms mediated by microorganisms.
- BNF is a process exclusively restricted to the prokaryotes of the domain bacteria.

BNF is accomplished by

1. free-living N_2-fixing bacteria which asymbiotically fix N in the soil. Organisms such as *Azotobacter*, *Azospirillium, Beijerinckia* etc
2. Cyanobacteria such as *Anabaena azollae*, a microsymbiont of water fern Azolla/lichen
3. symbiotic N fixing association between legumes and rhizobia e.g *Rhizobium japonicum* and soyabean
4. symbiotic association between actinorhizal plants (non legumes) and Frankia (actinobacteria/actinomycetes). Actinorrhizal plants examples are Alnus casuarinas

    - BNF is catalysed by the *Nitrogenase* enzyme which is present in nitrogen-fixing organisms.
    - BNF is a reduction process and can be represented by the following equation

$$N_2 + 6H^+ + 6e- \rightarrow 2NH_3$$

Mineralization of N

- The conversion of organic N into inorganic forms, NH_4^+ (ammonium) is termed as mineralization of N.
- N mineralization involves two reactions which are **aminization** and **ammonification**.
- The NH_4^+ produced from ammonification is subject to several fates which include

1. conversion to NO_2^- and NO_3^- by the process of nitrification
2. absoption directly by plants
3. utilization by microorganisms (immobilization)
4. adsoption into clay lattice
5. Volatilization (slowly released back to the atmosphere as N_2).

- Mineralization of N involves diverse groups of aerobic and anaerobic bacteria, fungi and actinomycetes. Soil faunas also play important role in the mineralization process

Nitrification

This is the oxidation of NH3 or NH4+ to nitrite (NO2-) and nitrate (NO3-) mediated by bacteria that are called nitrifiers. Nitrification is used by several organisms as an energy source and it involves two steps. The first step is the conversion of NH4+ to NO2 which involves obligate autotrophic bacteria known as Nitrosomonas (Nitrosomonas communis, Nitrosomonas oligotropha).

$$2NH_4 + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+$$

Nitrosomonas

The second step is the conversion from NO2- to NO3- which involves another group of obligate autotrophic bacteria known as Nitrobacter.

$$2NO2- + O\ 2 \rightarrow 2NO3-$$

Nitrobacter

Immobilization

The incorporation of inorganic N into an organism is known as immobilization. It is the conversion of inorganic N (NH_4^+ or NO_3^-) to organic N and is basically the reverse of N mineralization. Immobilization can result in a decrease of simple plant available form of N in the soil. The extent of immobilization is controlled by C:N ratio. Immobilization is also carried out by arrays of aerobic and anaerobic bacteria, fungi and actinomycetes.

Denitrification

Denitrification is the reduction of soil nitrates to the N gases NO (nitric oxide), N_2O (nitrous oxide) and N_2. Most microorganisms that undertake denitrification (denitrifiers) do it when O_2 is otherwise unavailable such as in waterlogged condition. Few particular kind of facultative anaerobic organisms (but numerous in population) are responsible for denitrification and the active species belong to the genera *Pseudomonas, Bacillus* and *Clostridium*. Autotrophs such as *Thiobacillus denitrificans* and *T. thioparus* are also involved.

BIOLOGICAL TRANSFORMATION OF PHOSPHORUS

- Phosphorus (P) is the most limiting element for biological productivity apart from N.
- The P cycle is divided into two subcycles; the biological one and a geochemical cycle

P mineralization

Numerous soil microorganisms digest plant residues containing P and produce many organic P compounds in the soil. Organically bound P is not directly available to plants because it cannot be absorbed into cells in this form. Therefore, P must first be released from the organic molecules through mineralization. The final stage in the conversion of organically bound P to inorganic phosphate occurs through the action of phosphatase enzymes. These enzymes are produced by up to 70 – 80 % microbial populations which include bacteria like *Bacillus subtilis*, *Proteus* spp. and *Streptomyces* spp. and fungi such as *Aspergillus, Penicillium* and *Rhizopus* spp.

