B.Sc (Agriculture)

Optional course

SAC 451 Designer Fertiliser Production (1+1)

Theory Lecture Notes

Compiled by

Dr. V. Arunkumar

Dr.R.Indirani

Dr.C.Sudhalakshmi

Dr.M.Yuvaraj

2019-20

Lecture 1

Designer Fertilizers – Definition – Concepts – Historical Development

Background

Fertilizer is a substance added to soil to improve plants' growth and yield. First used by ancient farmers, fertilizer technology developed significantly as the chemical needs of growing plants were discovered. Modern synthetic fertilizers are composed mainly of nitrogen, phosphorous, and potassium compounds with secondary nutrients added. The use of synthetic fertilizers has significantly improved the quality and quantity of the food available today, although their long-term use is debated by environmentalists.

The process of adding substances to soil to improve its growing capacity was developed in the early days of agriculture. Ancient farmers knew that the first yields on a plot of land were much better than those of subsequent years. This caused them to move to new, uncultivated areas, which again showed the same pattern of reduced yields over time. Eventually it was discovered that plant growth on a plot of land could be improved by spreading animal manure throughout the soil.

The advent of chemical/mineral fertilizers is a post 1800 development. By and large, the history of fertilizers and their development revolves around the discovery and invention of some key materials/processes. These concern industrial nitrogen fixation into ammonia, search for suitable catalysts, urea synthesis, sulphur, phosphate rock, potash minerals, sulphuric acid and phosphoric acid. The major contributions were those of Liebig, Lawes, Haber, Bosch, Wohler, Johansen and Frasch. Foundations of the fertilizer industry were laid primarily in Germany, Norway, UK and North America. Over the years, fertilisers, the end product of their efforts have benefited billions of people not once or twice but on a sustained basis and will continue to do so.

The first known mineral fertilizer was sodium nitrate (16% N), also known as nitrate of soda or **Chilean nitrate**. It is considered as the first natural mineral containing fixed N and , the only natural source of nitrate N. Although its deposits were found in several countries, the source of real commercial significance was found in north Chile (South America), hence the name

Chilean nitrate. First commercial mining of this material was done in the early 19th century by the Spaniards. It was imported into Europe and America around 1830. Synthetic sodium nitrate was first produced in 1928 in the US. Now it can also be manufactured through one of several processes. At present, it is a fertilizer of small, localised and special applications but it is still used as a standard against which the salt index of various fertilizers is measured. Its salt index is taken as 100.

Birth of the Phosphates – Bone meal, SSP and Basic Slag

Crushed bones were one of the first P-rich materials to be used as a phosphatic fertilizer. Justus von Liebig of Germany treated powdered bones with sulphuric acid and found them to be more effective than untreated bones. When phosphate rock was not discovered, most probably, crushed bones were used to acidulate to produce SSP in the mid 1840s**.**Historically, there were four main players in the development of phosphate fertilizers. They were ***Liebig*** of Germany, ***Lawes and Henslow*** of U.K. and ***Murray*** of Ireland.

Superphospate:

Liebig was the first person to point out in 1840 that sulphuric acid added to ground bones gave a form of phosphate which was more quickly available to plants than raw bones. He is generally regarded as the inventor of single super phosphate (SSP), but James Murray of Dublin, Ireland can also take the credit for doing so.

It is generally accepted that JohnBennetLawes was the first person to make the manufacture of a fertilizer, in this case SSP(mono calcium phosphate with gypsum Ca CaH2PO4.CaSO4) a practical possibility. He took out a patent in 1842 for treating mineral phosphates with sulphuric acid. However, it seems that Sir James Murray of Ireland was the first one who produced a fertilizer in 1808, many years ahead of Lawes. His process was based on the acidulation of phosphorite (a rock consisting chiefly of calcium phosphate) with sulphuric acid. The first product he made was a liquid but followed it up with a solid fertilizer. Later, Lawes purchased Murray's patent to get any competition out of the way and amended it. Lawes's first product consisted of solid and insoluble phosphates derived from coprolites or guano mixed with animal remains. It resembled a product which was described as soluble bones at that time.

Soon after, in 1845, Prof Henslow discovered the beds of coprolite near Cambridge, UK. These consisted of small roundish nodules of impure calcium phosphate mixed with bones, shell and teeth of sharks etc. These contained about 60 percent calcium phosphate, 10 percent calcium carbonate and 3 percent calcium fluoride. The dictionary meaning of coprolite is “a stony roundish fossil, the petrified excrement of a vertebrate”. The quantities mined were almost wholly used to manufacture SSP.First superphosphate plant complete with a sulphuric acid production facility was built in 1854 by Packard at Ipswich, England**. *SSP was also the first fertilizer to be manufactured in India, in 1906, at Ranipet in Tamil Nadu.***

Basic Slag:

In 1877, S G. Thomas, a British engineer developed the process in which steel was made using P-rich iron minerals (24). During the process, by-product slag (containing lime and phosphate) was formed which after solidification and cooling, could be used to fertilise acid soils. Thus basic slag or Thomas slag as it was popularly called, came into being. Thomas slag became a very popular fertilizer in many parts of Europe.

Urea[$CO(NH_2)_2$] - The First Organic Compound Synthesized

Urea was the first organic compound to be synthesized from inorganic materials. It was first separated from urine by Rouelle in 1773, hence the name urea. In 1782, Prout separated pure crystalline urea. It was first synthesized by Friedrich Wohler (1800-1882) of Germany in 1828 by heating ammonium cyanate . According to another source , urea was first synthesized by reacting ammonia with cyanuric acid. In any case, the synthesis of urea by Wohler revolutionized the chemical technology scene in general and the fertilizer scene in particular to such an extent that he himself may not have expected. Commercial production of urea had to wait until 1922 after the large scale synthesis of ammonia was made possible by Fritz Haber (1868-1934) and Carl Bosch in 1910. The I.G. Farbenindustrie in Germany was the first company to synthesise urea commercially from ammonium carbamatein 1920. In 1922, large scale production of urea by the BASF process started. Urea now dominates the N fertilizer scene. In India, the first urea plant was set up in 1959 at Sindri in Bihar. In India urea accounts for more than 80% of thetotal fertilizer N consumed in agriculture (17.64 million tones during 2018-19).

Ammonia Synthesis

Ammonia gas was first produced by J. Priestly in 1754 by distilling ammonium chloride with quick lime. Although, Ammonium Sulphate (NH4(SO4)2 arrived on the scene in the later half of 19th century as a by product of the coke oven industry, synthesis of ammonia had to wait. By 1905, the idea of passing air through an electric arc was successfully developed in Norway to produce nitric acid. The path-breaking synthesis of ammonia in a reactor was achieved by two Germans Fritz Haber and Carl Bosch in 1910. The key link in ammonia synthesis was the search for a suitable and easily available catalyst. One of Bosch's colleagues was fortunate to find that red iron oxide was as good as the scarcely available osmium. In recognition of their contribution, Haber was awarded the Nobel Prize in 1918 and Bosch in 1931. In his acceptance speech at the Nobel Prize award ceremony, Carl Bosch disclosed that more than 20,000 experiments were needed to develop a useful catalyst for industrial use (21).

The first commercial plant for ammonia synthesis began operation in 1913 by BASF AG at Ludwigshafen-Oppau in Germany. Soon it yielded 30 tonnes of fixed N/day. This period and development can be considered as the starting point for large scale production of a variety of concentrated fertilizers containing nitrogen alone as in urea or an array of NP/NPK materials.

Like all living organisms, plants are made up of cells. Within these cells occur numerous metabolic chemical reactions that are responsible for growth and reproduction. Since plants do not eat food like animals, they depend on nutrients in the soil to provide the basic chemicals for these metabolic reactions. The supply of these components in soil is limited, however, and as plants are harvested, it dwindles, causing a reduction in the quality and yield of plants.

Fertilizers replace the chemical components that are taken from the soil by growing plants. However, they are also designed to improve the growing potential of soil, and fertilizers can create a better growing environment than natural soil. They can also be tailored to suit the type of crop that is being grown. Typically, fertilizers are composed of nitrogen, phosphorus, and potassium compounds. They also contain trace elements that improve the growth of plants.

The primary components in fertilizers are nutrients which are vital for plant growth. Plants use nitrogen in the synthesis of proteins, nucleic acids, and hormones. When plants are nitrogen deficient, they are marked by reduced growth and yellowing of leaves. Plants also need phosphorus, a component of nucleic acids, phospholipids, and several proteins. It is also necessary to provide the energy to drive metabolic chemical reactions. Without enough phosphorus, plant growth is reduced. Potassium is another major substance that plants get from the soil. It is used in protein synthesis and other key plant processes. Yellowing, spots of dead tissue, and weak stems and roots are all indicative of plants that lack enough potassium.

Calcium, magnesium, and sulfur are also important materials in plant growth. They are only included in fertilizers in small amounts, however, since most soils naturally contain enough of these components. Other materials are needed in relatively small amounts for plant growth. These micronutrients include iron, chlorine, copper, manganese, zinc, molybdenum, and boron, which primarily function as cofactors in enzymatic reactions. While they may be present in small amounts, these compounds are no less important to growth, and without them plants can die.

Different substances are used to provide the essential nutrients needed for an effective fertilizer. These compounds can be mined or isolated from naturally occurring sources. Examples include sodium nitrate, seaweed, bones, guano, potash, and phosphate rock. Compounds can also be chemically synthesized from basic raw materials. These would include such things as ammonia, urea, nitric acid, and ammonium phosphate. Since these compounds exist in a number of physical states, fertilizers can be sold as solids, liquids, or slurries.

Over time, fertilizer technology became more refined. New substances that improved the growth of plants were discovered. The Egyptians are known to have added ashes from burned weeds to soil. Ancient Greek and Roman writings indicate that various animal excrements were used, depending on the type of soil or plant grown. It was also known by this time that growing leguminous plants on plots prior to growing wheat was beneficial. Other types of materials added include sea-shells, clay, vegetable waste, waste from different manufacturing processes, and other assorted trash.

Organized research into fertilizer technology began in the early seventeenth century. Early scientists such as Francis Bacon and Johann Glauber describe the beneficial effects of the addition of saltpeter to soil. Glauber developed the first complete mineral fertilizer, which was a mixture of saltpeter, lime, phosphoric acid, nitrogen, and potash. As scientific chemical theories developed, the chemical needs of plants were discovered, which led to improved fertilizer compositions.

Organic chemist Justus von Liebig demonstrated that plants need mineral elements such as nitrogen and phosphorous in order to grow. The chemical fertilizer industry could be said to have its beginnings with a patent issued to Sir John Lawes, which outlined a method for producing a form of phosphate that was an effective fertilizer. The synthetic fertilizer industry experienced significant growth after the First World War, when facilities that had produced ammonia and synthetic nitrates for explosives were converted to the production of nitrogen-based fertilizers.

During the 1800's Justus von Liebig, considered by many to be the F**ather of the fertilizerindustry**, made substantial contributions toward the organization and development of organic chemistry laboratory methods. He discovered that plants need nitrogen to survive. A basic assumption developed - to maintain plant health simply return to the soil what the plant removes.

Three Main Fertiliser Nutrients

Nitrogen, phosphorus and potassium, or NPK, are the "**Big 3" primary nutrients** in commercial fertilizers. Each of these **fundamental** nutrients plays a **key** role in plant nutrition. Nitrogen is considered to be the most important nutrient, and plants absorb more nitrogen than any other element

Commercial Fertilizers

With commercial types of fertilizers the following are identified as necessary for plant growth:

1. Primary nutrients - nitrogen (N), phosphorus (P), and potassium (K)
2. Secondary nutrients - calcium (Ca), magnesium (Mg), sulfur (S)
3. Trace minerals - boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), and selenium (Se). In addition, Na, Si, Co and V have also been added to the essentiality list in recent times.

Types of Fertilizers– based on the nature of the material

In the broadest sense all types of fertilizers include any substance, living or inorganic which aids in plant growth and health. We exclude water, CO_2, and sunlight.

(i) Organic :Generally the term "organic fertilizer" is used to refer to fertilizer that has gone through minimal processing, where nutrients are still found in their natural forms. This includes manure and compost, which you can prepare yourself, along with items which can be purchased. In the last 40 to 50 years, a phenomenon has happened in farming where farmers started using Inorganic fertilizers alone instead of integrated use of organics with inorganics (INM), leading to a gradual worsening of soil health and productivity.

(ii) Inorganic Fertilizers :Inorganic fertilizers generally refer to fertilizers that are synthetic or artificial, and generally are manufactured from petroleum products. These are normally "water soluble". They are minerals in concentrated form that are readily available to the plant. Unlike most organic fertilizers, they don't need the help of the soil to break them down so the plant can utilize them. They only need the soil to hold them until the plant takes them in. Water soluble inorganic fertilizers do nothing to contribute to the health of the soil. So over time, soils become run down and diseased, and become ever more limited in the types of crops they will grow.

Types of fertilizers – based on the role of the material in soil and crop

Direct fertilizer supplies essential nutrients to crops, including NPK fertilizer, compound fertilizer and micro-element fertilizer, etc.

Indirect fertilizer is used for improving soil physical and chemical properties, thereby making growth condition of crops better, such as lime, gypsum and bacterial fertilizers.

Why Farmers Choose Inorganic Fertilizers:

Soils and plants need so many more nutrients than Nitrogen, Phosphorus and Potassium (also called NPK). But research has shown that it is these three that are the primary nutrients needed to produce bigger yields. To the farmer, with all the expenses involved in farming, coupled together with low crop prices, if he doesn't produce larger yields, he very well won't be able to make enough money to stay in business.

The issue of Organic vs. Inorganic Fertilizer is the same issue faced by human beings. Do we live a healthy lifestyle and eat nutritious foods, or do we indulge ourselves with empty calories and then count on drugs to save us from the consequences? Because inorganic fertilizers do not supply most of the micro-nutrients needed by the soil and plants, soils become out of balance, and disease, insect problems and weed problems multiply. To counter these, the inorganic farmer utilizes poisons (insecticides, pesticides, herbicides) to treat these symptoms. Of course, these are highly detrimental to the soil. Along with killing the bad, they also kill the many beneficial insects, algae, nematodes, flagellates, amoebae, ciliates, fungi and bacteria in the soil.

Inorganic fertilizers may grow a greater volume of food, but organic fertilizers grow more nutritious food. Both plants and people need a host of micro-nutrients. Inorganic fertilizers only supply a handful of these nutrients, while organic fertilizers provide many more.

It has been said that blood plasma and plant sap have almost the identical proportion of minerals as are found in the ocean. In fact, one of the best sources for micro-nutrients is ocean water, where all 76 naturally occurring minerals are present in perfect balance. This is organic fertilizer at it's best. When you give plants and soil the nutrients they need, it means healthier plants, and greater nutrition for you.

Choice of Organic and Inorganic Fertilizer

If you choose to use only inorganic fertilizers, you are asking for trouble. Why not add in some organic fertilizers as well. Better yet, forget the inorganic fertilizers, and educate yourself in the use of organic fertilizers. Our research has shown that when used properly, they will result in less insect damage, fewer diseases, and less weed problems, while giving you a bountiful harvest of highly nutritious foods that have a great shelf life.

Agriculture and Fertilizers

According to the FAO, chemical fertilizers are the single most important contributor to the increase in world agricultural productivity [17]. Fertilizers containing nitrogen, phosphorus and potassium are viewed as the drivers of modern agriculture. Their use worldwide has been increasing since the onset of the so-called ‘green revolution’. Data in respect of India presented in Table 24.5 bear testimony to this trend, and it is very likely that many other developing and developed countries exhibit similar trends.

Table All-India Consumption of Fertilizersin Terms of Nutrients (‘000 Tonnes)

Year	N	P	K	Total
1950–1951	158.7	6.9	–	165.6
1955–1956	107.5	13.0	10.3	130.8
1960–1961	210.0	53.1	29.0	292.1
1965–1966	574.8	132.5	77.3	784.6
1970–1971	1,487.0	462.0	228.0	2177.0
1975–1976	2,148.6	466.8	278.3	2893.7
1980–1981	3,678.1	1,213.6	623.9	5515.6
1985–1986	5,660.8	2,005.2	808.1	8474.1
1990–1991	7,997.2	3,221.0	1,328.0	12,546.2
1995–1996	9,822.8	2,897.5	1,155.8	13,876.1
2000–2001	10,920.2	4,214.6	1,567.5	16,702.3
2005–2006	12,723.3	5,203.7	2,413.3	20,340.3

Year	N	P	K	Total
2010–2011	16,558.2	8,049.7	3,514.3	28,122.2
2015-2016	17, 372.3	6,978.8	2,401.5	26,752.6
2018-2019 (Provisional)	17,637.8	6,910.2	2,680.3	27,228.2

Source: Agricultural Statistics, Government of India

Unscientific and overzealous use and application of nitrogenous and phosphorus fertilizers in agriculture have led to the well-known ***eutrophication*** of all types of water bodies. Agricultural use of N and P very often lead to problems of 'non-point' pollution.

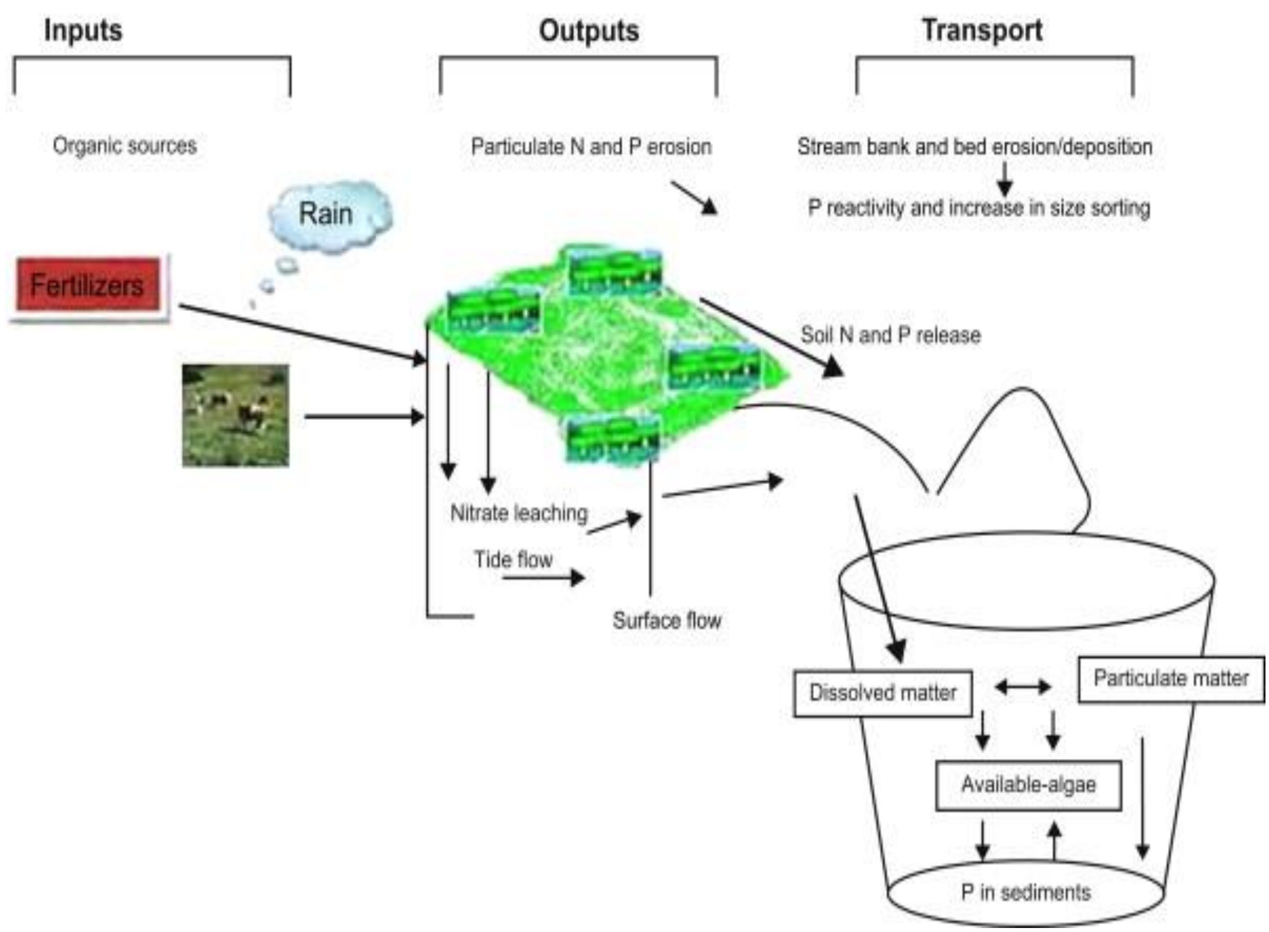


Figure :Inputs, outputs and transport of P and N from agricultural land .

In some parts of the world (e.g., Asia), organic fertilizers derived from animal and human excreta are used to supplement inorganic ones. Their eco-friendly dimension notwithstanding, they are associated with some human and animal health problems. There have been reports, especially from developing countries, of water quality deterioration caused by their discharge into water bodies. Infiltration of nitrates and to a very little extent, phosphates, may contaminate groundwater as well. Volatilizing ammonia may lead to acidification of water and land. Heavy metal fractions occurring in excreta may add to the mess.

From a futuristic view point, there is an urgent need to reverse the trend in N and P flows into and through the agro systems,apart from the other essential nutrients, before they reach their ultimate reservoirs. Nutrient input–output analyses coupled with modeling studies may help agro managers to achieve this. In this direction, the development of ***Designer fertilizers to suit the needs of the soil based on their fertility status; and crops based on their requirements*** has become the need of the present day agriculture for maximizing the crop yields and maintaining the soil health.

The Future

Fertilizer research is currently focusing on reducing the harmful environmental impacts of fertilizer use and finding new, less expensive sources of fertilizers. Such things that are being investigated to make fertilizers more environmentally friendly are improved methods of application, supplying fertilizer in a form which is less susceptible to runoff, and making more concentrated mixtures. New sources of fertilizers are also being investigated. It has been found that sewage sludge contains many of the nutrients that are needed for a good fertilizer. Unfortunately, it also contains certain substances such as lead, cadmium, and mercury in concentrations which would be harmful to plants. Efforts are underway to remove the unwanted elements, making this material a viable fertilizer. Another source that is being developed is manures. The first fertilizers were manures, however, they are not utilized on a large scale because their handling has proven too expensive. When technology improves and costs are reduced, this material will be a viable new fertilizer. The GOI has given instructions to all Manufacturing units of fertilizers in India that all the commercial fertilizers manufactured in factories should be brought out in granulated form hereafter; so as to avoid adulterations and making them environment friendly (avoiding wind drift and sticking to foliage causing scorching*)*. ***Granular fertilizers*** are the most safe and convenient form for application.

Lecture 2

Scope and Need for Designer Fertilizers–Multinutrient Deficiencies in Soils and Plants-Critical Limits - Current Scenario of MultinutrientDisorders

Fertilizers help meet the need of food, fiber, fuel and feed for our growing population. Deficiency of plant nutrients in soil is on rise. To replenish the same for ensuring food security, use of fertiliser is indispensable.Fertilisers contain essential nutrients in specific ionic forms which plant roots are capable of absorbing and help in better food production.

Fertilizer use in Indian agriculture is on the increase from 0.17 million tons in 1950-51 to 2.18 in 1970-71, 12.55 in 1990-91, 28.12 in 2010-11 and so on. The per hectare consumption has increased from less than 1 kg in 1950-51 to thepresent level of over 130.8 kg.

