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SOIL AND FERTILIZER IN INDONESIA

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AGRICULTURAL DEVELOPMENT COOPERATION DEPARTMENT
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--- Preface ---

This textbook, a guide for agricultural field workers, is intended to give a simple outline of soil and fertilizers for rice cultivation based upon knowledge and experiences obtained in work for the West Java Food Production Increase Technical Cooperation Project.-

The contents have been carefully selected, taking into consideration the technical levels and problems faced in rice cultivation.

It is unavoidable that the contents of this textbook overlap somewhat with those of other textbooks describing the general techniques of rice cultivation because of the original plan to compile independent textbooks according to the respective specialities of the Japanese experts.

Some changes in this textbook will be necessary in the future because of progress made in tests and research on fertilization techniques by Indonesian officials, alterations in social and economic conditions concerning fertilizer usage, etc.

Special efforts of the Indonesian side are expected for this revision.

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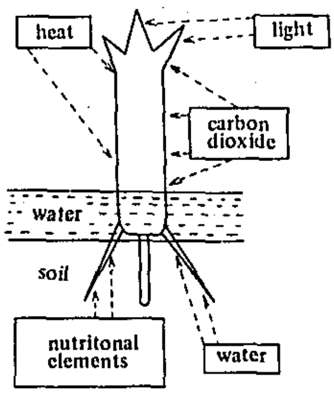
Part I : Basic Knowledge concerning Soil and Fertilizers

I-1. Nutritional Physiology of the Rice Plant

Receiving light and heat from the sun, green plants including rice synthesize themselves basically from carbon dioxide in the air, water and nutritional elements such as nitrogen absorbed through the roots by the action of chlorophyll as illustrated in Figure 1.

The elements required for normal physiological activities of rice plants are C, O, H, N, P, K, Si, Ca, S, Fe, Mn, Mg and Al, which are absorbed from the soil via the roots, except for C and O which come from the air.
Among the various nutritional elements required for production, N, P and K might be insufficient. They are recognized as the three primary nutrients which generally must be added in the form of fertilizer.

Figure 1 : Synthesis mechanism of the rice plant



The physiological characteristics of these three primary nutrients are summarized in Table 1.

I-2. Nutritional Elements and Chemical Fertilizers

1. Nutritional Elements

The following is an outline of the actions of N, P and K in soil. These are the most important elements for the growth of rice plants.

Table 1 : Physiological characteristics of the three primary elements.

Element	Absorption form	Main physiological activities	Deficiency symptoms	Excess symptoms
Nitrogen (N)	NH_4^{+} NO_4^{-}	1. Component of protein which protoplasm is mainly composed of.	1. Green uniformly vanishes from all part of the plant which subsequently turns light yellow.	1. Leaf becomes dark green sift and wettable. Pest and cold resistance decrease.
		2. Component of chlorophil, enzymes, hormones and nucleic acids.	2. Plants are dwarfed and number of tillers decreases.	2. Stem elongates and number of tillers increases. Lodging resistance weakens.
		3. Promotes growth and activates nutrient absorption and assimilation.	3. Development and elongation of roots slow down.	3. Although elongation of roots is accelerated, the number of cells is small.
			4. In most cases, grain yield, and quality decrease.	4. Maturity of grain is delayed.
Phosphorus (P)	PO_4^{-} HPO_4^{-} $H_2PO_4^{-}$	1. Important in intermediates of photosynthesis, respiration and glycolysis.	1. Deficiency symptoms generally appear the lower leaves and then rise to the upper ones.	1. Generally, excess symptoms are difficult to observe.
		2. Plays an important role as ATP and ADP in energy transformation of plants.	2. The leaf narrows and it becomes dark green.	2. Sometimes vegetative growth stops and maturity is so developed as to decrease yield.
		3. Component of nucleic acid and enzymes related to important physiological activities.	3. In case of rice plants, the number of tillers sharply decreases.	3. Heavy application of P causes deficiencies of Zn, Fe and Mg.
		4. Generally promotes growth, tillering, rooting, flowering and fruiting of the plant.	4. The number of flowers decrease, and flowering and fruiting are delayed.	
			5. Root hairs become larger to turn undergrown.	
Potassium (K)	K^{+}	1. Effects are greater the less the sun shine.	1. As K moves easily, deficiency symptoms become visible first in older leaves.	1. K can be absorbed as excessively as N, but excess symptoms are difficult to observe.
		2. Related to absorption and reduction of nitrates in the plant and to protein synthesis.	2. Central part and outside of leaf become dark green and yellow respectively, showing clear borders.	2. Excessive K in the soil inhibits absorption and promotes deficiencies of Mg and Ca.
		3. Controls Water by keeping the swelling pressure of cells constant (increases cold resistance).	3. Sometimes winkles and twists can be observed in the leaf.	3.
		4. Increases disease and insect resistance.	4. New roots are formed only axound the main root.	
		5. Promotes flowering and fruiting.		