Immobilization of P

Soil microorganisms immobilize solution P and some P in plant residues as microbial P which later produce labile and stable organic P. The extent of P immobilization is affected by the C:P ratio of the organic materials being decomposed and the amount of available P in solution. Immobilization of P in soil by microorganisms may contribute to P deficiency of crop plants. P in soil may also be taken up by mycorrhizas and transferred to plants causing P to be immobilized in plants.

Solubilization of P

Some phosphate-solubilizing microorganisms have been identified. These organisms are capable of converting the insoluble rock phosphate into soluble form through the process of acidification, chelation, and exchange reactions. Examples of some of these organisms are *Aspergillus niger*, *Pseudomonads* spp.

Biological transformation of sulphur

Mineralization of sulphur

Mineralization of S is the conversion of organic S to inorganic SO_4^{2-}. Conversion processes of organic S to inorganic SO_4^{2-} involves many oxidation processes carried out by microorganisms and action of some enzymes. Mineralization occurs through various pathways which include direct aerobic mineralization during oxidation of C as energy source, anaerobic mineralization of organic matter, incomplete oxidation of organic S into inorganic compounds, biological oxidation of H_2S to sulphate via elemental S and sulphite.

Immobilization of sulphur

Immobilization of S is the conversion of inorganic S to organic S. It is a reduction process involving series of enzymatic reactions. It is usually referred to assimilatory sulphate reduction. Microbial decomposition of plant residues results in S immobilization when the C:S ratio is high (> 400:1).

Oxidation

Sulphur oxidation is a reaction used by some particular group of microorganisms to obtain energy. One of such group is the genus of autotrophic bacteria. The oxidation of sulphur produces sulphate SO_4^{2-}. The reaction is

$$S \rightarrow SO_3^{2-} \rightarrow SO_4^{2-}$$

Many species of autotrophic microorganisms oxidize reduced S compounds to elemental S but the species of Thiobacillus such as *T. denitrificans*, *T thiooxidans* and *T. ferrooxidans* deserves special mention as it produces sulphuric acids when elemental S is added to soil reducing soil pH to as low as 2.0 after prolonged incubation with the bacteria. The H_2SO_4 produced helps in nutrient mobilization by increasing the level of phosphate thereby enhancing phosphorus nutrition of plants. Oxidation of sulphur occurs in extreme environments such as hot sulphur spring, saline lakes under anaerobic conditions by organisms such as *Chlorobium*.

Reduction

Reduction of oxidized form of S particularly SO_4^{2-}, by microorganisms occur in two different ways.

1 **Assimilatory sulphate reduction.** This process may also be referred to immobilization. Sulphur is incorporated into cellular constituents such as S in amino acids and protein biosynthesis by microorganisms and plants.

2. **Dissimilatory sulphate reduction**: This is a process in which reduction of sulphates leads to the formation of sulphides (e.g. H_2S) as the end product. The process is mediated by anaerobic organotrophic bacteria of the *Desulfovibrio* and *Desulfotomaculum* group.

Sulphate reduction is not important in well aerated soil but waterlogged soil. The sulphate-reducing bacteria are regulator of variety of processes in anaerobic upland and wetland soils including organic matter turnover, biodegradation of chlorinated aromatic pollutants etc.

Root nodule bacteria

Several genera of root nodule bacteria exist in rhizosphere. These include rhizobial group that nodulate legumes (*Allorhizobium, Azorhizobium, bradyrhizobium, Mesorhizobium, Sinorrhizobium* and *Rhizobium)* and *Frankia* that nodulate non-leguminous plants.