Contrary to the increased use of fertilizers, the use efficiency of the applied fertilizer nutrients is on the decrease because of the varied soil and climatic conditions, imbalanced fertilization, non adoption of crop rotations and INM practices, reduction in the use of organics because of non availability leading to reduction in organic carbon and fertility status of the soils etc. The fertilizer use efficiency of N has been reported to be only 30-40% in rice and 50-60% in other crops while that of P is only 15-20% in most crops. The efficiency of K is 60-80%, while that for S is 8-12%. The efficiency of most of the micronutrients is below 5%.

However, the fertilizer use efficiency can be augmented in a far better way through balanced fertilization; and most urgently customized soil and crop specific fertilizer materials need to be developed for major cropping and farming systems in different agro-ecological situations by following the soil test based and site specific nutrient recommendations.

Need of Designer Fertilisers

- Imbalanced fertilization and continuous nutrient mining from native soil led to secondary and micronutrient deficiency, declining productivity and deterioration of soil health.

- Balanced fertilization maintains a dynamic equilibrium between nutrient application and nutrient uptake by crops and thereby aims to harness benefits for farmers, consumer and for the nation. This can be mediated through site specific nutrient management (SSNM) and precision agriculture.

- The designer fertilizers (Customized / fortified / value added / coated / slow release / liquid / foliar formulations etc.) and nano enabling technologies are ideal tools for bringing balanced fertilization into reality.

Designing of fertilizers

Fertilizer and Soil improver can be designed according to customer requirements. The size and shape have a vital influence on the properties of the fertilizer by which the following can be influenced by selective coating with hydrophobing agents/minerals.

- Duration of effectiveness
- Solubility
- Stability of the granulates

Designing of the fertilizer product according to the wishes of the customers:

- Individual definition of grain size distribution
- Small grain size range (e.g. 0.2 – 2.0 mm) and high yield
- Optimization of granule shape and surface structure
- Coating with coloring agents, chalk and pigment blends
- Wetting with anti-caking agents and hydrophobing agents
- Use of odor-neutralizing minerals such as zeolites and adsorbents
- Influence over look and feel by rolling-in plant fibers
- Reduction of dust content to a minimum

Multinutrient deficiencies in soils and plants

Periodic changes in level of micronutrient deficiency

Monitoring the extent of micronutrient deficiencies on time scale showed that the Zn deficiency in the country declined from 48.8% in 1987- 1999 to 36.5% in 2011-2017.

Regular use of Zn fertilizers resulted into the Zn build-up in the soil, consequentially leading to a drop in Zn deficiency to 36.5% in 2017. Deficiencies of Fe and Mn increased slightly from 11.0 and 3.0% in 1967-1987 to 12.8 and 7.1%, respectively in 2011-2017. Increase in Mn deficiency figures was due to 25% of the samples being Mn-deficient in the rice-wheat growing areas of Punjab, Haryana and western Uttar Pradesh. Deficiencies of Cu fluctuated between 3 to 5% over the years. Based on the newly devised critical limits for S, 11.4, 29.4 and 17.8% area is in the acute deficient, deficient and latent deficient category, respectively (Figure 2). While 7.9, 28.6 and 14.7% area is acute deficient, deficient and latent deficient in Zn, respectively, about 4.0, 19.2 and 21.5% area is under acute deficient, deficient and latent deficient category for B.

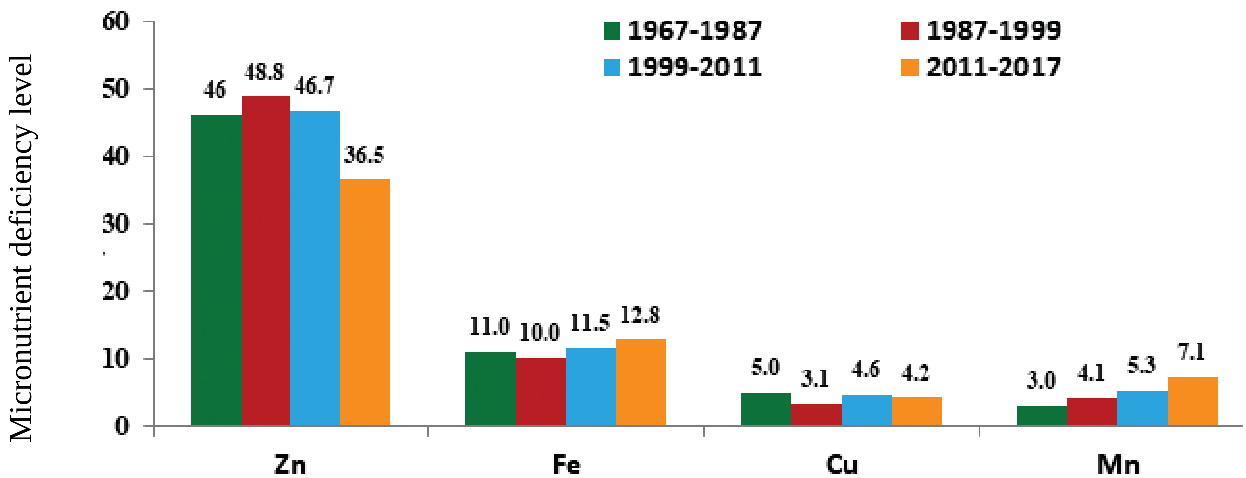


Figure. Periodic changes in the extent of micronutrient deficiencies in Indian soils on time scale

Multi Micro and Secondary Nutrient Deficiencies

Over the years, multi-micro and secondary nutrient deficiencies have emerged in different areas of the country. The data showed that average of 9.9, 8.3, 6.2, 5.8, 3.7, 3.3, 2.8 and 2.4% samples were deficient in S+Zn, Zn+B, S+B, Zn+Fe, S+Fe, Zn+Mn, Zn+Cu and Fe+B, respectively. Deficiency of S and Zn together was higher in states like Rajasthan (29.9%), Madhya Pradesh (18.8%), Goa (17.6%), Bihar (15.8%) and Gujarat (15. 6%). The Zn+B deficiency was higher in acid leached Alfisols and red and lateritic soils of Bihar (20.5%), Odisha (17.1%) and Karnataka (15.4%). Jharkhand (35.1%), Odisha (22.5%), West Bengal (20.1%) and Karnataka (16.6%) exhibited simultaneous occurrence of S and B deficiencies.

Rajasthan showed the maximum occurrence of multi-nutrient deficiencies with Zn+Fe, S+Fe, Zn+Mn and S+Zn+Fe deficiencies occurring on 23.3, 16.9, 22.5 and 11.8% soils, respectively. Simultaneous deficiencies of S+Zn+B, S+Zn+Fe and Zn+Fe+B were recorded in about 2.5, 1.9 and 1.1% soils, respectively. Simultaneous occurrence of deficiencies of 4 or more than 4 nutrients was very low (<0.5%) in most of the states. These results clearly signal that the single micronutrient deficiencies predominate over the combination of 2, 3, 4 or more elements. Consequentially, use of multimicronutrient mixtures is a wasteful practice and should be avoided. Only the nutrient identified as deficient through soil or plant analysis should be applied to harvest the sustainable higher productivity.

Micronutrient Mining

Micronutrient balance in the soil-cropping system is dependent on the removal or depletion of micronutrients from soils by different crops and their addition through fertilizers, manures, irrigation, and rain water etc. Micronutrient removal by the crop determines the degree to which soil resources are being progressively depleted due to farming. Data generated in the project showed that cereals removed higher amount of nutrients than oilseeds and pulses, because the yield of cereals were 1.5 to 3 times higher than that of oilseed and pulse crops. On an average, removal of Zn, Fe, Mn, Cu, B and Mo by cereals varied from 72 to 251, 197 to 1964, 112 to 489, 6 to 78, 11 to 125, and 0.9 to 11.2 g ha-1, with mean values of 189, 791, 333, 48, 79, and 5.4 g ha1, respectively (Table 3). On an average, 1,88,000 t of micronutrients are removed every year by the agricultural crops, of which Fe, Mn, Zn, B, Cu and Mo constitute 59, 20, 12.7, 4.9, 3.4 and 0.5%, respectively.

Table 3. Average micronutrient removal (g ha^{-1}) by grains/seeds of cereals, pulses and oilseed crops

Crops	Zn	Fe	Mn	Cu	B	Mo	Total
Cereals	189	791	333	48	79	5.4	1444
Pulses	88	591	69	18	24	6.9	796
Total food grains	169	753	266	40	69	6.1	1304
Oil seeds	130	743	199	42	41	6.4	1231
Food grain + oil seeds	162	751	254	43	62	6.2	1299

Multinutrient Deficiencies in Soils andPlants

Continuous nutrientmining from the native soil coupled with imbalanced use of fertilizers has caused rising deficiencies of secondary and micronutrients. Extensive use of high analysis fertilizers coupled with neglected application of organic fertilizers resulted in elevated deficiency ofsecondary and micronutrients in the soils. It is estimated that about 28 m t of primary plant nutrients are mined annually by crops in India, while only 18 m t or even less are added as fertilizer, which resulted in to a net negative balance of about 10 m t of primary plant nutrients . Deficiency of sulphur, zinc and boron are becoming more widespread and critical. At the same time the use efficiency of applied N, P, K, Zn, Fe and Ca in Indian soils are only about 30-50, 15-20, 70-80, 2-5, 1-2 and 1-2, respectively .Thus, the problem of nutrient deficiencies are aggravated further because of low efficiency of applied fertilizers particularly of P and micronutrients. Hence , there is an urgent need to develop customized fertilizers based on crop response to enhance the fertilizer use efficiencythrough balanced fertilization. The combined use of primary, secondary and micronutrients help in maintaining yield stability through correction of marginal deficiencies of these nutrients, enhancing efficiencies of applied nutrients and providing favourable soil physical condition.

Critical Limits of plant nutrients in Soils and Plants

Critical limit of a nutrient has been defined as the level in soil or plant tissues, below which there is a probability to get response to application of that particular nutrient. Cate and Nelson procedure (graphical or statistical) has been used for determining the critical levels of micronutrients in soils and the same have been usedfor delineating the micronutrient-deficiencies. Critical levels of deficiency (CLD) of $CaCl_2$ extractable S; DTPAextractableZn, Cu, Fe and Mn; and hot waterextractable B have been developed for the soils ofdifferent states. The critical levels of deficiency variedwith micro- and secondary nutrients, crops, soils, andthe extractants used (Table 4). Earliercritical levels of different micronutrients determinedunder pot culture experiments revealed only twolevels of concentration for each nutrient i.e. adequacyand deficiency (Takkar et al., 1989). Recently, criticallevels were redefined by conducting on-farm trials in cluster of villages . In total1421 field experiments were conducted on specificcrops to determine the critical nutrient concentrationof different micronutrients. Based on field experimentsand crop response to micronutrients, generalizedtransition zones were worked out for different nutrients across the soil types. First 3 categoriesindicate level of deficiency (acute deficient, deficient,latent deficient) and next 3 levels specify adequacy (marginally sufficient, adequate and high) (Table 5)

Table 4. Change in critical limit of micronutrients and S as influenced by soil type and crops

Location	Crop	Critical limit (mg kg^{-1})	
		Existing	Revised
Critical limit of $CaCl_2$ extractable S			
Muzaffarpur, Bihar (sandy clay loam soil)	Wheat	10.0	14.5
Nalanda, Bihar (alluvial calcareous soil)	Rice	10.0	13.5
Bhubaneswar, Odisha (alluvial soil)	Potato	10.0	15.0
Pantnagar, Uttarakhand (silty clay loam)	Chickpea	10.0	15.0
Critical limit of DTPA-Zn			
Ranga Reddy, Telangana (alluvial soil)	Rice	0.60	0.70
Pusa, Bihar (Calcareous soil)	Wheat	0.70	0.80
Coimbatore, Tamil Nadu (sandy clay loam)	Maize	1.20	0.90
Pantnagar, Uttarakhand (silty clay loam)	Maize	0.60	0.75
Nainital, Uttarakhand (silty clay loam)	Soybean	0.75	1.24
Jabalpur, Madhya Pradesh (Vertisol, clayey soil)	Soybean	0.55	0.70
Critical limit of DTPA-Cu			
Erode, Tamil Nadu (red and lateritic soil)	Onion	1.20	0.62
Ludhiana, Punjab (sandy loam)	Rice	0.20	0.30
Ludhiana, Punjab (loamy sand)	Wheat	0.20	0.40
Critical limit of B			
Jorhat, Assam (acid Soils) - hot water extractable	Mustard	0.50	0.55
Hisar, Haryana (calcareous soils) - hot water extractable	Mustard	0.50	0.80
Hisar, Haryana (calcareous soils) - salicylic acid	Mustard	-	0.61

Table 5. Generalized transition zone of critical limits for available sulphur and micronutrients in soils

Transition zone of critical limit	Available nutrients (mg kg^{-1})					
	$CaCl_2$-S	DTPA-Zn	DTPA-Fe	DTPA-Cu	DTPA-Mn	HWS-B
Acute deficient	≤ 7.5	≤ 0.3	≤ 2.5	≤ 0.2	≤ 1.0	≤ 0.2
Deficient	$>7.5 \leq 15$	$>0.3 \leq 0.6$	$>2.5 \leq 4.5$	$>0.2 \leq 0.4$	$>1.0 \leq 3.0$	$>0.2 \leq 0.5$
Latent deficient	$>15 \leq 20$	$>0.6 \leq 0.9$	$>4.5 \leq 6.5$	$>0.4 \leq 0.6$	$>3.0 \leq 5.0$	$>0.5 \leq 0.7$
Marginally sufficient	$>20 \leq 30$	$>0.9 \leq 1.2$	$>6.5 \leq 8.5$	$>0.6 \leq 0.8$	$>5.0 \leq 7.0$	$>0.7 \leq 0.9$
Adequate	$>30 \leq 40$	$>1.2 \leq 1.8$	$>8.5 \leq 10.5$	$>0.8 \leq 1.0$	$>7.0 \leq 9.0$	$>0.9 \leq 1.10$
High	> 40	> 1.8	> 10.5	> 1.0	> 9.0	> 1.10

Lecture 3

Classification-Types-Speciality/Customised, Fortified and Pelleted fertilizers, MultinutrientLiquid Formulations

Soils of India as well as Tamil Nadu in general, are low in available nitrogen, low to medium in phosphorus and medium to high in potassium. In the case of secondary nutrients, magnesium deficiency is observed in the cotton growing soils and in the hilly soils. Sulphur deficiency is prevalent in sizable area, particularly in coarse textured soils where pulses, oil seeds, legumes and forages are predominantly grown.

Micronutrients removal is also higher in the high yielding variety which indicates that there is a need for regular application of micronutrients in order to match their depletion from the native soil reserve. The delineation of the soils of Tamil Nadu for their micronutrient availability during the 1980s indicated that the overall per cent deficiency was 58, 17, 6 and 6 for Zn, Fe, Mn and Cu, respectively. The delineation of the soils for boron in six districts of Tamil Nadu indicated 34.5 per cent deficiency. The reassessment of micronutrient deficiency in five districts of the State during 2006-09 has indicated that the extent of the micronutrient deficiency in the recent years has increased considerably to 69, 28, 9 and 23 per cent for Zn, Fe, Mn and Cu respectively. The reasons for such increase in the deficiency levels are mainly due to imbalanced fertilization and indiscriminate use of fertilizers.

The real solution for the imbalanced fertilization lies in the adoption of soil test based fertilization and in the absence of such recommendations, the use of crop based macro and micronutrient fertilizer mixtures. The availability of the straight fertilizers, particularly the micronutrients to farmers become scanty in villages and remote areas and the farmers have no choice except to go for one or two major straight fertilizers more particularly nitrogen alone. Hence, the use of crop specific fertilizer mixtures will largely help the farmers to go for balanced fertilization thereby increasing the productivity of their farm holdings. The list of 16 MN mixtures as approved in the FCO in Tamil Nadu does not cover all the crops and some of them needs improvement in the context of the emerging multi-micronutrient deficiencies eg., the MN mixture meant for groundnut does not contain Cu , while larger occurrence of Cu deficiency has been reported in the crop in the recent years. Similarly, the MN mixture meant for millets is being advocated for maize, which needs improvement in the context of the heavy foraging nature of the crop. In line with the above observations, research on the new Designer Fertilizer Mixture formulations (Customised fertilizers) for crops is in progress in TNAU, which will largely help the farmers to manage the multinutrient deficiency problems involving major, secondary and micronutrients.

The following are the categories of Designer fertilizers developed to suit the different soil and crops and the need of the farmers:

(i) ***Speciality / Customized fertilizer*** may be defined as multi-nutrient carrier which contains macro and/or micronutrient, whose sources are from inorganic or organic, which are manufactured through systemic process of granulation and satisfies crop's nutritional demand, specific to area, soil and growth stage of plant.

(ii) Value-added fertilizer is a synergistic fertilizer, specifically refers to added alginic acid, humic acid and amino acids and other natural substances in the fertilizer production process in the production of fertilizer efficiency modified products.

(iii) Fortified fertilizers: Fortified fertilizers are a combination of multi-nutrient carriers which satisfies the crop's nutritional demand based on area, soil and growth stage of a plant. *Eg.:*Single Super Phosphates fortified with Zinc recommended for use in areas ofZinc deficiency which is probably the most common micronutrient deficiency in crops worldwide, resulting in substantial losses in crop yields and human nutritional health problems. Similarly SSP fortified with Boron, NPK mixture/compound fertilizer fortified with S and B. Gromor Ultra DAP is a fortified Di Ammonium Phosphate produced by Coromandel fertilizers.

(iv) Pelletted fertilizers:Fertilizer Pellets offer the most natural source of essential nutrients to promote vigorous plant growth, bountiful yields and brilliant flowering. Derived from dried organic manures / poultry waste, these **fertilizer pellets** are formulated with a broad spectrum of nutrients that slowly release as a plant needs them. These are convenient if you want to provide nutrients slowly and over a long time and are particularly good for heavy feeder crops like corn and tomatoes. These can be applied manually by broad cast or by point placement through machinery.

***(v) Liquid formulations*:** The objectives of fluid mixed fertilizer production are to produce in a plant with low operating cost that does not emit pollutants, a homogeneous fertilizer that has low raw material cost, high nutrient concentration, product versatility, and can be applied uniformly. The amount of labor required to deliver and apply liquid fertilizer mixtures are also found to be low.

(vi) Foliar formulations: Foliar fertilizationis a technique of feeding plants by applying liquid fertilizer directly to their leaves. Foliar feeding has been used as a means of giving supplemental doses of major and minor nutrients, plant hormones, stimulants and other beneficial substances. This technique is particularly useful in constrained soils (acidic, alkaline, calcareous etc.,) where, the soil application of fertiliser nutrients are subjected to high loss / fixation in soils.

Lecture 4

Speciality / Customised Fertilisers- Definitions- Production- Characteristics, Sources- Suitabilityfor Crops – MeritsandDemerits

The main objective of Customized Fertilizer is to promote site specific nutrient management so as to achieve the maximum fertilizer use efficiency of applied nutrient in a cost effective manner. The Customized Fertilizer may include the combination of nutrients based on soil testing & requirement of crop and the formulation may be of primary, secondary and micro-nutrients. It may include 100% water soluble fertilisers grades required in various stages of crop growth based on research findings.

Definition: Customized Fertilizer is a concept around balanced plant nutrition. Such fertilizers are based on the sound scientific plant nutrition principle and research, Customized Fertilizer provide the best nutrition al package for premium quality plant growth and yield. They are defined as package for premium quality plant growth and yield.

'Customized Fertilizers' are defined as multi nutrient carrier designed to contain macro and /or micro nutrient forms., both from inorganic and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop's nutritional needs, specific to its site, soil and stage, validated by a scientific crop model capability developed by an accredited fertilizer manufacturing/marketing company.

Such fertilizers also include water soluble specialty fertilizer as customized combination products. Prospective manufacturers or marketers are expected to use the software tools like. Decision Support System for Agro Technology Transfer(DSSAT). Crop Model etc. to determine the optimal grades of customized fertilizer.

Customized fertilizers:

Customized fertilizers may be defined as multi-nutrient carrier which contains macro and/or micronutrients, whose sources are from inorganic or organic which are manufactured through synthetic process of granulation and satisfies crops nutrient demand, specific to area, soil and growth stage of plant.

Soil fertility status, climate, and cropping pattern in a region cover the way for the development of customized fertilizer formulations

Customized fertilizers facilitate the application of complete range of plant nutrients in the right proportion and to suit the specific requirement of a crop in different stages of growth and are more relevant under site specific nutrient management practices

Customized fertilizers development process is complex but, the end very promising.

It optimizes the nutrient use for quality produce, high farm productivity and profitability.

Farmers will have choice for customized fertilizers on account of crop and area specificity and the advantage of ready to use fertilizer material available to them.

It can maximize NUE and ultimately programmed to improve soil fertility hence, are environmental friendly as well.

The customized fertilizers are developed in granular form; and all granular fertilizers are highly uniform in physical form and chemical composition.

These fertilizers are band / point placed at the time of sowing/planting

So far, the Government of India has notified over 36 customized fertilizers for around 100 districts of the states namely Andhra Pradesh, Telangana, Maharashtra, Uttar Pradesh,Uttarakhand, Tamil Nadu and Karnataka for crops namely Rice, Wheat, Oil Palm, Sugarcane, Chilli and Potato.

Development of Protocol :

- ❖ Defining fertility management zones
- ❖ Using empirical models like STCR
- ❖ Use secondary research data and experiential learning's
- ❖ The customization is done after conducting scientific research to find nutrients missing in a particular soil for growing specific crops. "Presently, such fertilizers are in use for wheat, paddy, sugarcane, menthe and potato.
- ❖ Every year, the fertilizer grade is changed depending upon the condition of soil at that point of time. The cost of customized fertilizers is the same to that of normal fertilizers. The technology has been launched in India for the first time. Developed on the basis of soil, crop and water sample analysis, they help correct nutrient imbalance in the soil caused by prolonged inadequate and indiscriminate use of fertilizers.

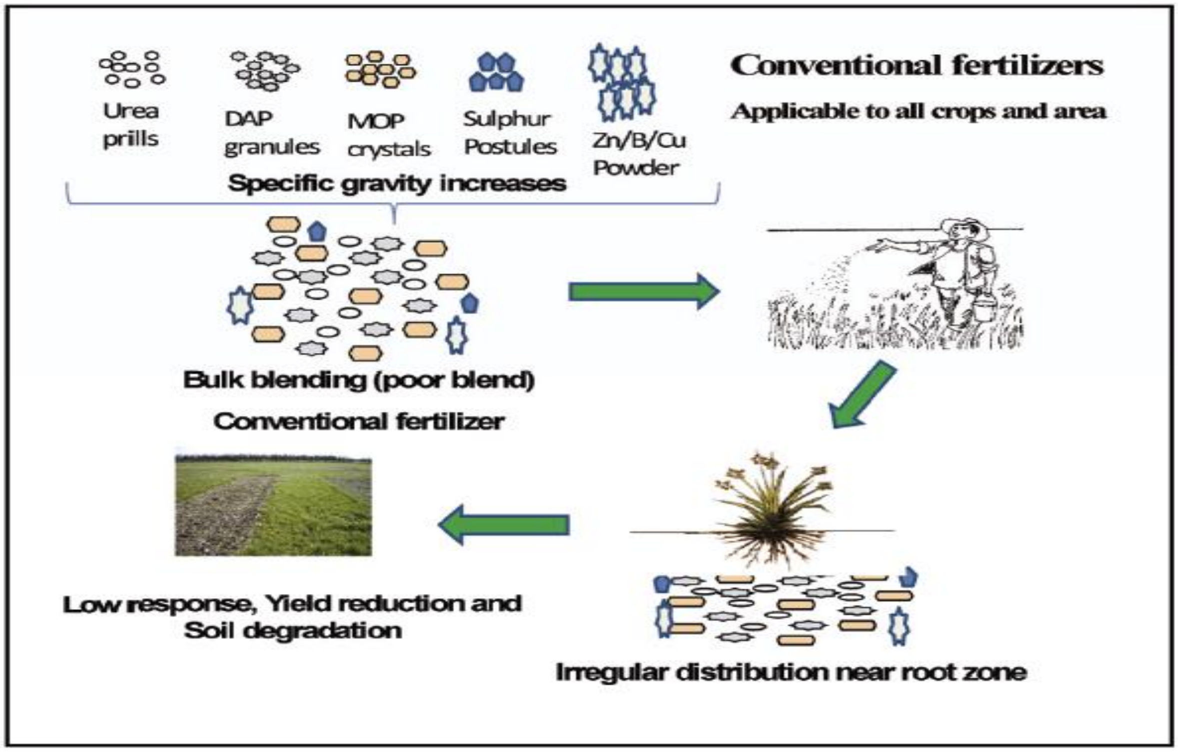
Fertilizer is an essential key input for production and productivity of crops. Fertilizer alone contributes towards 55% of additional food production. Since there is no scope for extending the cultivable area, more productivity per unit area is the only option and fertilizer is the main cart puller.

