CHAPTER

10

SOIL CONDITIONER AND FERTILIZER INDUSTRY

10.1 NECESSITY OF SOIL CONDITIONER

A soil conditioner is a material added to soil to improve its overall condition, especially plant growth and health and simultaneously it corrects the soil's deficiencies in structure and/or nutrients. It is also called a soil amendment. Physical conditions of soil such as porosity and permeability will be improved by using the materials for agriculture purpose, known as fertilizer. Here the type of conditioner depends on current soil composition and the type of plant. Some soils lack nutrients necessary for proper plant growth. Some examples of soil conditioner include peat, coffee grounds, compost tea, fertilizers, lime, and vermiculite and sphagnum moss. Beside this, mechanical property of soil also needs to be improved for some engineering aspects such as construction of dam, bridge etc. Thus the soil conditioner plays an important role to increase strength of soil.

10.2 ACTIVITIES OF SOIL CONDITIONER

Poor physical condition of soil can restrict water intake into the soil and subsequent movement, plant root development, and aeration of the soil. Producers and researchers alike are interested in improving the physical condition of the soil and, thus, enhance crop production. These goals can be accomplished in part through the use of good management techniques. In addition, there are amending materials that claim to improve the soil physical condition. Soil conditioners vary greatly in their composition, application rate, and expected or claimed mode of action. Claims for various products include, but are not limited to:

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- Increased water-holding capacity
- Reduced compaction and hardpan conditions
- Improved soil structure and aeration
- Alkali soil reclamation
- Increased availability of water to plants
- Better root development
- Improved tile drainage effectiveness
- Better chemical incorporation
- Higher yields and quality
- Release of "locked" nutrients

It is important to understand the nature, use and practical benefits of these products. Water-holding capacity, availability of water to plants, and drainage effectiveness are the three properties depending on porosity of soil. Porosity is influenced by presence of soil conditioner.

10.3 TYPES OF SOIL CONDITIONERS

Soil conditioners vary in both their origin and composition. Soil conditioners can be synthetic or naturally occurring; organic or inorganic.

Organic Soil Conditioners

Organic soil matter is defined as the organic fraction of the soil and includes plant and animal residues at various stages of decomposition, cells and tissues of organisms, and compounds synthesized by the soil organism population. Soil organic matter contains a wide array of compounds ranging from fats, carbohydrates and proteins to high molecular weight humic and fulvic acids. Both the diversity of compounds and the interaction of the different compounds are important in the beneficial effect attributed to organic matter. Soil organic matter is usually less than 10 per cent of the total weight of mineral soils. The beneficial effects of organic matter (humus) in the improvement or maintenance of soil physical properties has long been known. Soil organic matter serves as a reservoir for nutrients; improves soil structure, drainage, aeration, cation exchange capacity, buffering capacity, and water-holding capacity; and provides a source of food for microorganisms. Generally speaking, soils higher in organic matter have improved soil physical conditions as compared to similar soils lower in organic matter. For these reasons, many marketed soil conditioners try to emulate organic matter for improving soil physical properties.

The ratio of carbon to nitrogen (C:N ratio) of organic matter in surface soils commonly ranges between 8:1 and 15:1, with the median C:N ratio between 10:1 and 12:1. The C:N ratio of organic materials (Table 10.1) added to the soil is important in the availability of nitrogen and the rate of decay of the organic material. Competition for available nitrogen in the soil occurs when organic materials with wide or large C:N ratios are added to soil.

Table 10.1: Carbon:nitrogen ratios of organic material and soil microbes

	Material	*C:N ratio*
Crop residues	Clovers (mature)	20:1
	Alfalfa (young)	13:1
	Bluegrass	30:1
	Straw (small grain)	80:1
	Corn stalks	40:1
	Cattle manure	30:1
	Peat moss	58:1
	Sewage sludge	10-12:1
Soil microbes	Bacteria	5:1
	Fungi	10:1
	Actinomycetes	6:1
Sawdust	Pine	729:1
	Hardwood	295:1

Mineral Conditioners

Gypsum has long been recognized for its benefits on high sodium-containing soils. Gypsum is a mineral with the chemical composition $CaSO_4.2H_2O$. It occurs in nature as soft crystalline rock and varies in purity. Gypsum has been shown to displace exchangeable sodium from the cation exchange sites of soils high in sodium. With irrigation or dryland, gypsum can be used to reclaim saline areas or slick spots, soften and crumble alkali hard pans, supply calcium on low exchange capacity soils, and improve infiltration for some puddled soils. Gypsum is not recommended on soils containing native gypsum or areas irrigated with water containing abundant amounts of calcium and magnesium. The amount of gypsum to apply depends on the purity of the gypsum and the quantity of sodium present in the soil. Actual rates should be based on a salt-alkali soil test.

