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ESSENTIALS OF CHEMICAL FERTILIZER USE IN PRC

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[Text] Summary

This book briefly introduces the characteristics and application methods of various nitrogen fertilizers, phosphorus fertilizers, potassium fertilizers, composite fertilizers, mixed fertilizers, trace element fertilizers and other mineral fertilizers. In addition, the problems of packaging, transportation and storage are also described. This helps in understanding the application and basics of chemical fertilizers by comrades of the related units.

This book can be read by rural commune cadres, intellectually oriented youth and agricultural technicians. It may also be used as a reference by the appropriate comrades of chemical fertilizer plants and sales departments.

Chapter 1. What Are Chemical Fertilizers?

Section 1. Functions of Fertilizer

Like the food people eat, crops absorb all kinds of nutrients for growth. Long-term production practice and scientific experiment has shown that there are about 60 to 70 nutrients needed in various amounts by crop varieties and growing situation. Generally, most essent'al in large amounts are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulfur, calcium, magnesium and iron. In addition, traces of boron, manganese, copper, zinc and molybdenum are also required.

Carbon, hydrogen and oxygen are the main elements of plant bodies. Through roots or leaves, a crop absorbs oxygen and carbon dioxide from the air and moisture from the soil. Aided by sunlight, a crop photosynthesizes carbon dioxide and water to form carbohydrates. So these elements are not needed to be added by man.

Nitrogen, phosphorus, potassium, sulfur, calcium, magnesium and iron have different functions in crops.

Nitrogen is a vital element in forming protein, the main component of plant cells. Nitrogen-deficient crops will have small, withered stems and leaves with undesirable growth. If the nitrogen supply is severely hampered, the crop will then wither and die.

Phosphorus is the main element constituting fruits and seeds. In phosphorus-deficient soil, seeds will not bear roots and bud; leaves curl and are easily shed. Sometime, red, purple or brown spots appear on leaves bearing small fruits and hollow seeds.

Potassium increases resistance to crop diseases and promotes metabolism; these functions benefit the formation of carbohydrates and proteins for strong, firm stems and leaves, preventing collapse. Potassium-deficient signs of a crop are initially withering leaves then thin stems eventually.

Magnesium and iron are necessary in forming chlorophyll. Sulfur helps form protein in the plant body, especially in scallions and garlic. Sulfur is a nutrient for root nodule bacteria, indirectly aided a crop's absorption of nitrogen from the atmosphere. Calcium especially aids in adjusting physiological functions and improving soil characteristics. This is why lime is applied to soil in some parts of South China.

Some elements, like copper, manganese, molybdenum, boron and zinc, promote crop metabolism; some elements help crop respiration; and some elements greatly activate nitrogen-fixing bacteria.

Crops require many chemical elements, serving different functions in crops, therefore we should meet the crop requirements for deficient elements. As stated, carbon, hydrogen and oxygen come from the atmosphere and water. Enough calcium, magnesium, sulfur and iron in soil generally are present for crop absorption; only in rainy South China should calcium be supplemented because it is easily leached. Crops require only little boron, manganese, copper and zinc so these elements generally are absorbed from the soil with occasional supplement from outside sources. Not so for nitrogen, phosphorus and potassium. Although there are some of these elements in soil, the amounts are insufficient. Moreover, most nitrogen, phosphorus and potassium are used up at crop harvest. Constant supplement of these elements is a must. So the supply of nitrogen, phosphorus and potassium through fertilizer application is vital. These three elements are called the three elements of fertilizer.

There are many types of fertilizer: human feces and urine, manure of domestic animals and fowls, decayed animals and plants, rapeseed cake, urban sewage, river mud, garbage and young, tender green-manure crops. In addition to nitrogen, phosphorus and potassium, these fertilizers contain organic matter and sometime compounds of sulfur, boron, copper and zinc. So these fertilizers are called farmyard manure.

Sources of the above-mentioned farmyard manure are very wide; they contain many nutrients. However, nutrient amounts are quite low. So these farmyard manures cannot supply large farm fields. In addition, much labor is required to accumulate farmyard manure. Through research, coal, coke, natural gas, petroleum air and minerals can be used as raw materials to manufacture, through chemical processing, fertilizers containing nitrogen, phosphorus and potassium and other elements. Chemical fertilizers is the subject of this book.

Section 2. Advantages and Disadvantages of Chemical Fertilizers

Chemical fertilizers have these advantages:

1. Highly effective nutrients and rapid fertilizing effect: one chin of ammonium sulfate equals 30 to 40 chin of human feces and urine; one chin of calcium superphosphate equals 60 to 80 chin of barnyard manure; and one chin of potassium sulfate equals about 10 chin of pearl ash. Especially, some highly concentrated chemical fertilizer contains even more effective nutrient. So proper amounts of chemical fertilizer in each mou in addition to farmyard manure, according to soil and crop situations, can fill crop growth requirements. Most chemical fertilizers readily dissolve in water; so their applications to soil can be quickly absorbed by crops with fast and apparent fertilizing effect. Small, yellowing and withering crops can grow vigorously once nitrogen fertilizer like ammonium sulfate is applied.

2. Abundant raw materials: natural minerals are used as raw materials for manufacturing chemical fertilizer. Coal, petroleum, rock phosphate are principal raw materials of chemical fertilizer. China has heavy reserves of these minerals.

3. Large-scale plant production is feasible. Since the raw materials for chemical fertilizers are natural minerals and mechanization is used in manufacture, chemical fertilizer can be made in large plants. Such plant production is free of seasonal limitations.

4. Labor economies: the nutrient contents of chemical fertilizer is high, so generally small amount of fertilizer in granules or powder suffices for the crops. Therefore, labor required for applying chemical fertilizer is much smaller than for farmyard manure. Likewise, labor in transportation can be also properly reduced.

5. Chemical fertilizers can be conveniently stored for long periods. Since the bulk of chemical fertilizer is smaller than farmyard manure, proper steps can be taken based on its characteristics so as to store chemical fertilizer for a long time without deterioration. Large spaces should be set aside for piling and macerating farmyard manure; sometimes, farmland is required for piling up manure.

6. Chemical fertilizers can be applied broadly. After applying some chemical fertilizers, not only nutrients can be provided the crops but the fertilizer also kills bugs and protects against diseases. For example, once aqua ammonia or ammonium bicarbonate is applied in a field, mole crickets and mites will be eliminated. Calcium cyanamide protects against schistosomiasis. Urea can be added to the feeds of ruminants such as oxen and sheep. Precipitated tribasic calcium phosphate is another feed additive of domestic animals and fowls. Calcium cyanamide is a defoliant for cotton plants.

However, chemical fertilizers also have disadvantages, compared to farmyard manure. First, farmyard manure contains a bigger variety of nutrients, especially organic matter and plant growth hormones. Farmyard manure mixed into soil can bulk up humus content and loosen the soil for granulation*, bettering soil structure. Thus, in the entire crop growth period, essential nutrients can be uniformly supplied. Chemical fertilizers lack these features. Generally, chemical fertilizers do not have organic matter but only simple constituents. For example, ammonium sulfate has only nitrogen; calcium superphosphate, only phosphorus; potassium sulfate, potassium; and Ca-Mg-phosphate, only phosphorus, calcium and magnesium but no nitrogen and potassium. Although some composite and mixed fertilizers contain nitrogen-phosphorus, nitrogen-potassium or nitrogen-phosphorus-potassium constituents, these fertilizers still lack the variety of nutrients like farmyard manure does. Next, some chemical fertilizers favor certain crop and soil. In other words, not every chemical fertilizer is adaptable to all crops and soils for increased yields. For example, ammonium chloride cannot be applied to chlorine-avoiding crops, such as tobacco, sugar cane and sugar beet. Calcium cyanamide cannot be applied to alkaline soils.

So when chemical fertilizer manufacture is developed, farmyard manure should be collected at the same time with constant improvement in use technique. Today China's chemical fertilizer output is very low, not enough to meet the demands, so farmyard manure is a vital source of fertilizer. One must admit that farmyard manure is the foundation and chemical fertilizer, the supplement. Even in the future when chemical fertilizer output goes up, farmyard manure should still be spread on soil. In other words, farmyard manure and chemical fertilizer are both required. Both have pros and cons; they make up for each other's drawbacks.

Section 3. Classifying Chemical Fertilizers

Most chemical fertilizers are inorganic compounds, so they are also called

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Footnote*: Soil granulation means that the soil forms granular structure with particle diameters of 1 to 10 mm. After soil granulation, the soil can hold water and is well permeable by water and air; this favors burgeoning of the plant's root system.

inorganic fertilizer. Chemical fertilizers can be classified into different ways.

Classifying by Nutrients in the Fertilizers

1. Nitrogen chemical fertilizers: common nitrogen fertilizers are ammonium sulfate, ammonium nitrate, urea, ammonium bicarbonate, ammonium chloride, aqua ammonia and calcium cyanamide.

2. Phosphorus chemical fertilizers: common phosphorus fertilizers are calcium superphosphate, Ca-Mg-phosphate, concentrated superphosphate, defluorinated tricalcium phosphate and Thomas phosphate.

3. Potassium chemical fertilizers: common potassium fertilizers are potassium sulfate and potassium chloride.

4. Composite and mixed fertilizers: these fertilizers contain two or more nutritional elements; for example, ammonium phosphate contains nitrogen and phosphorus, and potassium nitrate, nitrogen and potassium.

5. Trace element fertilizers contain boron, magnesium, copper, manganese, zinc or molybdenum, by-products for making sodium borate or boric acid, boron and magnesium; copper sulfate, copper.

6. Indirect fertilizers differ from the above five fertilizers, directly aiding crop growth by adding to nutrients. Indirect fertilizers improve soil characteristics, bettering soil conditions for crop growth and supplying nutrients elements (calcium, magnesium or sulfur). Lime and gypsum are indirect fertilizers. Most soils in South China are acidic and after long application of acidic chemical fertilizers, the soil will crust over, denying crops access to nutrients. After spreading lime on this kind of soil, the soil tilth will benefit, giving nutrients to crops. Soil microbes can also multiply rapidly. Gypsum can improve alkaline soil but applying such fertilizer should be done heavily. This leads to high costs so the practice is not generally common over large areas.

Classifying by Rate of Fertilizing Effect

1. Quick-release fertilizer: some chemical fertilizers can quickly dissolve in soil moisture, so its nutrients are easily absorbed by crops. This is quick-release fertilizer. All nitrogen fertilizers, superphosphate and concentrated superphosphate among phosphorus fertilizers and potassium sulfate and potassium chloride among potassium fertilizers are quick-release fertilizers. These fertilizers can be follow-up or basic fertilizer, but are most effective as the former.

2. Delayed-release fertilizers: some chemical fertilizers are poorly dissolved in soil moisture or else these fertilizers dissolve slowly without apparent effects in a short period but with persistent fertilizing effect. The delayed-release fertilizers are Ca-Mg-phosphate, Thomas phosphate and pulverized

phosphate rock. Such fertilizers are best when mixed with farmyard manure or spread right on acid soil.

Classifying by Acid and Alkali Characteristics

By using chemical analysis the acidity or alkalinity of soils and fertilizers can be determined. This is how to decide what fertilizer is best for a particular soil type. By acidity and alkalinity, chemical fertilizers can be divided into acid, alkaline and neutral fertilizers.

1. Acid chemical fertilizers can be subdivided into two types: one type exhibits chemical acidity with its water solution showing an acid reaction, such as ammonium sulfate and calcium superphosphate. Another type exhibits physiological acidity with its water solution showing a neutral reaction. However, after a physiological acid fertilizer is applied to soil; part of the nutrients is absorbed by the crop. The rest in the soil is acidic. These fertilizers are ammonium chloride, ammonium sulfate and potassium sulfate.

2. Alkaline chemical fertilizers can also be subdivided into two types: one type exhibits chemical alkalinity with its water solution showing an alkaline reaction. One of these fertilizers is calcium cyanamide. Another type exhibits physiological alkalinity with its water solution showing an alkaline reaction. After these fertilizers are applied to soil, part of the nutrients is absorbed by the crop. The rest in the soil is alkaline. One such fertilizer is sodium nitrate.

3. Neutral chemical fertilizers do not show acid or alkaline reactions either before or after application to soil. Any soil can be treated with these fertilizers without affecting soil characteristics even after long use. One such fertilizer is urea.

Classifying Nutrients in Fertilizers

1. A single-element chemical fertilizer only contains one nutrient, such as ammonium sulfate (nitrogen), calcium superphosphate (phosphorus) and potassium sulfate (potassium).

2. Multi-element chemical fertilizers contain two or more nutrients, such as ammonium phosphate containing nitrogen and phosphorus.

Classifying by Fertilizer Forms

1. A solid fertilizer is a fertilizer made into crystalline, granular or powdered form in a factory; thus, it is convenient in packing, transportation and application. Except for liquefied ammonia and aqua ammonia, all nitrogen, phosphorus and potassium fertilizers are prepared as solids.

2. A liquid fertilizer is a fertilizer made as a liquid, such as liquefied ammonia and aqua ammonia. Production cost is lower than that of the solid

form, but certain containers and sprayers are required for packaging, transportation, storage and field use.

Section 4. History of Chemical Fertilizer Manufacturing

Chemical fertilizers are vital in increasing agricultural production so the industry of chemical fertilizers is an important sector in the national economy. The world history of chemical fertilizer production is not a long one. About more than a century ago, experiments and studies were made on chemical methods in fertilizer manufacture to increase crop unit yield and fertilizer sources. In 1842, the world's first factory appeared for making superphosphate by sulfuric acid treatment of bone meal. Later, since the amounts of bone meal could not meet the demand, it was found that phosphate rock can replace bone meal for making superphosphate. By 1870, large bodies of soluble potassium salt were discovered and the large-scale potassium fertilizer industry thus began. In 1913, the first synthetic ammonia factory for making various nitrogen fertilizers was built. Later, nitrogen, phosphorus and potassium fertilizers were made industrially. With better fertilizer application, chemical fertilizers showed rising benefits on crop yield gains in agricultural production. So the production and use of chemical fertilizer climbed rapidly. In 1900, chemical fertilizer use was only 8.3 million tons but the use in 1962 was 120 million tons. Over a little more than 60 years, chemical fertilizer use grew by 13 times: a 28.2 times gain for nitrogen fertilizer, 6.82 times for phosphorus fertilizer and 32.8 times for potassium fertilizer. Chemical fertilizer production also went up by leaps and bounds. Annual synthetic ammonia output in making nitrogen fertilizer went from 5 million tons in 1950 to 13.3 million tons in 1962, with the number of plants rising from about 130 to 400 for a more-than-double increase. The kinds and production and application techniques of chemical fertilizer were also much developed.

Like other pre-Liberation industries, China's chemical fertilizer industry was quite backward: only two ammonium sulfate plants made small amounts of nitrogen fertilizer. No potassium and phosphorus fertilizers were made either. Under the Party's leadership after the Liberation, the chemical fertilizer industry grew rapidly, with large gains in its output. All the main types of nitrogen fertilizers began to be industrially produced and the phosphorus and potassium fertilizers also began production, starting from nothing before the Liberation. However, China is a big country with wide variety of soils and crops, so the demand for chemical fertilizer is naturally quite high. Today's production is still far below the swelling demands of its developing agriculture. Based on China's present farm acreage with a mean annual demand of 30 chin of chemical fertilizer per mou, annual requirements for chemical fertilizer should be as much as tens of millions of tons. The increased output of chemical fertilizer directly promotes greater agricultural production. This is a necessary material condition for agricultural modernization and to consolidate the collective economy of people's communes. This necessity shows that the vigorous growth of chemical fertilizer industry is a difficult but glorious mission.

Small amounts of chemical fertilizer mean high agricultural yield; this is the most rational and economical task. Therefore, fertilizer application should be stressed. Today, demonstrations on fertilizing gains from chemical fertilizer use in experimental fields are underway in many people's communes by agricultural science researchers. These demonstrations instruct peasants about how to rationally utilize chemical fertilizer; results have been good. Propaganda and propagation functions need stressing to allow users to understand the characteristics and functions of various chemical fertilizers and to master economical and rational fertilizer application techniques. This book is written for this purpose.

Chapter 2. How a Crop Absorbs Chemical Fertilizer

Section 1. Relationship Between Soil and Fertilizer

Under certain conditions of temperature and humidity, a seed will sprout buds and grow once it has been sown into the soil. This is because soil can store and supply various nutrients required by the crop. Before we can understand the relationship between soil and fertilizer, we must learn about soil composition and characteristics and their effect on fertilizing power.

Composition and Function of Soil

The soil is composed of matter in three states: solid, liquid and gas. The solids are of soil granules and organic matter. The liquid is the water solution of various nutrients in the soil. The gas is air, occupying most of the space between soil granules. All these three states of matter should coexist in the soil. We cannot imagine either the ground as hard as stone slate without air space or waterless dry soil bearing crops. In ordinary soil, soil particles are more than 90 percent of the solid matter. Soil characteristics are classified by soil particle size. Soil particles greater than 0.01 mm are physical sand; soil particles smaller than 0.01 mm are physical clay. Soil containing much sand is called sandy soil; soil containing much clay is called clay loam; soil containing about equal parts of sand and clay is called loam, the most suitable soil type for ordinary crop growth.

Organic matter is made up of microbes and remains of animals and plants and can be as high as several percentage or as low as a few parts per 1000. Generally, soil with a high organic matter content is comparatively fertile. Soil applied with enough farmyard manure is often black and oily; this is because a high content of organic matter is in the soil.

In the soil water there are often nutrients which are necessary and absorbable by crops. The crop plants constantly absorb these elements during growth and remove them at harvest time. So these elements gradually become deficient. Although the solid part of soil can be gradually dissolved to supply some of the nutrients to the crop, this dissolved amount is much less than the crop needs. So fertilizer application is required as a supplement.