Custom mixed fertilizer is a mixed fertilizer formulated according to individual specifications furnished by the consumer before mixing.

CF also include water-soluble specialty fertilizer as customized combination products. Manufacturers or marketers are expected to use software tools such as the Decision Support System for Agro Technology Transfer (DSSAT) Crop Model to determine the optimal grades of customized fertilizer. Customized, crop, soil and area specific fertilizers may contribute to maintaining soil health Fig 1.

In order to overcome the limitations of blanket fertilizer recommendations, the concept of SSNM was introduced which is specific to soils and crops, yield oriented and takes into account nutrient interactions with the aid of models such as Quantitative Evaluation of Fertility of Tropical Soils (QUEFTS) and Soil Test Crop Response (STCR).

Undoubtedly, customized fertilizers can magnify the prospects of SSNM and precision agriculture.


Conventional fertilizers
Applicable to all crops and area
Urea prills
DAP granules
MOP crystals
Sulphur Postules
Zn/B/Cu Powder
Specific gravity increases
Bulk blending (poor blend)
Conventional fertilizer
Low response, Yield reduction and Soil degradation
Irregular distribution near root zone

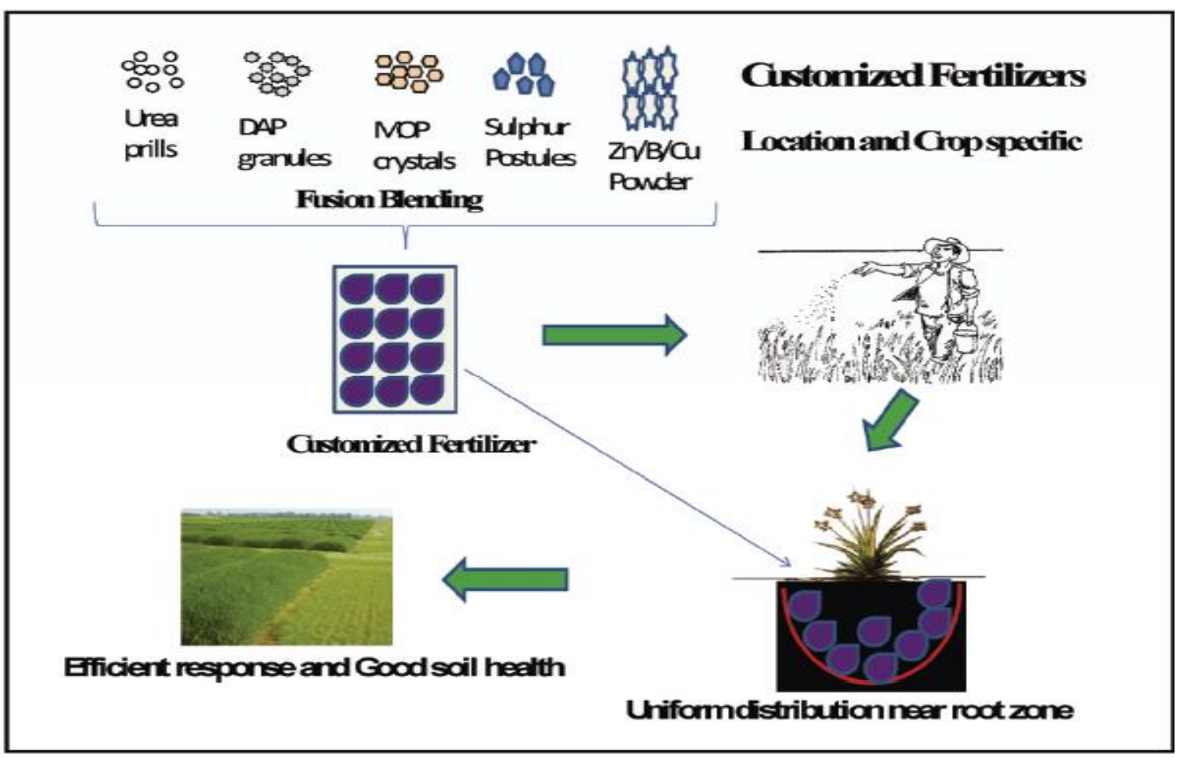

Customized Fertilizers
Location and Crop specific
Urea prills
DAP granules
MOP crystals
Sulphur Postules
Zn/B/Cu Powder
Fusion Blending
Customized Fertilizer
Efficient response and Good soil health
Uniform distribution near root zone

Fig. 1 Diagram showing differences between conventional versus customized fertilizers

Principles and procedures for arriving Customized fertilizer grades

- Geo-referencing of chosen area
- Selecting sampling points on appropriate statistical procedure
- Actual sampling of the sites
- Analyzing sampling of the sites
- Analyzing soil, plant and water samples for nutrients and some soil characteristics
- Defining management zones
- Yield targeting in major management zones
- Computing crop removal of nutrients
- Calculating nutrient requirement (amount and ratio)
- Blending of nutrients based on the generated information

Intervention of Government policies

- Customized fertilizer was included in the Gazette in 2006 under clause 20 B of the Fertilizer Control Order (FCO) of 1985. In 2008 customized fertilizer policy guidelines were issued.

- All the provisions of FCO of 1985 and FCA (1955) shall be applicable for manufacture and sale of customised fertilizer.

Manufacturing methodologies of Customized fertilizers

1. Bulk blending,
2. Compound granulation
3. Complex granulation

1. ***Bulk blending***involves pure mixing of solid fertilizers to obtain the desired nutrient ratio. It only requires a warehouse and weighing and mixing equipment. Due to the high cost involved in

manufacturing of customized fertilizers through bulk blending, this method appears to be a remote option for producing customized fertilizers in India.

2. ***Compound granulation***is commonly known as ‘steam granulation’ or ‘physical granulation’. The raw materials required for this method are available in solid form. Granulation is formed by the agglomeration process and requires the use of water, steam and heat in the dryer. In fact, almost all Asian countries are following the route to steam/physical granulation for NPK production and this method may also be the most effective way for India to produce customized fertilizers.

3. ***Chemical granulation***is also called ‘slurry granulation’ or ‘complex granulation’. NPKs are produced by a chemical reaction between ammonia and either sulphuric or nitric acid to form either ammonium sulphate or ammonium nitrate. This is granulated with the addition of discrete K_2O either in solid form or a liquid form. The process of granule formation comprises accretion plus agglomeration. This method is not convenient when many customized NPK grades are to be produced

Quality of customized fertilizer

For basal application, customized fertilizers should be granular in size with at least 90% of the material between 1 and 4 mm IS sieve and the material passing through sieve having size ≤1 mm IS sieve should not exceed 5% (clause 20B of FCO, 1985). The moisture content should not exceed 1.5%. For foliar application, however, 100% water solubility is required

Initially, four grades of customised fertilisers were created to provide a total nutrient package mainly for basal application.

Grade I:	$N_{10}:P_{20}:K_{10}:S_5:Mg_2:Zn_{0.5}:B_{0.3}:Fe_{0.2}$
Grade II:	$N_{20}:P_{10}:K_{10}:S_5:Mg_2:Zn_{0.5}:B_{0.3}:Fe_{0.2}$
Grade III:	$N_{15}:P_{15}:K_{15}:S_5:Mg_2:Zn_{0.5}:Fe_{0.2}$
Grade IV:	$N_{10}:P_{20}:K_{20}:S_3:Mg_2:Zn_{0.5}:B_{0.3}:Fe_{0.2}$

These customized fertilizer grades are liable to change every three yearsas per the changing soil fertility and crop need.There are over 36 formulations of customized fertilizers approved by

FCO. New additional formulations are also in the pipeline, designed based on the soil and crop data base available with the different States of India.

The important leading companies in the market producing customized fertilizers are :

- Tata Chemicals Ltd, Mumbai
- Deepak fertilizers, Pune
- Nagarjuna Fertilisers and chemicals, Hyderabad
- Coromandal International ltd., Secunderabad,etc

The different formulations prepared by different industries are given in Table 1 and 1a.

Specifications in respect of customized fertilizers:

Notwithstanding anything contained in this Order, the Central Government may by order published in the Official Gazette, notify specification, valid for a period not exceeding three years in respect of customized fertiliser to be manufactured by any manufacturing unit.

Specific grade of customized fertilizer shall contain **at least 30 units of all nutrients, combined**

Quality checking

i)Procedure for drawl of sample of fertilizers

a)The method of drawing samples shall be provided in the FCO.

b)Clause 4A (iii)-Weight of one sample should be 400g as specified under Clause 4 A (iii) for Part A in Schedule 1 of the FCO, 1985

ii)Methods of analysis of fertilizer

a)The methods of analysis of fertilizers shall be as per the procedure prescribed in FCO

b)For preparation of sample for analysis in the laboratory (Clause 1-1) under part B in schedule II of FCO, 1985 the whole sample size of 400g should be powdered. The whole sample size of 400gm shall be powdered

iii)Tolerance limit

The tolerance limits prescribed under the FCO, 1985 for NPK mixture and NPK with micronutrients shall be applicable to the customized fertilizers. However such tolerance limit shall not exceed 3% for all nutrients particularly when secondary and micronutrients are also present with NPK.

Table 1 Formulations of customized fertilizers as approved by GOI as on 1 November 2011

Formulation	Crop	Region	Fertilizer company
7N20P18K6S0.5Zn*	Sugarcane	Western UP	TCL**
10N18P25K3S0.5Zn	Wheat	Western UP	TCL
8N15P15K0.5Zn0.15B	Rice	Western UP	TCL
8N16P24K6S0.5Zn0.15B	Poatato	Western UP	TCL
15N32P8K0.5Zn	Rice	Andhra Pradesh	NFCL
18N33P7K0.5Zn	Rice	Andhra Pradesh	NFCL
18N27P14K0.5Zn	Rice	Andhra Pradesh	NFCL
18N24P11K0.5Zn	Rice	Andhra Pradesh	NFCL
23N12K	Rice	Andhra Pradesh	NFCL
27N10K	Rice	Andhra Pradesh	NFCL
11N24P6K3S0.5Zn	Rice (basal)	Adilabad, Nizamabad, Karimnagar, Warangal Medak, Ranga Reddy Nalgonda (All in A.P.)	NFCL
14N27P10K0.5Zn	Maize	Adilabad, Nizamabad, Karimnagar, Warangal Medak, Ranga Reddy Nalgonda (All in A.P.)	NFCL
22N12K	Rice	Adilabad, Nizamabad, Karimnagar, Warangal Medak, Ranga Reddy Nalgonda (All in A.P.)	NFCL
18N14K	Maize	Adilabad, Nizamabad, Karimnagar, Warangal Medak, Ranga Reddy Nalgonda (All in A.P.)	NFCL
10N20P10K5S2Mg0.5Zn0.3B0.2Fe	Grape (basal) and sugarcane	Nasik, Pune, Ahmednagar, Aurangabad	Deepak F.
20N10P10K5S2Mg0.5Zn0.3B0.2Fe	Grape, rice, pomegranate, sugarcane, tomato	Nasik, Pune, Ahmednagar, Aurangabad, Dhule, Jalgaon	Deepak F.
15N15P15K5S2Mg0.5Zn0.3B0.2Fe	Grape, cotton, onion, banana, potato	Nasik, Pune, Ahmednagar, Aurangabad, Dhule, Jalgaon	Deepak F.
10N20P20K3S2Mg0.5Zn0.3B0.2Fe	Sugarcane, citrus	Nasik, Pune, Ahmednagar, Aurangabad, Dhule, Jalgaon	Deepak F.
15N15P15K0.5Zn0.2B	Groundnut	Andhra Pradesh	Corom. Int.
20N15K0.5Zn0.2B	Maize	Andhra Pradesh	Corom. Int.
16N22P14K4S1Zn	Rice (basal)	E&W Godavari Krishna, Western Delta of Guntur (All in AP)	Corom Int.
14N20P14K4S0.5Zn	Maize	Karimnagar, Warangal, Nizamabad	Corom Int.
17N17P17K4S0.5Zn0.2B	Groundnut (basal)	Anantapur, Chittoor Kadappa, Kurnool, Mahabubnagar	Corom Int.
12N26P18K5S0.5Zn	Rice and wheat	Uttar Pradesh	Indo-Gulf
8N18P26K6S1Zn0.1B	Potato	Uttar Pradesh	Indo-Gulf

*%N, P_2O_5, K_2O, S, Mg, Zn, B and Fe. TCL, Tata Chemicals Ltd.; NFCL, Nagarjuna Fertilizers and Chemicals Ltd; Deepak F., Deepak Fertilizers; Corom Int., Coromandel International Ltd..

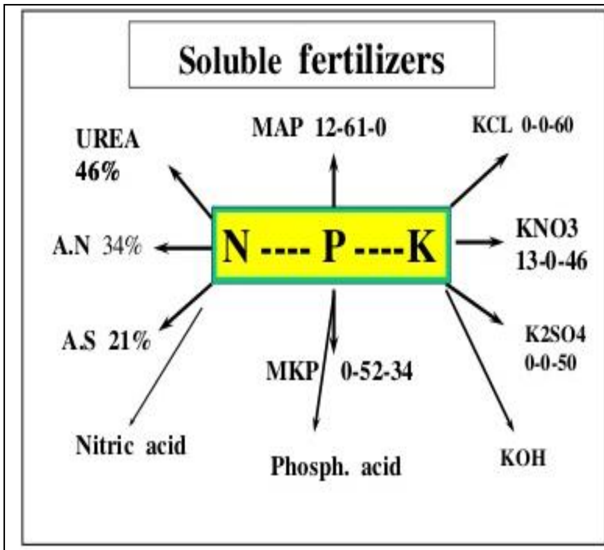
Table 1a.Different Customized Fertilizer Formulations available in India(contd..)

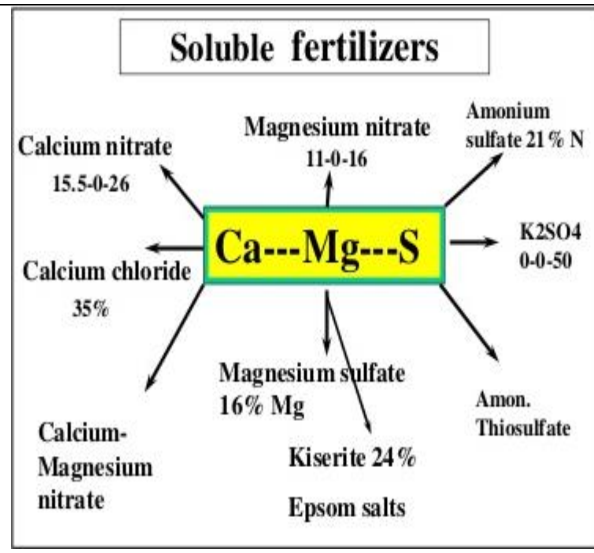
Sl. No	Crops	Formulations (N:P:K:S:Zn:B)/ N:P:K: Zn/ N:P:K:S:Mg:Zn:B:Fe/N:P:K:S:Zn:B)	Geography
1	Potato	8:16:24:6:0.5:0.15	Agra, Aligarh, Budaun, Bulandshahar and Baghpath
2	Wheat	10:18:25:3:0.5:0	Muzaffarnagar, Barielly, Bijnore, Hathras, Pilibhit, Mathura, Meerut
3	Sugarcane	7:20:18:6:0.5:0	Moradabad, KR Nagar, Farukhabad and Ferozabad
4	Rice Paddy	8:15:15:0.5:0.15:0 15:32:8:0.5,18:33:7:0.5, 18:27:14:0.5	GB Nagar, Ghaziabad, Rampur, Shahjahanpur, Mainpuri and US Bagar Andhra Pradesh
5	Rice(Basal)	11:24:06:3:0.5	Adilabad, Nizamabad and Medk
6	Maize (Basal)	14:27:10:4:0.5 14:20:15:4:0.6:0	Karimnagar, Warangal and Ranga Reddy Nizamabad
7	Grape, Sugarcane	10:20:10:5:2:0.5:0.3:0.2	Aurangabad, Nasik, Pune and Ahmednagar
8	Grape, Pomegranate, Paddy, Sugarcane, Tomato, Gourds and Leafy vegetables	20:10:10:5:2:0.5:0.3:0.2	Nasik, Dhule, Jalgaon, Pune, Ahmednagar and Aurangabad
9	Grape, Cotton, Onion,	15:15:15:5:2:0.5:0:0.2	-do-

Water Soluble fertilizers (WSF) - Characteristics and Uses

- 100% Water soluble fertilizers with low salt index, chloride content and high FUE
- High purity, applied low doses and give high benefit : cost ratio, FUE of WSF @ 80-85%, FUE of conventional fertilizers N- 30- 45% P- 10-30% K-50%
- This leads to lower return on money spent on per unit of fertilizer, along with increased soil salinity
- Water-soluble fertilizers dissolve easily in water and are applied to the crop in the irrigation water.
- One benefit is that growers can easily adjust the nutrient concentrations according to a crop’s changing needs over a growing season.
- Growers often choose a fertilizer concentration and apply this concentration at every watering. This is called continuous liquid feeding (CLF), or fertigation.

- By contrast there are fertilization programs in which growers apply higher rates of fertilizer less frequently, and irrigate with clear water between feedings
- Continuous feeding provides a more uniform nutrient supply to the crop over time.
- There may be as many as 50 in a single commercial brand (19:19:19).
- In addition to avoiding nutrient deficiencies and toxicities, can reduce secondary issues, such as insect and pathogen pressure.





Comparison b/w 100% WSFwith Conventional Fertilizers

Sl. No.	*Properties*	*100% water soluble fertilizers*	*NPK conventional fertilizers – complex mixture*
1	Solubility	Readily soluble in water	Nutrient may be in soluble form but carrier material not fully soluble
2	Uniformity of nutrients ions	Ionic distribution uniform depending upon concentration and composition of base material used	Ionic distribution not uniform as phosphatic ion fixation with other elements in carrier occurs frequently
3	Solubility time	1 to 4 minutes in water	12 to 24 hours at 25^{0} C water
4	Filtration of solution before application	Not required	Required 2-3 times

5	pH of 1% solution	Acidic varied 2.5 – 6.5	Neutrality/slightly alkaline 7.5-8.0
6	Salt index	8 to 40	Varies depending upon K2O source (if derived from MOP varies upto 50-125)
7	Time of application	Every irrigation application is possible, absorption by plants over come deficiency	Maximum 2 or 3 split doses. Not practical apply at the time of its demand i. e. flower initiation, fruit setting.
8	Microbial population	More due to less concentration of nutrient solution present near root zone and salt Cl and Na free	Less due to more application of one time dose releases more concentration solution which affects population, Cl, Salt index and Na affects population
9	NUE	Very high	Higher if split doses not applied

Cost of Water Soluble Fertilizers

S.No	Particulars	Rate (Rs.)	Photograph
1	Krista – K (KNO3)	130.00 / Kg	
2	CaNO3	120.00 / Kg	
3	19:19:19	190.00 / Kg	
4	20:20	210.00 / Kg	

Benefits of customized fertilizer

- Customized fertilizers is use of the Fertilizers Best Management Practices and are generally assumed to maximize crop yields while minimizing unwanted impacts on the environment and human health.
- FBMP will make it “easier” in “future” for farmers, extension agents, crop advisers and researchers to exchange their experiences.
- Application of customized fertilizer is compatible with existing farmers system and hence it will be comfortably accepted by the farmers.
- Production of customized fertilizers will ensure improved ‘Fertilizer Use Efficiency’ and creating a new “Virtual” source of nutrients implying from the existing quantity of DAP, MOP, Urea, SSP and A.S available and consumed in India, the agricultural produce output will increase, simultaneously the distribution and availability of fertilizer will be better. All this is achievable keeping the subsidy allocation constant.
- Customized fertilizer satisfies crop’s nutritional demand, specific to area, soil, and growth stage of plant.
- As the micro-nutrients are also added with the granulated NPK fertilizer the plants can absorb the micro-nutrient along with macro-nutrient which prevents nutrient deficiency in plant.
- Mixed fertilizers with micronutrients provide recommended micronutrient rates for the agricultural field at the usual fertilizer application.
- The farmer need not buy micro-nutrient separately at extra cost, thus reducing the total cost.
- It is found that incorporation of micro-nutrient with granular fertilizer at the time of manufacturing results in uniform distribution of micro-nutrient throughout granular NPK fertilizer.
- This is because micro-nutrient source is in contact with the mixed fertilizer under the condition of high moisture and temperature.
- Supplies the plant available nutrient in adequate amount and in proper proportion.
- It is a soil-crop-climate based fertilizer and is less influenced by soil, plant and climatic condition that lead to more uptakes of nutrients and less loss of nutrient.
- It supplies not only primary nutrients but also secondary and micronutrients.
- It reduces the cost of fertilizer application that ultimately reduces cost of cultivation.

- ❖ It is a major component of Site Specific Nutrient Management (SSNM) and Precision Agriculture, which promotes maximum fertilizer use efficiency of the applied nutrients in a cost-effective manner.
- ❖ Soil health can be improved by developing site and crops specific fertilizers

Issues in marketing of customized fertilizers

Ten most important issues which hinder the marketing of customized fertilizers are,

1. High cost of customized fertilizers without proper subsidy given by GoI,
2. Existence of diversity in product mix between producers,
3. Absence of healthy competition among fertilizer industries to avoid indiscriminate and imbalanced use of fertilizer,
4. Improper allocation of raw material among fertilizer industries,
5. Necessity of investing heavy capital in state of the art manufacturing facility for customized fertilizer,
6. No long term assurance from the government to keep the policy intact throughout the years,
7. Limited awareness and very low affordability of customized fertilizers among the farmers,
8. Segmentation and promotion in marketing,
9. Time consuming manufacturing process
10. Uncertainty in response when fertility is restored in the field.

Eligibility Criteria to manufacture and sale of Customized Fertilizer:

(i) Permission for manufacture and sale of Customised Fertiliser shall be granted to only such companies whose annual turnover is Rs. 500 crores or above.

(ii) Such manufacturing companies should have soil testing facility with an annual analyzing capacity of 10,000 samples per annum and should have analyzing capacity for NPK. Micronutrient and Secondary Nutrient. Such soil testing labs must process the requisite instruments as provided in Annexure.I).

(iii) The grade of customized fertilizer, which the company will manufacturer, must be based on scientific data obtained from area specific, soil specific and crop specific, soil testing results. These manufacturing companies, in association with concerned agricultural universities/KVKs concerned, should also conduct agronomy tests pf the proposed grade to establish its agronomic efficacy..

(iv) Such manufacturing companies should generate multi loctional trials(not on farm demonstration) on different crops for minimum one season.

Soil Sampling and Analysis : Suchmanufacturing companies must draw these soil samples from within its operational areas and should also ensure that minimum one sample is necessarily, drawn from each village. Scientific data on soil testing, results available with agricultural university /state Governments may also be used to prepare soil fertility map and for determination of required soil, area and crop specific grades for existing and potential marketing areas.