Rhizobium is well known to establish a symbiotic association with legumes and fix nitrogen for the use by plant. Rhizobia exist primarily as soil saprophyte that are widely distributed and are found in the rhizosphere of plant roots. The process of establishing the symbiotic relationship is highly specific. One *Rhizobium* strain can infect certain species of legumes but not others e.g. Soybean has a specific symbiotic partner, it is only nodulated by *Bradyrhizodium japonicum* and this species nodulates only soybean. However, some promiscuous (nodulate with many rhizobial strains) soybean or legume species exist.

Nodulation process is regulated by highly complex chemical communications between the plant and the bacteria. Once bound to the root hair, the bacteria stimulate the hair to curl. Rhizobia then invade the root through the hair tip where they induce the formation of an infection thread. The infection thread branches and penetrates into the root cortex, where cortical cells divide and enlarge to form a prenodule in response to the rhizobial invasion. Rhizobia are released from the infection thread into root cortical cells and are enclosed within plant-derived membrane called the peribacteroid membrane. They remain physically isolated from the host cell cytoplasm. Each membrane-enclosed bacterium is referred to as a “symbiosome”. The bacteria continue to produce nod factors which stimulate the root cells to proliferate, eventually forming a root nodule. Each root nodule is packed with thousands of living *Rhizobium* bacteria, most of which are in the misshapen form known as bacteroids. An enzyme called **nitrogenase** catalyses the conversion of nitrogen gas to ammonia in nitrogen-fixing organisms. In legumes it only occurs within the bacteroids. The reaction requires hydrogen as well as energy from ATP.

Mycorrhizal Relationship

Mycorrhiza is the mutualistic symbiosis between soil borne fungi and roots of higher plants. The word was coined by Frank (1985) to describe the union of two different organisms to form single morphological organ in which the plant nourishes the fungus and the fungus the plant. The fungi are usually non pathogenic. The host plant provides the fungus with soluble carbon sources, and the fungus provides the host plant with an increased capacity to absorb water and nutrients from the soil.Based on the physical association of mycorrhizal fungi with plant roots, two main types are distinguished; Ectomycorrhizae and Endomycorrhizae

These two were further subdivided into seven kinds by Smith and Read (1997): (1)Arbuscular mycorrhizas (AM), (2) ectomycorrhizas, (3) ectendomycorrhizas, (4) arbutoid, (5) monotropid, (6) ericoid and (7) orchid mycorrhizae.

Ectomycorrhiza

Ectomycorrhizal fungi form symbioses with several gymnosperm and angiosperm species and belong to the Phylum Basidiomycota and Ascomycota. In ectomycorrhiza, arbutoid and monotropid mycorrhiza, infection may arise from existing mycorrhizal roots which act as point inoculum sources. Mycelia fan out into soil and when they contact an uninfected root hyphae aggregate to form strands or mantle over the surface of the root. Hyphae penetrate the root and proliferate within the intercellular space forming an Hartig net.

Arbuscular mycorrhiza

Arbuscular mycorrhiza (AM) is probably the most widespread terrestrial symbiosis. It is formed between obligate biotrophic fungi of the phylum Glomeromycota and roots of around 80% vascular plants. The name arbuscular is derived from the characteristic structures, the arbuscles, which occur within the cortical cells. Arbuscular mycorrhiza has three important components; the root itself, the fungal structure within the cells of the root and extra radical mycelium in the soil. The AM symbiosis initiates when fungal hyphae, arising from spores in the soil or adjacent colonized roots contact the root. The colonization process includes arrival of the fungus at the root, penetration and development of the infection, and its spread to other parts of the root. Formation of an appressorium (a swollen structure formed on the end of a spore germ tube in contact with the root) often occurs as a prelude to infection. Hyphae then penetrate the epidermal cells or pass between these cells and penetrate the outer cortical cells. Some of the important genera of AMF are *Glomus, Paraglomus*, *Gigaspora, Acaulospora, Entrophospora* and *Scutellospora*. Unlike ectomycorrhiza, AM are non-cultivable outside host plant. However, their internal structure can be observed in clear and stained root sample under light or stereo microscope.