The soil gas components are generally similar to atmospheric constituents: mostly water vapor and carbon dioxide, besides nitrogen and oxygen. Oxygen meets the respiratory need of crop roots. After carbon dioxide is dissolved in the soil water, it can speed the dissolution of insoluble matter in soil and the chemical fertilizer for better crop absorption and utilization.

Relationship Between Soil Characteristics and Amounts of Chemical Fertilizer Applied

Clay has high water- and fertilizer-retaining power, so nutrients are not easily leached. However, the gas permeability of clay is low. Even with a single application of more easily soluble fast-release fertilizer, the fertilizing effect is still good. Sandy soil has low water-retaining capability, so nutrients are easily leached. When easily-soluble fast-release fertilizer is applied, small amounts and multiple applications should be the rule. Irrigation amounts should be controlled to prevent flooding irrigation from causing nutrients to be leached out.

The applied amounts of chemical fertilizer should also be determined by soil fertility. Less fertilizer is applied to fertile soil and more, to infertile soil with the balanced use of more farmyard manure.

Relationship Between Chemical Fertilizer and Soil Acidity and Alkalinity

There are acid, alkaline and neutral types of soils and chemical fertilizers. Generally, pH values indicate acidity and alkalinity. The pH value of neutral reaction is 7. Alkalinity is manifested by a pH greater than 7 and acidity by a pH less than 7. Generally, a crop will keep up good growth in a neutral environment. Therefore, acid soil is better applied with alkaline fertilizers, such as calcium cyanamide or Ca-Mg-phosphate. Thus, the function of fertilizer can be sufficiently exploited to neutralize the soil acidity and improve its characteristics. Alkaline soil is better applied with acidic fertilizers such as ammonium sulfate and calcium superphosphate. Of course, some acidic fertilizer can be applied to acid soils and likewise some alkaline fertilizer can be applied to alkaline soils, but the outcome is not as high as applying acidic fertilizer into alkaline soils and vice versa. Moreover, some supplementary measures should be adopted during or after applying fertilizer. For example, lime application can neutralize soil acidity. Sometimes, some alkaline fertilizers (such as Ca-Mg-phosphate) can be put on acid soils after acid fertilizer.

Besides soil characteristics, crop habits, growing period and climate should also be noted when applying chemical fertilizers. There are different sowing and ripening periods between grain and cash crops. There are different climates in North compared to South China. To the same crop may be applied different fertilizer types, with different amounts and methods. Some crops can be given heavy fertilizer one time and other crops can be given light fertilizer at other times. These steps vary to suit place and season. So experienced peasants advised that four factors (climate, soil, seedling and crop) should be mastered in applying chemical fertilizer.

Section 2. Absorption of Chemical Fertilizer by Crop

After being spread to soil, first the chemical fertilizer dissolves in soil water before crop absorption. Some chemical fertilizers dissolve rapidly, so absorption is also rapid. Some fertilizers dissolve slowly, so absorption is slow. Dissolving of a chemical fertilizer is closely related to pH, microbe count, temperature, water content and mineral content in the soil. Generally speaking, dissolution, absorption, redissolution and reabsorption process in cycles. This does not mean that once a fertilizer is applied, it is completely dissolved and completely absorbed by the crop.

Usually, once applied to soil, the fertilizer is absorbed by the crop root system. The roots can absorb waterand various nutrients since seedlings are sprouted. We can see many fine hairs intergrown around the crop roots; these fine hairs are called root hairs, growing close to the soil. In the central part of a root hair is a long string of cells, hollow at the center like a capillary. Water is contained in soil particles around the root hairs and mineral nutrients are in soil water. After the root hair absorbs these substances, they are conveyed through the capillaries to stems and to leaves.

Besides water and nutrients being absorbed by crop roots, crop leaves can also absorb water and nutrients. As a crop grows, leaves do many functions: photosynthesis, respiration and evaporation. Besides, leaves can also absorb nutrients. For example, spraying a dilute solution of calcium superphosphate on the leaves of wheat plants causes the phosphorus nutrient to be absorbed by the leaves. This absorption promotes formation and full growth of wheat grains. This way of applying fertilizer is called fertilizer application outside roots or at leaf surfaces.

Whether the root system or the leaf surfaces of a crop absorb the nutrients of the chemical fertilizer, nutrients rely on the leaf surfaces to be transformed into numerous complex substances via photosynthesis. This organic matter should be conveyed from leaves to various plant parts as nutrients to satisfy the growth demand of cells in the crop plant. Or the organic matter is brought to seeds or fruits as sugars, starch, protein, fat and fibers to form the entire fruit. The content of this organic matter differs in different crops. Grain crops, such as paddy rice and wheat, contain more starch; edible oil-seed crops, such as rape seed and peanut, have more fat.

Some of the nutrients goes to the crop for consumption during crop growth; the rest is stored for gradual consumption. Roots, stems, leaves, seeds and fruits are places for the storage of nutrients. Seeds of wheat, paddy rice, corn and sorghum, leaves of Chinese cabbage and borecole, and the fat stem tuber of potato are depots for organic matter. Seeds of some crops prepare to sprout after being sown the next spring, so essential nutrients should be stored.

Section 3. Are All Nutrients in Chemical Fertilizer Absorbed by a Crop?

A chemical fertilizer should be dissolved and decomposed in soil before absorption by crops. Then, after application to soil, can all the fertilizer be absorbed by the crop? This depends on the kind of chemical fertilizer; other determining conditions are soil characteristics, climate and management of field work. Generally speaking, these are the situations:

1. Chemical fertilizers such as ammonium sulfate, ammonium nitrate and ammonium chloride, are easily absorbed and leached because they are easily dissolved in water, thus providing fast fertilizing effects.

2. Highly volatile chemical fertilizer will evaporate a little before and after application in the field. However, if the fertilizer application method is appropriate, the evaporation losses can be greatly reduced. At the same time, after the fertilizer is applied to soil, it can be quickly absorbed by the crop. These fertilizers are ammonium bicarbonate and aqua ammonia.

3. Some phosphorus fertilizers can in part be quickly absorbed by soil. The rest is easily precipitated by iron and aluminum in soil, so the crop only can absorb a very small portion or none at all. Calcium superphosphate is such a fertilizer. Other phosphorus fertilizers are hard to dissolve in water, with slow decomposition in soil, so the crop does not readily absorb these fertilizers, but in contrast they do not tend to be leached and have longer fertilizing effects. Ca-Mg-phosphate is such a phosphorus fertilizer. Generally speaking, a crop will not absorb all the nutrients of a chemical fertilizer but only a percentage of it. The utilization rate of the first harvest is generally 50-65 percent for nitrogen fertilizers, 20-40 percent for phosphorus and 50-60 percent for potassium fertilizers. The fractions not currently utilized may be leached with water; only these are losses. So chemical fertilizer should be well preserved and application techniques should be mastered for its scientific utilization in reducing losses. Then its function can be more fully exploited. This is vital.

Chapter 3. Characteristics and Methods of Applying Chemical Fertilizers

There are many types of chemical fertilizers with many classification methods. However, the most common classification depends on the nutrient content, such as nitrogen fertilizer, phosphorus fertilizer, potassium fertilizer, trace element fertilizer, composite fertilizer, mixed fertilizer and mineral fertilizer. These fertilizers are introduced in the following:

Section 1. Nitrogen Chemical Fertilizer

Crop growth is cellular growth in the plant body. The important component of the cells is protein, approximately 16-18 percent nitrogen. This shows how important nitrogen is to crop growth.

Man gets nitrogen by eating grains and vegetables. In growing, grains and vegetables absorb nitrogen from the soil. As soil nitrogen is depleted by crops and nitrogen from other sources is leached by irrigation or rain water, the soil nitrogen becomes insufficient. So nitrogen fertilizer should be applied to supplement nitrogen in the soil.

Nitrogen is also richly present in the atmosphere, approximately four-fifths the entire volume of the atmosphere or 76 percent by weight. This nitrogen is called free nitrogen that the crop cannot absorb directly. After the nitrogen is embodied in nitrogen compounds, a crop can absorb it.

Although a crop should have enough nitrogen fertilizer, is it better to apply excessive nitrogen fertilizer? No. Like a man who eats food, if he consumes too little, nutritional deficiencies will develop. If he eats too much, indigestion will follow; this could lead to intestinal and stomach diseases. If a crop is given too much nitrogen fertilizer, especially uncoordinated with phosphorus and potassium fertilizers, the crop will grow excessively and be too green; the stems damp off easily; the crop is easily attacked by pest; and fruits ripen late without gains in yield. If excessive nitrogen fertilizer is applied at one time, the crop will exhaust its vitality by overgrowth. So nitrogen fertilizer should be used properly by crop variety and growing period. How much nitrogen fertilizer per mou? This depends on the soil and crop varieties. From experience in farmyard manure applied to ordinary soils, 4-10 chin of nitrogen element per mou is a good guide for main crops, such as paddy rice, wheat, corn and cotton. Converted into ammonium sulfate, this amount of nitrogen element is about equal to 20-50 chin per mou. High figures can be used for paddy rice, cotton and vegetables and low figures, for wheat and sweet potato. Even lower figures can be used for beans.

In the growing period, generally the most nitrogen fertilizer should be applied during the vigorous growth, such as sprouting to the tassel-growing period for paddy rice, incubation period of unopened flower buds to the flowering period for cotton, and the period following transplanting, for tobacco. Nitrogen requirements in the later growth period of crops is much less. If nevertheless nitrogen fertilizer is applied without any nitrogen deficiency in the later growth period, the crop ripening period will be delayed, resulting in excessive growth of stems and leaves. Thus, generally nitrogen fertilizer is most economical and effective as a follow-up fertilizer in the period of vigorous crop growth.

The fertilizing effect of nitrogen fertilizer is quite obvious. One chin of nitrogen (about equal to less than 5 chin of ammonium sulfate) can increase the output of paddy rice by 20-25 chin, wheat by 10-15 chin, about 10 chin of unginned cotton, 20-30 chin of corn and about 5 chin of rape seeds. When applied to vegetables, one chin of nitrogen can increase Chinese cabbage output by 200-270 chin, spinach by 150 chin, and 40-60 chin for potato, sweet potato and sugar beet.

Main Varieties of Nitrogen Fertilizer

1. Ammonium sulfate: it is a white, fine crystal. Because of impurities, sometime it is gray, yellow, or pink. Its shape is like granulated sugar. Many peasants in China call it field-fertilizing powder. This is a chemical fertilizer applied comparatively early in time in China's rural areas.

Ammonium sulfate contains 20-21 percent nitrogen. In other words, 100 chin of ammonium sulfate contains 20-21 chin nitrogen. Technical ammonium sulfate has an acid reaction because it generally contains free acid. It will increase soil acidity if applied over a long time. Since ammonium sulfate is a physiological acidic chemical fertilizer, the soil can crust over with excessive application. Why does soil crust over? This is because of increased acidity in soil and deficiency of organic matter. Thus, elements in soil such as potassium, sodium and calcium will be quickly leached by water. Therefore, the granular structure of the soil is destroyed; the soil becomes crusted. Ammonium sulfate is easily dissolved in water and it can be quickly decomposed in soil and be absorbed by crops. If ammonium sulfate is applied with the coordination of barnyard manure, compost and green manure, organic matter in the soil can be increased and likewise, the essential nutrients of the crop. Thus, the fertilizing effect is better.

There are generally two ways of making ammonium sulfate. One way is the direct reaction of synthetic ammonia and sulfuric acid; this is called the synthetic method because the source of ammonia comes from synthetic process. Another method is using sulfuric acid to absorb ammonia in coke oven gas during coking; this is generally called the recovery method of by-product ammonia. In the synthetic method, ammonia gas is added to dilute sulfuric acid, for a chemical reaction. The resultant product is a solution of ammonium sulfate. As the solution becomes more and more concentrated during the reaction process, finally crystals of ammonium sulfate are precipitated. After separation and drying, ammonium sulfate particles are formed. In the recovery method of by-product ammonia, during the coking process ammonia in the coke oven gas is absorbed by dilute sulfuric acid, to make ammonium sulfate. About 25 to 30 chin of ammonium sulfate can be recovered when refining one ton of coke. Ammonium sulfate made by the synthetic method is comparatively pure and white in color. Ammonium sulfate as the by-product of coking is frequently mixed with impurities with different colors. However, this has no undesirable fertilizing effect.

There are many ways of applying ammonium sulfate; it can be used as basic fertilizer, seed fertilizer or follow-up fertilizer. However, the fertilizing effect is best when using ammonium sulfate as follow-up fertilizer. When used as seed fertilizer, small amount of ammonium sulfate should be applied and it should be mixed wet with the seeds. Otherwise, some of seeds may fail to sprout. When used as basic fertilizer, the amounts should also be small. The best effect comes from mixing with farmyard manure as the basic fertilizer. When used as follow-up fertilizer, generally 10-50 chin of ammonium sulfate can be applied per mou. When nitrogen fertilizer is applied in paddy fields as follow-up fertilizer, overirrigation should be avoided. No water drainage should be conducted 7-10 days after application to avoid loss of fertilizing nutrients.

When ammonium sulfate is used as follow-up fertilizer, either dry or wet application is good. Application to cotton plants is best in the seedling period and the time between the incubation period of unopened flower buds to the vigorous period of growing cotton bolls. To sorghum or corn plant, fertilizer is better applied in the seedling period to sometime before tassel growing. Ammonium sulfate can be applied as follow-up fertilizer, one to three times, to paddy rice or wheat plants in the sprouting period or the time between node growing to the tassel incubation period. Follow-up fertilizer can be applied one to two times to hemps after seedling transplanting to the period when unopened flower buds appear. One to three times of follow-up fertilizer can be applied to vegetables after seedling transplanting.

Here are precautions when applying ammonium sulfate:

(1) As the ammonium sulfate is an acidic fertilizer, it is most appropriate in alkaline or neutral soils. The fertilizer can also be applied in acid soil but the application time should not persist too long. Otherwise, excessive buildup of sulfuric acid in soil will cause crusting, disadvantageous to crop growth. To avoid this phenomenon, enough lime should be applied to the soil. Generally, one-half chin of lime should be applied per chin of ammonium sulfate to neutralize its acidity. However, care should be taken that ammonium sulfate is not mixed with lime to be applied to the soil; alternate applications should be made at different times.

(2) Ammonium sulfate should be mixed with alkaline fertilizer, such as pearl ash, calcium cyanamide or Thomas phosphate. If mixed before application, ammonium sulfate will be decomposed with the loss of nitrogen. Alternate application is desirable.

(3) When applying ammonium sulfate, care should be taken not to let it stick to stems and leaves of the crop plant, otherwise the crop will exhaust its vitality due to excessive growth. When applying fertilizer, the proper distance should be kept from crop roots. It is best to conduct furrow or hill application in the space between two adjacent planting rows. Or else application is conducted by digging a ditch and then covered with soil after application. If the ammonium sulfate is dissolved in water for application, one chin of ammonium sulfate can be mixed with 30-50 chin of water. If dry soil is mixed with the fertilizer, one chin of ammonium sulfate can be mixed with 5-10 chin of dry, fine soil.

(4) Hygroscopicity of ammonium sulfate is low. However, since the fertilizer contains a small amount of free sulfuric acid, sometimes it can be moistened and cake. This does not affect fertilizing power. During application, caked ammonium sulfate can be crushed by knocking or applying pressure.

The output-increase effect of ammonium sulfate is as follows: one chin of ammonium sulfate can approximately increase yield of paddy rice by 4-5 chin, wheat by 2-3 chin, corn by 4-6 chin and unginned cotton by 1.5-3 chin. The fertilizing effect to other crops is also considerable.

2. Ammonium nitrate: it is white granules or powder. When containing impurities, the fertilizer sometimes is gray or light yellow. Granularity of ammonium nitrate is similar to that of ammonium sulfate. This fertilizer has rapidly developed in use in China in recent years, with large outputs.

The nitrogen content of ammonium nitrate is higher than in ammonium sulfate, about 34-35 percent. This is a highly effective nitrogen fertilizer. One chin of ammonium nitrate is equivalent to 1.75 chin of ammonium sulfate, therefore less can be applied than for ammonium sulfate. If 10 chin of ammonium sulfate is required per mou of farmland, then 6 chin of ammonium nitrate should be applied.

The water solution of ammonium nitrate is neutral, but after its application into the soil, nitric acid forms via bacterial reaction. Therefore, this is a physiological acidic chemical fertilizer. However, it is less acid than ammonium sulfate. In addition, nitric acid can be converted and be absorbed by the crop, then the acidity naturally disappears. So this is a fertilizer of nearly neutral reaction and can be adapted to various soil types. The fertilizing effect is concentrated and fast and causes significant output increase to grain crops, cash crops, fruit trees and vegetables. The fertilizer can be also applied in either upland or lowland field, yet the fertilizing effect on upland field is better. If ammonium nitrate is applied in paddy fields, the fertilizing power is little less than for ammonium sulfate with equivalent amounts of nitrogen. From experiments in Kiangsu Province, reported by the Institute of Soils and Fertilizers of China Academy of Agricultural Sciences, the fertilizing effect of ammonium nitrate for paddy rice is about 90 percent that for ammonium sulfate, with equivalent nitrogen content. Experiments in Kiangsi, Kwangsi, Szechwan and Ningsia provinces reported like results. There were also similar reports in Japan. Ammonium nitrate dissolves easily in water, with high hygroscopicity. Caking follow if improper storage leads to moisture contact. It is best to dissolve caked material in water, or lightly crush it with a wooden hammer. No iron hammer can be used in crushing because ammonium nitrate may then explode violently. Do not fear its explosion characteristics. When ammonium nitrate is not near flame and not violently shocked, it does not explode at ordinary temperatures.

Ammonium nitrate contains high percentages of nitrogen and is quite adaptable to crops and soils, so it is a good chemical fertilizer. In addition, it can be also made into dynamite as a trend in ammonium nitrate production.