Grant of permission to manufacture:Subject to the fulfillment of eligibility criteria referred to in the preceding paragraphs, the permission for the manufacture and sale of Customized Fertiliser will be granted by Joint Secretary(INM). Department of Agriculture and Cooperation, MOA,GOI. Such permission, for manufacture and sale of particular customized fertilizer grade shall be granted only for the specific area and for a period not exceeding three years. Such manufacturing companies must start their manufacturing and sales process with in a period of six months from the date of grant of such permission. For grant of permission to produce and to sell such customized fertilizers, the concerned manufacturing companies should necessarily apply for permission, to the office of the Joint Secretary(INM), Ministry of Agriculture under intimation to the State Government in the prescribed Performa as provided in annexure II. The competent authority shall expedite the requisite permission suthorization of otherwise within 45 days of the receipt of such applications

Renewal/ Revision of customized fertilizer Grade : On completion of three years or earlier, manufacturing company of customized fertilizer shall submit a renewal/revision application for varied customized fertilizer manufactured by it. In case no change in the already approved composition of customized fertilizer is required, the same shall also be declared by the manufacturer. The competent authority, shall thereon, accord its approval; within .a period of 45 days from the date of receipt of such application, failing which the application duly acknowledged copy of such application shall be treated as official approval.

Customized Fertilizer Grades : The grades of customized fertilizer which the manufacturing company propose to manufacture and sell, shall be based on area specific and crop specific soil testing results. The manufacturer may be in association with Agricultural Universities/KVKs concerned, shall also conduct agronomy tests of the proposed grade to establish its agronomic efficacy. The manufacturing company, preferably in association with concerned agriculture universities/KVKs may continue to conduct agronomy tests of the proposed grades on the farm, for at least one season. The minimum nutrient contents in a specific grade of customized fertilize, proposed to be manufactured, shall contain not less than 30 units of all nutrients, combined.

For manufacture of area-specific subsequent grades of customized fertilizers, duly approved by the Joint Secretary(INM) MOA from time to time, the company shall intimate the competent authority within at least 45 days prior to its introduction of the said grades in the market. Since these grades will be based on the scientific data, no formal approval will be necessary..

Raw Materials:

(i) Use of subsidized fertilizers by Manufacturer of customized fertilizer: . As per the existing policy, all subsidized fertilizers can be used for manufacturing of customized fertilizers. As such, domestic manufactures of all such subsidized fertilizers will have the choice to sell the requisite quantity to the manufacturing companies of customized fertilizers and the manufacturing company of such subsidized fertilizers shall be eligible to claim subsidy from DOF under relevant rules.

(ii) Captive use of subsidized fertilizers by the manufacturer of customized fertilizer. Domestic manufacturer of subsidized fertilizers will have the option to supply the required quantity of such fertilizers, as raw material, to its own manufacturing unit for production of customized fertilizers. All such supplies shall be eligible for subsidy as per the policy of DOF. .

(iii) Import of subsidized fertilizers by the manufacturer of customized fertilizers. All manufacturers of customized fertilizers will have option to import subsidized fertilizers under the existing Policy guidelines of GOI for the manufacture of customized fertilizers not exceeding its realistic requirements. On the imported quality of such fertilizer to be used for manufacture of customized fertilizer, such manufacturers shall be eligible for subsidy from DOF, under relevant rules.

(iv)Allocation of subsidized fertilizer as raw material for manufacture of customized fertilizers. . Specific allocations of subsidized fertilizers, to ensure adequate availability, in respect of States, may be made for use as raw material for manufacture of Customized Fertilizers, However, if required, permission for import of specific fertilizers as raw material (not included in schedule 1 of FCO, 1985) may also be granted to the manufacturers.

Quality of Customized Fertilizers: The Customized Fertilizers to be used for based application shall be granular in size with minimum 90% between 1-4 mm IS sieve and Below 1mm should not exceed 5%. The moisture content should not exceed 1.5%. For foliar applications, however, the grades should be 100% water soluble. The specifications of the customized fertilizers provided by the company to manufacture of Customized Fertilizer, duly approved by the Ministry, shall be strictly adhered to.

Quality Cheek

(i) Procedure for drawl of sample of fertilizers: (a) The method of drawing samples shall be provided in the FCO. (b) Clause 4A(ii) Weight of one sample should be 400g. as specified under Clause 4 A (iii) for Part A in Schedule 1 of the FCO,1985.

(ii) Methods of analysis of fertilizer: (a)The methods of analysis of fertilizers shall be as per the procedure prescribed in FCO. (b) For preparation of sample for analysis in the laboratory (Clause 1-1) under part B in schedule II of FCO,1985 the whole sample size of 400g should be powdered. The whole sample size of 400 gms shall be powdered.

(iii)Tolerance limit: The tolerance limits prescribed under the FCO ,1985 for NPK mixture and NPK with micronutrients, shall be applicable to the customized fertilizers. However such tolerance limit shall not exceed 3% for all nutrients particularly when secondary and micronutrients are also present with NPK.

Labeling:

(i) The word Customised Fertiliser shall be superscribed on the bags.

(ii) The name of the crop and geographical area for which the Customised Fertiliser recommended shall also be indicated on the bags.

(iii) The grades of Customised Fertiliser and the nutrient contents shall be mentioned on the bags.

(iv) The manufacture should preferably have tampered proof bagging so as to check on adulteration.

Pricing of Customised Fertiliser: The Company shall fix reasonable MRP for its approved grade of customized fertilizers taking all factors into consideration.

General: The permission for manufacture of customized fertilizer shall be restricted to such manufacturing companies of fertilisers who have the certificate of manufacture and authorization letter for selling fertilizers in a particular State. All the provisions of Fertilizer(Control) Order, 1985 and Essential Commodities Act 1955, shall be applicable for manufacture and sale of Customised Fertiliser.

Annexure.I

List of equipments for setting up of new soil testing laboratories for creating npk with micronutrient testing facilities

1. Atomic Absorption Spectrophotometer 2. Spectrophotometer 3.Flame Photometer 4. pH Meter 5. Conductivity Bridge 6. Colorimeter 7.Kjeldhal Distillation Set 8. Waster distillation Set(all glass) 9. Centrifuge 10.Deionizer 11.Balances 12. Grinders other instruments like Hotplate, gas Cylinders, heaters etc. 13. Stabilizers 14. Sample holding racks 15. Computer with printer 16. Software for preparation of recommendation and record of data.

Annexure.II

Application for grant of permission for manufacture of customised fertiliser

1. Name of the Company and address 2. Location of the unit where the Customised grade of fertilizer proposed to be manufactured. 3. Annual Turnjover of the company 4.

Location/Particular of the Area where the Customised Fertilizer is to be introduced 5. Soil Fertility Status of the Area.6. Introduction Season 7. Cropping Pattern of the Area 8. Soil PH 9. Irrigated or unirrigated land 10.Location of soil testing lab 11. Annual Analysing Capacity of soil samples 12. Area Climate 13.Grades and other details relating to composition of Customised Fertiliser 14. Raw Material(indicate whether the subsidized material to be used). 15. Quantity to be produced in each season 16. MRP 17. Whether the company possess any permission for manufacturing the graedes of Customised fertilizer in any area (i) Whether the company possess the soil testin facility as prsescribed in Annex II of guidelines. (ii) Whether the proposed grades are based on the soil testing results and crop requirement. (iii) Whether the multi locational trials have conducted or not (iv) Whether the agronomic test of the product in consultation with Agriculture Universities/KVK have been conducted or not. 1. Declaration:- (a) I/We declare tat the information given above is true to the best of my/our knowledge and belief and no part thereof is false. Date Signature of the Applicant(s) Place Note:

Lecture 5

Fortified Fertilizers-Definitions-Production –Characteristics – Sources - Suitabilityfor Crops – Merits and Demerits

Fortified fertilizers

- Fortified fertilizers are a group of straight and complex macronutrient fertilizers fortified with secondary and/or micronutrients.
- Application of fortified fertilizers with secondary and micronutrients will help to mitigate their deficiency (sulphur, magnesium, zinc, boron etc.,)and ensures balanced fertilization.
- All fertilizer products covered under nutrient based scheme (NBS) are eligible to be fortified or coated up to 20% of their production.
- Beginning has been made in production ofboronated SSP and zincated urea and both of these are notified by Government of India.
- Other fortified fertilizers includes NPK complex fortified with boron (N_{10}:P_{26}:K_{26}:$B_{0.3}$ and N_{12}:P_{32}:K_{16}:$B_{0.3}$),
- DAP fortified with boron (N_{18}:P_{46}:K_{0}:$B_{0.3}$and N_{18}:P_{46}:K_{0}:$B_{0.5}$), NPK complex fortified with zinc (N_{10}:P_{26}:K_{26}:$Zn_{0.5}$ and N_{12}:P_{32}:K_{16}:$Zn_{0.5}$), and nitro phosphate with potash fortified boron (N_{15}:P_{15}:K_{15}:$B_{0.2}$).
- Fertilizer companies have already started manufacturing these value added fertilizer products to address multi-nutrient deficiencies, conservation of soil health and enhancement of farm income.
- This includes coated fertilizers also

- The deficiency of secondary and micronutrients can thus be overcome by fortification of the presently manufactured N/P/NP/NPK fertilisers to develop value-added/fortified fertilizers
- First of its kind in India, DAP has been fortified with the most essential micro nutrient Zinc providing 18% Nitrogen, 46% phosphate along with 0.5% Zinc. In order to encourage the balanced use of fertilizer, the Government of India is encouraging the use of fortified fertilizers and so far over 25 fortified fertilizers have been incorporated in the Fertilizer Control Order (FCO), 1985.

Research findings to substantiate success of fortified products

- Deficiency of Zn is wide-spread in India and could be a barrier in achieving the targeted production of staple food crops like rice and wheat. It may be pointed out that that zincated urea guarantees quality of the produce and also assures that some Zn is applied by the farmer.

- Ferti-fortification with Zn for achieving increased grain yields can be a step towards nutritional security and healthier farm income in India. It may be pointed out that that zincated urea guarantees quality of the produce and also assures that some Zn is applied by the farmer

- Urea coating technology employing neem oil emulsion requiring 0.5-1.0 kg neem oil per ton of urea was found superior to prilled urea. The neem coated urea of National Fertilizers Limited (NFL) recorded better shelf-life, slow dissolution as well as nitrification inhibition property. With marginal additional cost for coating, the product showed increased nitrogen use efficiency.

- Silicate fertilizers increased significantly rice yield and N efficiency.

Table. Examples of 100 % Water soluble fertilizers and Fortified fertilizers

Sl. No.	100 % Water Soluble Complex Fertilizers	Fortified Fertilizers
1	Potassium nitrate (13-0-45)	Boronated single superphosphate (16% P_2O_5)
2	Mono potassium phosphate (0-52-32)	Zinc coated urea
3	Calcium nitrate	Zinc coated phosphate (suspension)
4	NPK(13-40-13)	Zincated NPK (12:32:16:0.5)
5	NPK(18-18-18)	Zincated NPK (10:26:26:0.5)
6	NPK(13-5-26)	Boronated DAP)18:46:0:0.3)
7	NPK (6-12-36)	Boronated NPK (12:32:16:0.3)
8	NPK(20-20-20)	Boronated NPK (10:26:26:0.3)
9	NPK(19-19-19)	Calcium nitrate with boron
10	Potassium magnesium sulphate	15:15:15:0.3B
11	Mono ammonium phosphate (12-16-0)	DAP:0.5 Zn
12	Urea phosphate (17-44-0)	SSP:0.5 Zn

Lecture 6

Pelleted fertilizers-Definitions – Production – Characteristics – Sources- Suitability For Crops-Merits and Demerits

Granulation/ Pelletisation/ Agglomeration is the process of particle sizeenlargement and most commonly refers to theupgrading of material fines into larger particles, suchas pellets or granules. In addition to material fines,agglomeration is also useful for sludge-like materials,such as manure or FGD sludge, to transform them intoa more usable, more easily handled form.

Pelleted form of Fertilisers:

Nutri-Rich Organic Fertilizer Pellets offer the most natural source of essential nutrients to promote vigorous plant growth, bountiful yields and brilliant flowering. Derived from dried poultry waste, these fertilizer pellets are formulated with a broad spectrum of nutrients that slowly release as a plant needs them.

Fertiliser products such as ***Nutri-Rich,*** are convenient if you want to provide nutrients slowly and over a long time. These are particularly good for heavy feeder crops like corn and tomatoes. To apply a pelleted fertilizer, just sprinkle it around each plant at the quantity directed on the packaging. You may only need to reapply once mid-season.

There are many types of agglomeration, all offering their own unique advantages anddisadvantages, but in general, they can all offer certain benefits.

Benefits of Agglomeration/ Granulation/ Pelletisation

- Significant dust reduction
- Improved handling convenience
- More complete utilization of raw materials, conversion of waste to amarketable product, reduced transportation and handling costs.

• Improved product characteristics and appearance, reduce caking and lump formation

Types of Agglomeration/ Granulation/ Pelletisation

While there are many agglomeration techniquesavailable, they generally fall under one of two main categories: pressure agglomeration, or non-pressure agglomeration (a.k.a., tumble growth agglomeration).Pressure agglomeration technologies use mechanicalcompression to shape a material into a desired form.Very little, if any, moisture is needed. Non-pressure agglomeration technologies use atumbling process to “grow” material into a sphericalpellet form. A liquid binder is often used to assist in theagglomeration process.

Pressure Agglomeration:

Briquetting:Typically a dry process, briquetting usespressure to form pillow-shaped briquettes from material fines.

Compaction:Also typically a dry process, compactionpresses material fines into a sheet-like form, which isthen broken up into jagged granules.

Non-Pressure Agglomeration:

Pelletizing:A wet process whereby material fines arerolled into uniform pellets with the help of abinding agent.

Micro Pelletizing:Also a wet process, in whichmaterial fines are mixed with a binder to form smallagglomerates, or prepare the material for pelletizing.

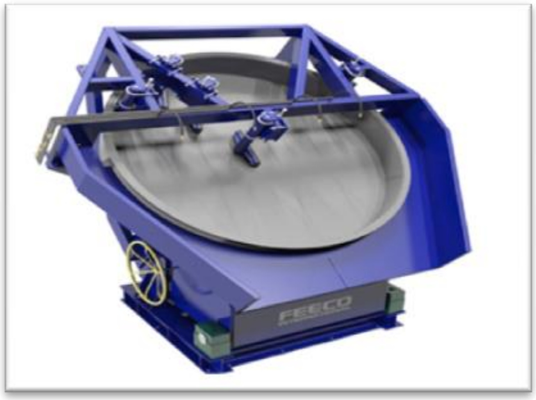
Conditioning:A process which often refers to themixing of material fins with a binding agent in orderto reduce dust and transform the material into amore usable form.

Industry Example:Agglomerated agricultural wastes(such as manure or compost) are easier to transport,store, and apply than unprocessed materials. Otherimproved characteristics include custom formulations,and opportunity for storing.

Granulation/Pelletisation techniques

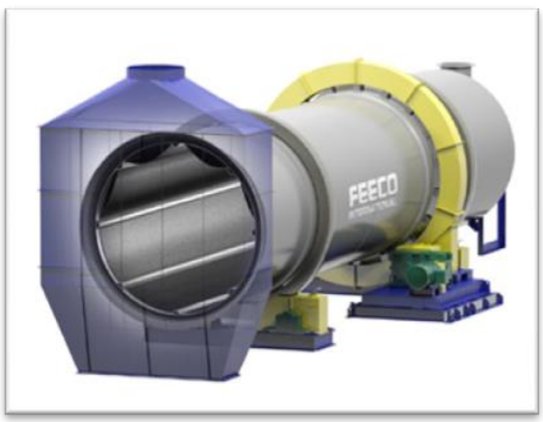
There are many choices on the market when it comesto agglomeration equipment. Additionally, new usesare being developed all the time, making currentequipment options increasingly flexible.

Disc Pelletizers : Disc pelletizers are a type of non-pressure (tumblegrowth) agglomeration equipment. In the world ofagglomeration equipment, the pelletizer is oftenchosen for its ability to fine-tune the product size—theprocess of which is a combination of both scienceand art.



The pelletizer offers several variables, all of which can be adjusted and work together tocreate the desired pellet product. Material is fed onto the disc, where it is taken up bythe rotation of the disc. Both material feedstock and a binder are continuously fed onto the discpelletizer,making this a continuous process. The binder causesthe fines to become tacky, allowing them to pick upmore fines as they tumble, resulting in an effect similarto rolling a snowball, referred to as *coalescence*.

Agglomeration drums & granulation drums (rotary drums) : Agglomeration drums also fall under the tumblegrowth non-pressure agglomeration category. Agglomerationdrums are valued for their high throughput, and whilethey are used throughout a variety of industries, theyare perhaps most common in the mining industry, dueto their ability to accept variance in feedstock, andtheir heavy-duty construction, ideal for the



demandingprocess needs of the mining industry. Here, they aid inthe heap leaching process by promoting optimal oreextraction through more uniform particle shape andsize. In addition, agglomeration drums can be used forspecialty applications such as coating.

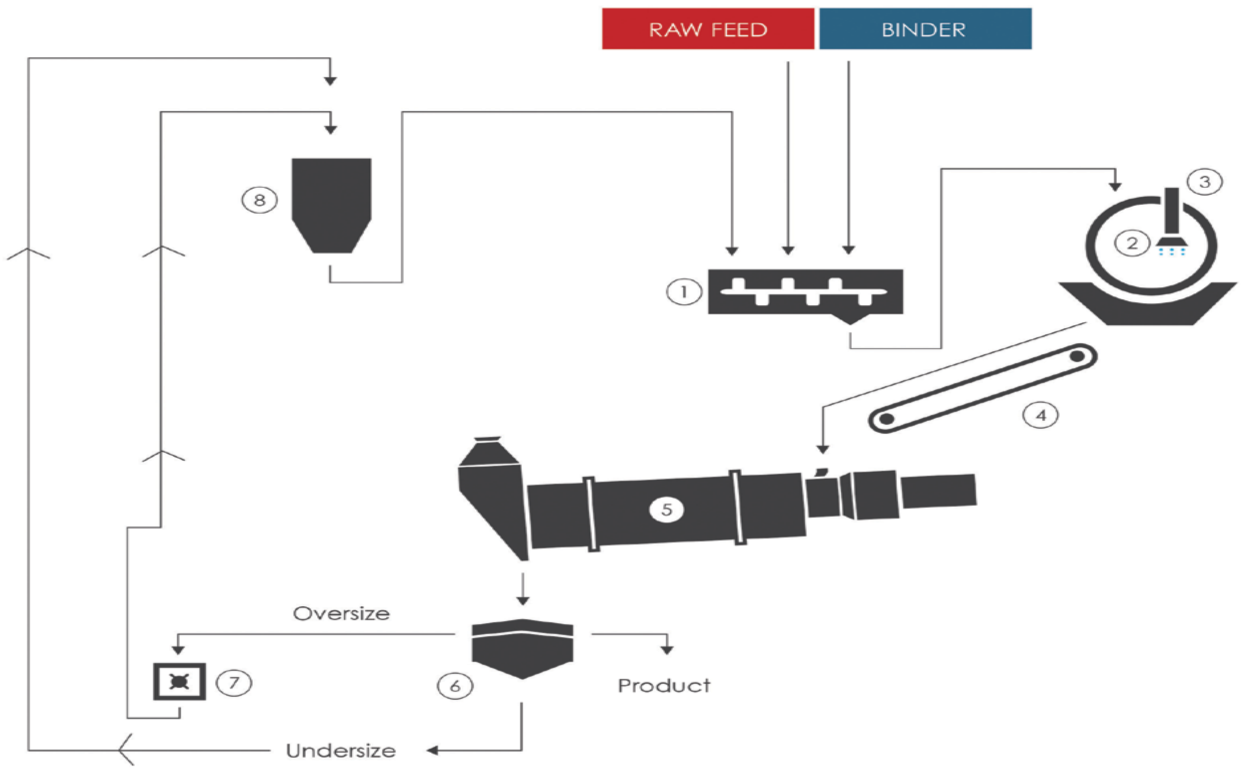


Fig.: Flow diagram of a typical pelletizing process

Diagram Key: 1. Pug Mill/Pin Mixer, 2. Disc Pelletizer, 3. Liquid Spray System, 4. Transfer Conveyor, 5. Rotary Dryer, 6. Vibrating Screen, 7. Over-size Mill, 8. Surge Hopper

Micro Pelletizing

Micro pelletizing is the process of agglomeratingmaterial fines into small pellets, or "micro pellets."Unlike traditional pelletizing, where slightly largerpellets are produced, micro pelletizing producespellets around 20-60 mesh.Micro pelletizing can be carried out either in a standalonepin mixer (this process is sometimes referred toas "conditioning"), or with a pin mixer/disc pelletizercombination. When a full-scale pelletizing operation isnot necessary, or when only smaller pellets or materialconditioning is needed, the use of a pin mixer to micro pelletize material offers a cost-effective alternative to a full-scale pelletizing operation and can provide sufficient results.

Advantages of Pelletizing:

(i) ***Faster nutrient delivery:***Because pellets are notcreated through pressure, they are less dense thantheir compaction granule counterparts. The less densepellets created in pelletizing can withstand handling,but can still quickly break down upon application,an ideal characteristic for soil amendments, fertilizers,and other applications that benefit from fast materialbreakdown.

(ii) ***Less dust and fines****:* Compared to compaction granules, pellets produce less fines. Since pellets areround, there are no edges to break off and create dust.

(iii)***Binders can serve as beneficial additives****:* Pelletization offers the opportunity to control formulation, throughthe addition of specially formulated binders, in orderto create optimum pellet characteristics.

(iv)***Lower capital costs****:* The pelletizing method oftenrequires a lower capital investment than compactiongranulation.

(v) ***A premium product is produced****:* The round, smoothpellets produced in the pelletizing process areconsidered a premium product. Additionally, the pelletizing process offers the opportunity to include additives to further customize and enhance theend product.

Disadvantages to Pelletizing:

Higher Processing Costs - The use of a binder, and therequired drying step results in higher processing costs when compared to compaction granulation.

Compactors : Compactors are a type of pressure agglomeration equipment that operate on the principle that under extreme pressure, some materials will adhere to themselves. Compactors use mechanical force top ress material fines into a compacted sheet, whichis then broken up into granules. Compactors are frequently used in fertilizer production. Material fines are first fed between two counter rotating rolls, which press the material into a compact sheet. The sheet is then fed through a flake breaker, followed by a granulator, which breaks the sheet upinto the desired size granules. Though compactor scan work with a binding agent, with most materials processed in a compactor, a binder is not needed.This is therefore considered a dry process and does not require a subsequent drying step, though this is not true of all compaction granulation processes.

Briquetters : Similar to compactors, briquetters also use mechanical force to press material fines into a desired shape. Briquetters are typically reserved for instances where larger agglomerates are desired, such as in themaking of water softener salt briquettes, or charcoal briquettes. Because small briquettes are difficultto make and have a low volume, the smaller the briquette, the higher the price of the equipment. Typically, briquettes are produced no smaller thanroughly a ½" square by ¼"thickness. Material fines are fedbetween two counter-rotatingrolls. Each roll has one half of the desired "pillow"shape, and as the rolls come together, the halvesunite, pressing the material into one complete pillowform. Here again, a binder is not necessary, butsometimes useful.

Why use a Binder?