Table 10.2: Materials used as conditioners

Materials	*Use*
Lime	Used to make soil less acidic
Gypsum	Used to release nutrients and improve soil structure
Peat, clay, vermiculite	Helps to make soil hold more water
Fertilizers	Digestate or compost adds depleted plant nutrients
Mulches	Used to help the soil retain moisture and nutrients so that plants remain healthy

Many soil conditioners are designed to improve soil structure in some way. Soils tend to become compacted over time, which is bad for plants, and soil conditioners can add more loft and texture to keep the soil loose. They also add nutrients, enriching the soil and allowing plants to grow bigger and stronger. Soil conditioners may be used to improve water retention in dry, coarse soils which are not holding water well, and they can be added to adjust the pH of the soil to meet the needs of specific plants or to make highly acidic or alkaline soils more usable. Before applying soil conditioner, it is a good idea to perform soil testing to learn more about the composition and structure of the soil, as this testing will determine which conditioners will be more appropriate for the conditions.

Advantage of conditioners: Soil conditioners are added to improve the soil quality. It can be used to rebuild soils which have been damaged by improper management, to make poor soils more usable, and to maintain soils in peak condition. A wide variety of products can be used to manage soil quality.

Disadvantage of conditioners: Soil conditioners are not productive when they are added in excess; over fertilization can make some plants sick, and it also generates runoff into neighbouring waterways, which is harmful for the environment.

Examples: Compost can be produced at home, along with compost tea. Coffee grounds can often be obtained for free from restaurants and coffee houses. Some examples of soil conditioner include: bonemeal, peat, coir, manure, straw, vermiculite, sulfur, lime, blood meal, chemical fertilizers and sphagnum moss. Mulches are also a form of soil conditioner, as they are used to help the soil retain moisture and nutrients so that plants remain healthy.

10.4 MEASURING PHYSICAL PROPERTIES OF SOIL

A variety of soil physical measurements can be used to evaluate the effectiveness of soil conditioners. These measurements include infiltration rate, air permeability, porosity, aggregate stability, penetration resistance, or bulk density. Reliable standardized procedures are needed to compare and/or evaluate the effect of soil conditioners on soil physical properties. For example, many companies rely on penetrometer measurements to evaluate their product, but do not standardize their measurements with respect to moisture content or bulk density. Such non-standardized observations may easily lead to erroneous claims about the product. Also, be cautious of studies relying on measurements that are not easily quantified such as soil tilth, stickiness, tightness, or hardness.

Table 10.3: Some physical properties of soil

Physical properties	*Description*	*Controlling process*
Porosity	Porosity is a measure of the fraction of the volume of voids over the total volume in a material.	With presence of soil conditioner void space of a material can be altered.
Permeability	A measure of the ability of a material to transmit fluids.	Permeability depends on the porosity and so changing of porosity also alters the permeability.
Bulk density	It is defined as the mass of many particles of the material divided by the total volume they occupy.	With increase of porosity and permeability bulk density will be decreased. Soil conditioner plays an important role to increase the bulk density.
Infiltration rate	Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation.	Infiltration is the process by which water on the ground surface enters the soil. Connected void spaces are primary factor which is controlled by presence of porosity.
Aggregate stability	Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces are applied.	Aggregation affect erosion and movement of water. Desirable aggregates are stable against rainfall and water movement. Pore space between aggregates are essential for water and air entry and exchange. These pore space provides zones of weakness through which plant root can grow. Aggregation is less important where rock has low bulk density with large pore space.

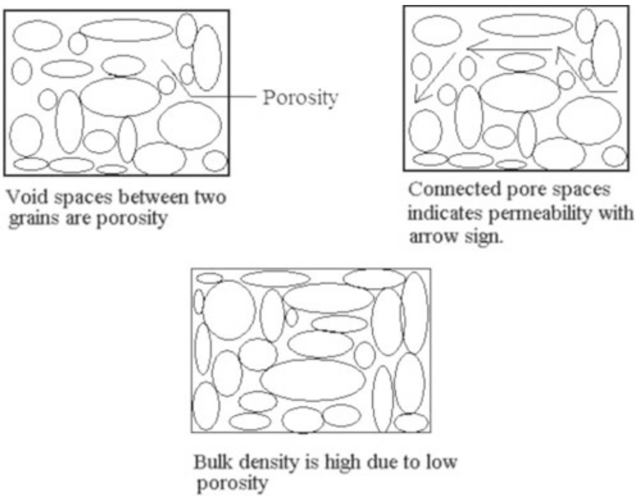

Fig. 10.1: Diagrammatical representation of physical properties of soil.