Ammonium nitrate is made by the reaction of ammonia with nitric acid, which reacts with ammonia and oxygen in the atmosphere through a catalyst at high temperatures. Then water is used to absorb the final product. So ammonia is used as the major raw material in making ammonium nitrate. Allow ammonia gas to pass through a dilute nitric acid solution; it then becomes an ammonium nitrate solution. The end product of ammonium nitrate forms through the steps of evaporation, crystallization, separation and drying. To avoid ammonium nitrate caking on contact with moisture, the fertilizer is made into granules, to which have been added fillers, such as dolomite, kaolin and diatomite to avoid caking.

Since ammonium nitrate has concentrated fertilizing power and a rapid effect, it is best as a follow-up fertilizer. The amount used should be less than that for ammonium sulfate, generally about 8-30 chin per mou of ammonium nitrate. When small amounts of this fertilizer is used, six to eight times fine dry soil can be mixed before a scattering application. Or, 50-70 times of water is mixed for a spraying application. It is forbidden to spray during dew, dense fog or drizzle because the fertilizer tends to stick to stems and leaves of the crop and injure through chemical etching.

These are precautions when applying ammonium nitrate:

(1) Protection from moisture is important because ammonium nitrate is highly hygroscopic. Explosion may occur at high temperatures or under violent friction, so special precautions should be followed in transportation, storage and application. Never store ammonium nitrate with flammables like kerosene, diesel oil and coal. Violent shock should be prevented when moving this nitrate. Never store ammonium nitrate in a place in high temperatures, as in direct sun exposure. No explotion will occur if flame, high temperatures or violent shock are avoided.

(2) The fertilizing power of ammonium nitrate is quite concentrated; its appearance is very similar to ammonium sulfate so care should be taken to

avoid overapplication to cause excessive growth, late ripening and chemical etching injury by direct contact with stems, leaves or roots.

(3) Ammonium nitrate should be mixed with alkaline fertilizer before application, otherwise partial decomposition will occur, causing nitrogen loss.

The yield increases from ammonium nitrate use are 3-5 chin of wheat, 2.5-5 chin of cotton or 6-10 chin of corn per chin of fertilizer applied.

3. Ammonium bicarbonate: it is a white crystalline powder but sometimes it is grayish white due to impurities. The fertilizer has a bad odor like that of ammonia; it has 17.5 percent nitrogen. Its solution is nearly neutral. No residue will remain after soil use, so the fertilizer does not cause soil to deteriorate. Therefore, a number of soil varieties can be treated with it. The fertilizer decomposes rapidly after applied to soil and it can be rapidly absorbed by crops. After decomposition, not only can nitrogen be used as fertilizer, but the other decomposed product, carbon dioxide, also benefits crops, such as promoting photosynthesis and adding chlorophyll content. So ammonium bicarbonate is a desirable nitrogen chemical fertilizer.

Ammonium bicarbonate has a drawback: it is unstable and easily decomposed. At 20°C, dry ammonium bicarbonate is fairly stable. However, when temperatures are high, or the water content in the fertilizer is high, it can decompose into ammonia and carbon dioxide, which are dissipated into the atmosphere. The higher the temperature and water content, the faster the decomposition. From experiments, for an ammonium bicarbonate sample with the same water content and stored for 100 days, losses are 2.5 percent in winter but 25 percent in summer. The difference in loss is tenfold. Similarly, for dry ammonium bicarbonate at 20 to 30°C and stored 12 days, decomposition is only 4.8 percent. If the fertilizer contains 4.8 percent water, almost all ammonium bicarbonate disappears in 12 days. In moist atmosphere, the fertilizer will absorb moisture and decompose. This constant decomposition appears as a strong irritating ammonia odor. This problem can be taken care of by tightly sealing bags. Otherwise, the volume of fertilizer will be reduced gradually in the warehouse by escaping into the atmosphere.

Although ammonium bicarbonate has the failing of constant decomposition into the atmosphere, yet losses can be considerably cut back by packaging with plastic bags or other sealing container. Also, ammonium bicarbonate should be quickly consumed once manufactured.

Ammonium bicarbonate is manufactured by using ammonia and carbon dioxide as raw materials. Carbon dioxide is a by-product of synthetic ammonia plants or it can be obtained from a lime kiln. First, ammonia gas is dissolved in water to form aqua ammonia; this then reacts with carbon dioxide to form ammonium carbonate, which further absorbs carbon dioxide, to yield ammonium bicarbonate.

Since making ammonium bicarbonate is simple and plant construction is rapid, capital investment is low and its costs are low. The fertilizer can be extensively used in various crops and soils with good fertilizing effect. So ammonium bicarbonate output is climbing rapidly in China.

Ammonium bicarbonate can be used either as follow-up fertilizer or as basic fertilizer, but it should not be used as seed fertilizer. It is best to make ditch or hill application of dry ammonium bicarbonate; the application depth into the soil should be deep and covered with soil immediately afterwards to avoid the evaporation and loss of nutrients. Or, 30 to 50 times of water by weight can be mixed with the fertilizer for spraying or ditch application and immediately covered with soil. Or, five to ten times of fine dry soil can be mixed with the fertilizer for deep application and covered immediately with soil. The quantity of ammonium bicarbonate applied is generally 18 percent more than that for ammonium sulfate, with 20-60 chin per mou.

Ammonium bicarbonate can be applied to various crops. For paddy rice, seedling fields or fields after seedling transplanting can be treated with the fertilizer. One single application can be adopted as the basic fertilizer or multiple applications as the follow-up fertilizer. For wheat plant, ammonium bicarbonate can be used as the follow-up fertilizer during periods of sprouting, return-to-green, node sprouting and tassel incubation. For use on corn plant, the fertilizer can be used as follow-up fertilizer in the period after seedling transplanting to sprouting of male tassel. Application can be made in the time between seedling and incubation of unopened flower buds, flowering period, or even vigorous growing period of bolls for cotton. Each application is between 10 and 20 chin.

Here are precautions for applying ammonium bicarbonate:

(1) Since ammonium bicarbonate is highly volatile, packages should be well sealed whether in transportation, storage or before application. Usually, plastic bags are used for packaging. During application, it is best to open the next package only after using up the previous one. Fasten the package tightly if there is some fertilizer left, or the plastic bag can be covered by a pot or earthenware jar to prevent evaporation.

(2) Application conducted for ammonium bicarbonate should be by ditches or hills then covered with soil right away. It is forbidden to spread on the soil surface, otherwise all nutrients will escape into the atmosphere or even cause chemical etching injury to crop stems and leaves.

(3) Ammonium bicarbonate should not be mixed with farmyard manure to make compost, or even mixed with lime or other alkaline fertilizers, such as calcium cyanamide and pearl ash. The yield-increase effect of ammonium bicarbonate is 3.5-4.5 chin of paddy rice per chin of fertilizer. The fertilizing effect is generally higher than with ammonium sulfate for applying same quantity of nitrogen per mou.

4. Ammonium chloride: the industrial form of ammonium chloride is the halogenide, white or light yellow granulated crystals like table salt. The fertilizer is hygroscopic but it does not cake easily. It can be completely dissolved in water with a weak acid reaction. The fertilizer is fairly stable at ordinary temperatures. At 100°C, it can easily dissolve to form hydrogen chloride gas. The nitrogen content of ammonium chloride is 24-25 percent, slightly higher than for ammonium sulfate but not as high as ammonium nitrate.

In industrial production, ammonium chloride is made in the soda ash industry. First ammonia gas is passed into a saturated solution of table salt, then carbon dioxide is let in to yield sodium bicarbonate. Next, the right amount of table salt is added to precipitate ammonium chloride. The water then can be removed, to obtain ammonium chloride crystals as the end product. Since ammonium chloride is produced together with soda ash, rational utilization of resources should be done to get low costs. Therefore, ammonium chloride is a fertilizer deserving of broader use.

In experiments and practice, domestically and abroad, ammonium chloride was shown to have significant effect in boosting crop yields. Especially is the fertilizer well suited for calcareous and neutral soils. The fertilizer has a good fertilizing power for paddy rice, wheat, cotton, rape and ramie. However, ammonium chloride contains chlorine, besides nitrogen. Chlorine can easily absorb water, increasing the water content in the crop. Therefore, when the fertilizer is applied to sugar crops, such as sugar cane, sugar beet and orange, their sweetness will be reduced. When applied to starch crops, such as potato and sweet potato, the starch content will be also reduced.

When applied to tobacco plant, cigarette flavor will suffer and can cause burning to stop in smoking from time to time.

Basically, ammonium chloride is used the same way as ammonium sulfate, either as follow-up fertilizer or basic fertilizer but not as seed dressing. The fertilizer can be applied either dry or wet, 15-40 chin per mou. When ammonium chloride is applied to grain crops, the percentage of flour yield is 10-15 chin higher per 100 chin than for ammonium sulfate. When ammonium chloride is applied to cotton or hemp crops, fiber tension can be increased.

Here are precautions when applying ammonium chloride:

(1) Ammonium chloride has selectivity toward crops so the fertilizer should not be applied to chlorine-avoiding crops, such as sugar cane, sugar beet, potato, tobacco and tea leaves.

(2) Ammonium chloride is a physiological acid fertilizer. Like ammonium sulfate, if the fertilizer is applied to acid soil, it should be coordinated with lime or farmyard manure. However, these should not be mixed, in order to retain the fertilizing power.

(3) Ammonium chloride should not be applied to upland fields with saline soil, or to fields with poor drainage or irrigation.

(4) Ammonium chloride is better applied several times in small amounts each or the application should be as early in the season as possible to flush the chlorine by water into lower soil strata.

(5) If ammonium chloride is wetted by absorbing moisture, it should not be dried in the sun or over fire because ammonium chloride will decompose into gas when heated. Fine, dry soil can be used to mix the wet fertilizer, or it can be mixed with water for spraying application.

Ammonium chloride has about the same strength in yield increase as that of ammonium sulfate.

5. Urea: human urine contains urea and water. By analysis, generally there is 1.5-2 percent of urea by weight in human urine since urine contains only little nitrogen. Because urea is manufactured in chemical method with 45-56 percent of nitrogen, the nutrient content is much increased. Urea is also called synthetic urea.

Beside use as a fertilizer, urea is an industrial raw material in making plastics, synthetic fiber, paint and artificial leather. In medicine, urea can be used as a drug or as raw material for certain drugs. In addition, urea can be used in oil refining, ore dressing and as a developer in photography. Since these subjects are not part of the book, they are not described further. Another important agricultural use for urea is feed for ruminants, such as oxen or sheep.

The raw material in making urea is carbon dioxide. By synthesizing ammonia and carbon dioxide at high temperature and high pressure, the end product is urea. In recent years, urea output rose greatly because of these reasons:

(1) The raw material for urea is carbon dioxide, a by-product of synthetic urea plants. This is easily obtained compared with ammonium sulfate, which requires sulfuric acid, or ammonium chloride, which takes table salt.

(2) Urea can be applied to a wide variety of crops and soils and it will not cause the soil deteriorate even after long use.

(3) Besides fertilizers, urea is also a supplementary feed for ruminants as well as many important industrial high-tonnage uses.

(4) Urea contains a high level of nitrogen, resulting in low transportation costs, low labor costs in application, low packaging cost and finally low production costs.

(5) Urea is stable and is easy to store.

Urea is a white or light yellow needle-shaped or prismatic crystal. The industrial product is powdered or granulated crystals. Some cold feeling will appear if urea is placed on the tip of the tongue because urea absorbs heat as it dissolves. Urea contains 45-56 percent of nitrogen; this is one of the highest nitrogen-containing chemical fertilizers.

The nitrogen content of 1 chin of urea is equivalent to 2.2 chin of ammonium sulfate, 1.3 chin of ammonium nitrate, 1.8 chin of ammonium chloride or 2.6 chin of ammonium bicarbonate. In addition to nitrogen content, urea also contains carbon dioxide which can also be absorbed by crops after decomposition in soil, promoting photosynthesis. This feature is the same as for ammonium bicarbonate.

Urea also contains about 1 percent semicarbazones, a substance harmful to crop growth. By experiments, when the semicarbazones content exceeds 3 percent in urea, absorption by root system for seed sprouting will be affected. This problem has been noted in industrial production, so agricultural urea does not contain much semicarbazones.

Urea can be used as follow-up or basic fertilizer but not as seed fertilizer. As basic fertilizer, it is best to mix urea with farmyard manure before application. When used as follow-up fertilizer, either dry or wet application is allowed. During dry application, urea can be mixed with 8-10 times fine dry soil and during wet application it can be mixed with 80-100 times of water in spraying application. Generally, 7-25 chin of urea can be applied per mou of farmland.

Urea is hygroscopic so it dissolves easily in water. It is a neutral fertilizer adaptable to a variety of soils and crops. It does no damage to soil even after long-time application. Urea does not remain as a residue in the soil. Generally, the fertilizing effect of urea is 3-5 days slower than ammonium sulfate. Although the fertilizing effect is a little slower yet the effect is persistent. Urea dissolves at different rates when applied in soils of different characteristics. It dissolves faster in neutral and alkaline soils than in acid soils. Urea dissolves faster in clay loam than in sandy soil. After decomposition, the chemical nutrient easily adheres to soil and is not likely to be leached.

Urea can also be applied outside roots or on leaf surfaces. This can be done by spraying urea solution on crop leaf surfaces so that the solution can infiltrate into leaf cells for photosynthesis in making sugar compounds, amino acids and finally protein. The crop absorbs nutrient faster if applied externally to roots, starting to absorb as early as 5 hours after spraying and absorbing 50-75 percent after 24 hours spraying with fertilizing power persisting about 7-10 days. So when applying urea outside roots, it is better to spray every 7-10 days. Usually, fertilizer application outside roots is used in these cases:

(1) applied to creeping crops of fruits or melons;

(2) applied to crops after grafting, frost freezing or wind damage for urgent requirements of large amount of nitrogen fertilizer;

(3) applied to crops whose roots are injured due to pests, flood or drought, lowering the roots' capability of absorbing fertilizer; and

(4) in other special conditions, such as improving tea, tobacco or mulberry leaves to form extralarge leaves.

Very dilute urea solution is required when applied outside crop roots. Generally, 1 percent urea solution (1 chin urea per 100 chin urea solution) is used in grain crops. A more dilute urea solution, 0.3-0.8 percent, can be used for melons, fruits or vegetables. If the solution is too concentrated, crops will be damaged through chemical etching. When spraying, care should be taken to only slightly moisten leaf surfaces; the fertilizing effect is higher when applied on leaf undersides but this operation is more difficult. Except during the flowering period, leaf surface fertilizer application can be conducted in all other periods. Night spraying is best because the solution will dry slowly since the dew is present. Or, spraying is done at dusk, after five o'clock in the afternoon. High noon spraying is not allowed because of rapid drying to cause chemically etching to the crops.

There are many advantages for applying fertilizer outside roots, such as: the crop absorbs much fertilizer so the amounts applied can be smaller. The fertilizing effect is timely so this is convenient in controlling crop growth. The fertilizer can be mixed with insecticide before spraying for dual purposes. However, application times are longer for outside roots, thus consuming more labor. Sprayers should be used for outside-root application, so this way is not as simple as root application. The fertilizing effect when applied outside roots cannot replace all root treatment, so this kind of application can be only supplementary.

Since urea has these advantages, world urea production climbed sharply. Vigorous gains in urea output are also happening in China. This is a type of nitrogen fertilizer with a great future.

Here are precautions in applying urea:

(1) Since urea's nitrogen content is high and its fertilizing effect is fairly slow, the amount used should be small. Otherwise, the crop will grow thin stems, causing damping-off, late ripening, or chemical etching injury. Also, urea should be applied as early as possible to allow enough time for decomposition in the soil. Urea should be applied on sunny days so as to intensify microbial activity in the soil and promote early decomposition of urea. These stipulations should be strictly followed, based on soil, climate and crop conditions.

(2) When applying urea dry, care should be taken not to contact seeds, stems, leaves and roots and thus to avoid injury through chemical etching.

(3) Urea is hygroscopic (less so than ammonium nitrate but more so than ammonium sulfate) so it should be placed in dry places.

The yield-gain effect of urea is 10-15 chin of paddy rice, 5-8 chin of wheat, 3-5 chin of cotton and 8-15 chin of corn per chin of urea application.

As stated, urea can be also used as a supplementary cattle feed. Why? Because nitrogen in urea can be utilized by microbes inside the ruminant stomachs to convert into protein, which is then digested by the stomaches and absorbed by the intestine as nutrients. Calculation shows that each chin of urea equals more than 2 chin crude protein, 2 chin digestible protein or 5.5 chin bean cake. After a cow eats feed mixed with urea, the lactating period can be one month longer, the milk yield -- 10-20 percent more and feed expenses -- 10-20 percent less.

Daily urea given as supplementary feed is generally 0.05 percent of animal body weight. The daily ration should be fed in several sessions. To start, less than 0.05 percent of body weight should be given. Later, the amount fed can be gradually increased, based on animal's adaptation. Overfeeding of urea is not allowed. Urea cannot be used as the only feed because it does not contain carbohydrates and fat, so it cannot replace grain feed. The amount of urea mixed is generally less than 1 percent of total feed. Never exceed this value. Urea cannot be dissolved in water as a feed because this may poison the animal. Generally, urea can be made into cakes or balls together with other feeds. However, urea should not be mixed with uncooked soybean, bean cake, melon seeds or green grass. At present, there has not been enough experience in using urea as a supplementary feed. So before feeding urea, get consultation and guidance from veterinarians or the appropriate technicians.

6. Aqua ammonia: the main component in aqua ammonia is ammonium hydroxide, colorless or faintly yellow. Aqua ammonia is a volatile liquid with a bad odor, irritating to the nose. Its volatility increases with temperature. Aqua ammonia has an alkaline reaction and is corrosive. Its nitrogen content is determined from its water content. In other words, the more water in aqua ammonia, the lower the nitrogen. Usually, there is 12-16 percent nitrogen of agricultural aqua ammonia. Sometimes there may be as little as 10 percent nitrogen.