There are three main reasons for using a binder in the agglomeration process:

1. To achieve the desired final dry pellet crush strength:Achieving the appropriate dry crush strength is necessary to ensure the pellets are durable enough to survive all handling points prior to and during end product use. From screening and packaging, to shipping, distribution, and application, product breakage and dust needs to be kept to a minimum. A dry pellet crush strength that is too low will break up tooeasily, while a dry pellet crush strength that is too high won't break up easily enough, or will take too long to dissolve. Adjusting binder concentration, or testing different binders, can help to hit the target dry crush strength.

2. To achieve the desired green strength: Green strength refers to the strength of a pellet in its'wet' state, prior to drying. Often, materials need to be able to hold up as they move throughout the process before they are dried. A material with a green strength that is too low has the potential to break up as it drops off of conveyors or goes through chutes.Achieving the appropriate green strength will help the product to stay intact through the end of the process.

3. To assist in the actual agglomeration/granulation process :A binder helps to achieve the tackiness needed for a material to stick to itself. Though some materials may agglomerate without a binder, most materials require some sort of binding agent to pull and hold particles together while forming the pellets. And while ideally water will do the job, many times it does not have the tackiness to give the pellet enough wet strength to hold up to the rolling, tumbling, and dropping that apellet is exposed to during processing.

Molasses, starches, and other organicbinders, however, not only function well as binders forfertilizer products, but also allow the product to breakdown quickly and can even add micro nutrients.

Lecture 7

Multi nutrient Liquid Formulations – Definitions – Production – Characteristics Sources-Suitabilityfor Crops-Merits and Demerits

Liquid fertilizers are becoming more and more common. Multinutrient liquid fertilizers also are becoming more popular. The major advantage is in handling. The disadvantages are the generally higher price and lower possible analysis compared to dry fertilizers, especially when the material contains potassium.

The liquid fertilizers may becategorized into two groups:

(i) Clear solutions and
(ii) Suspensions.

Solution mixtures usually are free of solids and clear enough to see through. Suspensions are of higher concentration and have small crystals of plant nutrients suspended by a gelling clay, such as ***attapulgite*** or ***sodium bentonite***, in saturated fertilizer solutions. Suspension fertilizers, which are much less common, are fluids in which the components' solubility has been exceeded and in which very fine insoluble particles are kept from settling out by the inclusion of clay. Again, the major advantage of these materials is in handling. Suspensions also can be formulated at much higher analyses than can the clear solutions. Analyses similar to those for dry materials are possible. The major disadvantage of suspensions is that they require constant agitation, even in storage. Furthermore, suspension fertilizer cannot be used as a carrier for certain other chemicals.

The objectives of fluid mixed fertilizer production and marketing are much the same as those for solid materials, namely, to produce in a plant with low operating cost that does not emit pollutants, a homogeneous fertilizer that has low raw material cost, high nutrient concentration, product versatility, and can be applied uniformly.

Special Features of Liquid fertilisers

- Liquid form fertilizers are applied with irrigation water or for direct application.

- ❖ Ease of handling, less labour requirement and possibility of mixing with herbicides have made the liquid fertilisers more acceptable to farmers.
- ❖ Liquid fertilizers include N fertilizers, anhydrous liquid NH_3, aqueous ammonia, ammoniates, concentrated solutions of NH_4andNO_3andurea, and complex fertilizers conta ining two or three basic plant food elements (N, P, K) invariousproportions.
- ❖ Liquid fertilizers are introduced intothe soil to a specific depth (to avoid ammonia loss) b y trailer or tractor mounted machines with plows or cultivators
- ❖ Ammonia solution and liquors are introduced at a depth of 10 to12 cm, and anhydrous liquid ammonia at 15to20 cm (depending on the mechanical state of the soil).

Organic liquid extracts

(a) Composition

- Amino acids : Asparagine, Threonine, Serine,Glutamine, Proline,Glycine, Analine, Valine, Methionine, Isoleucine, Leucine,Tyrosine, Phenylalanine,Histidine, Lysine, Arginine

- Organic substances: Carotene, sterols, proteins, vitamins E, Cobalamin (B12), Biotin (H), Thiamine (B1), Pyridoxine (B6), Niacin (PP) , D, C, minerals, chlorophyll , oils, xanthophylls', sugars, enzymes, triacontanol, alcohols, natural organic stimulators, natural antibiotics , probiotics, peptides, carbohydrates, estrogens, ketones, flavonida, cycloalkanes, phenol, naftalan, metalloporphyrins,

- Natural micro - macro elements: N, P, K, Ca, Na, Mg, Cd, Ni, Pd, C, Cr, Cu, Zn, S, I, Se, Mo, Fe, As, U, Th, Sr,Sh, Bi, V, La, Cr, Mg, Ba, Ti, Al, W, Hg, Ga, Si , Mn, F, Be, Co, B.

- Soil bacteria : 59 000 000 in 1 gr.Lactobacillaceaeplantarum, Lactococcuslactis, Leuconostae, Streptococcus cremoris, S. diacetilactum, S. Salivarium, Sacccharomycescerevisae, S. unisporum, Torulapsischaerica, Torulasporadelbrueskii, Kluyveromyceslactis, Mammococcus, L. acidophilus, LB Bulgaricum, Candida, Yeast, C. holmii, C. friendrchii, Bacillus, Ammonifiers, Trichoderma, St. Aureus, C. Diphythriac gravis, fungi.

- Humic, fulvic ,indole butyric, pantothenic and naphthylacetic acids, carboxylic acids , humic salts, para amino benzoic acid.

- Natural NPK minerals

(b) Direct use of Liquid extracts

(i) For the production of liquid NPK fertilizer

(ii) For stimulation of plants and soils enrichment

(iii) For seeds and roots soaking

(iv) As protection measure of drought and diseases

(v) Capillary, hydroponic and watering systems as nutrients

(vi) For substitution in animals and poultry feed

Uses of Liquid fertilizers

- As nutrient for hydroponics through watering or other feeding systems
- Seed and roots soaking
- For stimulation and growth of plants through foliar spraying

Basics of liquid fertilizer – a natural, biologically active full complex fertilizer

Production :

1. Liquid fertilizer is made by NANO technology. Low molecular parties of fertilizer very good absorb the plants.
2. By special technology is activating soil bacteria and increasing amount in need temperature and pressure in liquid form and become biologically active.
3. Liquid fertilizer basis is producing from natural ingredients, such as peat, nature humus, minerals, rock mix.
4. All ingredients are natural and sterile. It does not have any contaminants, pathogens or chemicals.
5. There is no food residues , industry antibiotic or hormones as from industrial manure or similar raw in fertilizer production.
6. This basis can be used as all complex nutrient for ecological farming or intensive farming sector, also if need for growing we adding mineral or organic NPK
7. Natural liquid extract is good diluting in water and have low-use norms, can work by all types other fertilizer, pesticides or herbicides.

Benefits of Liquid Fertilisers

1. Running of the plant to the physical, chemical and biological properties
2. Improves absorption of nutrients
3. Reduces the uptake of toxic substances by plants
4. Promotes plant fermentationand productivity
5. Increases plant resistance from diseases
6. Stimulates triacontanolof the root, increases upto 50% and and respiration
7. Increases the vitamin, mineral content and promotes sugar for taste qualities.
8. Increase yields by 15-25% in cereals, 25-30% of fruit and vegetables
9. Used effectively by leaves; the rain does not wash from the leaves, but dilute it and fertilize the plant again.
10. Improve soil structure - constantly balancing pH, promotes the growth of microorganisms, enriched organic deposits. Does not drain the soil as other fertilizers.
11. Breaks down the sand and clay in soil (colloidal - combines soil particles, increases the absorption of water, reduces soil erosion and cracks,darken the soil and increase the solar absorption)
12. Reduce the levels of salt content in the soil.
13. A lot of humic, amino acids, fulvic acids, stimulants added in the preparation process, improves soil structure.

Liquid fertilizer packing system:

The normal standard packing sizes of 1000 lit., 100 lit., 20 lit., 10 lit., 5 lit., 1 lit. and 0,5 lit. are followed in most of the cases.

Lecture 8

Foliar Formulations-Leaf Nutrient Analysis – Organicand Synthetic Chelates

Foliar fertilization is a technique of feeding plants by applying liquid fertilizer directly to their leaves. Foliar feeding has been used as a means of giving supplemental doses of major and minor nutrients, plant hormones, stimulants and other beneficial substances. Foliar fertilization is generally used for better management of nutritional status, growth, to correct deficiencies quickly, and improve disease resistance for batter crop quality.

Observed effects of foliar fertilization included yield increases, resistance to diseases and insect/pests, improved drought tolerance and enhanced crop quality. Plant response is dependent on species, fertilizer form, concentration and frequency of application as well as the stage of plant growth. Foliar applications are often time to coincide with specific vegetative or fruiting stages of growth.

The soil application of any fertilizer including organic and commercial forms for higher crop production may be relatively inefficient due to biological, chemical and physical properties of the soil that can decrease nutrient availability.

Increasing cost of commercial fertilizers (nitrogen, phosphorus, and potassium) also make their non-traditional fertilizer applications, specifically foliar fertilization is more attractive, but foliar fertilization take care of all the plant’s nutrient needs.

Objectives of Foliar Fertilization

1. To stimulate the production process of high yielding crops by application at deficit peak / critical requirements.
2. To promote crop growth under adverse conditions (Stress).
3. To improve nutrient use efficiency.
4. To reduce chemical load.

Components of Foliar Fertilization

1. Liquid fertilizer:

Materials added to the soil or applied directly to crop foliage to supply elements needed for plant nutrition. These materials may be in the form of liquid, aqueous solutions. Liquid fertilizers provide plants with concentrations of easily-absorbed, soluble nutrients, thereby enhancing their health and productivity.

2. Water soluble fertilizer:

A powdered and granule synthetic fertilizers that is mixed with water and poured on the soil or sprayed on the foliage of plants. Water Soluble Fertilizers are Urea, Urea phosphate, Magnesium Sulphate, Potassium Sulphate, Ammonium Sulphate, NPK 18-18-18, NPK 15 -30- 15

3. Sticker:

Sticker are the agent which improve the adhesion of spray droplet on target plant. A fertilizer is fairly water soluble, it may be washed off the leaf during heavy rainfalls that follow deposition.

4. Neutralizing agent:

It is a foam concentrate formulation that can be mixed with either acid or alkaline water-based solution and discharged through an air-aspirated foam discharge device to produce an expanded foam. The foam produced is extremely stable, meaning that it will slowly release its solution from the bubble walls and neutralize the spill.

Why Foliar fertilization?

- Better management of nutritional status of plant
- Improve plant growth
- Quickly correct nutrient deficiencies
- Improve disease resistance
- Improvement of crop quality

Criteria for Foliar fertilization

- The amount of nutrient required by the crop.
- The effectiveness of the application at the growth stage that best matches the crop response.
- The suitability of a product formulation for uptake.
- The impact of method, time and concentration of applied foliar product on crop foliage.

Keys to success

- Understanding the interaction between the leaf surface and the foliar material.
- Uptake and mobility.
- Spray coverage, droplet size, etc.
- Understanding product quality–avoid Chloride and Nitrate based products especially.

Foliar application may be preferred under the following conditions

- When visual symptoms of nutrient deficiencies observed during early stages of deficiency.
- When unfavorable soil physical and chemical conditions which reduce fertilizer use efficiency (FUE).
- Small quantity of micronutrient is needed to apply and it cannot be applied effectively through root or soil.
- During drought period where in the soil application could not be done due to lack of soil moisture.
- Foliar application is effective for the application of minor nutrients like iron, copper, boron, zinc and manganese.

Ideal Period for Foliar Spray

The cuticle is more permeable when swollen. Foliar Fertilization should be carried out at times when the relative humidity of the air is high i.e. in the early hours of the morning and in the evening, not during the hot hours of the day. Another advantage is the spray deposit evaporates more slowly and so there is less danger to the leaves being burned by bright sunlight. The high humidity in the evenings and during the night causes the nutrients from dried spray deposits to be dissolved so that they can enter in the leaf.

Mechanism of foliar Fertilization

Foliar fertilizer nutrient to be utilized by the plant for growth, it must first gain entry into leaf prior to entering the cytoplasm of a cell in the leaf. To achieve the nutrient must effectively penetrate the outer cuticle and wall of the underlying epidermal cell. Once penetrate is occurs, nutrient absorption by the cell is the similar to absorption by the roots. All the components of the pathway of foliar-applied nutrients, the cuticle offers the greatest resistance.

When foliar fertilization is best?

In the case of calcium, transport from roots to fruit is limited, so foliar applications are the best method we know to get more calcium into fruit tissue to reduce post harvest disorders. The expense of the calcium spray is more than justified by the potential post harvest losses.

Leaf cuticle:

The leaf cuticle is a thin covering on the outside of the leaf and other organs which protects the plant from the extremes of the environment. The cuticle is dynamic and responds to changes in the environment and also to management.eg. Drought stress and extreme temperatures.

Movement of nutrients through the cuticle:-

Originally it was held that movement of solutes occurred in ectodesmeta. These pores have a diameter of <1nm, with a density of about 10^{10} pores/cm and are lined with negative charges increasing in density towards the inside facilitating movement of cations. Actual movement through the cuticle depends on the nutrient concentration, molecular size, organic or inorganic form, time as a solution on the leaf surface, charge density across the cuticle.

Change in the leaf cuticle with water deficit stress:-

Cuticle thickness was increased by 33%. Cuticle composition changed to predominantly high molecular weight (longer chain) waxes which increased the hydrophobicity. The caused a resultant decrease in uptake of agrochemical (urea, defoliants etc.)

Factors influencing Foliar fertilization:-

- Air temperature: In higher temperature it causes evaporation of nutrition and decreases the effect of spray solution.
- Relative humidity: High relative humidity increases nutrient absorption and also maintains turgidity of cell, uptake is lower at the time of low relative humidity.
- Post-application irrigation: Irrigation after foliar spray is neglected due to solution may down word movement to the soil.
- Time of day for application: Foliar spraying should be done at early in the morning and in the late evening it is most profitable.
- Rainfall: Foliar spraying should not be done immediate after and before rainfall.

Advantages of Foliar Fertilization:-

- ***Higher Yields**:* Foliar fertilizer gives extra boost for growing to their truly potential.
- ***Healthier Plants**:* Foliar fertilizer provides extra nutrients that plant may need to boost its immunity against pest and disease incidence.
- ***Immediate Results**:* The stomata of a leaf have the ability to soak up the nutrients quickly.
- ***Less expensive**:* One of the most significant benefits of using a foliar fertilizer is that it is cheap as compared to many other means of boosting crop plant growth.

Leaf Nutrient analysis

Plant analyses can be a powerful tool in the diagnosis of yield depressions. Critical plant composition data can be useful in interpreting plant analyses.

The goal in tissue analysis is to adjust fertilization programs so that nutritional problems and their costly consequences are prevented.

Rapid tissue test for nutrients

The crop growth and productivity is conditioned by many factors of which, the nutrient status (Content) of plant parts such as leaf, stem, etc play a critical role. Moreover the leaf and stem are considered as the indicator parts of plants for assessing the nutrients content of plant. Each crop plant requires the essential element at a specific concentration at different growth stages and it is known as ‘critical level’. When the nutrients content of plant depletes below the critical level the plants may exhibit some symptoms. The requirement or otherwise the availability of nutrients can be assessed by i) plant diagnosis ii) soil analysis and iii) plant analysis by two methods a) by qualitative test and b) by quantitative estimation. Based on the plant or soil tests, the required nutrients can be applied for crops to sustain the growth and rectify the deficiency disorders. The rapid tissue test would pave way for rectifying the nutritional problems for quick recovery, however the quantitative estimation of both plant and soil for nutrients concentration will be more useful and economic for applying fertilizers either as basal or foliar and would be the long term strategy to cope up with nutritional problems.

On dry weight basis, the normal healthy cultivated crop plant will have the foliar concentration of essential elements. Nevertheless it will vary depends up on the variety, type of soil, growth stage and other environmental and cultural operations.

Nitrogen	:	1.0 to 3.0 %	Iron	:	20 to 100 ppm
Phosphorus	:	0.05 to 1.0 %	Zinc	:	15 to 50 ppm
Potassium	:	0.8 to 1.2 %	Manganese	:	2.0 to 10 ppm
Calcium	:	0.3 to 0.6 %	Copper	:	10 to 20 ppm
Magnesium	:	0.2 to 0.4 %	Boron	:	5 to 15 ppm
Sulphur	:	0.2 to 0.3 %	Molybdenum	:	0.5 to 5.0 ppm

For rapid tissue test to assess the nutrient status, different parts of plant should be taken as indicator tissue and some of the representative crops are furnished below:

Crops	**Nutrients**					
	N	**P**	**K**	**Ca**	**Mg**	**S**
Cereals	Stem/Midrib	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Pulses	Petiole	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Oil seeds	Petiole	Leaf blade	Leaf blade	Leaf lamina	Leaf lamina	Leaf blade
Cotton	Petiole	Petiole	Petiole	Petiole	Petiole	Petiole
Banana	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina	Leaf lamina
Papaya	Petiole	Petiole	Petiole	Petiole	Petiole	Petiole
Vegetables	Petiole, Leaf blade	Petiole Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade	Petiole, Leaf blade

Chelates

A Chelate is a word derived from the Greek word ‘Chela’ meaning ‘claw’ to describe a kind of organic chemical compound in which the metal part of the molecule held so tightly encircled by the larger organic molecule (the claw), usually called a ligand or chelator, that it cannot be ‘stolen’ by contact with other substances which would convert it into an insoluble form.Each ligand, when combined with a micronutrient, can form a C**helated fertilizer**

To form a **chelated** product for adding to **fertilizer**, the chelating agent is ground to a fine powder. It is then mixed with the sulfate of the desired micronutrient, for example, ferrous sulfate if iron is to be the chelated micronutrient to form Iron chelate.

Chelation is a biochemical process that bonds critical micronutrient metal ions (such as manganese, magnesium, copper, zinc and iron-each are called a **chelate**) to larger organic molecules (**chelating** agents such as amino acids, citric acid, glucoheptanates and other organic acids).

The **chelate effect** is the enhanced affinity of **chelating** ligands for a metal ion compared to the affinity of a collection of similar nonchelating (monodentate) ligands for the same metal.

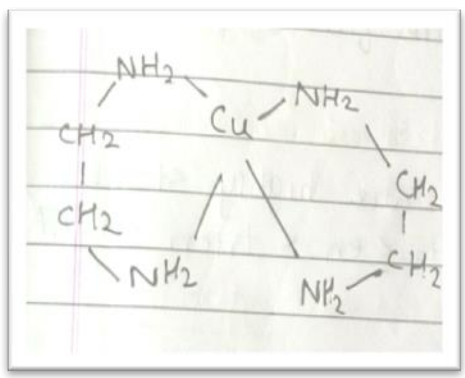
Citric, malic, lactic and tartaricacid sand certain aminoacids are **naturally** occurring **chelating agents,** but they are not as powerful as EDTA.

Complexes involving multidentate ligands are **more stable** than those with only unidentate ligands in them. The underlying reason for this is that each multidentate ligand displaces **more** than one water molecule. An increase in entropy makes the formation of the **chelated complex more favourable**

A complex consists of a metal atom (centre) to which ligands are attached(Where ligands are the species which donate electron pairs to central metal atom).

Example : K4[Fe(CN)6] Here, Fe is the metal atom and CN ions are the ligands.

Now, ligands are classified according to their dentecity, which is defined as number of lone pairs donated by a ligand to a metal atom.



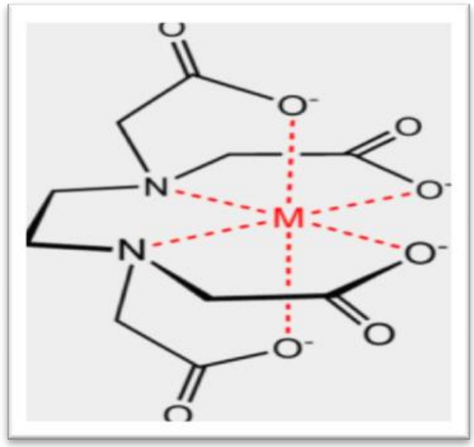
In case of *polydentate ligands*, rings are formed. These complexes are known as **chelates**.

Chelates are more stable than normal complexes.

Eg.:[Cu(en)2]2+2+ where `en` is ethylene diamine.

The metal micronutrients such as iron, copper, zinc, magnesium and manganese which are being hard metallic substances; and in order for plants to use them, the metals needs to be converted into a water soluble form called ions.

These ions float around in the water that surrounds soil particles. If they react with oxygen they are converted into a form that plants can't use. They can also interact with other ions which may cause them to precipitate as solids, making them unavailable to plants.



This is the point where chelates become important. Chelates are organic molecules (in the chemical sense) that pick up and hold the metal ions so that they don't react with oxygen or other ions. Even though chelates hold on to the metal ions, plants can still absorb them through the roots and use them as nutrients.

Chelates make it easier for plants to find certain nutrients. In fact, plants use chelates internally to move metal ions from roots to leaves. Any chemical that has the properties described above has so-called *chelating properties*.

Table: 1. Common chemical names and abbreviations for chelating agents

Abbreviation	Name
CIT	Citric acid (Citrate)
CDTA	Cyclohexane diamine tetra acetic acid
DTPA	Diethylenetriaminepenta acetic acid
EDDHA	Ethylene diaminedihydroxy phenyl acetic acid
EDTA	Ethylene diamine tetra acetic acid
EGTA	Ethylene glycol tetra acetic acid
HEEDTA	Hydroxy ethyl ethylene diamine tri acetic acid
NTA	Nitrilo tri acetic acid
OX	Oxalic acid
PPA	Pyrophosphoric acid
TPA	Tri phosphoric acid

The following are some of the ways Chelates benefitting soils and plants

(i) ***Required in lower quantities:*** Because of their higher use efficiency, their requirement will be less as against the conventional inorganic fertilisers

(ii) ***Make Ions soluble and available:***Some nutrient ions are less soluble in water than others and unless they are dissolved in water plants can't use them. Chelation makes these ions more soluble, making them more bioavailable and accessible to plants.

(iii)***Prevent Precipitation:***At higher pH some metal ions, like iron, react with another ion called hydroxl (OH-). When these two ions join together, they are no longer soluble in water and precipitate (ie form a solid). This helps explains why some plants become chlorotic and show iron deficiency symptoms in alkaline soil even though the soil has lots of iron in it. Chelation will reduce this reaction making more iron available to plants.

(iv) ***Reduce Toxicity of Metal Ions:*** Some metal ions become toxic to plants at higher concentrations. Chelation removes the ions from the water, reducing their concentration. Since plants are no longer exposed directly to the ion, the toxic effects are also reduced.The chelating moleculesresponsible for this are usually large organic molecules that are commonly called humic acid.

(v) ***Reduce Leaching:*** Chelates hold ions and keep them out of the soil water. Water running past the chelating molecules will no longer wash the ions away, reducing leaching. Chelates don't completely eliminate leaching, but they certainly slow down the process.

(vi) Suppression of Plant Pathogens:By holding the ions, chelates make it more difficult for some pathogens to get access to them, thereby reducing their growth.

(vii) ***Compatibility with other fertilisers/chemicals:***It does not involve in any of the interactions with other nutrients / chemicals in soils, it is more compatible.

Table .Chelated fertilizers, formulaand nutrient content (%).

Source	**Formula**	**Nutrient content (w/w, %)**
Iron chelates	NaFeEDTA	5–14
	NaFeEDDHA	6
	NaFeDTPA	10
Copper chelates	Na2CuEDTA	13 Cu
	Na2CuHEDTA	9
Manganese chelates	Na2MnEDTA	5–12 Mn
Zinc chelates	Na2ZnEDTA	14 Zn
	Na2ZnHEDTA	9–13 Zn
Natural organic materials	-	5–10 Fe, 0.5 Cu, 0.2 Mn, 1–5 Zn

Lec. 10. Value added fertilizers- enriched with organics/chelates

****

Value-added fertilizer is a synergistic fertilizer composition applied to agricultural crops to increase yields with reduced fertilizer use. Compared with traditional fertilizers, value-added fertilizers have additional nutrients such as humic acids, amino acids, alginic acid, proteoglycans and other natural substances.