Benefits of mycorrhizae

1. Enhanced nutrient uptake.
2. Improved tolerance to water stress
3. Disease tolerance in crop.
4. Improvement of soil structure.

Organic manures and wastes

Organic manures are materials largely of plant and animal origin in different states of decomposition that are added to soil to supply plant nutrients and improve soil physical properties. They are made from cattle dung, excreta of other animals, rural and urban composts, other animal wastes, crop residues, green manures and industrial organic wastes such as paper and sugar industries and sewage sludge. Organic manures are rich in water and C compounds but poorer in plant nutrients than inorganic manures.

Types of organic manures

1. **Farm yard manure**: This is the waste from mixed arable and livestock farming used to fertilize crops. It consists of animal excreta (cattle, goat and sheep dung and urine, poultry litters) mixed with bedding materials such as straw, wood chips, crop residues etc. Farm yard manure supplies both macro and micronutrients to plants.
2. **Crop residues**: These include plant parts that remain on land after crop harvest.
3. **Compost manure**: This is made by accelerating the rate of humification of plant and animal residues by microorganisms in well aerated condition.
4. **Green manure:** These are green plants used in fertilizing soil. Green manuring is the practice of ploughing in a quick-growing leafy crop before maturity. Leguminous plants are largely used as green manure due to their symbiotic N fixing capacity. Some non-leguminous plants may also used due to local availability, drought tolerance, quick growth and adaptation to adverse conditions e.g *Tithonia diversifolia*
5. **Slurry**: This is a suspension of dung in the urine and washing water coming from animal houses and milking parlours.

6. **Sewage sludge:** It is an end product of wastewater treatment process, consisting of solids separated from liquid raw sewage. Sewage sludges vary in condition from sticky materials containing half their weight of water to well dried powder, easy to handle and spread. Sludges are processed and transformed into biosolids using a number of complex treatments such as digestion, thickening, dewatering, drying, and lime/alkaline stabilisation. Digested sludges are fermented anaerobically to eliminate offensive odours and lower the count of pathogens and may safely be applied to the land. However, sustained heavy application of sludges may introduce pathogens into soil and/or raise heavy metals content such as Zn, Cu, Ni and Cd to levels that are detrimental to plants.

Benefits of organic manure to sustainable agriculture

1. It builds soil organic matter thus improving soil quality
2. It serves as nutrient reserves thus improving soil fertility
3. It improves soil physical properties like
4. It buffers against rapid changes in acidity, alkalinity and salinity of soil
5. It improves soil structure and reduces soil crusting
6. It provides energy substrate for microbial transformations.

Composition of manures

Organic manures vary in composition of their nutrients. Variability in elemental and composition among and within organic fertilizer types is due to factors such as differences in source (whether animal or plant origin), animal species or breed, population of animal, feed ration and conversion rate of animal, bedding material type and composition if present, climatic condition during manure accumulation, plant species or variety added as residues, age of plant material and environment of operation (industrial or domestic)

Soil Biotechnology

Soil biotechnology is the study and manipulation of soil microorganisms and their metabolic processes to optimize crop productivity. It involves the use of techniques of recombinant deoxyribonucleic acid (DNA) technology, gene transfer, embryo manipulation and transfer, plant regeneration, monoclonal antibodies and bioprocessing to generate unique organisms with new traits or organisms that have the potential to produce specific products. Soil biotechnology application in agriculture has played major role in

1. Improving the growth and yield of crops through application of bio-inoculants such as rhizobia, mycorrhiza and other plant growth promoting organisms.

2. Protecting crops against pests and diseases through the use of organisms such *Bacillus thuringiensis* (Bt) which is a microbial insecticide.
3. Remediating the soil of wide range of pollutants by using catabolic versatility of microorganisms to degrade or convert toxic compounds in the soil.