10.5 CHANGING PHYSICAL PROPERTIES OF SOIL

A wide variety of conditioners, which claim to improve a number of soil physical properties, are commercially available today. Some of the claimed benefits include improved water holding capacity, infiltration, drainage, soil structure, aeration, aggregate stability, organic matter content, and certain chemical properties. The interrelating nature of these soil properties makes it difficult to single out the exact effect of a specific soil conditioner. All conditioner promotions, however, imply improved plant growth in response to their soil conditioning effect. Soil conditioners will not behave in the same manner and with the same results on all soil types. Different soil types vary greatly in physical, chemical and biological properties, which influence the effectiveness of soil conditioners. For instance, gypsum may improve infiltration on high-sodium soils but may be of no benefit on non-sodic soils or soils already high in gypsum. The addition of large amounts of organic material will be more effective on soils with very low organic matter levels than on higher organic matter soils. It is very important to know the soil properties under which the product was evaluated. Recommended application rates of soil conditioners range from less than a pound/acre for some synthetic or biological soil conditioners to several tons/acre for gypsum or manure. For soil conditioners that attempt to emulate soil organic matter, the application rate should be evaluated in comparison to the amount of organic matter already present in the soil.

10.6 FERTILIZER

Fertilizer is any organic or inorganic material of natural or synthetic origin that is added to a soil to increase fertility of soil as it supplies one or more plant nutrients essential to the growth of plants. Fertilizers provide six macronutrients and seven micronutrients in varying proportions:

Six macronutrients: Nitrogen (N), potassium (K), phosphorous (P), sulphur (S), magnesium (Mg), calcium (Ca)

Seven micronutrients: Chloride (Cl), boron (B), manganese (Mn), iron (Fe), copper (Cu), molybdenum (Mo), zinc (Zn)

Only three other macronutrients are required by all plants: carbon, hydrogen and oxygen. The macronutrients are consumed in large quantities and present in plant tissues and micronutrients are consumed in small quantities and also present in plant tissues.

Fertilizers come in various forms. The most typical form is granular fertilizer and the next most common form is liquid fertilizer. Some advantages of liquid fertilizer are its immediate effect. There are also slow-release fertilizers which reduce the problem of “burning” the plants due to excess nitrogen.

10.7 SEVERAL FUNCTIONS OF FERTILIZERS

1. It provides direct food for plants to promote plant growth.
2. It provides special food for specific plant and replenishes soil depletion.
3. It helps transform material and soil substance into more soluble form for the plant food.
4. It serves to neutralize unhealthy acidity or alkalinity of soil.
5. It gives strength to plant bodies to make them more vigorous and resistant to diseases.

The common fertilizer materials are given as:

1. Potash minerals
2. Nitrogen and nitrate bearing minerals
3. Phosphate minerals
4. Sulphur bearing minerals

Table 10.4: Various fertilizers with examples

Types of fertilizers	*Description*	*Example*
Potash minerals	The potash deposits have some modes of occurrences which are as marine evaporates, placer deposits etc. K is a constant of such common minerals such as orthoclase feldspar, muscovite, mica etc. While micas are resistant to weathering, orthoclase feldspar becomes decomposed very easily and its potassium content is then carried away in solution by running water and deposited along with bed in sea. Due to evaporation of sea water, large amount of K salts remain as residual product.	Orthoclase feldspar
Nitrogen and nitrate minerals	The natural occurrences may be deposits of Na nitrate ($NaNO_3$) with minor amount of potassium nitrate (KNO_3). Ammonium sulphate, another source of nitrogen, is produced during the preparation of coal gas from coal. The nitrogen-rich fertilizer ammonium nitrate is also used as an oxidizing agent in improvised explosive devices, sometimes called fertilizer bombs, leading to sales regulations.	Potash Nitrate
Phosphate minerals	Phosphate is important for plants. It plays a vital role in photosynthesis, i.e. growth. So phosphates form an important group of fertilizers and usually are prepared from apatite by treatment with H_2SO_4. The sources of phosphate minerals may be marine sedimentary phosphate bed, phosphetic	Apatite