Value-added fertilizer has no secondary processing, the process of manufacture is simple, low cost, do not corrode equipment, environmental safety and the effect is stable. According to FCO, customized fertilizers are multi-nutrient carriers designed to contain macro, secondary and/or micro-nutrient both from inorganic sources and/or organic sources, manufactured through a systematic process of granulation, satisfying the crop's nutritional needs, specific to its site, soil and stage validated by a scientific crop model, capability developed by an accredited fertilizer manufacturing /marketing company.

Advantages

- It supplies the plant available nutrients in adequate amount and in proper proportion, leads to the balanced application as it supplies not only primary nutrients but also secondary and micro nutrients and the particular texture ensures uniform distribution of nutrients.
- Enhanced nutrient use efficiency
- As the micronutrients are also added with the granulated NPK fertilizer the plants can absorb the micronutrient along with macronutrient which prevents nutrient deficiency in plant.
- Uniform distribution of nutrients.
- Increased crop yields
- Labour saving
- Improve soil fertility hence are environmental friendly and improve soil health.

Methods of developing value added fertilizers

The three modes of manufacturing value added fertilizers are through modified release method, employing stabillization act and synergistic law.

- **Modified-release method** represents addition of slow release polymers and other sparingly soluble synthetic forms to enhance the efficiency
- **Stabilization Act** refers to the addition of urease inhibitors and digestion inhibitors to stabilize the fertilizer and enhance the efficiency.
- **Synergist law** refers to addition of biologically active substances and nitrogen synergists such as alginic acid, humic acid etc.,

Fortified fertilizers

These are the fertilizers manufactured by the addition of secondary and micronutrients to the existing N / NP / NPK fertilizers as a means of value addition or fortification.

Examples

1. Boronated single super phosphate (16P – 15O – 20B)
2. Zincated urea (43N – 2Zn)
3. Zincated phosphate suspension (12.9 P – 19.4 Zn)
4. NPK fertilizer fortified with boron (10N - 26 P – 26K – 0.3 B)
5. NPK fertilizer fortified with boron (12N - 32 P – 16K – 0.3 B)
6. DAP fortified with B (18N - 46 P – 0.3 B)
7. Calcium nirate with boron (14.6N - 0.25 B)
8. NPK fertilizer fortified with zinc (12N - 26 P – 26K – 0.5Zn)
9. NPK fertilizer fortified with zinc (12N - 32 P – 16K – 0.5Zn)

Commercial value added fertilizers

- **Zincated Factamphos :** Addition of zinc to the complex fertilizer. A single fertilizer satisfies both macro and micronutrient requirement of plants. Produced by FACT
- **Zincated Gypsum :** Serves as a soil conditioner and fertilizer. Mainly preferred for alkaline soil.

- **10:26:26 :** Granular form of N – P – K. Manufactured by Mahadhan Smartek Company. Suitable for sugarcane, cotton, groundnut, soybean, grapes, pomegranate, banana, vegetables and pulses.
- **12:32:16 :** Granular form of N – P – K. Manufactured by Mahadhan Smartek Company. Ideal for soybean, potato and other commercial crops which require high phosphorus during the early stages of crop growth.
- **20:20:0 :13:** Granular form of N – P – K - S. Manufactured by Mahadhan Smartek Company. Suitable for sulphur loving crops.

Value added organic fertilizer

- **Poultry manure and biosolids**

The value added organic fertilizers maximize the sustainability and farmers income by reducing the cost of production. Value-added granulated organic fertilizers are produced from poultry litter and biosolids using agglomeration techniques. The granulated organic fertilizer includes biosolids, a nitrification inhibitor, such as dicyandiamide, and a binding agent, such as lignosulfonate, urea formaldehyde, or water. The nitrogen concentration of the granulated organic fertilizer is increased by fortifying with urea. The poultry litter and biosolids formulated into the granulated organic fertilizer aid in flowability, storage, and spreading, while value-added plant nutrient ingredients provide an environmentally safer fertilizer than fresh poultry litter, municipal biosolids etc., commonly used in urban and agricultural systems. The nitrification inhibitor reduces nitrogen losses via leaching and denitrification.

- **Phosphorus enriched FYM**

Farmyard manure enriched with Single Super Phosphate is a common value added organic fertilizer. Superphosphate required for one hectare of a crop is treated with 750 kg of FYM and incubated for 30 days. Enriched FYM helps in preventing the fixation losses of phosphorus.

- **Zinc enriched FYM**

Micronutrients help in preventing the fixation loss of nutrients thereby enhancing their use efficiency.

- **Vermicompost enriched with biofertilizers**

Azospirillum and Phosphobacteria @ 1 kg per tonne of the compost helps in enhancing the nutritional value of the compost.

Priority Areas of Research

- Development of crop specific customized fertilizers. In developing these fertilizers, special precautions are needed when boron, copper, manganese and molybdenum are incorporated in N / NP / NPK fertilizers, because there is a narrow margin between deficiency and toxicity limits of these nutrients.
- Development of low cost indigenous nitrification inhibitors and nano – VAFs.
- Coating of N / NP / NPK fertilizers with biodegradable polymers, nano clay, gypsum and other low cost indigenous materials
- Development of bio impregnated phosphate fertilizers

References

https://www.yumpu.com/en/document/view/39341070/value-added-fertilizers-and-site-specific-nutrient-management
http://www.freepatentsonline.com/8062405.html
https://global.chinadaily.com.cn/a/202001/13/WS5e1c570ea310128217270960.html
https://mahadhan.co.in/product-portfolio/value-added-fertilizers/

Lec. 11. Methods and Guidelines for Preparing Designer Fertilizers - Filler Materials

****

Need for Customized Fertilizers

India has diverse and numerous agro-ecological zones and production environment. Most of the farmers are in small and marginal category with variable investment capacity. Therefore developing customized fertilizers is essential to decrease the cost of production incurred on fertilizers.

Preparation of Customised fertilisers

Scientific principles are used as a guiding factor in deciding the grades of customized fertilisers. The following procedure is followed to develop crop-soil specific customized fertiliser grades (CFG).

- Geo-referencing of chosen area
- Selecting sampling points adopting appropriate statistical procedure
- Actual sampling of the sites
- Analysing soil, plant and water samples for nutrients and some soil characteristics
- Defining management zones
- Yield targeting in major management zones
- Computing crop removal of nutrients
- Calculating nutrient requirement (amount and ratio)
- Blending of nutrients based on the generated information

Solutions

- Identifying the major crops grown in the region
- Nutrient indexing in the study area based on soil analysis.
- Formulation of Customized Fertilizer solutions to provide a total nutrient package as basal application.

Eg.:

Grade 1-	N10	: P20	:K10	: S5	: Mg2	: Zn0.5	: B0.	: Fe0.2
Grade 2-	N20	: P10	:K10	: S5	: Mg2	: Zn0.5	: B0.3	: Fe0.2
Grade 3-	N10	: P20	:K20	: S3	: Mg2	: Zn0.5	: B0.3	: Fe0.2
Grade 4-	N15	: P15	:K15	: S5	: Mg2	: Zn0.5	: Fe0.2	

These customised fertiliser grades are subjected to change every three years as per the changing soil fertility and crop need

Development of Protocol

The protocol for development of customized fertilizer grades has three primary components:

(i) Defining fertility management zones
(ii) Using empirical models like QUEFTS/STCR
(iii) Use of secondary research data and experiential learning'

(i) Defining Fertility Management Zones

Soil fertility management zones are developed by a qualified team of crop specialists. Geo-referenced sampling is a rigorous process which is done in a two months' time available after *Rabi* and *Kharif* season [after *Rabi* season (June) and after *Kharif* season (October and November). Crop specialist use hand held GPS (Global Positioning System) and record latitude, longitude and altitude value of the field from where they take sample. Soil, crop and water samples are analysed for nutrients to build database for deciding the management zones.

(ii) Use of Empirical Models like QUEFTS/STCR

QUEFTS (Quantitative Evaluation of Fertility of Tropical Soils) needs to be calibrated for 'a' and'd' values for N, P and K; which basically refers to the nutrient uptake efficiency under adequate and limited growth conditions For this purpose, the database from secondary literature and from crop cutting trials are collected for the test crop to develop customized fertilizer grade. The soil supplying capacity is computed on the basis of soil test. The mechanistic model of QUEFTS is run for optimizing N, P and K requirement for a targeted crop yield by using the ‘a’ and ‘d’ values and soil test values for N, P and K. On the basis of the general availability of the micronutrient, common representative dose of these specific nutrients are decided. Soil Test Crop Response (STCR) approach is also applied in optimization of N, P and K for the same target yield of the crop.

(iii) Use of Secondary Research Data and Experiential Learning

Value of N, P and K requirement from both the approaches are compared and evaluated. The final decision making is however based on secondary research data and experiential learning.

Validation of Formulation Grade

Multi-location trials are conducted on the farmers’ fields and KVK farms using prevalent recommendations for the test crop. In all these tests, RBD design is used with four replications.

Eligibility Criteria for Manufacture and Sale of Customized Fertilizers

- Permission for manufacture and sale of customized fertilizers shall be granted to only such manufacturing companies whose annual turnover is Rs.500 crores and above.
- Manufacturing companies should have soil testing facility with an annual analysing capacity of 10,000 samples per annum for NPK, secondary and micro nutrients. Such laboratory must possess the requisite instrument viz., Atomic Absorption Spectrophotometer, Flame Photometer, pH meter Conductivity Bridge, Kjeldhal Distillation etc. The grades of customized fertilizers, which company will manufacture, must be based on scientific data obtained from area-specific, soil-specific, crop specific and soil testing results.
- Prospective manufacturers or marketers are expected to use the software tools like Decision Support System like DSSAT, crop models, etc. to determine the optimal grades of customized fertilizers.
- The manufacturing companies, in association with Agricultural universities / KVKs concerned, should also conduct agronomy tests of the proposed grade to establish its agronomic efficacy.

- Such manufacturing companies should generate multi-location trials (not On-Farm Demonstrations) on different crops for minimum one season. Such manufacturing companies must draw these soil samples from within its operational areas and should also ensure that minimum one sample necessarily drawn from University/State government may also be used to prepare soil fertility map and for determination of crop specific grades for potential marketing areas.

Grant of Permission

- Subject to fulfilment of eligibility criteria referred above, the permission for manufacture and sale of customized fertilizers is granted by Department of Agriculture & Cooperation, Ministry of Agriculture, GOI.
- Permission, for manufacture and sale of particular customized fertilizers grade is granted only for the specific area and for a period not exceeding three years.
- For grant of permission to produce and sell such customized fertilizers, the concerned manufacturing companies should necessarily apply for permission, to the Ministry of Agriculture under intimation to the State Government, in the prescribed proforma.
- The competent authority shall expedite the requisite permission/authorization or otherwise within 45 days of the receipt of such applications.
- Such manufacturing companies are required to start their manufacturing and sales process within a period of six months from the date of grant of such permission.

Renewal and Revision of Customized Fertilizer Grades

- On completion of three years or earlier, manufacturing company of customized fertilizers shall submit a renewal/revision application for varied customized fertilizers manufactured by it.
- In case, no change in the already approved composition of customized fertilizers is required, the same shall also be declared by the manufacturer.
- The competent authority, shall, accord its approval within a period of 45 days from the date of receipt of such applications.

****

Lec. 12 Industries and Approved formulations and mixtures – Advantages and Disadvantages - Key Challenges

****

Customized formulations available in India

There are about 36 formulations approved by Fertilizer Control Order of India. The important companies in the market producing customized fertilizers are Tata Chemicals Ltd., Deepak Fertilizers, Nagarjuna Fertilizers, Coromandel Industries Ltd. Etc. Integrated with soil information, the customized fertiliser is formulated on sound plant nutrition principles, thus becoming soil and crop-specific fertilizer.

Tata Chemicals Ltd (TCL), launched the 'ParasFarmoola', the country's first ever customized fertilizer product specifically targeted at farmers in Western-Central Uttar Pradesh (UP). For manufacturing customized fertilizers, TCL has set up a Rs 60-crore 130,000 tonnes per annum facility at its existing area unit at Babrala in UP, with technology sourced from A.J. Sackett of the US.

Farmers' Preference for customized fertilisers

Presently about 80 formulations having N, NP, NPK, NPKS are available in the country depending upon crops and regions. Development of customized fertilizers like zincated urea and boronated super phosphate in early period did not catch up popularity among the farmers-due to predominance of single micronutrient deficiencies, high cost and fear of toxicities due to their indiscriminate use. Even now farmers prefer to use straight sulphate salts of micronutrients like zinc, iron, and manganese compared to Zn or B fortified fertilizers. Blending of iron and manganese fertilizers with N/NP/NPK may not prove beneficial. High cost is another issue for developing customized fertilizers.

Application of customized or speciality fertilizers in horticultural and vegetable crops is widely practiced either for soil, foliar application or in fertigation. Development of soil and crop specific customized fertilizer may prove beneficial in achieving balanced nutrition of crops.

Customized fertilizer grades

The grades of customized fertilizer which the manufacturing company propose to manufacture and sell shall be based on area and crop specific soil testing results. The manufacturer may be in association with Agricultural Universities/KVKs concerned, shall also conduct agronomy tests of the proposed grade to establish its agronomic efficacy. The minimum nutrient content in a specific grade of customized fertilizer, proposed to be manufactured, shall contain not less than 30 units of all nutrients, combined.

Quality of customized fertilizers

Customized fertilizers to be used for basal application shall be granular in size with minimum 90% between 1-4 mm IS sieve and that below 1 mm should not exceed 5%. The moisture content should not exceed 1.5%. For foliar application, the grades should be 100% water soluble. The specifications of the customized fertilizers provided by the company to manufacture of customized fertilizer, duly approved by the Ministry, shall be strictly adhered to.

Quality check

(i) Procedure for drawal of sample of fertilizers

a. The method of drawing samples shall be provided in the FCO.

b. Weight of one sample should be 400g. as specified under Clause 4 A

(ii) Methods of analysis of fertilizer

a. The methods of analysis of fertilizers shall be as per the procedure prescribed in FCO.

b. For preparation of sample for analysis in the laboratory, the whole sample size of 400g should be powdered.

(iii)Tolerance limit

The tolerance limits prescribed under the FCO, 1985, for NPK mixture and NPK with micronutrients, shall be applicable to the customized fertilizers. However such tolerance limit shall not exceed 3% for all nutrients particularly when secondary and micronutrients are also present with NPK.

Labeling

1. The word Customized Fertilizer shall be superscribed on the bags.
2. The name of the crop and geographical area for which the customized fertilizer recommended shall also be indicated on the bags.
3. The grades of customized Fertilizer and the nutrient content shall be mentioned on the bags.
4. The manufacture should preferably have tampered proof bagging so as to check on adulteration

Pricing of customized fertilizer

The Company shall fix reasonable MRP for its approved grade of customized fertilizers taking all factors into consideration.

Customized fertilizer for higher crop productivity

Custom mixed fertilizer is a mixed fertilizer formulated according to individual specifications furnished by the consumer before mixing. Some land needs much higher quantities of balanced fertilizer mixtures in granulated form, for soil application; water soluble form for drip irrigation, mini sprinkler and foliar spray systems. Customized fertilizer may also be defined as multi-nutrient carrier which contains macro and/or micronutrient, whose sources are from inorganic or organic, which are manufactured through systematic process of granulation and satisfies crop's nutritional demand, specific to area, soil and growth stage of plant. Customized fertilizers are enriched with both macro and micro nutrients and are manufactured with stringent quality checks.

Application

The objective behind customized fertilizer is to provide site specific nutrient management for achieving maximum fertilizer use efficiency for the applied nutrient in a cost effective manner. A fertilizer formulated for a consumer prior to mixing, is usually based on the results of soil tests. Customized fertilizers depends on soil, crop, water and specific nutrients. Manufacture of Customised fertiliser basically involves mixing and crushing of urea, DAP, MOP, ZnS, bentonite sulphur and boron granules for obtaining the desired proportion of N, P, K, S and micronutrients. The mixture is subjected to steam injection, drying, sieving and cooling, so as to get a uniform product with every grain having the same nutrient composition.

Benefits

- Customized fertilizers generally maximize crop yields while minimizing unwanted impacts on the environment & human health.
- Fertilizer Best Management Practices make it for farmers, extension agents, crop advisers & researchers to exchange their experiences and also to restrict the unwanted nutrient impact on the ecosystem.
- Application of customized fertilizer is compatible with existing farmers’ system and hence it will be comfortably accepted by the farmers.
- Production of customized fertilizers ensure improved Fertilizer Use
- Customized fertilizer satisfies crop’s nutritional demand, specific to area, soil and growth stage of the plant.
- As the micronutrients are also added with the granulated NPK fertilizer the plants can absorb the micronutrient along with macronutrient which prevents nutrient deficiency in plant.
- Mixed fertilizers with micronutrients provide recommended micronutrient rates for the agricultural fields at the usual fertilizer application.
- The farmer need not buy micronutrient separately at extra cost, thus reducing the total cost.
- Incorporation of micronutrient with granular fertilizer at the time of manufacturing results in uniform distribution of micronutrients throughout granular NPK fertilizer.

Customized fertilizers for Site Specific Nutrient Management (SSNM)

Nutrient management is a major component of a soil and crop management systems. Site specific nutrient management involves nutrient management within a field that are known to require different management options. Site-specific nutrient management does not require special equipment and does not require a large farming operation. It is basically a systematic approach to apply sound agronomic management to small areas of a field that needs special treatment.

Priority areas for customized fertilizers

The introduction of SSNM strategies start with the priority areas facing one or more of the following problems:

- Areas having inadequate or unbalanced use of fertilizer nutrients with low yield levels.
- Areas with crops showing nutrient deficiency symptoms at large scale.
- Areas with occurrence of pest problems linked to nutrient imbalance or overuse of fertilizer N.
- Areas with inefficient fertilizer N use at higher rates
- Areas having evidence of multi-nutrient deficiencies including secondary and micronutrients in soils and crops.

Approach

The promotion of customized fertilizers aims at increasing farmers' profit by achieving the goal of maximum economic yield (MEY) of crops. The main features of customized fertilizers are:

- Application of nitrogen, phosphorus, and potassium fertilizer is adjusted to the location- and season-specific needs to the crop.
- Site-specific application of secondary and micronutrients based on soil tests.
- Promotion of customized fertilizers provide guidelines for selection of the most economic combinations of nutrients.
- Promotion of customized fertilizers should also ensure recommendations for wise and optimal use of existing indigenous nutrient sources such as crop residues and manures.
- Customized fertilizers to be effective should ensure adoption of all the components of integrated crop management (ICM) *viz.* the use of quality seeds. Optimum plant density, Integrated pest management, and good water management.

Achieving the goal of yield maximization through customized fertilizers

To achieve potential yields in crops, collaborative on-farm trials /demonstrations should be conducted by the scientists and fertilizer industry personnel to evaluate the effect of customized fertilizers for higher yields. The scientists and the industry personnel should ensure providing the technology for continued higher yields.

Key Challenges

- Production of customized fertilizers requires technical expertise and huge investment
- Not applicable for all soil types and conditions
- Costly compared to straight fertilizers
- May sometime result in precipitation reactions affecting the crop

Lec. 13. Quality of Designer Fertilizers - Compatibility of Fertilizer Materials - Issues In Storability- Hygroscopicity- Clogging- Toxicity

****

Quality of Designer Fertilizers

- Designer fertilizers to be used for basal application shall be granular in size with minimum 90% between 1-4 mm IS sieve
- The moisture content should not exceed 1.5%.
- For foliar application the grades should be 100% water soluble.
- The specifications of the customized fertilizers provided by the company should be duly approved by the Ministry.

Quality control of customised fertilizers

Fertilizer Control Order has laid down fertilizer-wise detailed specifications and fertilizers not meeting the specification, cannot be sold in the country for agricultural purposes. It also lays down detailed procedure for sampling and analysis of each fertilizer. The Central Fertilizer Quality Control and Training Institute (CFQC&TI), Faridabad and its three Regional Fertilizer Control Laboratories (RFCL) (Chennai, Navi Mumbai and Kalyani) under the Department of Agriculture & Co-operation (DAC) take samples of imported fertilizers at the discharge port for analysis. The States also have their own State Notified Quality Control laboratories that analyse samples taken from field (Warehouses/Dealers/ Retailers) as well as from the manufacturing plants. Based on the analysis, the labs declare samples as **standard** or **non-standard** in terms of specifications laid down in the FCO. The sub-standard quantities are arrived at as per the procedure laid down in the FCO and the copies of analysis report are sent to DAC, DOF, the concerned manufacturer/importer etc. No subsidy is payable on quantities declared as sub-standard.

Quality check

(i) Procedure for drawal of sample of fertilizers

a. The method of drawing samples shall be provided in the FCO.
b. Clause 4A (iii) Weight of one sample should be 400g as specified under Clause 4 A (iii) for Part A in Schedule 1 of the FCO, 1985.

(ii) Methods of analysis of fertilizer

a. The methods of analysis of fertilizers shall be as per the procedure prescribed in FCO.
b. For preparation of sample for analysis in the laboratory (Clause 1-1) under part B in schedule II of FCO, 1985 the whole sample size of 400g should be powdered.

(iii)Tolerance limit

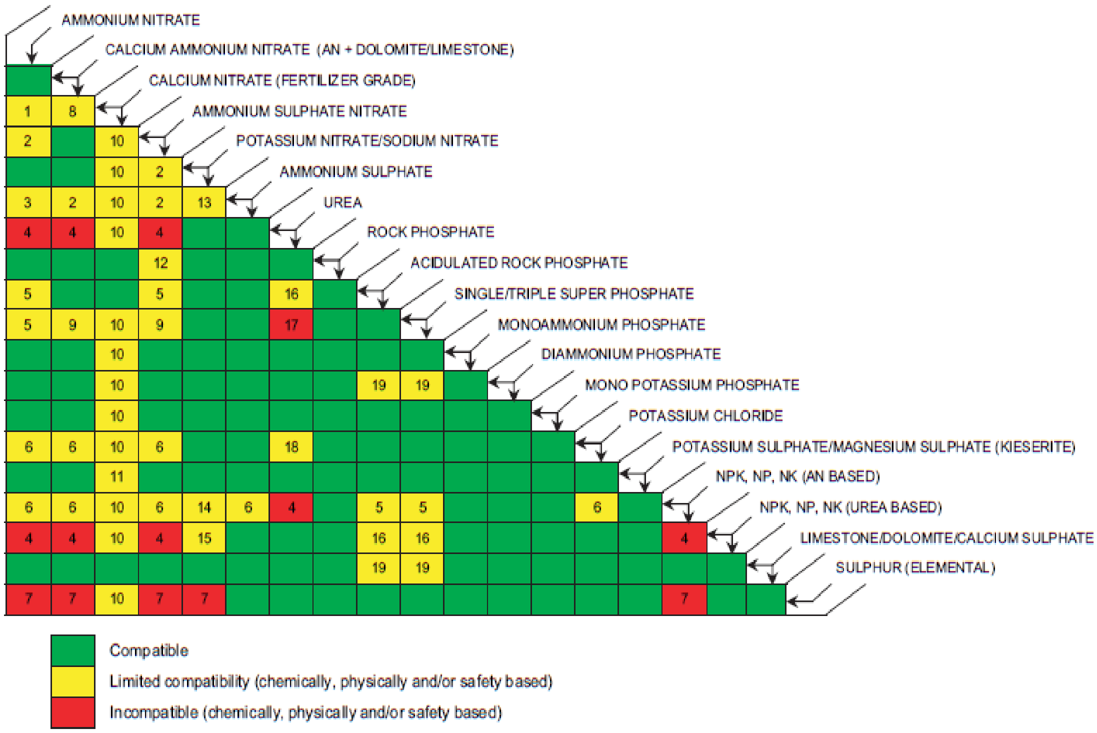
The tolerance limits prescribed under the FCO, 1985 for NPK mixture and NPK with micronutrients, shall be applicable to the customized fertilizers. However such tolerance limit shall not exceed 3% for all nutrients particularly when secondary and micronutrients are also present with NPK **(Table 1).**

Compatibility of fertilizer materials

Some raw materials are not compatible with others and blends containing such mixtures will be of very poor quality. The compatibility data are presented in three categories (Figure 1).