(1) Nitrogen

Among various forms of N, the important ones for rice Plants aie urea - N and ammonia-N.

Organic-N, including cyanamide-N which produces urea as an intermediate, is finally changed into ammonia by the action of soil micro-organisms. Nitrates are usually not used in paddy fields because they are easily washed away (run off) Urea, which became one of the important chemical fertilizers after the recent success in synthesizing it using ammonia and carbon dioxide, is decomposed in the soil by the urease of micro-organisms to produce ammonium carbonate as shown in the following formula.

$$CO(NH_2)_2 + 2\ H_2O \qquad (NH_4)_2CO_3$$

Many micro-organisms are considered to have this urea-decomposing capacity. The decomposition rate of urea which differs according to environmental conditions, especially the soil temperature, is very slow if the soil temperature is less than 10°C. In Indonesian climate the decomposition proceeds very rapidly.

Decomposition rates according to soil texture are shown in Table 2.

Table 2 : Decomposition rate of urea

Soil Texture	Rate of ammonification (%)		
	1st day	2nd day	3rd day
Sandy soil	39	61	73
Sandy loam soil	76	95	71
Loam soil	85	98	98
Clay soil	96	98	100

Remarks : Paddy field soil
Added N : N 20 mg/100 g soil, 30°C

The ammonia in ammonium carbonate produced after the decomposition of urea is quickly absorbed by the soil, but, urea itself which does not ionize can not be adsorbed electrically.

Although urea can be adsorbed slightly by humus-rich soil, the degree of absorption is considerably lower than that of ammonia. When ammonium sulphate is applied, most of the ammonia replaces calcium in the soil colloid, as shown below.

$$\text{Colloid} \quad Ca^{++} + (NH_4)_2SO_4 \qquad \text{Colloid} \begin{array}{l} NH^{+}{}_4 + CaSO_4 \\ NH^{+}{}_4 \end{array}$$

The ammonia absorbed by the soil colloid in this way is dissolved again in the soil solution by the action of hydrogen ions originating from acid secreted by plants, and is finally absorbed by the plant root.

The quantity of ammonia absorbed by the soil dependends on the kind of anion of the salt to be applied; for instance, the amount of ammonium phosphate or ammonium carbonate absorbed greater than that of ammonium sulphate or ammonium chloride.

Under upland conditions, ammonia changes by nitrification into the nitrate, some of which is absorbed by the plant and the rest of which is leached out by rainfall.

Among the practical problems of fertilizer application to be considered because of the above-mentioned characteristics of urea, it is especially important to take care not to lose N before the decomposition of urea so as to apply the urea as effectively as possible, since the absorption of urea itself in the soil is almost negligible.

Almost all of the urea changes into ammonium carbonate in less than 3 days after being applied to soil under tropical conditions. Therefore, water control in this short period is very important.