(*Contd.*)

Table 10.4 (*Contd.*)

Types of fertilizers	*Description*	*Example*
	modules and apaptite deposits. The most important occurrence are marine beds. Singhbhum nodules and trichinopally nodules form important occurrences.	
Sulphur bearing minerals	Raw sulphur dust and sulphuric acid are added to soil to neutralize alkalinity and to reduce S deficiency since sulphur is an important food for plant. S in the soil prevents the absorption of selenium by plants. Sulphur is chiefly used as sulphuric acid to form superphosphate by the action of phosphatic mineral with H_2SO_4.	Gypsum

10.8 FERTILIZATION OF SOILS

The use of manure for fertilizing the soil is probably as old as agriculture itself. The Romans had even a particular God, Sterculius, to preside over the protection of fertility of the soil. The use of commercial fertilizers is relatively of recent origin. Fertilizer consumption in India is 69 kg of plant nutrient per hectare of arable land. The common fertilizers and the nutrients they provide are shown in Table 10.5.

Table 10.5: Name of nutrients and their corresponding percentage

Name of nutrients	*Percentage of nutrients*
Sulphate of ammonia	20.5% N
Urea	45% N
Potassium chloride	39-42% K
Ammonium nitrate	35% N
Rock phosphate	11-15% P
Bone meal	7-13% P
Super phosphate	7-8% P
Basic slag	2-8% P

10.9 TYPES OF FERTILIZERS

Fertilizers are broadly divided into organic fertilizers and inorganic fertilizers.

Organic fertilizers: Composed of enriched organic matter—plant or animal.

Inorganic fertilizers: Composed of synthetic chemicals and/or minerals.

Inorganic Fertilizer (Synthetic Fertilizer)

Inorganic fertilizer is often synthesized using the Haber-Bosch process, which produces ammonia as the end product. This ammonia is used as a feedstock for other nitrogen fertilizers, such as anhydrous ammonium nitrate and urea. These concentrated products may be diluted with water to form a concentrated liquid fertilizer. Ammonia can be combined with rock phosphate and potassium fertilizer in the Odda Process to produce compound fertilizer.

10.10 DISADVANTAGES OF INORGANIC FERTILIZER

(a) Trace mineral depletion

Many inorganic fertilizers may not replace trace mineral elements in the soil which become gradually depleted by crops. Studies have linked this depletion with marked fall (up to 75%) in the quantities of such minerals present in fruits and vegetables.

(b) Over-fertilization

Over-fertilization of a vital nutrient can be as detrimental as under-fertilization. 'Fertilizer burn' can occur when too much fertilizer is applied, resulting in a drying out of the roots and damage or even death of the plant.

(c) High energy consumption

A 2002 report suggested that the production of ammonia consumes about 5% of global natural gas consumption, which is somewhat under 2% of world energy production. Ammonia is overwhelmingly produced from natural gas, but other energy sources, together with a hydrogen source, can be used for the production of nitrogen compounds suitable for fertilizers. The cost of natural gas makes up about 90% of the cost of producing ammonia. The increase in price of natural gases over the past decade, along with other factors such as increasing demand, have contributed to an increase in fertilizer price.

(d) Long-term sustainability

Inorganic fertilizers are now produced in ways which theoretically cannot be continued indefinitely by definition as the resources used in their production are non-renewable. Potassium and phosphorus come from mines and such resources are limited. However, more effective fertilizer utilization practices may decrease present usage from mines. Improved knowledge of crop production practices can potentially decrease fertilizer usage of P and K without reducing the critical need to improve and increase crop yields. Artificial nitrogen fertilizers are typically synthesized using fossil fuels such as natural gas and coal, which are limited resources.

10.11 ORGANIC FERTILIZER

Organic fertilizers include naturally occurring organic materials (e.g. worm castings, seaweed), or naturally occurring mineral deposits.

(a) Benefits of organic fertilizer

Organic fertilizers have been known to improve biodiversity (soil life) and long-term productivity of soil, and may prove a large depository for excess carbon dioxide.

Organic nutrients increase the abundance of soil organisms by providing organic matter and micronutrients for organisms and can drastically reduce external inputs of pesticides, energy and fertilizer, at the cost of decreased yield.