Biofertilization by Rhizobia inoculation

The introduction of rhizobium into soils through a carrier substance such as peat containing the organism onto the legume seed represents the earliest attempt at inoculation. Researchers are pursuing a no of different strategies to improve N fixation. They want to genetically engineer rhizobium to fix N more efficiently for their natural host legumes and to create rhizobium that could infect and fix N for other plants particularly cereals.

Biofertilization by Mycorrhizal inoculation

The root of most plant species in natural environment or in cultivation form symbiotic association, termed mycorrhiza, with specialised fungi. Inoculation of mycorrhizas is possible through the use of mycorrhizal inoculum which is usually a mixture of soil, plant root and mycorrhizal propagules (spores and hyphae or mycelium). Pure mycorrhizal inoculum contains only a species of mycorrhizal fungi while mixed inoculum contains two or more species of mycorrhizal fungi. Tree crops such as cocoa, citrus, apple and some forest trees are inoculated with mycorrhiza in the nursery to aid their vigour and establishment on the field. Annual crops like maize, wheat, yams and many horticultural crops are also inoculated during planting in pots and on the field. There are now commercial mycorrhizal inoculants being sold in many developed countries.

Genetically modified organisms (GMOs)

A genetically modified organism (GMO) is an organism whose genetic material has been altered using techniques generally known as recombinant DNA technology. The organism can be a plant or animal. GMOs are created when DNA molecules from different sources are combined into one molecule to create a new set of genes. This DNA is then transferred into an organism, giving it modified or novel genes. Transgenic organisms (GMOs which have inserted DNA that originated in a different species) and or cisgenic organisms (GMOs that contain no DNA from other species) are formed when genetic modification of organisms occurs.

There are environmental and health concerns about the use of GMOs especially modified microorganisms. It will soon be possible to engineer bacteria and viruses to produce deadly pathogens. This could open a new era in biological weapons in addition to the environmental problems that could result from the release of organisms into the environment. The environmental assessment of the widespread introduction of engineered microorganisms has only barely begun to receive attention.

Biodegradation of Pesticides

Pesticides are the chemical substances that kill pests and weeds. In the context of soil, pests are fungi, bacteria insects, worms, and nematodes etc. that cause damage to field crops. Thus, in broad sense pesticides are insecticides, fungicides, bactericides, herbicides and nematicides that are used to control or inhibit plant diseases and insect pests. From the agricultural point of view, longer persistence of pesticides leading to accumulation of residues in soil may result into the increased absorption of such toxic chemicals by plants to the level at which the consumption of plant products may prove deleterious or hazardous to human beings as well as livestock's.

Process of biodegradation of pesticides in soil

The process of degradation of pesticides and conversion into non-toxic compounds by microorganisms is known as “biodegradation”. Not all pesticides reaching the soil are biodegradable and such chemicals that show complete resistance to biodegradation are called “recalcitrant”. The biodegradation of compounds of pesticides is often a complex series of biochemical reactions and is often different when different microorganisms are involved.

Two major mechanisms are involved in pesticides degradation. In the first, pesticides are degraded by the organisms with **specific enzymes** which usually provide nutrient or energy benefits to the organism. In a process known as mineralization, microorganisms convert the organic molecule to obtain C and energy for growth and multiplication releasing inorganic form of nutrients or elements. In the process, the parent molecule becomes detoxicated by enzymatic reaction. In the second form of degradation, pesticides are degraded by the metabolic pathways which exist for other purposes i.e. pesticides compound is metabolized alongside the normal functioning of the cell virtually by accident, the process known as co-metabolism..

The chemical reactions leading to biodegradation of pesticides fall into several broad categories which include, detoxification, degradation**,** conjugation (complex formation or addition reaction), activation and **c**hanging the spectrum of toxicity.

Factors affecting biodegradation of pesticides

Biodegradation of pesticides is greatly influenced by the soil factors like moisture, temperature, pH and organic matter content, in addition to microbial population and pesticide solubility. The chemical structure of pesticides seriously affects its degradation.