Like ammonium nitrate, urea and ammonium bicarbonate, once aqua ammonia is applied to soil it can be completely absorbed by the crop without any residue. Thus we see that aqua ammonia adapts readily to soil conditions. Since it is liquid,aqua ammonia is not as convenient as a solid in transportation.

Aqua ammonia is made fairly simple. Generally, ammonia gas is passed through water, dissolving to yield aqua ammonia. Or ammonia-containing coke oven gas during coking absorbs ammonia content in its water forming aqua ammonia. Sometimes aqua ammonia has been made; carbon dioxide is admitted in to yield the mixed solution of ammonium carbonate and aqua ammonia in order to lower its volatility. This kind of ammonia, with carbon dioxide passed into it, is called carbonated aqua ammonia. Manufacturing it is simple and its production costs are low; the raw materials are ammonia, water and a little carbon dioxide. Volatility losses of carbonated ammonia are smaller than for aqua ammonia. Especially in the case of small chemical fertilizer plants, making carbonated aqua ammonia means savings and convenience for use near the plant. Aqua ammonia and carbonizing ammonia were developed rapidly in recent years in China. These products receive ready acceptance by peasants.

Aqua ammonia is a colorless liquid like water. However, one should not apply aqua ammonia like irrigation water, else the crop will be chemically etched then die. Ordinarily aqua ammonia is diluted with water before used: generally with 30-50 times of water. If the soil is moistened, the dilution ratio can be smaller.

Aqua ammonia can be used as follow-up or basic fertilizer. Ditch or hill application is best in upland fields at depths of 2-3 ts'un. After the fertilizer is applied, the place should be covered with soil to avoid evaporation. In spraying, aqua ammonia is diluted with 150 times of water, but it is not allowed to splash it onto the soil. Usually this fertilizer solution is mixed with irrigation water for a homogeneous application. Two ts'un of irrigation water should be left in the field to avoid fertilizer losses or to avoid chemical etching damage to crops. In some area, aqua ammonia-filled pots or jars are placed on raised field partitions and a rubber hose feeds aqua ammonia on the siphon principle into the irrigation ditch. Then the fertilizer can be spread with irrigation water through the entire field. If weeding follows, the fertilizing effect is even better. The amount of aqua ammonia applied to each mou is about 20-60 chin, 20 percent more than the amount of ammonium sulfate used.

Application of aqua ammonia in lowland fields can keep pest insects out and its application in wheat fields can prevent and treat wheat blight. This can have two purposes.

Here are precautions for applying aqua ammonia:

(1) Since aqua ammonia is liquid, its transportation and packaging is not as convenient as with a solid. Its containers must be sealed due to its volatility. If it no longer has a bad odor, its nutrient value is zero.

(2) In applying, the aqua ammonia concentration should be kept constant. Too low a concentration will result in low fertilizing effect and too high a concentration, chemical etching of crops.

(3) In lowland fields, irrigation water should not be immediately drained after fertilizer application. Otherwise, fertility will be lost.

(4) Aqua ammonia is corrosive, especially so to copper. So copper containers should never be used. Crop seeds should not be allowed to touch aqua ammonia, to avoid affecting sprouting. Stems and leaves must also not be allowed to contact the fertilizer, to avoid chemical etching. One's hands

should not touch aqua ammonia during application, otherwise the skin will be burned or injured.

From experience in applying aqua ammonia in China, the yield-gain effect of 3 chin aqua ammonia (containing 20 percent nitrogen) equals that of 2.5 chin of ammonium sulfate. In aqua ammonia, each chin of nitrogen (equivalent to 6-7 chin of aqua ammonia, containing 20 percent nitrogen) can boost the paddy rice yield by 20-25 chin, wheat yield, about 15 chin, corn yield, 25-35 chin, unginned cotton yield, about 10 chin, rape seed yield, 6-8 chin, Chinese cabbage yield, about 60 chin and sugar beet yield, about 140 chin.

7. Liquefied ammonia: cooled ammonia gas and condensed under pressure ends up as liquefied ammonia; this may be directly applied as a fertilizer. Liquefied ammonia is a colorless liquid containing 82 percent nitrogen. Although its nitrogen content is high, it is very volatile at room temperature. If liquefied ammonia is not enclosed in a special container, all of it will escape as gas. In production, the container for liquefied ammonia is a steel storage tank capable of withstanding a pressure of 16-17 atm. When the fertilizer is delivered, it is packed into a specially-made steel bottle, which can also withstand a pressure of 16-17 atm. During application, machinery under compression should also be used and ejectors to eject liquefied ammonia into the soil. Since applying it is fairly complicated, liquefied ammonia is limited in its acceptance. The concentration of liquefied ammonia is high and so is its pressure. Therefore, application machinery should be required to eject the fertilizer deep into soil, followed by covering with more soil. Usually, 3-8 chin of liquefied ammonia is enough for each mou of farm field. The seven nitrogen chemical fertilizers discribed about are made with ammonia as raw material. To help readers to remember these fertilizers, Figure 2 shows a graphical illustration as follows:

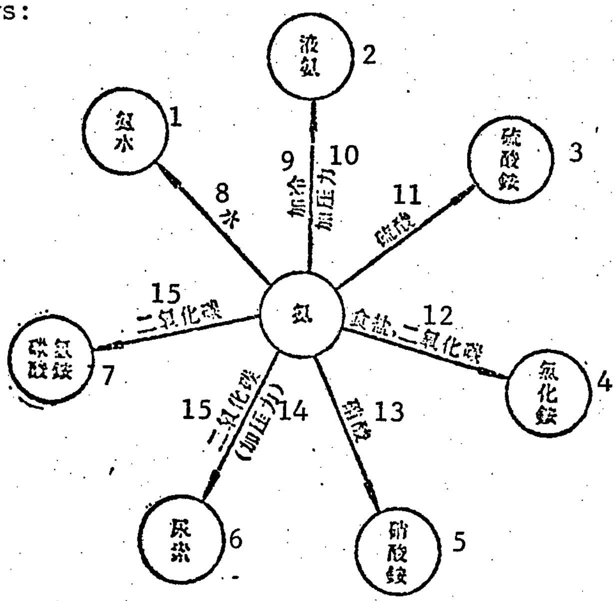

Figure 2. Nitrogen Fertilizers Made With Synthetic Ammonia

[Key on following page]

/Key of Figure 2 on preceding page/

1. Aqua ammonia	9. Cooling
2. Liquefied ammonia	10. Applying pressure
3. Ammonium sulfate	11. Sulfuric acid
4. Ammonium chloride	12. Table salt, Carbon dioxide
5. Ammonium nitrate	13. Nitric acid
6. Urea	14. (Applying pressure)
7. Ammonium bicarbonate	15. Carbon dioxide
8. Water	

8. Ammonium calcium nitrate: it is also called as lime ammonium nitrate. Ammonium calcium nitrate is made by first melting ammonium nitrate to which the right amount of limestone or dolomite powder has been added. Since ammonium nitrate is an acid fertilizer and is explosive and easily caking under certain conditions, it is further processed into ammonium calcium nitrate fertilizer to improve its characteristics.

Ammonium calcium nitrate consists of grayish white or grayish brown particles; the color differences come from the different origins of the raw materials added. The fertilizer is hygroscopic but not likely to cake. It can be dissolved in weakly alkaline water, with about 20 percent nitrogen. Owing to different combining ratios in manufacturing, nutrient content varies. This fertilizer is well adaptable to acid soils found in Hunan, Hupeh, Kiangsi, Chekiang and Fukien provinces. It can be widely accepted in these areas.

Ammonium calcium nitrate is applied just like ammonium sulfate and ammonium nitrate. The fertilizer can be used as basic fertilizer or as a follow-up fertilizer. Dry, fine soil can be mixed with the fertilizer for ditch or hill application. Alternatively, 30-50 times of water can be mixed for spraying applications. Soil moisture should be properly maintained after application by covering with soil. Thus, a certain water content can be kept to sufficiently dissolve the fertilizer in order to exploit its full fertilizing effect. Ammonium calcium nitrate is best combined with soil loosening and weeding, such as during the return-to-green period of winter wheat. Here first one digs ditches between two adjacent planting rows to apply the ammonium calcium nitrate. Then one loosens the soil and covers the ditches with soil to have a good fertilizing effect.

The amount of ammonium calcium nitrate applied should be generally 10 percent more than for ammonium nitrate.

Ammonium calcium nitrate cannot be mixed with calcium superphosphate, to avoid undercutting the calcium superphosphate fertilizing effect.

The ammonium calcium nitrate increases corn yield by 50 percent, paddy rice, by 21 percent, wheat, by 20 percent and cotton by 17 percent, if 15-45 chin of fertilizer is applied per mou.

9. Sodium nitrate: it is found as natural sodium nitrate and synthetic sodium nitrate. The former is mined in Chile, so it is also called Chile niter. Before ammonia was synthesized, Chile niter was the main nitrogen fertilizer, about 15 percent nitrogen. Its color may vary: light yellow, pink or brown, due to impurities. The fertilizer is in granular form. Synthetic sodium nitrate generally is a by-product of nitric acid manufacture; it is made by letting soda ash solution absorb the waste gas of nitric acid manufacture. This waste gas has nitrogen oxide and nitrogen dioxide not absorbed by the nitric acid. By this method, sodium nitrate is made to contain sodium nitrate, which can be oxidized by adding dilute nitric acid to the sodium nitrate. Synthetic sodium nitrate is 15-16 percent nitrogen and consists of grayish white particles with minute impurities. Sodium nitrate tastes bitter and astringent and dissolves easily in water. Sodium nitrate is a physiological alkaline chemical fertilizer. After applied to soil, the nitrate is converted and absorbed by the crop, the sodium remaining in the soil. It is alkaline in reaction. Sodium nitrate is highly hygroscopic and cakes easily. It is adaptable to acid soil. It is best mixed with farmyard manure if applied to alkaline soil. Alternate, sodium nitrate can be applied by coordination with calcium superphosphate or potassium sulfate.

Sodium nitrate can be used as basic fertilizer or follow-up fertilizer, but its fertilizing effect is better as follow-up fertilizer. It can be applied dry or wet. Dry, the fertilizer can be mixed with five to six parts fine, dry soil. Wet, it can be mixed with 40 to 50 parts water. The amount is 15-50 chin per mou, especially for root crops, like sugar beet and turnip, to promote starch formation. However, sodium nitrate is unsuited to saline alkali soil.

The fertilizing effect of 1.5 chin sodium nitrate is about equal to 1 chin ammonium sulfate. Application in clay loam should be limited to avoid soil deterioration.

Here are precautions when applying sodium nitrate:

(1) Sodium nitrate poisons farm animals, so they should be kept from mistakenly eating the fertilizer.

(2) Sodium nitrate is highly hygroscopic so it should be kept dry to avoiding caking. Lightly crush any caked fertilizer with a wooden hammer, just as in crushing sodium nitrate, to prevent explosions.

(3) Sodium nitrate is easily combustible and explosive, so fire prevention practices need to be watched in storage and transportation.

10. Calcium cyanamide: it is a nitrogen fertilizer used for quite a long time. Conversely to ammonium sulfate, calcium cyanamide is an alkaline fertilizer because it contains calcium beneficial to acid soils.

Pure calcium cyanamide appears as colorless crystals. However, its industrial product contains lime, carbon, calcium carbide and other impurities, so it consists of black or grayish black particles. Some calcium cyanamide is powdery. Its smell is like that of calcium carbide and slightly dissolved in water. Since calcium cyanamide is highly hygroscopic, it resembles slaked lime, after absorbing moisture. It will be caked after prolonged storage. Pure calcium cyanamide is 34.9 percent nitrogen but the common industrial product has impurities, with only an 18-20 percent nitrogen content.

Nitrogen content in calcium cyanamide can be hydrated with soil moisture and reacts with carbon dioxide in the atmosphere decomposing into cyanamides, which is then converted into urea, and finally to ammonium carbonate, to be absorbed by crops. In this conversion, cyanamides are toxic to man, animals and crops. However, in soils with vigorous microbial activity, cyanamides can be quickly converted and absorbed by crops. In alkaline or dry soil, or soil where microbial activity is weak, decomposition of calcium cyanamide is not complete, possibly halting as the dicyandiamide and persisting in soil. So calcium cyanamide cannot be applied in the above-mentioned soils in order not to poison crops.

Beside its nitrogen as a crop nutrient, calcium cyanamide can also eliminate weeds and pest insects. It can eliminate schistosomes in lowland fields and eggs of parasitic insects in vegetables. In cotton fields, treating with calcium cyanamide can defoliate cotton plants early to mature the bolls sooner, thus boosing cotton yields. When using cotton picking machinery, leaves should be shed first for convenience in collecting unginned cotton. Other fertilizers normally lack these side benefits.

Raw materials to make calcium cyanamide are limestone, coke and nitrogen. First, limestone and coke are fed into an electric furnace and made into calcium carbide. This is then ground into powder to be fed into a nitrading furnace*. First, switch on the electric current then admit nitrogen for nitrading. After cooling, grinding and packaging, the end product is ready. Calcium cyanamide is made differently from nitrogen fertilizer made with synthetic ammonia, but high-pressure equipment is not required. Production equipment is comparatively simple but power consumption is fairly high. Calcium cyanamide is a chemical fertilizer capable of wider use in areas that have abundant power, low power cost and availability of raw material, espicially where there is much hydroelectric power.

Since calcium cyanamide shows a slower fertilizing effect in soil and becomes toxic during its decomposition, it should be applied 10-15 days before sowing, when used as basic fertilizer. After application, the fertilizer should be plowed over deeply and the application should be done even earlier in the case of sandy soil. If the time when the basic fertilizer is applied is very close to sowing time, cyanamides during decomposition can often affect the sprouting of seeds or harming the growth of

Footnote*: Nitrading furnace is a unit of equipment for nitrading calcium carbide with nitrogen.

young seedlings. Of course, calcium cyanamide cannot be used as a seed dressing. In lowland fields, calcium cyanamide should be applied before seedling are transplanted, with about 1 ts'un of irrigation water kept in the field. The fertilizer can be sprayed or mixed with stable manure and compost for spraying application to be uniformly distributed and overturned into the soil. Then sowing can follow 10-15 days later. If calcium cyanamide is used as follow-up fertilizer, it should be uniformly mixed with 10 parts dry soil and barnyard manure to be piled and macerated 10-15 days. After the compost is ready, it is then ditch-applied to bury the manure in the soil. However, care should be taken that the piling time is not too long after the calcium cyanamide and compost are mixed. Otherwise, the nitrogen nutrient will be reduced.

The amount of calcium cyanamide applied is usually 20-40 chin per mou.

Here are precautions for applying calcium cyanamide:

(1) Calcium cyanamide is toxic to both man and animals, therefore mouth masks should be worn during application to avoid harming the respiratory organs. In addition, the operator should wear gloves and goggles. A short rod can be used to stir calcium cyanamide, dry soil and farmyard manure to avoid hand contact and later chemical burns. Ground areas piled with calcium cyanamide should be swept clean to keep animals from being poisoned by eating the fertilizer dust.

(2) Calcium cyanamide is highly hygroscopic. On contacting water, it cakes and swells. Caked calcium cyanamide should be crushed before application. When crushing, strokes should be light to avoid scattering dust. Tools should be washed clean after use. When mixed with much water, calcium cyanamide gives off heat and a bad odor. Thus, some of its fertility is lost. So it should be protected against moisture. If calcium cyanamide contacts water, it should not be dried out under the sun.

(3) Calcium cyanamide cannot be allowed to contact seeds and seedlings, to avoid chemical injury.

(4) It is best not to use calcium cyanamide in very arid area that cannot be irrigated.

(5) Calcium cyanamide should not be mixed with ammonium sulfate, ammonium nitrate or calcium superphosphate to be applied. Otherwise, the nitrogen nutrient in ammonium sulfate or ammonium nitrate will be lost, or the phosphorus content in calcium superphosphate be excessively reduced.

The yield-gain effect of calcium cyanamide is like that of ammonium sulfate. In acid soil, the fertilizing effect of calcium cyanamide is superior to that of ammonium sulfate. From work at Japanese agricultural experimental stations, sometimes the fertilizing effect on paddy rice is 5 percent higher than for ammonium sulfate. Though calcium cyanamide is not widely used in China, comparison experiments were made in Chekiang and Fukien provinces, with good fertilizing effect. From general experience, the fertilizing effect is better for lowland fields than upland fields, better in acid than in neutral soil, and better used as basic fertilizer than as follow-up fertilizer.

Section 2. Phosphorus Chemical Fertilizer

Phosphorus is not found in soils in large amounts, generally only 0.05-0.35 percent of total phosphorus /1_7. The percentage of available phosphorus /2_7 absorbable by crops is usually about 30 percent. So supplements should be applied.

Phosphorus has these functions:

(1) Phosphorus is a constituent of nucleoproteins; it can intensify plant cell division, for faster crop growth.

(2) Phosphorus aids the growth of crop roots and root hairs. The more numerous the root hairs, the more nutrients and moisture can be absorbed from the soil.

(3) Phosphorus helps ripen seeds and makes stalks stronger, for added disease resistance and better fruit quality.

If nitrogen fertilizer is properly applied with phosphorus fertilizer, crop yields will be much higher. So applying phosphorus fertilizer is essential. Here are some problems in applying phosphorus fertilizer:

1. Relationship between soil and the fertilizing effect of phosphorus fertilizer: the fertilizing effect is closely related to soil characteristics and soil fertility. For a few years after cultivation, when soil maturation is low, application of farmyard manure is not sufficient, soil fertility is low, or where are acid soils or alkaline soils, generally the effects of phosphorus fertilizer are good. The fertilizing effect is high when phosphorus fertilizer is used to treat phosphorus-deficient soils: laterite, white bentonite colloidal clay and South China's low-yield paddy fields. Applied to acid soils, phosphorus fertilizer should be coordinated with lime without mixing the two. In alkaline soils, phosphorus fertilizer application should be coordinated with farmyard manure.