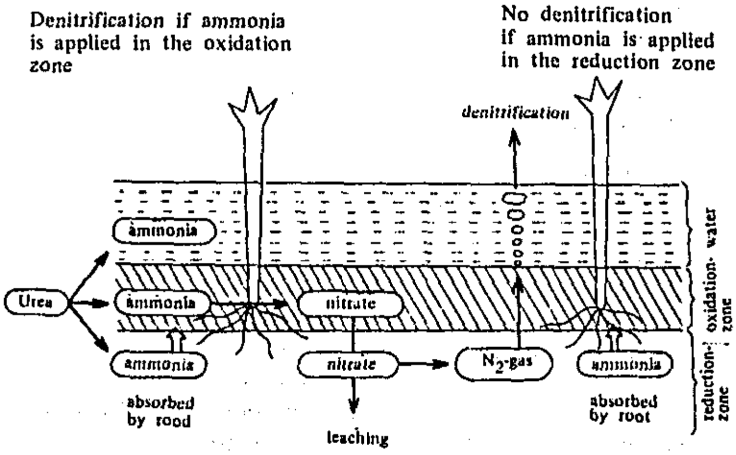
There should never be continuous flowing irrigation during the 3 days after application of urea.

Another key point in urea application is to mix it well with the soil as deep as possible to promote the ammonification of the urea and to avoid the nitrification of ammonia.

The utilization rate of N in a paddy field reaches 20-50%. Among the reasons for N loss from soil, denitrification is considered to be the most important.

The *mechanism of denitrification* is illustrated in Figure 2.

Figure 2 : Denitrification



As is shown, the soil of the paddy field is divided into oxidation and reduction zones. If N is applied after puddling the paddy field, it stays in the water layer or oxidation zone where ammoniacal N is changed by oxidation into nitrate.

Then the nitrate produced moves further down to the reduction zone with the irrigation water since nitrate can not be absorbed by the soil.

Consequently it follows that, as oxygen runs short in the reduction zone, nitrate is converted by reduction into N gas which disperses in the air. In contrasts if N is applied at the time of plowing and mixed deeply with the soil the loss caused by denitrification becomes smaller as ammonia can exist in the reduction zone.

For the above reasons it is important to apply N deeply in soil that it reaches to the reduction zone.

The method of applying fertilizer in the reduction zone is whole soil layer placement, which has been recognized as one of the most important techniques for fertilizer application in the paddy field.

Besides denitrification, other causes of N loss in paddy fields are leaching, run-off and the ammonia velatilization although the amounts are generally not so great.

(2) Phosphorus

The available form of phosphorus in fertilizer is PO_4^{---}, which has a minus charge and is seldom lost from the soil exept in the case of plant absorption or soil erosion.

The lower loss of P from the soil is due to the fact that phosphoric compounds generally become insoluble after combining with metals such as Ca, Mg, Al and Fe in the soil.

This reaction is known as "fixation of phosphoric acid", and is the main reason why the utilization rate of P fertilizer remains at low levels of 5-20% even in paddy fields.

The water solubility of phosphoric compounds combined with Ca, Mg, Al, Fe, etc. differs according to the form of the combination.

When super phosphate, the main component of which is mono calcium phosphate $Ca(H_2PO_4)_2$, is applied, it releases water-soluble PO_4^{---} which is directly usable by the plant, although it partially combines with Al and Fe, or changes to other kinds of calcium salts, in both cases finally to form slightly water-soluble compounds.

Phosphate under oxidized conditions such as in upland field soil exists. However, Fe combined with phospheric acid exists as water-insoluble ferric as a water-soluble ferrous phosphate under reduced conditions such as in paddy field soil.

P in the form of ferrous compounds easily dissolves in water and is consequently utilized by crops.

Therefore, P fertilizer can be utilized far more in paddy fields than in upland fields where more P fertilizer must generally be applied than in paddy fields.

To decrease the fixation of water-soluble phospheric acid and to promote fortilizer response, an effective measure which can be recommended is to apply P fertilizer mixed with compost to decrease the contact of P with Fe, Al, etc. in the soil.

(3) Patassium

The organic form of K does not exist in the soil, However there is a lot of potassium rock in the soil, which is considered to be the prime source of K.