Compatibility (chemical and physical)

Compatibility primarily relates to blending of different fertilizers, cross contamination and other problems in safety and/or quality; e.g. caking, weakening, dust formation, and loss of resistance to thermal cycling in the case of ammonium nitrate.



Notes for the numbers in the boxes in the compatibility table

- Due to the hygroscopic behaviour of both the products, the type of stabilisation of the ammonium nitrate grade with calcium nitrate could influence the storage properties.
- Safety and legislative implications are concerned regarding Ammonium nitrate /Ammonium Sulphate mixtures. (Ammonium sulphate nitrate, Calcium Ammonium Nitrate with Ammonium Nitrate, Ammonium sulphate nitrate with Potassium Nitrate / Sodium nitrate)
- If free acid is present it could cause a very slow decomposition of Ammonium nitrate, affecting the packaging .(Ammonium Nitrate with Partially acidulated rock phosphate, Single/Triple super phosphate)
- Sulphur is combustible and can react with nitrates e.g. Ammonium nitrate, KNO_3 and $NaNO_3$.
- Due to the hygroscopic behaviour of both products, the type of stabilisation of ammonium nitrate based fertilizer could influence the storage properties.(Ammonium Nitrate, Calcium Ammonium Nitrate, Ammonium sulphate nitrate with Potassium chloride and NPK, NP, NK (AN based))
- Consider the moisture content of the SSP/TSP.

- Consider the relative humidity during blending Rock Phosphate with Ammonium sulphate nitrate
- Consider impurities in Ammonium sulphate and the drop in the critical relative humidity of the blend.
- Consider the possibility of ammonium phosphate/potassium nitrate reaction with urea and the relative humidity during blending, to avoid caking.
- If free acid is present, there is a possibility of hydrolysis of urea giving ammonia and carbon dioxide.
- Formation of very sticky urea phosphate on mixing urea with rock phosphate.
- If free acid is present, there is risk of a reaction e.g. neutralisation with ammonia and acid attack with carbonates (Limestone/ Dolomite/Sulphate/Calcium carbonate with single/Triple super phosphate)

Table 2: Common blending raw materials

Name	Abbr	Formula	N	P_2O_5	K_2O	SO_3	MgO	CaO
Ammonium Nitrate	AN	NH_4NO_3	33-34.5					
Calcium Ammonium Nitrate	CAN	$CaCO_3$/ NH_4NO_3	26-28					11
Ammonium Sulphate Nitrate	ASN	$(NH_4)_2SO_4$/NH_4NO_3	26			35		
Ammonium Sulphate	AS	$(NH_4)_2SO_4$	21			60		
Urea		$CO(NH_2)_2$	46					
Superphosphates:								
Single Superphosphate	SSP	$Ca(H_2PO_4)_2$*		18-20		30		
Triple Superphosphate	TSP	$Ca(H_2PO_4)_2$*		45-48		3		
Potassium Chloride	MOP	KCl			60-62			
Potassium Sulphate	SOP	K_2SO_4			50	45		
Potassium Magnesium Sulphate		K_2SO_4 + $MgSO_4$			30	42	10	
Ammonium Phosphates :								
Di-ammonium Phosphate	DAP	$(NH_4)_2HPO_4$	18	46-48				

Mono-ammonium Phosphate	MAP	$NH_4H_2PO_4$	12	52-53				
Calcium Carbonate		$CaCO_3$						52
Compacted Dolomite		$CaCO_3$ - $MgCO_3$					20	30
Magnesium Carbonate		$MgCO_3$					10	40
Kieserite		$MgSO_4$				50	25-28	

Mixing Fertilizers - Fertilizer Compatibility

Some fertilizers should not be mixed together in one stock tank because an insoluble salt might form very quickly. Some fertilizer materials interact to form insoluble compounds and precipitates. The precipitates tie up the nutrients and make them unavailable to the plant and cause clogging in the irrigation equipment. An example for such incompatibility is mixing fertilizers that contain calcium with those that contain phosphate or sulphate.

The Principle of Fertilizers Mix

Fertilizers that are not mutually compatible should be avoided from being mixed in one tank. The rule is that neither phosphoric nor sulphate fertilizers should be mixed with calcium or magnesium fertilizers in the same tank. This separation prevents precipitation of calcium phosphate or calcium sulphate compounds in the tank or in the pipeline.

Corrosivity of Water Soluble Fertilizers

Corrosivity is a characteristic that expresses the degree to which fertilizer solution attacks various metals.

- **Very Corrosive Solutions:** (with a pH below 3.5) corrode all metals, including stainless steel.
- **Weakly Corrosive Solutions:** (with a pH in the range from 3.5 to 6.0) corrode iron and steel but do not attack stainless steel.
- **Non-Corrosive Solutions:** (with a pH above 6.0) do not corrode metals such as: iron, steel, stainless-steel, aluminium, bronze, etc. The composition of a fertilizer solution determines its corrosivity. As a general rule, a strongly acid solution with a pH below 3.5 is considered to be very corrosive. Solutions with a pH above 3.5 are generally weakly

corrosive or non- corrosive. Most fertilizer solutions containing phosphorous are corrosive. Acid fertilizer solutions containing chloride (Cl) are considered to be very corrosive; these solutions are prepared with Potassium Chloride (KCl)

Storage

Raw material storage must be arranged to avoid segregation within the materials, cross contamination and deterioration of the physical quality

Fertilizer Storage

- Store fertilizers separately from other chemicals in dry conditions.
- Extra care needs to be given to concentrate stock solutions. Secondary containment should be used.
- Provide pallets to keep large drums or bags off the floor. Shelves for smaller containers should have a lip to keep the containers from sliding off easily. Steel shelves are easier to clean than wood if a spill occurs.
- If storage is planned in large bulk tanks, a containment area large enough to confine 125 percent of the contents of the largest bulk container is to be provided.
- Keep the storage area locked and clearly labeled as a fertilizer storage area. Preventing unauthorized use of fertilizers reduces the chance of accidental spills or theft. Labels on the windows and doors of the building give firefighters, information about fertilizers and other products present during an emergency response to a fire or a spill.
- Provide adequate road access for deliveries and use, and in making the storage area secure, also make it accessible, to allow getting fertilizers and other chemicals out in a hurry.
- Never store fertilizers inside a wellhouse or a facility containing an abandoned well.
- Untimely application of fertilizer leads to excessive release from the production system to surface and/or ground water. Potential problems can be minimized through adequate environmental awareness, employee training, and emergency preparedness.

Storage Location

- Greenhouse fertilizer storage areas contain relatively large quantities of concentrated chemicals. Risks in storage areas include release through broken, damaged, or leaking containers; loss of security leading to irresponsible use; accumulation of outdated materials leading to excessive quantity of fertilizer unnecessarily raising risk level; and combustion of oxidizing compounds in fertilizer (e.g., nitrates) caused by fire or another disaster event.
- A building or area dedicated to fertilizer storage can be maintained, separated from offices, surface water, neighboring dwellings and bodies of water; separate from pesticides and protected from extreme heat and flooding.
- The storage area should have an impermeable floor with secondary containment, away from plant material and high traffic areas. Clean-up equipment should be readily available.
- Storage areas should not contain pesticides, or other greenhouse chemicals; There should be no food, drink, tobacco products, or livestock feed present.
- Sound containers are the first line of defense against a spill or leak. If a container is accidentally ripped open or knocked off a shelf, the spill should be confined to the immediate area and promptly cleaned up. The building should have a solid floor and, for liquid fertilizers, a curb. The containment volume should be large enough to hold the contents of the largest full container.

Containers

Fertilizer should be stored in their original containers unless damaged; labels should be visible and readable; food or beverage containers should never be used for storage. Labels should be in plain sight; no containers should come in contact with the floor; all containers should be stored up-right; aisles should be wide enough to comfortably accommodate workers; containers should not be crowded on shelves or pallets.

Partially-used Containers

Paper bags and boxes should be opened with a box cutter or scissors; Open containers should be resealed and returned to storage; all open paper bags should be sealed inside another, larger container, sealed and labeled.

Damaged Containers

Containers should be checked often for damage; when damaged containers are noticed, contents should be repackaged and labeled or placed in suitable secondary containment which can be sealed and labeled.

Containment

There should be no floor drain; the floor should provide containment in the event of a spill; there should be secondary containment routinely used for most open containers; damaged or leaking containers should be repaired and/or replaced as soon as possible; all spilled material should be cleaned up upon discovery; and cleanup materials should be discarded promptly and properly.

Fire Prevention and Suppression

Fire detection and alarm system should be present; oxidizers and flammable materials should be stored separately; fire extinguisher should be immediately available; the Fire Department should be notified at least annually of current inventory.

Inventory and Recordkeeping

Inventory should be actively maintained as chemicals are added or removed from storage; Containers should be dated when purchased; outdated materials should be removed on a regular basis; inventory should be controlled to prevent the accumulation of excess material that may become difficult to use

Lighting

Electrical lighting should allow view into all areas and cabinets within the storage area.

Monitoring

There should be monthly inspection of storage for 1) Signs of container corrosion or other damage - leaking or damaged containers should be repackaged as appropriate, 2) Faulty ventilation, electrical, and fire suppression systems – problems should be reported and corrected.

Security

The storage room should be locked and access restricted to trained personnel.

Signage

There should be signs posted; warning signs should be used as needed; emergency contact information should be posted.

Temperature Control

There should be active mechanical temperature control and no direct sources of heat (sunny windows, steam pipes, furnaces, etc.).

Ventilation

Mechanical ventilation should be working and used.

Storage and Record Keeping

Fertilizer stock tanks should be labeled with fertilizer formulation and concentration; Records should have information on fertilizer formulation, concentration, date, and location of application; records should be kept of media nutrient analyses.

Containment of Concentrated Stock

Concentrated stock should be stored near the injector in high density polyethylene or polypropylene containers with extra heavy duty walls; secondary containment should be provided.

Disposal

Sufficient planning should be made to eliminate the need for disposal; empty fertilizer containers should be discarded based on latest advice from environmental protection authorities.

Precipitate and Residue Disposal

Fertilizer systems should be cleaned. Solids and rinse solution should be composted.

Spill Prevention and Preparedness

Opening fertilizer product containers, measuring amounts, and transferring fertilizer to the delivery system involves some level of risk from spills. Secondary containment should be used for fertilizer stock tanks routinely; spill clean-up materials should be used for liquids (e.g., absorbent materials) and solids (e.g., shovel, dust pan, broom and empty and/or buckets) should be available within the general area.

Delivery System

The fertigation equipment should be checked monthly for accuracy. Recommendations of the manufacturer recommendations should be followed when calibrating or working on fertilizer injector equipment; stock solution tanks and the areas surrounding fertilizer injectors and concentrated solutions should be kept clean and free of debris.

Hygroscopicity

Some fertilizer raw materials are hygroscopic and stores holding these materials should be air conditioned or the material should be covered when not being used. The lower the critical relative humidity, the more moisture will be taken from the air. Generally the phosphates including the ammonium phosphates have a high critical relative humidity and thus almost never present hygroscopic problems. The opposite applies to nitrates such as calcium ammonium nitrate, ammonium nitrate and especially calcium nitrate **(Table 3).**

Table 3. Critical relative humidity of fertilizers

Component	Critical RH (%)
Triple Superphosphate	93.6 %
Mono-ammonium Phosphate	91.6 %
Di-ammonium Phosphate	82.5 %
Ammonium Sulphate	79.9 %
Potassium Chloride	77.0 %
Urea	74.6 %
Sodium Nitrate	72.4 %
Calcium Ammonium Nitrate	61.3 %
Ammonium Nitrate	59.4 %
Calcium Nitrate	46.7 %

Clogging of fertilizers

Since fertigation is a combination of irrigation and fertilization, clogging problems can be traced back to either the water supply or injected fertilizer. Water quality includes the physical, chemical, and biological qualities of irrigation water.

a. Water

- **Physical:** The irrigation water can have too many suspended solids, such as debris and tiny clay particles, which can plug irrigation lines and emitters. When suspended solids exceed 50 parts per million (ppm) in the irrigation water, clogging problems are likely. The clogging problem will be severe if suspended solids are in excess of 100 ppm.
- **Chemical :** Chemical problems include high pH and high concentrations of cations and/or anions in the irrigation water. In the presence of high pH and oxygen within the water, the ferrous iron species is vulnerable to oxidation and creates a ferric iron precipitate. This oxidization not only reduces the bioavailability of iron applied through fertigation but also creates clogging problems. Studies indicate that approximately 50% of the ferrous iron species can be oxidized to ferric iron at pH 6.3 in 20 minutes. Irrigation with "hard" water, which is high in minerals such as calcium and magnesium, can also cause clogging problems because the calcium and magnesium ions are susceptible to precipitation with carbonates and phosphates.
- **Biological :**Bacterial growth can cause clogging problems when the bacterial population is greater than 2,600 colony-forming units (CFU) per gallon. Water sources rich in nutrients have greater potential to support the growth of bacteria and clog irrigation systems. The bacteria oxidize iron and manganese and initiate the slime-like growth of biofilms, which can clog the system. The presence of algae in surface water supplies can also clog fertigation systems, as can root intrusion into buried drip emitters.

b. Fertilizer

Some fertilizers can also cause clogging problems if they are incompatible with fertigation. Chemical reactions may occur after the fertilizers are injected into the irrigation system. Additional problems can occur with regard to the temperature of the mixing water, the coagulation and secondary chemical reactions in the mixing tank, or failure to keep suspensions for a number of reasons.

- **Fertilizer incompatibility :** For example, calcium nitrate and diammonium phosphate are fertilizers commonly used for commercial crop production, but these two fertilizers are NOT compatible. If these fertilizers are mixed together, calcium from calcium nitrate and phosphate from diammonium phosphate can form calcium phosphate, which is insoluble and precipitates out, clogging lines and emitters during fertigation.
- **Chemical reactions:** There may be additional chemical reactions after the selected fertilizers are injected into irrigation water. These reactions include hydrolysis, dissociation, oxidization, and precipitation. The first two types of reactions can accelerate the second two types of reactions. These chemical reactions can all cause clogging.
- **Fertilizer Toxicity :** Fertilizer toxicity is an issue that is important for all farmers who place their seed and fertilizer in one operation, and the interaction between the two during germination and emergence. Producers must gain a good understanding of the benefits and dangers of seed & fertilizer placement to avoid an environment that is toxic to the crop.

  All fertilizer salts are toxic to germinating seeds and to plant roots if applied in sufficient concentration near or in contact with the seed. Fertilizers vary in toxicity per unit of plant nutrient due to

  ~ differences in the amount of salts contained in the fertilizer,

  ~ differences in the solubility of the salts in the soil,

  ~ the presence of specific materials or elements that are particularly toxic (for example, ammonia and boron).

  ~ Many nitrogen fertilizers, although they have a relatively low salt index, release free ammonia into the soil

Lecture No. 14. Crop response to designer fertilizers - Agricultural and horticultural crops- yield and quality- Soil health and nutrient use efficiencies

Crop response to fertilizer

Crop response to fertilizer application depends not only on the level of available plant nutrients in the soil but is also related to crop physiology and morphology. For a well-balanced nutrition the rate of nutrient supply to the roots must correspond with the rate of nutrient required for growth. Species or cultivars with a high growth rate generally respond more favourably to fertilizer application than those with low growth rates. An analogous relationship holds for the biomass produced per unit soil surface. Thus modern rice and wheat cultivars tolerate a more dense spacing than older ones. Due to the dense stand the yield and particularly the grain yield of the modern varieties may be several times higher than those of older cultivars, and therefore also the nutrient requirement, especially the demand for N and P, is higher for the modern cultivars.

On-farm trials

Fertilizer use development requires teamwork through collective and coordinated effort of several agencies involved in research, extension and input supply. In the larger context even agencies providing irrigation, credit energy and produce markets are also important because fertilizer use is a means to increase crop productivity leads which in tum to a marketable surplus, which can be sold by the farmers to increase their incomes and standard of living. Fertilizer use thus has a direct effect on raising the living standard of the rural population.

Effects on crop production

Concept of customized fertilizers may be new in India but it is common in agriculturally advanced countries. This shows the need for realization of the importance of CF by our government for attaining the food and nutritional security. Even though the production of customized fertilizers is difficult, the end is very promising. This can be substantiated by studying its performance on farmer’s field.

Performance of customized fertilizers at farmers’ field

The study was conducted by Tata chemicals Ltd. in Noida to know the effect of customized fertilizers in farmer’s field. Here they compared the yield from customized fertilizers and the yield from common farmer practice. They got 14%, 20%, 15% and 40% increase in yield of rice, wheat, potato, and sugarcane respectively over the common farmer practice. They are saying that it has been heartening to observe that farmer using lower dose of customized fertilizer also got superior performance over their conventional practice.

Effect of nutrient management practices on castor-sorghum cropping system

Experiment conducted at Directorate of oil seed research, Hyderabad by Ramesh *et al.* in 2013 to study the effect of nutrient management practices like recommended dose of fertilizers (RDF), integrated nutrient management(INM), organic nutrient management(ONM), fertilizers based on soil test crop response(STCR) and customized fertilizers(CF) on the productivity and economic return of castor-sorghum cropping system.

Effect of nutrient management practices on yield attributes and economic returns

Application of customized fertilizers recorded significantly higher yield attributing characters compared to other nutrient management practices both in case of castor and sorghum. But were comparable with the treatment receiving fertilizers based on STCR resulted in about 18 and 15% increase compared to RDF and so system income and B:C ratio was also maximum in CF followed by STCR. CF recorded the highest uptake of nutrients in cropping system compared to RDF. Higher seed yields of castor and sorghum with customized fertilizers or STCR was due to favourable crop growth and higher yield attributing character. In these treatments, nutrients are applied in proportion to the magnitude of deficiency of a particular nutrient and the correction of nutrient imbalances in soil helps in harness the synergistic effects of balanced fertilizer application (Ramesh *et al.,* 2013) [11].

Effect of customized fertilizers on yield parameter of rice

The pooled analysis of two locations indicated that application of 100% RDF in the form of CF II increased the productive tillers (21 nos.), panicle length (27.70 cm) and number of filled grains per panicle (203 nos.).The number of productive tillers recorded in the treatment that received 100 % RDF in the form of CF II was on par with 100 % RDF through CF I +25 kg Zn SO4 ha-1 and 100% RDF through straight fertilizers. The lowest number of productive tillers, panicle length and number of filled grains per panicle were recorded in the treatment that received 50 % RDF through CF I +25 kg Zn SO4ha-1.Successive increase in fertilizer levels from 50% RDF to 100% RDF had marked influence on the yield attributes of rice. Application of 100% RDF of straight fertilizers recorded a grain yield of 5628 kg ha-1. Application of 100% RDF in the form of CF II recorded the highest grain yield of 6878 kg ha-1followed by the application of 100 % RDF as CF I + 25 kg Zn SO4 ha-1 (6622 kg ha-1). The lowest yield of 5061 kg $ha^{-1}$was recorded with the application of 50 % RDF in the form of CF I+ 25 kg Zn SO_4 ha^{-1}.An increase in yield of 15.1 per cent over the application of 100 % RDF of straight fertilizers was obtained with the application of 75% RDF through CF II. Application of 100 % RDF through CF II registered an increase in yield of 22.2 per cent over the application of straight fertilizers. This could be attributed to the addition of Zn increased the number of tillers and reduced the spikelet sterility. The increase in grain yield over the application of straight fertilizers was 11.1 per cent in the treatment that received 75% RDF in the form of CF I + 25 kg Zn SO4 ha-1. Application of 100 % RDF as CF I + 25 kg Zn SO4 ha-1 registered an increase in yield of 17.7 per cent over the application of straight fertilizers. **Effect of customized fertilizer on nutrient uptake (NPKS & Zn) of wheat (*Triticumavistivum*) crop**

The maximum uptake of N (117.3 kg/), P (21.4 kg/ha), K (150.5 kg/ha), S (96.1 kg/ha) and Zn (229.9 g/ha) were observed under 150% dose of CF (T6) which is statistically significant due to different doses of customized fertilizer. The higher nutrient uptake was mainly due to higher biological (straw+ grain) yield. Application of customized fertilizer helps to provide essential nutrient to get the targeted yield.

The availability of soil NPK in the mulberry garden was increased due to application of 150% nutrients through CF which recorded maximum available NP_2O_5, K_2O of 282.84,78.09 and 281.04 kg/ha, over other treatments. The next best treatment was T5(274.93N,76.69 P and 261.27K kg/ha) respectively.

Influence of customized fertilizers on yield and economics of finger millet

Significant differences in the yield of both grain and straw of finger millet were observed due to use of different doses of customized fertilizer. Highest grain and straw yield of 3279 and 4510 kg/ha, respectively were recorded in 150% customized fertilizer dose and was on par with 125% customized fertilizer dose (3227 and 4438 kg/ha) and 100% customized fertilizer dose (3031 and 4249 kg/ha, respectively). RDF as per package of practice recorded on par grain and straw yield (2138 and 3102 kg/ha, respectively) with 50% customized fertilizer dose (2130 and 3007 kg/ha, respectively). This was due to the fact that the crop has not experienced nutrient stress at any growth stage because of balanced nutrition and improved vegetative growth and growth parameters such as total dry matter production and increased number of tillers resulted in good grain yield.

Effect of customized fertilizers on the performance of potato

Results of the study indicated that Initial and final plant stand were non-significant under various customized fertilizer. Yield attributes viz. total number, weight (grade wise), total weight of tubers hill-1, plot^{-1} and ha^{-1} were recorded significantly higher under customized fertilizer F4 which was statistically at par with F6 and superior over rest of the customized fertilizers. Quality parameters viz. specific gravity, dry matter and starch content did not influenced significantly due to effect of customized fertilizers. The suitable customized fertilizer for potato crop was found to be F4-8 : 18 : 26 : 1 : 0.1 : 6 (N:P:K:Zn:B:S kg ha-1 150 : 67.5 : 97.5 : 3.75 : 0.37 : 22.5).

Effect of customized fertilizers on yield and micronutrients contents of okra grown on TypicUstochrepts soils of Anand

Okra yield increased significantly due to foliar treatment, i.e. micronutrient mixture grade-IV (for Fe and Zn deficiency), soil application of mixture Grade-V and also due to soil application of $FeSO_4$ at 15 kg/ha and $ZnSO_4$ at 8 kg/ha as per soil test value. The soil application of multi-micronutrients mixture grade-V was found beneficial and economical in increasing okra yield.

Effect of different levels of customized fertilizer on soil nutrient availability, yield and economics of onion

A field experiment was conducted to study the effect of different levels of customized fertilizer (CF) on soil nutrient availability, yield and economics of onion. The results revealed that the significantly highest plant height (57.77cm), stem diameter (6.03cm) and bulb diameter (15.13cm) at the time of harvest, fertilizer use efficiency, bulb yield (22.34 t ha^{-1}) and B:C ratio (2.56) of onion were recorded in 100 % recommended dose of NPK through CF in three equal split doses. The significantly highest available nitrogen (213 kg ha^{-1}), phosphorus (14.42 kg ha^{-1}) were recorded in 125 % recommended dose of NPK through CF in two equal split doses and available K (804 kg ha^{-1}) in 100 % recommended dose of NPK through CF in three equal split doses over the rest of the other treatments. The application of 100% recommended dose of fertilizer (100:50:50; $N:P_2O_5:K_2O$ kg ha^{-1}) either two or three splits through CF to onion appears to be improving soil fertility, yield and yield contributing character of onion and getting higher net monetary returns.