2. Relationship between crop varieties and fertilizing effect of phosphorus fertilizer: different crops have different needs and assimilability for phosphorus content in phosphorus fertilizers. The best effect comes from applying phosphorus fertilizer to legumes and green-manure crops -- Astragalus

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Footnote /1_/: Total phosphorus includes assimilable and unassimilable phosphorus.
Footnote /2_7: Available phosphorus is phosphorus that can be assimilated by the soil.

sinicus, L., Tacoma grandiflora, Loisel and Hibiscus esculentus. Next in effectiveness are buckwheat and rape and less so in effectiveness -- paddy rice and wheat. The effect of applying phosphorus fertilizer is generally higher for winter or spring crops. Since there are different phosphorus fertilizer requirements by crops and the phosphorus content in seeds and straw of legumes and edible-oil crops are higher than for cereals, the fertilizing effects of phosphorus fertilizer differ for different crops.

3. Relationship between application method and fertilizing effect of phosphorus fertilizer: generally, the effective part of phosphorus fertilizer that can be utilized by crops is generally only 20-40 percent of amount applied that year. When part of a phosphorus fertilizer is precipitated by the soil, generally the fertilizing effect shows up one or more years later. In addition, by scattering, very little of the fertilizer can be utilized by the crop. The fertilizing effect is much higher if the furrow, ditch or hill application is used, because application in concentrated spots is more effective than scattering.

4. Relationship between individual and coordinated application of phosphorus and nitrogen fertilizers: coordinated application of phosphorus fertilizer and nitrogen fertilizer allows these two fertilizers to exploit more of their potential for higher yields than in individual application. From wheat field experiments in the Wu-kung area of Shensi Province, 8 chin nitrogen fertilizer per mou can increase the wheat yield by 190.5 chin and 8 chin phosphorus fertilizer per mou -- by 23.3 chin. If these two fertilizers are coordinated, by applying 8 chin each of nitrogen and phosphorus fertilizer, the wheat yield goes up by 229.5 chin, 15.7 chin more than the total of individual applications of the two fertilizers.

Phosphorus fertilizer on legumes can increase nitrogen nutrient. This is experience coming from phosphorus fertilizer use by Chinese peasants. Because root nodule bacteria can fix atmosphere nitrogen in the case of leguminous green-manure crops. This adds to nitrogen compounds in the soil for nutrients favoring the current harvest as well as the crop from the next planting. More phosphorus fertilizer can grow better green-manure crops. So phosphorus fertilizer used in the growing period of leguminous green-manure crops increases the soil nitrogen fertilizer for the current and next crops. This is the increase in nitrogen content coming from the application of phosphorus. From calculations on the nitrogen gain in leguminous green-manure crops treated with phosphorus fertilizer, each chin phosphorus can mean 1 more chin of nitrogen. As indicated in the fertilizing effect experiments on Tacoma grandiflora, Loisel, by the Szechwan Agricultural Research Institute, Kuan-hsien County, the yield was 1638 chin per mou without phosphorus applied but 2205 chin per mou, when 50 chin Ca-Mg-phosphate was used -- an increase of 567 chin Tacoma grandiflora, Loisel. The wheat yield was 338 chin per mou without phosphorus fertilizer in the preceding cultivation of green-manure crop. However, the wheat yield was 384 chin per mou with phosphorus fertilizer applied in the preceding green-manure crop cultivation -- a gain of 46 chin per mou. However, if this 50 chin Ca-Mg-phosphate is applied right in the wheat field, only a gain of 18 chin of wheat results. This explains why it is best to increase nitrogen by applying phosphorus.

By characteristics of phosphorus fertilizers, generally there are these three types:

1. Water-soluble phosphate fertilizer: the available phosphorus, phosphorus pentoxide, can be dissolved in water and a crop can directly absorb such nutrient. So the fertilizing effect is fast. Some of the water-soluble phosphate fertilizers are calcium superphosphate and concentrated superphosphate.

2. Citric-acid-soluble phosphate fertilizer: the available phosphorus of this phosphate fertilizer is insoluble in water, but dissolved in 2 percent citric acid or neutral and slightly alkaline solution of ammonium citrate. So a crop cannot absorb and utilize this fertilizer directly. The fertilizing effect of such phosphate fertilizer is better in acid than in alkaline soil, although the fertilizing is slow yet persistent. Some of this citric-acid-soluble phosphate fertilizers are Ca-Mg-phosphate, Thomas phosphate, defluorinated phosphate and precipitated phosphate.

3. Slightly soluble phosphate fertilizer: this phosphate fertilizer is insoluble in water and is only slightly dissolved in weak acid. After this fertilizer is spread in the soil, the fertilizing effect is even slower, indicating some yield gain as long as one or two years later. After one application, the fertilizing effect can persist several years. Some slightly soluble phosphate fertilizers are pulverized phosphate and bone meal, which are appropriately applied to soils that are more acidic.

Since the phosphate fertilizers have these characteristics of slow fertilizing effect except for a few types with faster effects, application to soils does not result in an immediate fertilizing effect. However, this fertilizer is still important to increase yields through familiarizing with its characteristics and optimal use.

Common Phosphate Fertilizers

1. Common calcium superphosphate: this is a phosphate fertilizer causing high gains when used heavily.

Calcium superphosphate is grayish white or light brown, in powder or particle form. The fertilizer is hygroscopic and its phosphorus content is soluble in water, displaying acid reaction.

Since there are different mineral raw materials in making this fertilizer, it is differently colored, but generally has the same phosphorus content as the main nutrient. Grade A calcium superphosphate contains 18 percent available phosphorus, less than 4.5 percent free acid*, and water content between 13.5 and 15 percent. Grade B product contains 16-18 percent available phosphorus and grade C contains 14-16 percent available phosphorus. In China, the end products are either grade A or grade B; there is no grade C in China. Calcium superphosphate also contains gypsum and other sulfates, such as ferric sulfate and aluminum sulfate.

Bone meal was the raw material in the beginning for making calcium superphosphate. Then phosphate rock was found to be a substitute for bone meal. Phosphate rock is first broken to a certain fineness and concentrated sulfuric acid is added to decompose the broken rock into calcium superphosphate. Calcium superphosphate requires large amounts of sulfuric acid; its output is decisively boosting calcium superphosphate output.

These characteristics of calcium superphosphate should be understood before applying it. These characteristics are:

First, calcium superphosphate dissolves easily in water and has a fast fertilizing effect. After soil treatments, the available phosphorus nutrient is dissolved in soil water.

Secondly, though calcium superphosphate is readily soluble, yet some of the fertilizer is often precipitated by iron and aluminum in the soil to deny full utilization by a crop. In acid soil, this precipitation is very serious and even tends to crust soil.

Thirdly, after phosphorus nutrient is precipitated, the nutrient moves sluggishly and stays at the application sites. If these sites are distant from the crop roots, the roots cannot absorb this nutrient. If the fertilizer application sites are too close to the sowed seeds, evaporation of free acid will hamper seed sprouting. So particular attention should be paid to the depth and distance from the crop plant when applying calcium superphosphate. Calcium superphosphate is most suitably applied to neutral and alkaline soils; application is also feasible for acid soils. This fertilizer can be used as basic, seed and follow-up fertilizer and can also be mixed with farmyard manure, like barnyard manure and compost. Application depth is about 3-5 ts'un. When used as seed dressing, calcium superphosphate can greatly promote the growth of crop radicles, causing vigorous life in the later period of plant life. Applications to cotton plants should be lighter. Once the fertilizer adheres to the fine hairs of a cotton seed, seed sprouting will be hampered. When used as follow-up fertilizer, ditch and furrow applications should be used; the application onto the topsoil is not allowed. Depth and distance from the crop plant should be paid particular attention during application to allow the fertilizer to be easily absorbed by crop roots.

Footnote*: Free acid -- when calcium superphosphate is made using sulfuric acid for the decomposition of phosphate rock, small quantities of phosphoric acid are produced and remain in the end product. Too much free phosphoric acid harms crops, so its content should be limited.

Calcium superphosphate can also serve as a follow-up fertilizer outside roots. Just like urea in nitrogen fertilizer, calcium superphosphate solution can be sprayed on leaf surfaces. Its concentration is 2 percent; in other words, 2 chin calcium superphosphate is mixed with 98 chin water. Stir the solution while mixing and let the solution stand overnight to fully dissolve the calcium superphosphate, then screen the solution before application. The solution should not be placed in an iron drum, so as to avoid chemical reaction affecting solution quality. Generally, spray this solution two or three times 7-10 days apart. The advantage of spraying on crop leaves is avoidance of precipitating calcium superphosphate by soil. However, this is only one way of fertilizer application and cannot completely replace application outside crop roots in the soil.

The quantities of calcium superphosphate used are determined by crop varieties. Generally, 30-50 chin or more of this fertilizer per mou can be applied to paddy rice. The amounts are smaller for other cereal crops. As a seed dressing, the amount is 5-10 chin per mou. Here the fertilizer is mixed with fine, dry soil immediately before application. First the fertilizer can be applied in a sowing ditch, then a thin layer of soil covers the application sites before sowing the seeds. Little mud should be used to mix the seeds of green-manure crop right before sowing.

Here are precautions for applying calcium superphosphate:

(1) Like acidic nitrogen fertilizer, calcium superphosphate should be coordinated with lime and farmyard manure in application to keep the soil from deteriorating. However, it is not allowed to mix lime with calcium superphosphate.

(2) Calcium superphosphate can increase the cold tolerance of winter wheat. Therefore, the fertilizer can be applied once before freezing as a follow-up fertilizer or it is used as the basic fertilizer when sowing winter wheat. These applications ensure good fertilizing power.

The yield-gain effect of applying 1 chin calcium superphosphate is 1-3 chin paddy rice, 1-3 chin wheat, about 1-3 chin cotton, 1.5-2.5 chin rape seed or 2-5 chin corn. The yield gain is very pronounced for green-manure crops: 30-100 chin lucerne per chin of calcium superphosphate.

2. Concentrated superphosphate: it contains much more phosphorus nutrient than does calcium superphosphate. Generally, the available phosphorus content is 45-52 percent, three times the content in calcium superphosphate. Gypsum and other impurities are low in content. Because of high available phosphorus content, the application, transportation and storage can save labor, expenses and cost. So concentrated superphosphate is more welcome than calcium superphosphate.

In making concentrated superphosphate, add phosphoric acid into the finely pulverized phosphate rock to decompose into the end product. Its shape and characteristics are similar to those of calcium superphosphate. The water solution of concentrated superphosphate is acidic reaction, so this is also a type of acid chemical fertilizer.

Application of concentrated superphosphate is also like that of calcium superphosphate. The fertilizer can be appropriately applied to a variety of soils and crops, used as basic, follow-up or seed fertilizer in ditch, hill or furrow application. Because the concentration of this fertilizer is high, the application amount should be reduced by two-thirds of the calcium superphosphate. In fertility, 30 chin calcium superphosphate equals 10-12 chin concentrated superphosphate.

The yield-gain effect of concentrated superphosphate is the same as that of calcium superphosphate at the equivalent amounts.

3. Ca-Mg-phosphate: this is a gray or dark green powder, odorless and tasteless. Ca-Mg-phosphate is a citric-acid-soluble phosphorus fertilizer and usually is insoluble in water, not hygroscopic and not caking. Ca-Mg-phosphate is alkaline in reaction.

In making Ca-Mg-phosphate, first phosphate rock, serpentine, dunite or dolomite with silica addition are melted at high temperatures. The end product can be obtained after cooling, breaking and pulverizing. There are three types of melting processes: blast furnace, electric furnace and open hearth. The production scale and the content requirements of the phosphate rock are flexible since no other chemicals are needed as raw materials. In many parts of China, remodeled small blast furnaces (used for iron smelting before) are used to produce Ca-Mg-phosphate to supply local demand. Packaging and transportation are also convenient. This is one phosphorus fertilizer type with rapid acceptance and good fertilizing power in China in recent years.

There are different phosphorus nutrient contents of Ca-Mg-phosphate due to the different raw materials and material compounding ratios. The phosphorus content is 14-18 percent and magnesium content is 12-13 percent.

Generally, Ca-Mg-phosphate is used as basic fertilizer although it can be also used as follow-up or seed fertilizer. The fertilizer can be applied to paddy rice, wheat, barley or legumes; however, the best fertilizing effect is in legumes and green-manure crops. Ca-Mg-phosphate is suitable to acid and slightly acid soils as well as to magnesium-deficient infertile sandy soils. The fertilizing effect in acid soils resembles or even exceeds calcium superphosphate. Ditch, hill or furrow application of the fertilizer is feasible. The amount applied is 30-50 chin per mou. If the fertilizer is mixed first with farmyard manure, the fertilizing effect is even better.

Ca-Mg-phosphate is widely applied in various areas of China, especially in southern provinces, such as Chekiang, Kiangsi, Yunnan, Kweichow, Hupeh, Hunan and Szechwan. The fertilizing effect is quite good according to application experiences in these areas. As indicated by studies on the fertilizing effect of Ca-Mg-phosphate in Kiangsi Province, the yield gain is 60-80 percent for Tacoma grandiflora, Loisel, 10-23 percent for paddy rice, 30 percent for cotton and over 60 percent for wheat. From paddy rice experiments at Chin-hua County of Chekiang Province, the fertilizing effect of Ca-Mg-phosphate is 110 percent of calcium superphosphate. From corn experiments at Kweiyang, Kweichow Province, the fertilizing effect is 108.6 percent of that of calcium superphosphate. These experiments show that Ca-Mg-phosphate is a good phosphorus fertilizer that can be vigorously propagated.

4. Thomas meal: this fertilizer gained its name because it was first manufactured in a Thomas steel-smelting furnace. The fertilizer is a steel smelting by-product. In an alkaline steel-smelting furnace, impurities like phosphorus, lime and calcium silicate become slag floating on liquid steel. This slag is then poured out and the end product is obtained after cooling, grinding, magnetic dressing and packaging. In the magnetic dressing process, steel particles are removed. Thomas meal is a desirable fertilizer type since it is a steel smelting by-product and the Chinese iron and steel industry has seen great growth.

Thomas meal resembles fly ash under a cooking pot. It is a blackish brown powder, about 16 percent phosphorus. Also, there are mostly lime content as well as amounts of magnesium, iron, silicon, sulfur, molybdenum, vanadium and cobalt. The specific gravity of the fertilizer is high. In some area, the peasants called it "iron crumbs", but actually the fertilizer contains little iron.

Thomas meal is an alkaline chemical fertilizer; this is a citric-acid-soluble phosphate fertilizer, suitably applied to acid soils. The fertilizing effect is slower than others; the fertilizer is usually applied as basic fertilizer, unsuited as follow-up or seed fertilizer. Before application, Thomas meal can be mixed and piled with barnyard manure for a better fertilizing effect. Thomas meal contains large amounts of lime and it can promote decomposition of compost and the organic acid content in the compost can promote phosphorus decomposition in the fertilizer to become a quick-release fertilizer. The fertilizer is appropriately applied to soybean, cotton, corn and paddy rice. When Thomas meal is used, the fertilizing effects are good in clayey, acid, lowland or irrigated soils but less so in sandy, alkaline and upland soils where irrigation is infeasible. For application in upland soils, the fertilizer should be plowed into deep soil. Dry application is acceptable, but not wet application. Spraying application is feasible. Usually, the amount of Thomas meal used is 30-60 chin per mou.

The yield-gain effect of Thomas meal is 3-23 percent for paddy rice, 10-100 percent for corn, 15 percent for sorghum, 24-46 percent for millet, 5-27 percent for soybean or 9 percent for cotton. In Manchuria, application in lowland fields led to a mean yield gain of about 10 percent and in upland fields, of about 5 percent. Thomas meal can have fertility persisting for several years. Moreover, the fertilizer can raise the oil content of soybean and sunflower seed, the starch content in paddy rice and sugar content in sugar beet.

5. Precipitated phosphate: it is a white or light yellow powder, insoluble in water. The precipitated phosphate is a citric-acid-soluble phosphorus fertilizer, not hygroscopic and not caking. In manufacture, hydrochloric acid, nitric acid or sulfuric acid (or the used acid in some plant) can be used to treat phosphate rock to first extract phosphoric acid. Then lime water and pulverized limestone or either of them are added to neutralize the solution. The end product is obtained after screening, washing, drying and grinding.

The phosphoric acid used to precipitate calcium phosphate is generally manufactured with hydrochloric acid because hydrochloric acid is comparatively low priced and also it is a by-product after electrolysis of table salt and processing chlorine*. In addition, hydrochloric acid is made quite simply. The end product by using nitric acid usually contains ammonium nitrate and precipitated phosphate.

The precipitated phosphate is generally used as basic fertilizers. The fertilizing effect of the precipitated phosphate is better than calcium superphosphate andthe fertilizer is not easily precipitated by soil iron and aluminum. The fertilizer contains much calcium, which can neutralize some of the soil acid as it dissolves. Thus soil acidity is reduced. In neutral soil, the fertilizing effect of precipitated phosphate is less than with calcium superphosphate.

The way of applying precipitated phosphate is like that of calcium superphosphate, usually 15-35 chin per mou.

Besides fertilizer, pure precipitated phosphate can be used as supplementary feed for domestic fowls or animals to supplement phosphorus and calcium nutrients.

The precipitated phosphate should not be mixed with alkaline fertilizers, such as calcium cyanamide, lime or pearl ash, otherwise the fertilizing effect will be reduced.

In the fertilizing effect of the precipitated phosphate, in acid soil 1 chin of this fertilizer is equivalent to 1.5-2 chin calcium superphosphate.

6. Defluorinated phosphate fertilizer: this is grayish white or grayish black in the form of particles or powder. The fertilizer does not dissolve readily in water. By different manufacture processes, the fertilizer can be divided into sintered and fusion defluorinated phosphate fertilizers, containing usually 20 percent available phosphorus and sometimes as much as 38 percent.