The reason why the fertilizer response of K is generally insensible is that K can be often supplied from irrigation water.

When K fertilizer with components which are almost completely water-soluble is applied, it is quickly absorbed by soil colloid.

As in the case of ammonium salts, K mainly replaces the Ca in soil, releasing equivalent Ca into the soil solution which is absorbed by the plant.

However, the intensity of adsorption is stronger in the case of NH_4^+ than for K which runs off more easily.

As mentioned above, most of the K applied is adsorbed by the soil, while some is leached out with irrigation water.

Utilization of K fertilizer in paddy fields is highest among the three primary elements, ranging from 40 to 70%.

2. Chemical Fertilizers

There are many kinds of well-known chemical fertilizers at present. Typical fertilizers are listed in Table 3, together with their characteristics.

Although fertilizers which have not yet become popular in Indonesia are included in Table 3, they all seem to be important, with the future possibility of extensive use.

I-3. Main soil Types and their characteristics

In Indonesia, there are various types of tropical soils on which the Bogor Soil Research Institute has been conducting surveys for a long time to elucidate types, distribution and characteristics.

Various kinds of survey maps published by the Institute are commercially available.

To carry out adequate fertilization it is necessary to understand the soil thoroughly since it is the "parent" of crop growth.

A soil survey is required as a matter of course for effective fertilization, but it is not always easy to conduct such a survey correctly even for a small area.

Therefore it is advisable to utilize the authorized survey maps issued by the Institute as much as possible.

Figure 4 shows a survey map concerning the classification of soil phosphate contents in paddy field areas of West Java Province.

It might not always be possible to refer to the results in Figure 4 to make application standards for P fertilizer.

Figure 4 should be understood only showing the basic tendencies in phosphate content. The characteristics of the main soils found in West Java Province and technical comment on soil management and fertilizer application in accordance with the respective characteristics of the soil concerned are summarized in Table 4.

Table 3 : Characteristics of main chemical fertilizers.