(b) Disadvantages of organic fertilizers

- Organic fertilizers may contain pathogens and other disease causing organisms if not properly composted.
- Nutrient contents are very variable and their release to available forms that the plant can use may not occur at the right plant growth stage.
- More expensive to produce.

(c) Example of organic fertilizer

- Chicken litter, which consists of chicken manure mixed with sawdust, is an organic fertilizer. Researchers at the Agricultural Research Service (ARS) studied the effects of using chicken litter, an organic fertilizer, versus synthetic fertilizers on cotton fields, and found that fields fertilized with chicken litter had a 12% increase in cotton yields over fields fertilized with synthetic fertilizer.
- Other ARS studies have found that algae used to capture nitrogen and phosphorus runoff from agricultural fields cannot only prevent water contamination of these nutrients, but also can be used as an organic fertilizer.

(d) Organic fertilizer sources

1. **Animal:** Animal-sourced and human urea are suitable for application in organic agriculture, while pure synthetic forms of urea are not. The common object that can be seen through these examples is that organic agriculture attempts to define itself through minimal processing (in contrast to the man-made Haber process), as well as being naturally occurring or via natural biological processes such as composting.
2. **Plant:** Leguminous cover crops are also grown to enrich soil as a green manure through nitrogen fixation from the atmosphere, as well as phosphorus content of soils.

3. **Mineral:** Mined powdered limestone, rock phosphate and sodium nitrate are inorganic compounds which are energetically intensive to harvest and are approved for usage in organic agriculture in minimal amounts.

10.12 NEGATIVE ENVIRONMENTAL EFFECTS

Eutrophication

The nitrogen-rich compounds found in fertilizer runoff is the primary cause of a serious depletion of oxygen in many parts of the ocean, especially in coastal zones; the resulting lack of dissolved oxygen is greatly reducing the ability of these areas to sustain oceanic fauna.

Blue baby syndrome

High application rates of inorganic nitrogen fertilizers in order to maximize crop yields, combined with the high solubilities of these fertilizers, leads to increased runoff into surface water as well as leaching into ground water. The use of ammonium nitrate in *inorganic fertilizers* is particularly damaging, as plants absorb ammonium ions preferentially over nitrate ions, while excess nitrate ions which are not absorbed dissolve (by rain or irrigation) into run off or ground water.

Soil acidification

Nitrogen-containing inorganic and organic fertilizers can cause soil acidification. This may lead to decrease in nutrient availability.

Heavy metal accumulation

The concentration of up to 100 mg/kg of cadmium in phosphate minerals increases the contamination of soil with cadmium. Steel industry wastes, recycled into fertilizers for their high levels of zinc (essential to plant growth), can include the toxic metals: lead, arsenic and cadmium. The most common toxic elements in this type of fertilizer are mercury, lead, and arsenic.

Radioactive element accumulation

Uranium is another example of a contaminant often found in phosphate fertilizers. Also, highly radioactive Polonium-210 contained in phosphate fertilizers is absorbed by the roots of plants and stored in its tissues; tobacco derived from plants fertilized by rock phosphates contains Polonium-210 which emits alpha radiation estimated to cause lung cancer.

Atmosphere

Methane emissions from crop fields (notably rice paddy fields) are increased by the application of ammonium-based fertilizers; these emissions contribute greatly to global climate change as methane is a potent greenhouse gas. Through the increasing use of nitrogen fertilizer, nitrous oxide (N_2O) has become the third most important greenhouse gas after carbon dioxide and methane. It has a global warming potential 296 times larger than an equal mass of carbon dioxide and it also contributes to stratospheric ozone depletion. Ammonia gas (NH_3) may be emitted following application of 'inorganic' fertilizers and/or manures and slurries. The use of fertilizers on a global scale emits significant quantities of greenhouse gases into the atmosphere. Emissions come about through the use of:

- animal manures and urea, which release nitrous oxide, ammonia and carbon dioxide in varying quantities, and
- fertilizers that use nitric acid, the production and application of which results in emissions of nitrous oxide, ammonia and carbon dioxide into the atmosphere.

QUESTIONS

1. What are the differences between soil conditioners and fertilizers?
2. How does C:N ratio differ in various materials.
3. Give an idea about advantages and disadvantages in both aspects of soil conditioner.
4. How do you measure the physical properties of soil.
5. What are the six macronutrients and seven micronutrients provided by fertilizers?
6. What is the function of fertilizers?
7. Briefly describe the activities of soil conditioner.
8. Give an idea about the sources of fertilizers.

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