Footnote*: Table salt is mostly sodium chloride. Dissolve table salt in water to get a solution, which is then poured into an electrolysis bath. Switch on the electric current. The table salt solution is electrolyzed into caustic soda, chlorine and hydrogen. Chlorine and hydrogen are then led into a chamber to start the combustion reaction to get hydrogen chloride gas, which is dissolved in water to yield hydrochloric acid.

In manufacturing, first the phosphate rock is sintered with small amounts of silica or Glauber's salt and phosphoric acid (or low melting-point phosphate rock is used) at high temperatures. Then water vapor is admitted to remove fluorine in the phosphate rock and the mixture is mixed with water for sudden cooling. The end product of defluorinated phosphate is obtained after drying and grinding. Why does fluorine have to be removed? Because fluorine is not a crop nutrient and too high a content is harmful. The finer the ground defluorinated phosphate, the better the fertilizing power. Fertilizer containing less than 0.1 percent of fluorine can be used as supplementary feed for cattle.

The fertilizing power of defluorinated phosphate is like that of Ca-Mg-phosphate, but it is lower than for calcium superphosphate. However, if defluorinated phosphate is applied in acid soils, the fertilizing power is not less than calcium superphosphate. The fertilizer is generally used as basic fertilizer in the amount of about 15-40 chin per mou.

7. Pulverized phosphate rock: it is made by grinding monite rocks. Pulverized phosphate rock is brown in the form of dry soil passing through a fine sieve.

What is monite? The answer lies in the classification of phosphate rocks.

Natural phosphate rocks can be classed into two types:

(1) Apatite: this is a rock formed by condensed magma ejected through a gap in earth's crust. Geologically, this is called igneous rock in the form of light green or gray crystals. The main content is calcium fluophosphate or calcium chlorophosphate. The phosphorus pentoxide content is usually less than 15 percent; the level of impurities is high. This is a slightly soluble phosphorus fertilizer.

(2) Monite: it is in the form of fragmented or powdered rock; geologically, it is called sedimentary rock since it was deposited through hydraulic sedimentation onto the water bottom. Monite is light gray or brown in the form of amorphous powder. The main contents are the same as that of apatite but the phosphorus pentoxide content is higher, usually over 15 percent and as high as 38 percent. One part of the phosphorus content was decomposed by organic acid secreted by plants, so the phosphorus content is easily absorbed by plants and the impurity content is low.

The pulverized phosphate rock is suitably applied to acid soils, but not to neutral or alkaline soils. The powder can be used as a basic fertilizer, but not as a follow-up or seed fertilizer. The fertilizing power is high if the powder is mixed and piled with farmyard manure before its application. Usually, 100 chin barnyard manure, 4 chin pulverized phosphate rock and 5 chin slaked lime are mixed, piled and macerated. One week before sowing, the mixture is ditch applied and a thin layer of soil is covered over theappplication sites before sowing. Or, the powder can be uniformly spread to the soil before deep plowing. The fertilizing effect is quite long; sometimes it lasts as long as 2 or 3 years. Since the fertilizing power is slow but persistent, the amount used can be as high as 50-100 chin per mou, which is one to two or three times the amount of calcium superphosphate used.

The finer the pulverized phosphate rock, the easier the fertilizing power can be exploited. The fertilizing effects of pulverized phosphate rock differ for different crops: good effect for legumes, radish, buckwheat and rape seed, but lower effects in gramineae, such as barley, wheat and corn.

Section 3. Potassium Chemical Fertilizer

Potassium is another important element in fertilizers. Potassium is closely related to the formation of carbohydrates in crops and potassium exists in almost all organs and tissues of crop plants, especially abundant in young, tender parts of leaves and stalks. Potassium can promote starch and sugar accumulating in a crop, whose photosynthesis and respiration are normal with sufficient supply of potassium nutrient. The crop plant then will grow large, strong stalks and filled seeds with higher tolerance against cold and disease. When there is not enough potassium for grain crops, germination weakensand the internodal spacing shortens. When there is serious potassium deficiency, brown spots appear on drooping leaves, and the fruit ripening periods are not uniform. So potassium nutrient is essential to a crop.

Potassium is quite widespread in the natural environment. Granite has 4-6 percent potassium. The total potassium in the soil is high and if all the potassium nutrient were to be absorbed by crops, the supply could last for many years. However, 98-99 percent of soil potassium cannot be absorbed by crops. So artificial means are needed to supplement the potassium absorbable by crops from the soil. Then potassium fertilizer becomes necessary for better agricultural output.

The fertilizing effect is significant when potassium fertilizer is applied in potassium-deficient sandy soil, but insignificant in fertile soils. The fertilizing effect of potassium is good in hemp, tobacco, sweet potato and potato. From experiments in Chekiang Province on fertilizing effects in jute, jute peel can be thickened, the percentage of finished jute fiber after washing is increased, the stalks become tougher and the ultimate tension of the jute fiber is increased by 2-5.5 kg. After potassium fertilizer is applied to tobacco plants, the quality is much improved and the burning characteristics of tobacco leaves are desirable. After potassium fertilizer is applied to sugar cane or sugar beet, the sugar content can be raised by 2 percent and their root tuber is not likely to decay. After potassium fertilizer is applied to cotton plants, yellow-withering diseases can be prevented. For corn plants, stripe plague can be prevented.

The crop demand of potassium nutrients is greater during the young seedling period than the ripening period. In some crop plants, such as paddy rice and wheat, the consumption of potassium nutrient halts almost completely in the flowering period. However, in some other crops, potassium consumption is comparatively uniform throughout the growing period. So potassium fertilizer should be applied at the right times to suit different crops and different growth periods. Generally, the fertilizing effect is significant when potassium fertilizer is applied early.

The raw materials used in making potassium fertilizers are sylvite, alum stone, carnallite, brine and niter. Sylvite is a mixture of potassium chloride and sodium chloride; carnallite is a double salt of potassium chloride and magnesium chloride. The pulverized rock of these minerals can be used as a crude potassium fertilizer. Like pulverized phosphate rock, this is the simplest processable fertilizer. However, high amounts of impurities are in these minerals and some impurities harm the soil or crop growth. If processing and refinement of these minerals are done, the fertilizing power can be raised and impurities reduced.

Here are main types of potassium fertilizers.

1. Potassium chloride: this is one main kind of potassium fertilizer; it is a white, brown or yellow crystal like table salt. Potassium chloride is easily soluble in water, is hygroscopic and has a caking tendency. This is a water-soluble quick-release potassium fertilizer.

The raw material of potassium chloride is sylvite or carnallite. Sylvite is mainly about one-quarter potassium chloride and three-quarters sodium chloride, table salt. These two chemicals have different solubilities* in water, so they can be separated to yield potassium chloride. First, place sylvite in water and heat to get a saturated solution, which is then gradually cooled. On decrease in temperature and solubility, potassium chloride precipitates. However, sodium chloride does not vary much in solubility because of temperature differences, so the solution remains not precipitated. Then the potassium chloride crystals are separated from the solution to yield the end product, potassium chloride. Making potassium chloride from carnallite also relies on the principle of higher solubility of magnesium chloride than potassium chloride. Potassium chloride varies in purity because of different production methods. So-called pure potassium chloride contains more than 90 percent potassium (including potassium chloride). For potassium chloride used as a fertilizer, the potassium content is about 50 percent and the crude potassium salt contains 20-30 percent potassium. Potassiumchloride is a physiological acid fertilizer, containing chlorine and potassium. The crops absorb potassium and only chlorine radicals remain in the soil just like ammonium chloride in nitrogen fertilizer staying in the soil after application. The chlorine radical is disadvantageous to the growth of chlorine-avoiding crops (refer to text page 23 [translation page 20]). If these crops need potassium nutrients, potassium sulfate or other potassium fertilizers can be used as substitutes.

Footnote*: Solubility in water -- this is the maximum amount of a substance dissolved in water at a certain temperature and pressure.

Potassium chloride can be used as a basic fertilizer or as a follow-up fertilizer. The fertilizer may be mixed with farmyard manure when used as a basic fertilizer. Used as a follow-up fertilizer, potassium chloride can be mixed with five to six parts dry, fine soil for furrow or spraying application. Wet application is also feasible by mixing with 30 to 60 parts water. The amount of potassium chloride applied is 10-25 chin per mou.

When potassium chloride is used as a follow-up fertilizer, the growing period of a crop should be understood. For wheat plants, the follow-up application is a week before germination to one week before the tassel-sprouting period. For paddy rice, two follow-up applications are made in the period of transplanting and from the return-to-green to the tassel-sprouting period. The follow-up application in cotton plants can be made from the period after seedling transplanting to the incubation period of unopened flower buds. The application to hemp plants is the same as for cotton plants. For ramie plants, one additional application of potassium chloride can be conducted after each cutting.

Here are precautions when applying potassium chloride:

(1) The potassium chloride solution should not come into contact with seeds and tender leaves, to avoid chemical burns.

(2) No potassium chloride should be applied to some chlorine-avoiding crops, like tobacco, sugar beet and potato.

(3) In sandy soils, potassium chloride should be mixed with farmyard manure before application to prevent loss of nutrients.

(4) In acid soils, potassium chloride should be coordinated with lime in application. However, mixing of these two is not allowed.

(5) Potassium chloride is highly hygroscopic and moisture and storage waterproof measures are in order.

The yield-gain effect of potassium chloride is , from experimental results, 17 percent for corn, 11-17 percent for early or late ripening rice, 21 percent for cotton and about 30 percent for hemp.

2. Potassium sulfate: it is a white, grayish white or brown crystal as a water-soluble quick-release fertilizer. Potassium sulfate is soluble in water and is hygroscopic but is not likely to cake. If there is occasional caking, light rapping is all that is needed to scatter the fertilizer. Potassium sulfate contains 48-52 percent potassium nutrient.

The raw material of potassium sulfate is potassium chloride or alum stone. Potassium chloride and sulfuric acid can react to produce potassium sulfate. However, potassium chloride itself is a fertilizer, so generally this method is not used except in special situations. Alum stone is a mineral and contains potassium sulfate, aluminum sulfate and aluminum oxide. Through thermal decomposition, maceration, screening and evaporation, potassium sulfate is obtained. Also obtained is aluminum oxide, a raw material to be refined into metallic aluminum. Therefore using alum stone to make potassium sulfate is an approach to the comprehensive utilization of resources.

Potassium sulfate does not have a chlorine radical, so it can be applied to chlorine-avoiding crops. However, potassium sulfate contains a sulfate radical, a physiological acid fertilizer, like ammonium sulfate in nitrogen fertilizer. A crop absorbs potassium in potassium sulfate and the sulfate radical remains in the soil. As a consequence, prolonged use of potassium sulfate cakes soil. So this fertilizer should be alternated with lime.

Potassium sulfate can be a basic or a follow-up fertilizer, but better as a basic fertilizer. Generally, 8-15 chin potassium sulfate can be applied per mou, but use can be as high as 15-30 chin for tuber roots or tuber stem crops. If pearl ash is applied at the same time, potassium sulfate can be properly reduced in amount. Application in lowland fields should avoid too much irrigation water and drainage should be halted afterwards to prevent loss of fertilizing power. The fertilizer can be applied dry or wet. Dry, four to five times of moistened soil can be mixed. Wet, the concentration of potassium sulfate should be kept at about 5 percent, that is, mixing 95 chin water with 5 chin potassium sulfate.

Here are precautions for applying potassium sulfate:

(1) Potassium sulfate should not be applied near crop roots or on stems and leaves to prevent chemical burns to the plant.

(2) Potassium sulfate is a physiological acid fertilizer, so it is best applied to alkaline or neutral soils. If acid soils, lime should be applied alternately.

(3) Potassium sulfate is readily soluble in water, so the nutrient is liable to dissipate in running water. When the fertilizer is applied to sandy soils, it is best applied several times, or else mixed with farmyard manure before application.

The yield-gain effect in applying potassium sulfate is like that with potassium chloride but the amounts should be slightly more.

3. Potassium carbonate (pearl ash): peasants usually burn straw or firewood as fuel; the remaining ash is called pearl ash. The ash contains potassium carbonate and considerable impurities. The potassium nutrient amount is small, generally about 5 percent. This potassium fertilizer does not require manufacture and have extensive sources of supply. So pearl ash has long been used as a fertilizer. Industrially produced potassium carbonate has not yet been applied as a fertilizer.

Pearl ash differs from potassium sulfate or potassium chloride since the ash is an alkaline fertilizer. We often see that in rural villages clothes are laundered with the soaking water of pearl ash. This is because the ash contains alkali, which can remove dirt.

Pearl ash can be applied to most soils and especially, to laterite in South China. However, the ash is unsuitable in saline and alkaline soils. Pearl ash can be applied to all crops and best of all to chlorine-avoiding crops, such as tobacco, sugar cane, sugar beet and potato. If the ash is applied for a long time, the soil will not crust over as in the case of potassium sulfate. Pearl ash can be used as a basic or a follow-up fertilizer. Generally, the amount of the ash applied is 50-100 chin per mou and even more for crops requiring more potassium, such as sugar beet and potato. The fertilizing effect of 5-10 chin pearl ash equals 1 chin potassium sulfate.

Here are precautions for applying pearl ash:

(1) The pearl ash should not be mixed with ammonium sulfate or ammonium bicarbonate, since this mixing will cause nitrogen loss. In addition, ash should not be mixed with calcium superphosphate: mixing will impair crop ability in absorbing phosphorus nutrients.

(2) Potassium nutrient in the pearl ash is readily soluble in water, therefore the ash should not be wetted by rain to avoid loss of the fertilizing power.

Besides these potassium fertilizers, potassium-calcium composite fertilizer can be made through improvized methods, with orthoclase and limestone as raw materials and by mixing them and calcination to meet local demands.

Section 4. Composite Fertilizers and Mixed Fertilizers

The above-mentioned nitrogen fertilizers, phosphorus fertilizers, or potassium fertilizers contain only one nutrient. The composite fertilizer and mixed fertilizer contain more than two nutrients, so they are called multi-effect fertilizers. The composite fertilizer is usually made through chemical reactions and mixed fertilizer is made through mechanical means.

Here are the advantages of composite fertilizer and mixed fertilizer:

(1) A crop plant can obtain more than two kinds of nutrients through one fertilizer application.

(2) The undesirable characteristics of chemical fertilizer can be improved and disadvantages of some fertilizers in soil can be avoided.

(3) Since a type of fertilizer contains more than two nutrients, transportation and application labor can be reduced.

Therefore, composite fertilizer and mixed fertilizer have a good future. At present, there are up to a thousand brands of composite fertilizer and mixed fertilizer in the world. Here are the common types:

1. Ammonium phosphate: this is a composite fertilizer of light yellow particles. Ammonium phosphate contains nitrogen and phosphorus elements and the nutrients are water-soluble as a quick-release fertilizer. The fertilizer is slightly hygroscopic but it will not deteriorate after long-term storage.

The raw materials for making ammonium phosphate are phosphoric acid and ammonia, which is first added to phosphoric acid. Through the tablet-making and drying processes, the end product of ammonium phosphate is then obtained as tablets or powder. Since the minerals for making phosphoric acid are impure, ammonium phosphate also has impurities of ferric phosphate, aluminum phosphate, magnesium phosphate and fluosilicic acid.

There are different nutrient contents in ammonium phosphate because of different components in phosphate rock and manufacturing methods. Generally speaking, total nutrient content is 55-70 percent with a 1:2.5-5 ratio between nitrogen and phosphorus (calculated on a basis of phosphorus pentoxide). For example, the total nutrient content in monoammonium phosphate is 64 percent, including 12 percent nitrogen and 52 percent phosphorus pentoxide. The nutrient content of 1 chin ammonium phosphate equals 2 chin calcium superphosphate and 0.6 chin ammonium sulfate. Another example: the total nutrient content of diammonium phosphate is also 64 percent, including 18 percent nitrogen and 46 percent phosphorus pentoxide.

Ammonium phosphate can be used as basic, follow-up or seed fertilizer. The amount of the fertilizer used should be determined by soil fertility, crop variety and cultivation method. Generally, 20-30 chin ammonium phosphate is applied per mou. The application method is similar to that of calcium superphosphate and ammonium sulfate.

Here are precautions in applying ammonium phosphate:

(1) Ammonium phosphate is easily soluble in water, so wetting by rain should be prevented during transportation and storage.

(2) Ammonium phosphate should not be mixed with other alkaline fertilizers, such as lime, to prevent loss of nitrogen nutrient.

(3) Ammonium phosphate has more phosphorus nutrient than nitrogen nutrient, so usually nitrogen fertilizer should be added when applying ammonium phosphate.

The yield-gain effect of ammonium phosphate is higher if applied to nitrogen- and phosphorus-deficient soils. Usually, ammonium phosphate can mean an 8-20 percent above that of calcium superphosphate besides a steady fertilizing power. With this fertilizer, 30 percent of paddy rice, 18 percent of wheat, 14-26 percent of cotton or 20-28 percent of sugar beet can be increased in their respective yields.

2. Potassium nitrate: in rural areas, niter is mixed with pearl ash and added to water. After screening, cooking the mixture solution within a pot and letting it crystallize, the end product is potassium nitrate. This is one of the composite fertilizers containing nitrogen and potassium nutrients. In the industrial manufacture of potassium nitrate, first potassium chloride reacts with nitric acid to yield a potassium nitrate solution, which is then evaporated, crystallized and dried to obtain the end product.

Potassium nitrate is a grayish white crystal, containing 14-20 percent nitrogen and 36-45 percent potassium (calculated in terms of potassium oxide). Potassium nitrate is not easily hygroscopic, but readily soluble in water. The fertilizer is easily absorbed by crops, as being a quick-release fertilizer. Upon heating, potassium nitrate will burn with bright flame and smoke. Therefore, potassium nitrate can be used as a raw material in the manufacture of dynamite or firecrackers. Usually, the price of potassium nitrate is high, so it is seldom used as a fertilizer.

Potassium nitrate is most suitable as a follow-up fertilizer in dry or wet application. Dry, eight to ten parts fine,dry soil is mixed with the fertilizer for scattering or furrow application. However, the application should not be conducted after a rain or in the presence of dew, otherwise leaves or stems will be burned if the fertilizer particles adhere to these parts of the crop plant. Wet, 80-100 parts water can be mixed with the fertilizer for spraying application or applying to the leaf surfaces.