Name of fertilizer	Raw material	Product	Property	Guaranteed component content	Characteristics
Urea	Ammonia Carbon dioxide	Urea $(NH_2)_2CO$	White Crystalline granules	Total-N 46 %	1. Quick-acting 2. Urea-N easily runs off, but changes quickly in soil into ammonium carbonate which does not run off easily 3. Physiologically neutral fertilizer
Ammonium sulphate	Ammonia Sulphuric acid	Ammonium sulphate $(NH_4)_2SO_4$	White Crystalline granules	NH_4-N 21 %	1. Quick-acting 2. Easily adsorbed and retained by soil 3. Physiologically acidic fertilizer not suitable for degraded paddy fields
Ammonium chloride	Sodium chloride Ammonia Carbon dioxide	Ammonium chloride NH_4CL	White Crystalline granules	NH_4-N 25 %	1. Quick-acting 2. Easily adsorbed and retained by soil 3. Physiologically acidic fertilizer
Ammonium nitrate	Ammonia Nitric acid	Ammonium nitrate NH_4NO_3	White Crystalline granules Strong hygros copicity	NH_4-N 17.2 % NO_3-N 17.2 %	1. Quickest-acting 2. Not suitable for basic fertilizer in paddy fields because of loss by run-off and denitrification 3. Physiologically neutral fertilizer, especially suitable for upland crops
Calcium cyanamide (Line nitrogen)	Carbide Nitrogen	Calcium cyanamide $CaCN_2$	Dark gray power/ granules	Total-N 21 %	1. Quick-acting, but slower than ammoniacal fertilizer 2. Sowing and transplanting just after fertilization must be avoided 3. Easily adsorbed and retained by soil 4. Effective for adjusting soil acidity and exterminating weeds, germs and insects. 5. Alkaline fertilizer
Triple super phosphate (TSP)	Phosphate rock Sulphuric acid Phosphoric acid	Mono calcium phosphate $Ca(H_2PO_4)_2$	Dark gray balls	Soluble- P_2O_5 46 %	1. Quick-acting 2. Easily fixed by soil 3. Physiologically neutral fertilizer
Di super phosphate (DSP)	Phosphate rock Sulphuric acid Phosphoric acid	Mono calcium phosphate $Ca(H_2PO_4)_2$	Dark gray balls	Soluble- P_2O_5 38 %	1. Quick-acting 2. Easily fixed by soil 3. Physiologically neutral fertilizer
Super phosphate	Phosphate rock Sulphuric acid	Mono calcium phosphate $Ca(H_2PO_4)_2$	Gray-brown power	Soluble- P_2O_5 17 % Water soluble- P_2O_5 15 %	1. Quick-acting 2. Easily fixed by soil 3. Physiologically neutral fertilizer
Fused phosphate	Phosphate rock Serpentine	Fused compound consisting of P, Ca, Mg, Si, etc.	Light-green, black powder/ crude granules	Citrate soluble- P_2O_5 19 % Citrate soluble- MgO 15 % Alkaline 50 % Soluble- SiO_2 20 %	1. Citrate soluble, slow release 2. No run-off 3. Very effective for soil improvement 4. Alkaline fertilizer
Potassium chloride	Refined from potash ores	Potassium chloride KCL	White Crystalline power	Water soluble- K_2O 60 %	1. Quick-acting 2. Retained by soil 3. Physiologically acidic fertilizer
Potassium sulphate	Potassium chloride sulphuric acid	Potassium sulphate K_2SO_4	White/ gray white crystalline power	Water soluble- K_2O 50 %	1. Quick-acting 2. Retained by soil 3. Physiologically acidic fertilizer
Ammonium phosphate/ potassium chloride (Compound fertilizer 14-14-14)	Ammonia Phosphoric acid Ammonium chloride Potassium chloride	Mono ammonium phosphate $NH_4H_2PO_4$ Ammonium chloride NH_4CL Potassium chloride KCL	Gray brown granules	NH_4-N 14 % Soluble- P_2O_5 14 % Water soluble- P_2O_5 11.5 % Water soluble- K_2O 14 %	1. Quick-acting 2. Easily retained by soil 3. High analysis mixed fertilizer 4. Physiologically acidic fertilizer