Nutrient use efficiency

- **Crop characteristics**: including root structures and root activity, stress tolerance, nutrient uptake (into roots), and efficiencies in nutrient incorporation (into plant tissue) and utilization (movement of nutrients to growth areas)
- **Soil characteristics**: including microbial diversity and biomass, pH, soil structure, salinity, organic matter content and water-holding capacity, and whether the soil is tilled
- **Fertilizer characteristics**: including their composition and when and how they're applied

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field. NUE addresses some but not all aspects of that performance. Therefore, system optimization goals necessarily include overall productivity as well as NUE. The most appropriate expression of NUE is determined by the question being asked and often by the spatial or temporal scale of interest for which reliable data are available. In this chapter we suggest typical NUE levels for cereal crops when recommended practices are employed; however, such benchmarks are best set locally within the appropriate cropping system, soil, climate and management context. Global temporal trends in NUE vary by region. For N, P and K, partial nutrient balance (ratio of nutrients removed by crop harvest to fertilizer nutrients applied) and partial factor productivity (crop production per unit of nutrient applied) for Africa, North America, Europe, and the EU-15 are trending upwards, while in Latin America, India, and China they are trending downwards. Though these global regions can be divided into two groups based on temporal trends, great variability exists in factors behind the trends within each group. Numerous management and environmental factors, including plant water status, interact to influence NUE.

Soil health

- Soil health has been defined as: “the capacity of soil to function as a living system. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production. To that definition, an ecosystem perspective can be added: A healthy soil does not pollute the environment; rather, it contributes to mitigating climate change by maintaining or increasing its carbon content.
- Soil contains one of the Earth’s most diverse assemblages of living organisms, intimately linked via a complex food web. It can be either sick or healthy, depending on how it is managed. Two crucial characteristics of a healthy soil are the rich diversity of its biota and the high content of non-living soil organic matter. If the organic matter is increased or maintained at a satisfactory level for productive crop growth, it can be reasonably assumed that a soil is healthy. Healthy soil is resilient to outbreaks of soil-borne pests.
- The diversity of soil biota is greater in the tropics than in temperate zones. Because the rate of agricultural intensification in the future will generally be greater in the tropics, agro-ecosystems there are under particular threat of soil degradation. Any losses of biodiversity and, ultimately, ecosystem functioning, will affect subsistence farmers in the tropics more than in other regions, because they rely to a larger extent on these processes and their services.

Lecture No. 15 Feasibility of using designer fertilizers for drip fertigation - Poly houses - roof gardening

Water Soluble Fertilizers

Water-soluble fertilizers are 100% water soluble with very low salt index to minimize the potential for burning of plant tissue. The water soluble fertilizers are characterized by high purity and high benefit –cost ratio. The use of water-soluble fertilizers is largely concentrated in horticultural growing areas of different parts of the country besides it is ground in floriculture and vegetable crops also. The market size of water soluble fertilizers is constantly increasing in India. The annual usage of water soluble fertilizers estimated about 50,000 tonnes at present.

Water-soluble fertilizers dissolve easily in water and are applied to the crop in the irrigation water. One benefit of this type of fertilization is that growers can easily adjust the nutrient concentrations according to a crop's changing needs over a growing season. Growers often choose a fertilizer concentration and apply this concentration at every watering. This is called continuous liquid feeding (CLF), or fertigation. By contrast there are fertilization programs in which growers apply higher rates of fertilizer less frequently, and irrigate with clear water between feedings.

Specialty Water Soluble Fertilizers Approved in India under FCO

At present there are 12 Water-soluble fertilizers listed in FCO. By recognizing the importance of water soluble fertilizers, Govt. of India created a separate category for 100% WS fertilizers in FCO 2003.In the Union budget 2012-13, Govt. of India reduced basic customs duty on water soluble fertilizers from 7.5% to 5%.

Water Soluble Fertilizers	Nutrients Composition %					
	N	P	K	S	Ca	Mg
Mono Potassium Phosphate	12	61	0	-	-	-
Mono Ammonium Phosphate	0	52	34	-	-	-
Potassium Nitrate	13	0	45	-	-	-
Calcium Nitrate	15.5	-	-	-	18.8	-
NPK	13	40	13	-	-	-
NPK	18	18	18	-	-	-
NPK	13	5	26	-	-	-
NPK	6	12	36	-	-	-
NPK	20	20	20	-	-	-
NPK	19	19	19	-	-	-
Potassium Magnesium Sulphate	-	-	22	20	-	18
Urea Phosphate	17	44	-	-	-	-

Source: FCO, Fertilizer Association of India, New Delhi (2011)

The Solubility of Some Water Soluble Fertilizers are Given Below

Fertilizer	Solubility (gL^{-1} at 20°C)
Potassium Nitrate (13:0:46)	310
Ammonium Nitrate	1950
Ammonium Sulphate (20:0:0)	770
Urea Phosphate (17:44:0)	495
Urea(46:0:0)	1060
Potassium sulphate (0:0:50)	100
Calcium Nitrate (15.5:0:0)	1200

Source: Fertilizer Statistics, the FAI (2010-2011)

Fertigation

Fertigation is the application of water soluble solid or liquid fertilisers through drip irrigation system. The factors that governs the fertigation are soil type, crop, method of irrigation used, water quality, types of fertilisers available, economic feasibility etc. Fertigation has become a striking method of fertilisation in modern intensive agriculture systems. Water and nutrient are the main factors of production in irrigated agriculture and are the major inputs in contributing higher activity. In intensive agriculture, both fertiliser and irrigation management have contributed immensely in increasing the yield and quality of crops. The method of fertiliser and irrigation application of these inputs in arid and semi-arid regions arid conditions of the world. Of late, it is also becoming popular in the arid and semi-arid region of India parti where canal irrigation systems are not developed (Hagin and Lowengart, 1999). With the advent of this new method of irrigation system, traditional method of fertilisation which is still practised by the farmers is being slowly replaced by fertigation. In drip irrigation, the wetted soil volume and thus the active root zone is reduced under drippers and this small volume does not allow the addition of all plant nutrients needed by the plants (Krishna needed is to be applied frequently and periodically in small amount with irrigation to ensure adequate supply of water and nutrient in the root zone (Biswas and Kumar, 2010). Therefore, as a result of the shift from surface irrigation to drip method of irrigation, fertigation becomes the most efficient fertilisation in the irrigated agriculture.

Major advantages of fertigation

1) In drip fertigation, fertiliser can be applied directly to the effective root zone of plant growth. Fertiliser application is synchronized and optimised with plant need and the amount and form of nutrient supply is regulated as per the need of the critical growth stages of plant.

2) Nutrients can be applied any time during the growing season based on crop need, thus saving in amount of fertiliser applied, due to better fertiliser use efficiency and reduction in leaching due to unseasonal weather.

3) Reduction in labour and energy cost by making use of water distribution systems for nutrient application.

4) Well-designed injection systems are available and are simple to use and suit automation, ensures better yield and quality of products obtained.

5) Timely application of small but precise amounts of fertilisers directly to the roots zone, which improves fertiliser use efficiency and reduces nutrient leaching below the root zone.

6) Ensures a uniform flow of water and nutrients causing minimal crop damage.

7) Smaller amounts of fertiliser can be applied quickly to address any deficiency issues and highly mobile nutrients such as nitrogen can be carefully managed to ensure rapid crop uptake.

8) Safer application method, as it eliminates the danger affecting roots due to higher dose.

9) Soil erosion is prevented.

The vertical garden or green wall is comprised of plants grown in supported vertical systems that are generally attached to an internal or external wall, although in some cases can be freestanding. Like many green roofs, Vertical gardens incorporate vegetation, growing medium, irrigation and drainage into a single system. Vertical gardens differ from green facades in that they incorporate multiple ‘containerized’ plantings to create the vegetation cover rather than being reliant on fewer numbers of plants that climb and spread to provide cover. They are also known as ‘green walls’, ‘living walls’, ‘bio-walls’. Green roofs are constructed for multiple reasons - as spaces for people to use, as architectural features, to add value to property or to achieve particular environmental benefits (for example, storm-water capture and retention, improved species diversity, insulation of a building against heat gain or loss). Vegetation on green roofs is planted in a growing substrate (a specially designed soil substitution medium) that may range in depth from 50 mm to more than a metre, depending on the weight capacity of the building’s roof and the aims of the design. For growing different types of plants- either perennially or annually there is a need to supply constant, reliable and sustainable systems of irrigation and drainage; and preferably with a fertigation scheduling along with the sprinklers or overhead irrigation system.

Lecture No 16. Quality Standards-Specifications for Designer Fertilizers

The main objective of customized fertilizer is to promote site specific nutrient management so as to achieve the maximum fertilizer use efficiency of applied nutrient in a cost effective manner. The Customized Fertilizer may include the combination of nutrients based on soil testing and requirement of crop and the formulation may be of primary, secondary and micro-nutrients. It may include 100% water soluble fertilizers grades required in various stages of crop growth based on research findings.

Eligibility criteria to manufacture and sale of customized fertilizer

(ii) Such manufacturing companies should have soil testing facility with an annual analyzing capacity of 10,000 samples per annum and should have analyzing capacity for NPK. Micronutrient and Secondary Nutrient.

(iii) The grade of customized fertilizer, which the company will manufacturer, must be based on scientific data obtained from area specific, soil specific and crop specific, soil testing results. These manufacturing companies, in association with concerned agricultural universities/KVKs concerned, should also conduct agronomy tests pf the proposed grade to establish its agronomic efficacy.

(iv)Such manufacturing companies should generate multi locational trials (not on farm demonstration) on different crops for minimum one season.

Soil sampling and analysis

Such,manufacturing companies must draw these soil samples from within its operational areas and should also ensure that minimum one sample is necessarily, drawn from each village. Scientific data on soil testing, results available with agricultural university /state Governments may also be used to prepare soil fertility map and for determination of required soil, area and crop specific grades for existing and potential marketing areas.

Grant of permission to manufacture

Subject to the fulfillment of eligibility criteria referred to in the preceding paragraphs, the permission for the manufacture and sale of Customized Fertilizer will be granted by Joint Secretary(INM). Department of Agriculture and Cooperation, MOA,GOI. Such permission, for manufacture and sale of particular customized fertilizer grade shall be granted only for the specific area and for a period not exceeding three years. Such manufacturing companies must start their manufacturing and sales process with in aperiod of six months from the date of grant of such permission. For grant of permission to produce and to sell such customized fertilizers, the concerned manufacturing companies should necessarily apply for permission, to the office of the Joint Secretary(INM), Ministry of Agriculture under intimation to the State Government in the prescribed

Performa as provided in annexure II. The competent authority shall expedite the requisite permission authorization of otherwise within 45 days of the receipt of such applications.

Renewal/ revision of customized fertilizer grade

On completion of three years or earlier, manufacturing company of customized fertilizer shall submit a renewal/revision application for varied customized fertilizer manufactured by it. In case no change in the already approved composition of customized fertilizer is required, the same shall also be declared by the manufacturer. The competent authority, shall thereon, accord its approval; within .a period of 45 days from the date of receipt of such application, failing which the application duly acknowledged copy of such application shall be treated as official approval.

Customized fertilizer grades

The grades of customized fertilizer which the manufacturing company propose to manufacture and sell, shall be based on area specific and crop specific soil testing results. The manufacturer may be in association with Agricultural Universities/KVKs concerned, shall also conduct agronomy tests of the proposed grade to establish its agronomic efficacy. The manufacturing company, preferably in association with concerned agriculture universities/KVKs may continue to conduct agronomy tests of the proposed grades on the farm, for at least one season. The minimum nutrient contents in a specific grade of customized fertilize, proposed to be manufactured, shallcontain not less than 30 units of all nutrients, combined. For manufacture of area-specific subsequent grades of customized fertilizers, duly approved by the Joint Secretary (INM) MOA from time to time, the company shall intimate the competent authority within at least 45 days prior to its introduction of the said grades in the market. Since these grades will be based on the scientific data, no formal approval will be necessary.

Raw Material

(i) Use of subsidized fertilizers by Manufacturer of customized fertilizer

As per the existing policy, all subsidized fertilizers can be used for manufacturing of customized fertilizers. As such, domestic manufactures of all such subsidized fertilizers will have the choice to sell the requisite quantity to the manufacturing companies of customized fertilizers and the manufacturing company ofsuch subsidized fertilizers shall be eligible to claim subsidy from DOF under relevant rules.

(ii) Captive use of subsidized fertilizers by the manufacturer of customizedfertilizer.

Domestic manufacturer of subsidized fertilizers will have the option to supply therequired quantity of such fertilizers, as raw material, to its own manufacturing unit forproduction of customized fertilizers. All such supplies shall be eligible for subsidy as perthe policy of DOF.

(ii) Import of subsidized fertilizers by the manufacturer of customizedfertilizers.

All manufacturers of customized fertilizers will have option to import subsidizedfertilizers under the existing Policy guidelines of GOI for the manufacture of customizedfertilizers not exceeding its realistic requirements. On the imported quality of suchfertilizer to be used for manufacture of customized fertilizer, such manufacturers shallbe eligible for subsidy from DOF, under relevant rules.

(iv)Allocation of subsidized fertilizer as raw material for manufacture of customizedfertilizers.Specific allocations of subsidized fertilizers, to ensure adequate availability, inrespect of States, may be made for use as raw material for manufacture of CustomizedFertilizers, However, if required, permission for import of specific fertilizers as rawmaterial (not included in schedule 1 of FCO, 1985) may also be granted to themanufacturers.

Quality of customized fertilizers

The Customized Fertilizers to be used for based application shall be granular in sizewith minimum 90% between 1-4 mm IS sieve andBelow 1mm should not exceed 5%. The moisture content should not exceed 1.5%. Forfoliar applications, however, the grades should be 100% water soluble. Thespecifications of the customized fertilizers provided by the company to manufacture ofCustomized Fertilizer, duly approved by the Ministry, shall be strictly adhered to.

Quality Cheek

(i) Procedure for drawl of sample of fertilizers

(a) The method of drawing samples shall be provided in the FCO.

(b) Clause 4A(iii)- Weight of one sample should be 400g as specifiedunder Clause 4 A (iii) for Part A in Schedule 1 of the FCO,1985.

(ii)**Methods of analysis of fertilizer**

(a)The methods of analysis of fertilizers shall be as per the procedureprescribed in FCO.

(b) For preparation of sample for analysis in the laboratory (Clause 1-1) underpart B in schedule II of FCO,1985 the whole sample size of 400g should bepowdered. The whole sample size of 400 gms shall be powdered.

(iii)Tolerance limit

The tolerance limits prescribed under the FCO,1985 for NPK mixture and NPKwith micronutrients, shall be applicable to the customized fertilizers. However suchtolerance limit shall not exceed 3% for all nutrients particularly when secondary andmicronutrients are also present with NPK.

Labeling

(i)The word CustomizedFertilizer shall be super scribed on the bags.

(ii) The name of the crop and geographical area for which the CustomizedFertilizerrecommended shall also be indicated on the bags.

(iii)The grades of CustomizedFertilizer and the nutrient contents shall be mentioned onthe bags.

(iv)The manufacture should preferably have tampered proof bagging so as to check onadulteration.

Pricing of customized fertilizer

The Company shall fix reasonable MRP for its approved grade of customizedfertilizers taking all factors into consideration.

General

The permission for manufacture of customized fertilizer shall be restricted to such manufacturing companies of fertilizers who have the certificate of manufacture and authorization letter for selling fertilizers in a particular State. All the provisions of Fertilizer(Control) Order, 1985 and Essential Commodities Act 1955, shall be applicable for manufacture and sale of Customized Fertilizer.

Application for grant of permission for manufacture of Customized fertilizer

- Name of the Company and address
- Location of the unit where the Customized grade of fertilizer proposed to be manufactured.
- Annual Turnjover of the company
- Location/Particular of the Area where the Customized Fertilizer is to be introduced
- Soil Fertility Status of the Area.
- Introduction Season
- Cropping Pattern of the Area
- Soil PH
- Irrigated or unirrigated land
- Location of soil testing lab
- Annual Analyzing Capacity of soil samples
- Area Climate
- Grades and other details relating to composition of CustomizedFertilizer
- Raw Material(indicate whether the subsidized material to be used).
- Quantity to be produced in each season
- MRP

- Whether the company possess any permission for manufacturing the grades of customized fertilizer in any area

(i) Whether the company possess the soil testing facility as prescribed in Annex II of guidelines.

(ii) Whether the proposed grades are based on the soil testing results and crop requirement.

(iii) Whether the multi locational trials have conducted or not

(iv) Whether the agronomic test of the product in consultation with Agriculture Universities/KVK have been conducted or not.

Lecture No. 17 Guidelines for Patenting- Licensing and Registration of Newer Products

Guidelines for patenting

patent is an exclusive monopoly right granted by the Government for a new invention to an inventor for his/her disclosed invention for a limited period of time. This exclusive monopoly right is valid only within the territorial limits of a country of grant. Exclusivity of right implies that no one else can make, use, manufacture or market the invention without the consent of the patent holder. This right is available only for a limited period of time

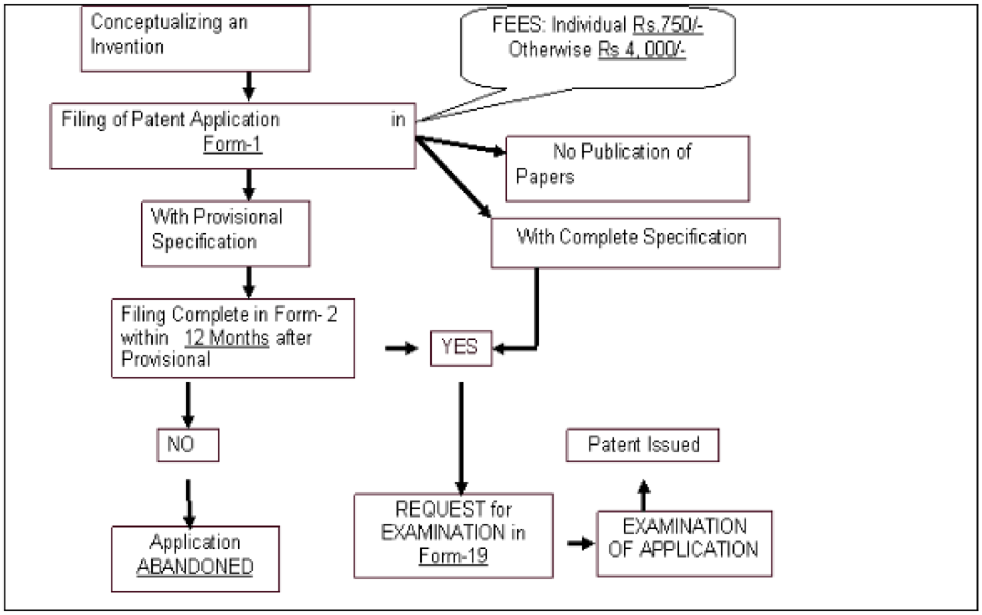
Requirements of Patenting

- Novelty
- Non obviousness
- Marketability and Utility

It is important to remember

- A patent has a time limit (20 years)
- A patent has a geographical limit
- A patent is restricted to the claims made in the application

Procedure for patent application



How to arrive at customized fertilizers?

Scientific principles were used as an ultimate guiding factor in deciding the grades of customized fertilizers. Following procedures were used to arrive at crop-soil specific customized fertilizer grades.

- Geo-referencing of chosen area
- Selecting sampling points on appropriate statistical procedure
- Actual sampling of the sites
- Analysing sampling of the sites
- Analysing soil, plant and water samples for nutrients and some soil characteristics
- Defining management zones
- Yield targeting in major management zones
- Computing crop removal of nutrients
- Calculating nutrient requirement (amount and ratio)
- Blending of nutrients based on the generated information

Development of protocol

The research on customized fertilizers aims at developing and perfecting the scientific protocol to arrive at a crop and region specific grade. Conventional approach adopted by soil scientist/ agronomist might not be appropriate in handling multi-nutrient deficiency and inter-nutrients interaction. Crop and soil-process modeller also has limitation of integrating these phenomena in the mechanistic growth models. Most of the dynamic models in the globe deal with one nutrient at a time. The basic framework of logistic evolution of customized fertilizer grades, as a currently under development have three primary components:

- Defining fertility management zones
- Using empirical models like QUEFTS/STCR
- Use secondary research data and experiential learning's

Eligibility criteria for manufacture and sale of customized fertilizers

Permission for manufacture and sale of customized fertilizers shall be granted to only such manufacturing companies whose annual turnover is Rs.500 crores and above. Manufacturing companies should have soil testing facility with an annual analysing capacity of 10,000 samples per annum for NPK, secondary and micro nutrients. Such laboratory must possess the requisite instrument viz., Atomic Absorption Spectrophotometer, Flame Photometer, pH meter, Conductivity Bridge, Kjeldhal Distillation etc. The grades of customized fertilizers, which company will manufacture, must be based on scientific data obtained from area-specific, soil-specific and crop specific and soil testing results.

The manufacturing companies, in association with agricultural universities/KVKs concerned, should also conduct agronomy tests of the proposed grade to establish its agronomic efficacy. Such manufacturing companies should generate multi-location trials (not on farm demonstrations) on different crops for minimum one season. Such manufacturing companies must draw these soil samples from within its operational areas and should also ensure that minimum one sample is necessarily, drawn from University/ State government may also be used to prepare soil fertility map and for determination of required soil, area, and crop specific grades for existing and potential marketing areas.

Grant of permission to manufacture

Subject to the fulfilment of eligibility criteria referred to in the preceding paragraphs, the permission for the manufacture and sale of Customized Fertilizers will be granted by Joint Secretary (INM). Department of Agriculture and Cooperation, MOA, GOI. Such permission, for manufacture and sale of particular customized fertilizer grade shall be granted only for the specific area and for a period not exceeding three years. Such manufacturing companies must start their manufacturing and sales process with in aperiod of six months from the date of grant of such permission. For grant of permission to produce and to sell such customized fertilizers, the concerned manufacturing companies should necessarily apply for permission, to the office of the Joint Secretary (INM), Ministry of Agriculture under intimation to the State Government in the prescribed Performa as provided in annexure II. The competent authority shall expedite the requisite permission authorization of otherwise within 45 days of the receipt of such applications

Application for grant of permission for manufacture of customized fertilizer

- Name of the Company and address
- Location of the unit where the customized grade of fertilizer proposed to be manufactured
- Annual Turnover of the company
- Location/Particular of the Area where the customized fertilizer is to be introduced
- Soil Fertility Status of the Area
- Introduction Season
- Cropping Pattern of the Area
- Soil PH
- Irrigated or unirrigated land
- 10.Location of soil testing lab
- Annual Analyzing Capacity of soil samples
- Area Climate
- Grades and other details relating to composition of customized fertilizer
- Raw Material(indicate whether the subsidized material to be used)
- Quantity to be produced in each season
- MRP
- Whether the company possess any permission for manufacturing the grades of customized fertilizer in any area

Renewal and revision of customized fertilizer grades

On completion of three years or earlier, manufacturing company of customized fertilizers shall submit a renewal/revision application for varied customized fertilizers manufactured by it. In case, no change in the already approved composition of customized fertilizers is required, the same shall also be declared by the manufacturer. The competent authority, shall, thereon, accord its approval within a period of 45 days from the date of receipt of such applications, failing which the duly acknowledge copy of such application shall be treated as official approval.