Since potassium nitrate contains nitrogen and potassium nutrients and usually a crop requires more nitrogen fertilizer than potassium fertilizer, the potassium fertilizer will become a surplus and a waste if the amount is based on the requirement of nitrogen fertilizer. So the amount should rest on the requirement of potassium fertilizer and any deficiency of nitrogen nutrient can be supplemented by a different nitrogen fertilizer. Usually, 20-40 chin potassium nitrate is applied per mou.

The fertilizing effect of 1.5 chin potassium nitrate is about equal to a total of 1 chin ammonium sulfate and 1 chin potassium chloride.

Here are precautions in potassium nitrate use:

(1) Potassium nitrate is best mixed with farmyard manure, like barnyard manure and compost, to avoid loss of nutrients.

(2) Potassium nitrate should not be stored with flammables, like gasoline, diesel oil and coal, and its storage should not expose directly under the sun to avoid fire risks.

(3) Potassium nitrate is best applied to upland fields with abundant irrigation or rain because its fertilizing effect is lower when applied to lowland field.

3. Ammonium calcium superphosphate: like calcium superphosphate, ammonium calcium superphosphate is a water-soluble quick-release composite fertilizer. The fertilizer is manufactured by ammonia reaction with free acid in calcium superphosphate. Thus, the disadvantage of calcium superphosphate due to its free acid content, which corrodes packaging material and harms crop growth, can be overcome. In addition, nitrogen nutrient is added. So ammonium calcium superphosphate is an improved version of calcium superphosphate. Ammonium calcium superphosphate has 16-18 percent phosphorus and 2-3 percent nitrogen. The application technique and amount are similar to calcium superphosphate.

4. Potassium-nitrogen mixed fertilizer: this is a mixed fertilizer of nitrogen and potassium nutrients. In manufacturing, alum stone is heated and added to aqua ammonia for precipitation and removal of aluminum. Then the end product results from evaporation and crystallization. This is a white powder, water soluble. Potassium-nitrogen mixed fertilizer contains approximately 69 percent ammonium sulfate, with a converted nitrogen content of 13-14 percent and approximately 31 percent potassium sulfate, with a converted potassium content of 15-16 percent. The fertilizer does not easily cake or absorb water and has a fertilizing effect in all soils and crops, especially crops requiring potassium, like tubers, tobacco and hemp. The application method is the same as with ammonium sulfate, with an amount of 15-30 chin per mou.

The characteristics of potassium-nitrogen mixed fertilizer are like those of ammonium sulfate, to be applied to acid soils. Lime should be coordinated, but not mixed, in application to prevent soil caking.

For the fertilizing effect of potassium-nitrogen mixed fertilizer, 2 chin of mixed fertilizer equals 1.2 chin ammonium sulfate as to nitrogen nutrient; 2.5 chin of mixed fertilizer equals 1 chin potassium sulfate as to potassium nutrient.

Besides these composite fertilizers and mixed fertilizer, we can turn to the nutritional requirements of crops when compounding mixed fertilizers by different nitrogen, phosphorus and potassium content. Section 7 "Mixed Application of Fertilizers" of this chapter will recommend feasibilities of mixing fertilizer types.

Section 5 Trace Element Fertilizers

As described above, three main types of fertilizers have been enumerated: nitrogen, phosphorus and potassium fertilizers. These are fertilizers in heavy demand through artificial means. Besides nitrogen, phosphorus and potassium, there are dozens of different chemical elements essential to roots, stems, leaves and fruits of a crop plant from analyses and studies of scientific observations. Although the amount of some elements are in the micro-range, they are necessary to crop growth and maturation. Like the human body, besides needing large amounts of fat, protein and carbohydrates, some trace amounts of elements are essential; otherwise, nutrient-deficiency diseases will appear. Iodine-deficient leads to goiter and calcium-deficiency leads to osteomalacia. Crops require minute amounts of elements that although there are some amounts in the soil yet they may not be available to crops. Take boron as an example: only 3-10 percent of the total boron in soil can be absorbed by crops. So these elements should be artificially supplemented and we call them trace element fertilizers because of minute amounts required. The term "trace" does not mean minute amounts in the natural environment but mean very minute amounts required by crops.

Generally, trace element fertilizers are those containing boron, copper, manganese, molybdenum and zinc. The need for these elements are only several parts per 10,000 or even per 100,000; however, they have effects on crop yield and quality. If there are no trace elements in the soil, a crop will be plagued by various diseases and be stunted. If legumes are planted in boron-deficient soil, root tubercle formation will be affected. If copper is deficient, tobacco leaves will wither. If molybdenum nutrient is deficient, yellow spots will appear on leaf margins of the borecole plant and the plant may not curl and become withering. Plant metabolism and soil microbial activity and reproduction are closely linked to trace elements.

The trace element fertilizers are best mixed with nitrogen, phosphorus and potassium fertilizers as well as farmyard manure in application. Separate application of trace element fertilizers is of course allowed; however, this application tends to lead to waste because of the minute amounts needed.

Trace element fertilizers can also be used to soak (in the case of a solution) or be mixed with seeds to prevent seed diseases, to promote healthy germination and to cause vigorous growth. Generally, the seed soaking time is 24 hours but a longer soaking time is required if the crop has seeds with tough hulls. The trace element fertilizer should be finely ground when mixed with seeds. It is best mixed uniformly with dry, fine soil or powdered talc before application.

Here are principal trace element fertilizers:

1. Boron fertilizer: boron is also an essential element in crop growth and maturation. Boron can promote metabolism and boost resistance to crop diseases. In legumes, boron can promote nitrogen fixation in the atmosphere. A boron-deficient crop will be easily affected by disease and their fertilization and fruition are hampered. However, excess boron is harmful to crops, even poisoning them. Generally, 0.1-1 chin boron nutrient is applied per mou. Usually, boric acid and borax are used as boron fertilizer; these are white crystal powder, easily soluble in water. Boric acid contains 17.5 percent boron and borax contains 11.3 percent. A by-product, boron-magnesium fertilizer, when making borax, can also be applied in soil. This fertilizer is 1.37 percent boron; the other contents are calcium and magnesium, which also have a fertilizing power in crops.

2. Manganese fertilizer: the main functions of manganese are to promote germination of seeds and growing of young seedlings. In addition, manganese can increase photosynthesis and promote metabolism. Manganese deficiency hampers crop growth and causes diseases. The manganese content in soil is approximately 0.1 percent, which is higher than that of boron. However, in soils to which large amounts of lime are applied or in calcareous soil, frequently manganese cannot be absorbed by crops. Therefore, more manganese fertilizer is necessary here.

Common manganese fertilizers are manganese sulfate and manganese ore slag. Manganese sulfate consists of pink crystals, readily soluble in water. It is 24.6 percent manganese.

Manganese ore slag has 12-22 percent manganese and is insoluble in water. During application, the amount of manganese sulfate should be small, usually 2-5 chin per mou. The amount of manganese ore slag is 20-40 chin per mou since its water-soluble manganese content is low.

3. Copper fertilizer: the main function of copper is promoting crop respiration for more germination and good tassel growth. Copper can also raise crop cold-hardiness. Copper's functions are quite pronounced in cereal crops and legumes. In a copper deficiency, leaves wither, tassels do not sprout and the crop yield suffers.

Commonly, copper sulfate or copper ore slag is used as the copper fertilizer. Copper sulfate consists of blue crystal, is easily soluble in water and has 25-26 percent copper. Copper ore slag is a by-product of copper refining and contains less copper than does copper sulfate. During fertilizer application, generally 2-4 chin copper sulfate per mou is enough but the amount of copper ore slag should be properly increased.

4. Zinc fertilizer: zinc's main function is promoting crop respiration and growth. If there is a zinc deficiency, grayish green spots will appear on the leaves of the wheat plant.

Usually, ammonium molybdate is used as a molybdenum fertilizer: it consists of white crystals. The fertilizer contains 50 percent molybdenum and 6 percent nitrogen and can be used as a follow-up fertilizer or a seed fertilizer.

All theabove-mentioned trace element fertilizers are best used as a follow-up fertilizer outside roots. Alternatively, the fertilizers can be used to mix and soak with seeds. Boric acid can be compounded into a solution of boric acid, 0.1-0.15 percent in concentration. Manganese sulfate and copper sulfate can be compounded into a 0.1 percent water solution; zinc sulfate can be compounded into a 0.05-0.15 percent water solution for spraying application on leaf surfaces. The amount used is 50-100 chin per mou for a total of two to four times of application.

The amount of trace element fertilizer used should be appropriate and if in excess, waste and sometimes even toxicity will result.

If the trace element compounds are melted with glass powder and after the precipitation the mixture is ground, the so-called glass fertilizer is obtained. This kind of fertilizer has many advantages:

First, the trace element content is lowered, so excessive amounts of this fertilizer are not likely to be applied.

Secondly, the acid secreted by crop roots can slowly dissolve the glass fertilizer for persistent fertilizing effect.

Thirdly, fertilizer can be applied evenly to distribute the trace element uniformly into the soil.

Fourthly, after trace elements are fused with glass, the mixture exists in the soil as the silicate, not leachable by rainwater.

Section 6 Other Mineral Fertilizers

Raw materials for these chemical fertilizers are natural minerals, which are processed chemically into the end products. Some other minerals can be used by simple treatment; these are the indirect fertilizers. They were long used widely in China's rural areas. Some of these fertilizers furnish certain nutrients and some improve the crop growth environment. There are many varieties with local materials and traditional usage. Here are common varieties:

1. Lime: lime is widely applied in rural areas of South China. Its main function is to improve soil characteristics to provide advantageous crop growing conditions. Therefore lime is regarded as an indirect fertilizer. Here are some functions served by lime:

(1) Lime can adjust soil acidity or alkalinity. In acid soils, especially after physiological acid chemical fertilizer is applied, soil acidity is too high, hampering the growth of crop roots. Lime is alkaline and its application to the soil can neutralize or reduce acidity.

(2) Lime can promote microbial activity in soil as the lime adjusts soil acidity or alkalinity and loosens the soil into lumps, providing microbes with a good environment. Thus, some soil nutrients not absorbable by a crop can be converted into absorbable nutrients.

(3) In addition to neutralizing soil acidity, lime can eliminate insects and weeds. There are three types of lime used as fertilizer: quicklime, slaked lime and limestone.

Quicklime is called calcium oxide chemically and is made by heating limestone. Quicklime is white or grayish white blocks or powder, highly hygroscopic. Heat is liberated when water is added to quicklime to obtain slaked lime.

Slaked lime is calcium hydroxide; it is made by adding water to quicklime to get a white powder. Slaked lime is also an alkaline fertilizer.

Limestone is a mineral containing calcium carbonate. Limestone reserves are large and its distribution is extensive. This is the raw material for making quicklime. Finely ground limestone powder can also serve as a fertilizer. The finer it is ground, the better is its fertilizing effect. Powdered limestone is not readily soluble in water so its effect is slow but persistent. In addition, oyster shells or clam shells can also be finely ground to be used as fertilizers because their calcium carbonate content is more than 90 percent.

Here are precautions for applying lime:

(1) Lime should mainly be applied to acid and never alkaline soils.

(2) Ordinarily, lime is used as a basic fertilizer. The best application time is 10 days before sowing. Application should be even and sometimes a plow is used to rake the soil evenly after application.

(3) Lime should not be applied each year and the amount used not too high; otherwise, the microbes generated will decompose too much organic matter, leading to infertile soil. This is called "exhaustion" of fertility and is contrary to soil conservation.

2. Gypsum: it is called calcium sulfate. Gypsum's main function is improving soil characteristics and structure and supplying calcium and sulfur to the crop. In South China, gypsum has long been applied to paddy field.

There are three types of gypsum in agriculture: common gypsum, snow white gypsum and phosphorus-containing gypsum. Natural gypsum ore is crystalline, ground finely to yield the common gypsum. It is white or grayish white, slightly soluble in water. By heating and calcining the common gypsum, water of crystallization is removed to yield snow white gypsum, a white powder. Phosphorus-containing gypsum is a residue after decomposing phosphate rock by sulfuric acid for making phosphoric acid. Phosphorus-containing gypsum can also be applied as a fertilizer but experiments must precede application and acceptance.

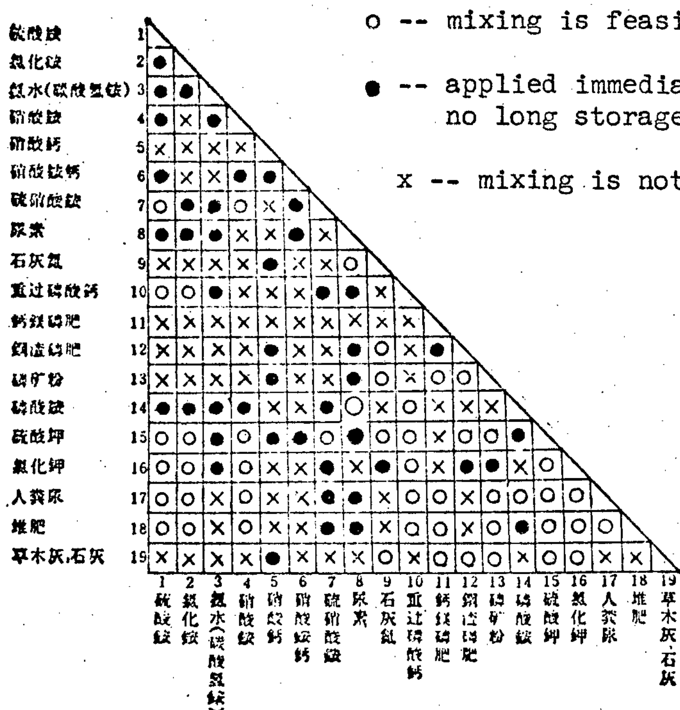
If gypsum is used to provide calcium and sulfur nutrients to soils and crops, the amount used should not be too high, usually 4-6 chin per mou. If gypsum is used to improve soil, the amount used should be as high as 200 chin per mou, depending on soil characteristics. Gypsum need not be applied every year.

3. Copperas: it is called ferrous sulfate -- a green crystal. Copperas is a by-product when iron pyrite is used to refine sulfur; it contains iron and sulfur. Iron can promote the formation of chlorophyll and crop growth and sulfur is a protein component. So these two are elements necessary to crop growth. Copperas is customarily applied in areas like Shansi, Chekiang and Hunan with good effects.

Section 7 Mixed Application of Fertilizers

There are great advantages for mixed application of fertilizers: first, the crop can obtain multiple nutrients in proper ratios at the same time. Secondly, the fertilizer applied can be fully exploited. Thirdly, labor can be saved in fertilizer application. Chemical fertilizer can be mixed with farmyard manure and other chemical fertilizers. However, not all fertilizers can be mixed before application. After some fertilizers are mixed, some fertilizing effect will be lost. For example, after mixing ammonium sulfate and calcium cyanamide, ammonium sulfate will decompose and get lost to the environment. Although some fertilizers can be mixed, the mixture should still not be stored for long; mixing should come right before application, such as aqua ammonia and potassium sulfate. Fertilizer characteristics determine the feasibility of mixing. All nitrogen fertilizers with ammonium, such as ammonium sulfate, ammonium nitrate or ammonium chloride, cannot be mixed with alkaline fertilizers, like pearl ash, calcium cyanamide or lime. This is because by mixing nitrogen fertilizer (such as ammonium sulfate) with an alkaline material, the ammonium will decompose into ammonia gas, escaping into the environment and the nitrogen nutrient is then lost. Likewise, human feces and urine should not be mixed with lime for application.

Figure 3 shows a graphic solution for checking which fertilizers can be mixed.



o -- mixing is feasible anytime.

● -- applied immediately after mixing, no long storage.

x -- mixing is not feasible.

Figure 3. Graphic Solution for Mixing Application of Fertilizers

[Key on following page]

[Key of Figure 3 on preceding page]

1. Ammonium sulfate
2. Ammonium chloride
3. Aqua ammonia (ammonium bicarbonate)
4. Ammonium nitrate
5. Calcium nitrate
6. Ammonium calcium nitrate
7. Ammonium sulfonitrate
8. Urea
9. Calcium cyanamide
10. Concentrated superphosphate
11. Ca-Mg-phosphate
12. Thomas meal (Thomas phosphate)
13. Pulverized phosphate rock
14. Ammonium phosphate
15. Potassium sulfate
16. Potassium chloride
17. Human feces and urine
18. Compost
19. Pearl ash, lime

Figure 3 shows a method of checking feasibility fertilizer mixing, for example:

(Example 1): Can ammonium nitrate be mixed with potassium chloride?

Answer: At the bottom of the table in Figure 3, (4) indicates ammonium nitrate. At the left of the table, (16) indicates potassium chloride. The symbol at the intersection is o, which means mixing is feasible.

(Example 2): Can ammonium phosphate be mixed with calcium cyanamide?

Answer: At the bottom of the table, (9) indicates calcium cyanamide. At the left, (14) indicates ammonium phosphate. The symbol at the intersection is x, which means mixing is not feasible.

(Example 3): Can urea be mixed with potassium sulfate?

Answer: At the bottom, (8) indicates urea. At the left, (15) indicates potassium sulfate. The symbol at the intersection is ●, which means mixing should be made immediately before application.

(Example 4): Can the three fertilizers, ammonium chloride, potassium sulfate and pearl ash, be mixed?

Answer: At the bottom, (2) indicates ammonium chloride. At the left, (15) indicates potassium sulfate. The symbol at the intersection of the two is o. In addition, at the left, (19) indicates pearl ash and the symbol at intersection between left (19) and bottom (2) is x. Moreover, the symbol at the intersection between left (19) and bottom (15) is o. These symbols mean that ammonium chloride can be mixed with potassium sulfate and potassium sulfate can be mixed with pearl ash. However, ammonium chloride cannot be mixed with pearl ash. Therefore, these three fertilizers cannot be mixed together. This means that in case of mixing three or more fertilizers, only two of them cannot be mixed together so all three cannot be mixed. Similarly, if two of them can be mixed only immediately before application, then all fertilizers can be mixed only immediately before application. Storage for some time is not allowed.

Chapter 4. Packaging, Transportation and Storage of Chemical Fertilizers

Chemical fertilizers are industrial products, so the output is high because continuous production is feasible. Frequently, chemical fertilizer produced in a plant can meet the demands of several communes or even several counties. However, agricultural demand is seasonal. Therefore, packaging, transportation and storage are required. Since there are solid or liquid chemical fertilizers and different types have different characteristics, inappropriate treatment will lead to loss of fertilizing power, to waste, or even to major incidents. Thus, there are problems in packaging, transportation and storage.

When the characteristics and application methods of various chemical fertilizers are described, some precautions on packaging, transportation and storage have been enumerated. However, the descriptions are not conducted systematically. Here are comprehensive descriptions of these problems.

Section 1 Protection Against Moisture and Water

Most chemical fertilizers are hygroscopic. Fertilizers like ammonium nitrate, ammonium sulfate and potassium chloride cake after absorbing moisture. So these fertilizers should be broken up before application. Many chemical fertilizers are soluble in rainwater, like urea, calcium superphosphate and potassium sulfate. The nutrients will be lost once wetted in a shower. Chemical fertilizers like ammonium bicarbonate decompose readily after absorbing moisture.

To protect the fertilizer from moisture and water, gunny bags are used to pack ammonium sulfate and calcium superphosphate; four to five layers kraft paper bags with asphalt interlayers are used to pack ammonium nitrate; plastic bags are used for ammonium bicarbonate; and iron drums, for calcium cyanamide. If the packing bag is broken, the bag should be mended or discarded.

Dryness is essential during transportation and storage. The bag should not be placed in moist place and protection should be provided against wetting by rain. A cover should be provided during transportation and waterproofing should be maintained during the rainy season. When wooden boats transport the fertilizer, overloading is strictly forbidden and waterproofing is vital.

Storage warehouses should be well ventilated and leaking roofs repaired on time; these warehouses should have an elevated foundation and drainage ditches for removing rainwater. Chemical fertilizers should not be stored on a muddy floor; they should be raised on brick or wooden supports. Some bulk chemical fertilizer, such as pulverized phosphate rock and Thomas meal, can be placed outdoors but protection against rain should be provided.

Section 2 Prevention of Decomposition and Evaporation

Generally speaking, phosphorus fertilizer, potassium fertilizer, trace element fertilizer and some nitrogen fertilizer are comparatively stable, such as Ca-Mg-phosphate, potassium sulfate and urea. However, some other nitrogen fertilizers, like ammonium bicarbonate, will decompose at normal temperatures; the higher the temperature and the higher the water content, the faster the decomposition. Other nitrogen fertilizers, like aqua ammonia, will evaporate at normal temperatures; the higher the temperature, the faster the evaporation. Packages should be well sealed for less stable chemical fertilizers -- plastic bags or multilayer kraft paper bags should be used. When an irritating ammonia odor is detected, this means the decomposition of fertilizer is underway due to bag leaking. The bag should be mended or some other container should be used. Aqua ammonia should be contained in a well-sealed drum, jug or jar. Clay or gypsum should be used as a filler to seal the cover.

Ambient temperatures should not be too high during transportation and storage. Direct exposure to sunlight should be avoided during transportation. Store the fertilizer in the shade. If aqua ammonia is stored outdoor without shading, containers will be ruptured through explosion due to thermal expansion.

Section 3 Prevention of Fire and Explosion

Ammonium nitrate and potassium nitrate tend to explode, causing great losses. Therefore, strict attention should be paid during transportation and storage. No smoking should be a strict rule in the vehicle or boat and warehouse. Direct sun exposure and violent collision should be avoided. During storage, the fertilizers should not be placed close to flammables, such as gasoline, diesel oil, kerosene, alcohol, sulfur, firewood and oil paper. Fire-fighting equipment should be kept in the warehouse. The residual ammonium nitrate and potassium nitrate should be well stored and attention should be given not to keep them near heat sources.

Section 4 Corrosion Prevention

Liquid fertilizers, like aqua ammonia, are corrosive, especially so to iron and copper. So corrosionproof containers are required for these corrosive fertilizers. Iron or copper containers should not be used for aqua ammonia;

if an iron drum has to be used, its inner side should be coated with unboiled varnish, red lead, asphalt or other corrosionproof paints. Wooden drums cannot long withstand corrosion by aqua ammonia, so corrosion-proof paints should be applied to the inner surface. Earthenware jugs are corrosionproof, so they can be used as containers for aqua ammonia. Leakage should be checked by pouring in water.

Section 5 Toxicity Prevention

Calcium cyanamide is a toxic fertilizer, so paper bags or iron drums containing the fertilizer should be protected from accidental tearing during transportation or storage. The operator should wear a mouth mask and gloves during packaging and transportation. Afterwards, the hands should be washed, especially before meals.

Chapter 5. Simple Distinguishing Methods of Chemical Fertilizers

From this description it is understood that chemical fertilizers have different characteristics and methods of use. We should rely on their characteristics to rationally store and utilize these fertilizers to exploit their full fertilizing power and avoid crop loss and harm. If urea is mistaken for ammonium sulfate, the fertilizer amount used may be too much, thus wasting urea. If ammonium bicarbonate is mistaken for ammonium chloride and not well sealed, the fertilizer will decompose and escape into the environment. If ammonium chloride is mistaken for ammonium sulfate and applied to a tobacco field, the yield will be lowered. Therefore, the fertilizer should be correctly recognized before application.

Usually, the name brand is marked on the bags of solid fertilizer. However, in case of marking damage or mixup of containers, the fertilizer in question should be correctly recognized. The best way to determine a chemical fertilizer is chemical analysis. Chemical laboratories are quite widespread in most areas and analysis of samples can determine the correct name brand. However, in localities without well-equipped laboratories simple methods should be used with local materials to determine the fertilizer. Here are suggestion for several ways of recognizing chemical fertilizers without using any chemical test equipment.

Section 1 Determination From Appearance

Exterior appearance, color and odor of an unknown fertilizer are guides for determination. For example, calcium cyanamide is a black or grayish black powder with a carbide odor. Thomas meal is an odorless blackish brown powder. Ammonium bicarbonate is a white crystal with an irritating ammonia odor.

Section 2 Water Solubility

If the name brand of a fertilizer cannot be ascertained from its appearance, water solubility can be used. A glass cup or a porcelain bowl is filled to the brim with cooling boiled water. A teaspoon of fertilizer sample is slowly poured into the cup and a pair of chopsticks are used to stir the solution. The solution condition is then observed.

1. Ammonium sulfate, ammonium nitrate, ammonium chloride, urea, sodium nitrate, potassium chloride, potassium sulfate, ammonium phosphate and potassium nitrate can be completely dissolved in water.

2. Ammonium calcium nitrate, common calcium superphosphate and concentrated superphosphate are partially dissolved and partially precipitated.

3. Ca-Mg-phosphate, precipitated phosphate, Thomas meal, defluorinated phosphate and pulverized phosphate rock mostly settle out and show little dissolution.

4. Calcium cyanamide is only slightly soluble in water with gas bubbles. Its odor resembles carbide.

Section 3 Mixing With Lime Addition

Take a sample to be mixed with lime or other alkaline substance, like caustic soda. If an ammonia odor is detected, the sample then can be held to be a nitrogen fertilizer, a composite or mixed fertilizer containing nitrogen.

Section 4 Heating and Combustion

If the determination still cannot be made in these ways, heat or place the sample in a fire to observe its melting, smoke color and smoke odor. The sample can be placed over a thin iron sheet heated by a coal or charcoal stove.

1. If the sample does not melt on the iron sheet after heating and the sample does not catch fire when placed in contact with redhot charcoal, but an irritating ammonia odor is released, this sample is ammonium sulfate.

2. If the sample does not melt on hot iron sheet and white smoke is released when the sample is thrown onto redhot charcoal, this sample is ammonium chloride.

3. If the sample releases white smoke when it is thrown on redhot charcoal, but no ammonia odor is detected, this sample is potassium nitrate.

4. If the sample melts quickly and white smoke released once it is thrown onto redhot charcoal, this sample is ammonium nitrate.

In the above experiments, special attention should be given to see that very little sample is used because potassium nitrate and ammonium nitrate will explode over fire.

5. Place the sample to be heated over a thin iron sheet. If it melts quickly and is illuminating and catches fire when thrown on redhot charcoal and an ammonia odor is released, this sample is urea.

These methods can be alternated or repeated for rapid determination. For example, for a certain chemical fertilizer one can first use the water solubility method and if one part is soluble and the rest precipitates, the sample can then be mixed with lime. If an ammonia odor is released, the sample is ammonium calcium nitrate. If the sample tastes sour and astringent, it is calcium superphosphate. If the sample is insoluble and all of it precipitates, then by observation of its appearance one can determine that it is Ca-Mg-phosphate, precipitated phosphate or defluorinated phosphate fertilizer.

This is the simple way of distinguishing chemical fertilizers. This is only for distinguishing fertilizer types. If nutrient content is in question, then quantitative analysis should be done in a chemical laboratory. To systematize these methods, the following table presents a simple determination technique for the principal fertilizers:

Type of chemical fertilizer	Appearance	Solubility	Mixing with lime	Heating, combustion	External observation after other processes
Ammonium sulfate		completely soluble	ammonia odor	not melting, not combustible but with ammonia odor	
Ammonium nitrate		completely soluble	ammonia odor	fast melting and release of white smoke with ammonia odor	
Ammonium bicarbonate	white crystals with ammonia odor	completely soluble	ammonia odor	quick decomposition	
Ammonium chloride		completely soluble	ammonia odor	not melting, release of white smoke with ammonia odor and taste of hydrochloric acid	

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Type of chemical fertilizer	Appearance	Solubility	Mixing with lime	Heating, combustion	External observation after other processes
urea		completely soluble	ammonia odor	fast melting and glowing, combustible and release of ammonia odor	
ammonium calcium nitrate		partially soluble and partially precipitated	ammonia odor		
sodium nitrate		completely soluble	without ammonia odor		
calcium cyanamide	black or grayish black with carbide odor				
common calcium superphosphate		partially soluble and partially precipitated	without ammonia odor		sour, astringent taste at the tip of tongue
concentrated superphosphate		partially soluble and partially precipitated	without ammonia odor		
Ca-Mg-phosphate		insoluble			gray or dark green powder
Thomas meal	blackish brown, high specific gravity	insoluble			

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Type of chemical fertilizer	Appearance	Solubility	Mixing with lime	Heating, combustion	External observation after other processes
precipitated phosphate		insoluble			white or light yellow powder
defluorinated phosphate		insoluble			white, grayish black particles or powder
pulverized phosphate rock	brown powder				
potassium chloride		completely soluble	without ammonia odor		white powder
potassium sulfate		completely soluble	without ammonia odor		white tiny crystalline particles
ammonium phosphate		completely soluble	ammonia odor		
potassium nitrate		completely soluble	without ammonia odor	glowing and smoking but without ammonia odor	

Chapter 6. Calculating Application Amount of Chemical Fertilizers

The application amount of a chemical fertilizer is closely related to its nutrient content. The nutrient content in a nitrogen fertilizer is calculated from the nitrogen content; phosphorus pentoxide content is the basis of nutrient calculation for phosphorus fertilizer; and potassium oxide content is the nutrient basis for potassium fertilizer calculation. Since the nutrient content of various chemical fertilizers varies widely, conversion calculation should be made in applying a new fertilizer. The following table shows the nutrient content in some chemical fertilizers.

Fertilizer type	Nutrient content		
	nitrogen %	phosphorus pentoxide %	potassium oxide %
ammonium sulfate	20.8		
ammonium nitrate	34		
ammonium bicarbonate	17~17.5		
ammonium chloride	24		
urea	46		
aqua ammonia	12~16		
liquefied ammonia	82		
Ca-Mg-phosphate		14~18	
Thomas meal		16	
precipitated phosphate		28~36	
defluorinated phosphate		20~35	
pulverized phosphate rock		20~34	
potassium chloride			50

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Fertilizer type	Nutrient content: nitrogen %	phosphorus pentoxide %	potassium oxide %
ammonium calcium nitrate	20		
sodium nitrate	15		
calcium cyanamide	18~20		
calcium superphosphate		16~18	
concentrated superphosphate		more than 45 (46 is used in calculations of examples)	
potassium sulfate			48~52
ammonium phosphate	12~18	45~52	
potassium nitrate	14		45
ammonium calcium superphosphate	2~3	16~18	

How to make conversion calculations? For example, 30 chin of ammonium nitrate was applied per mou as the fertilizing norm. If urea is applied instead, how many chin should be used? We should calculate by the following formula:

$$30 \text{ chin} \times \frac{\text{nitrogen content in ammonium sulfate}}{\text{nitrogen content in urea}} = \text{required amount for urea.}$$

From this table, the nitrogen content in ammonium sulfate is 20.8 percent and that of urea, 40 percent; then these figures are substituted into the above formula:

$$30 \text{ chin} \times 18/46 = 7.8 \text{ chin.}$$

That is, 7.8 chin of calcium superphosphate should be applied.

This calculation method requires a separate computation each time. To simplify, the following table can be used to directly read out the figure representing the converted amount to be used. However, only integers are used for the nutrient content, so the decimal remainder may differ in the table figure and the calculated figure.

b 施肥量，斤/亩 / a 养分含量，%	c 纯养分施用量（氮，五氧化二磷，氧化钾），斤/亩						
	2	3	4	5[4]	6[3]	7	8
10	20.0	30.0	40.0	50.0	60.0	70.0	80.0
12	16.7	25.0	33.3	41.7	50.0	58.4	66.7
14	14.3	21.4	28.6	35.7	42.9	50.0	57.2
16	12.5	18.7	25.0	31.3	37.5	43.8	50.0
18[2]	11.1	16.7	22.2	27.8	33.3[2]	39.9	44.4
20[1]	10.0	15.0	20.0	25.0[1]	30.0	35.0	40.0
22	9.1	13.6	18.2	22.6	27.3	31.8	36.4
24	8.3	12.4	16.6	20.8	24.9	29.2	33.3
30	6.6	10.0	13.3	16.6	20.0	23.3	26.6
32	6.2	9.3	12.4	15.5	18.7	21.9	24.8
34[1],[3]	5.9	8.8	11.8	14.7[1]	17.7[3]	20.6	23.6
40	5.0	7.5	10.0	12.5	15.0	17.5	20.0
44	4.5	6.8	9.1	11.4	13.6	15.7	18.2
46[1],[2],[3]	4.3	6.5	8.7	10.9[1]	13.6[2], [3]	15.2	17.4
50[4]	4.0	6.0	8.0	10.0[4]	12.0	14.0	16.0

Remark: The bracketed figures in the table show the number of the particular example referred to.

Key:

a. Amount of fertilizer used in chin per mou
b. Nutrient content, percent
c. Amount of pure nutrient used (nitrogen, phosphorus pentoxide, potassium oxide), chin per mou

Here are examples:

(Example 1) The amount of ammonium sulfate used is 25 chin per mou as the fertilizing norm. If ammonium nitrate or urea is now used, how many chin should be applied?

Referring to this table, the nitrogen nutrient content in ammonium sulfate is 20 percent (neglecting decimals) and in the "amount of fertilizer used" column locate the figure 20, then trace rightward to the figure 25 (the amount of ammonium sulfate used in chin). Then trace downward to the figure 34 (ammonium nitrate contains 34 percent nitrogen nutrient) and trace parallel to 14.7; that is, 14.7 chin of ammonium nitrate should be applied. Similarly, trace downward from 25 to 46 in the "amount of fertilizer used" column (urea contains 45 percent nitrogen nutrient) and then parallel to 10.9. That is, 10.9 chin of urea should be applied per mou.

(Example 2) The amount of concentrated superphosphate used is 13 chin per mou as the fertilizing norm. If now calcium superphosphate is applied, how many chin should be required?

Referring to the table, the phosphorus nutrient content in concentrated superphosphate is 46 percent. In the "amount of fertilizer used" column, locate the figure 45. Then trace rightward to locate the figure 13.0 (the amount of concentrated superphosphate used per mou in chin). Trace upward from 13.0, and at the same time trace rightward from 18 (calcium superphosphate contains 18 percent phosphorus nutrient) and meet at the intersection 33.3. This means that the amount of calcium superphosphate used should be 33.3 chin.

(Example 3) The amount of effective nitrogen nutrient needed is 6 chin per mou as the fertilizing norm. How many chin of urea or ammonium nitrate should be applied?

It is known that urea contains 46 percent nitrogen nutrient and ammonium nitrate contains 34 percent nitrogen nutrient. From column 6 (apply 6 chin pure nitrogen nutrient) of "amount of pure nutrient used", trace downward. At the same time, trace rightward from 34 in the "amount of fertilizer used" column and meet at 17.7, the intersection at column 6. This means that 17.7 chin of ammonium nitrate is required. Trace rightward from 46 in the "amount of fertilizer used" column and extend to column 6 at 13.0. This means that 13.0 chin of urea is required. A similar procedure can be applied for the other values.

(Example 4) The amount of effective potassium nutrient (potassium oxide) needed is 5 chin per mou as the fertilizing norm. How many chin of potassium chloride is required?

Referring to the table, it is known that potassium chloride contains 50 percent potassium nutrient. At column 5 (apply 5 chin potassium nutrient) of "amount of pure nutrient used", trace downward. At the same time, from 50 in the "amount of fertilizer used" column trace rightward and extend to column 5 at an intersection 10.0. This means that 10 chin potassium chloride should be applied.

Of course, other factors should also be considered in changing a fertilizer type, besides the nutrient amount. These examples only show the calculation procedures for different fertilizers required based on nutrient content.

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