Figure 3 : Transformation of fertilizer components in soil

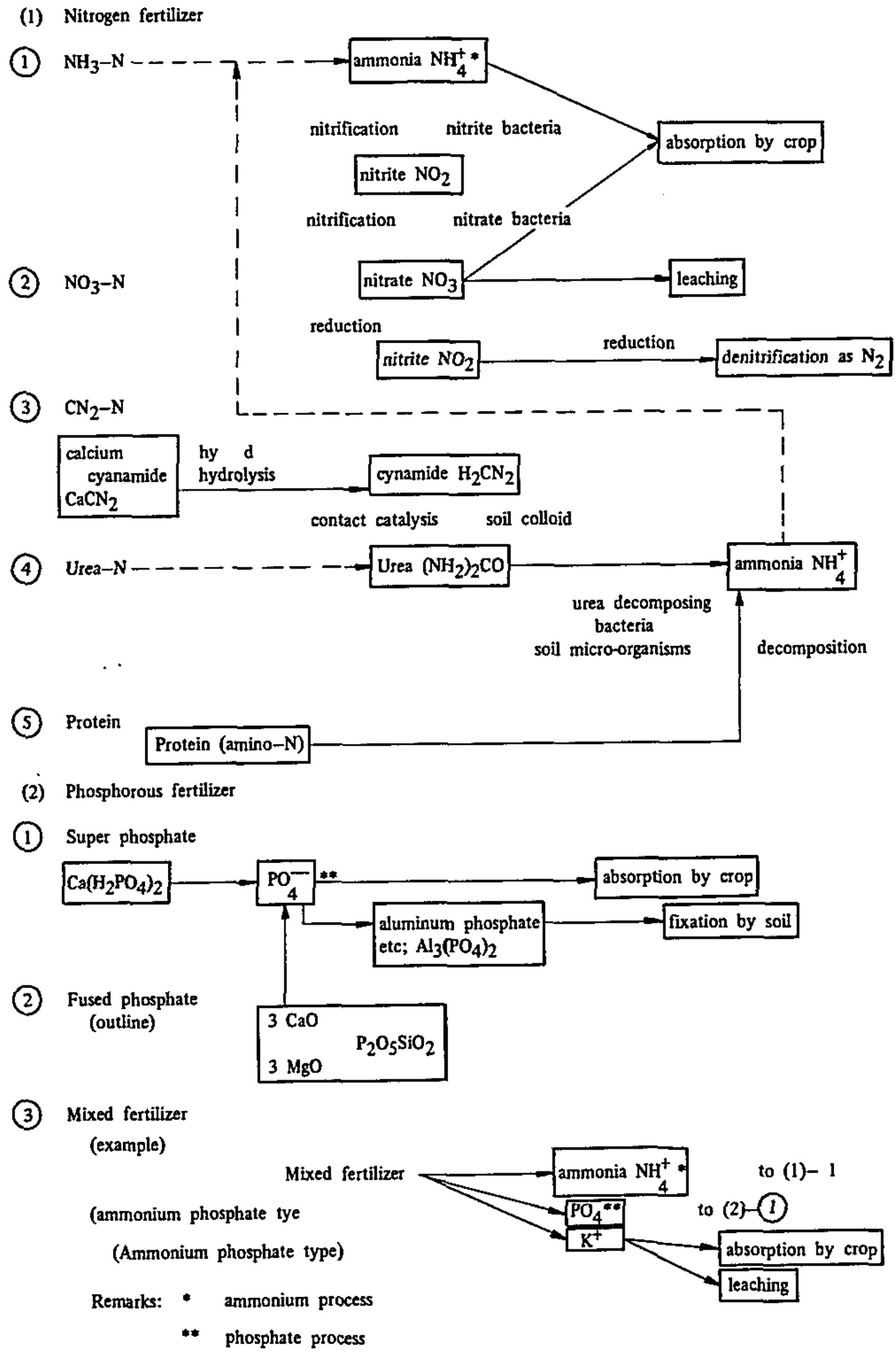
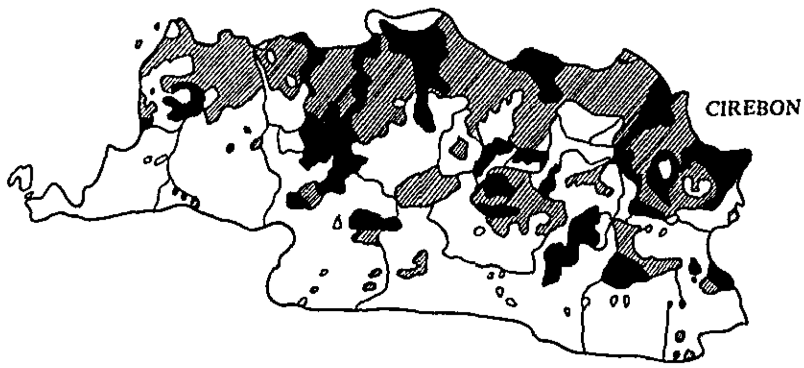


Figure 4 : Distribution of P centents in the paddy fields

— West Java Province —



more than P_2O_5 40 mg/100 g soil ... not responsive to P.

less than P_2O_5 40 mg/100 g soil ... responsive to P.

(P is extracted by 25% HCL solution)

Source: Soil Research Institute (Bogor).

Table 4 : Main soils in West Java Province and their characteristics

No.	Soil type	Characteristics	Soil management and fertilization techniques
1	Aluvial	Although consisting of river transported soil, the longitudinal specialization is not very clear. Development of organic matter in upper layer is weak. Rich in clay and beneficial chemical components, as well as peat under bad drainage condition. Thus shows high productivity. In some areas, H_2S or Fe^{++} exists owing mainly to heavy reduction caused by bad drainage. Degradation of soil occurs easily in plains and lower land. Distributed widely on northern coast of *Java Island*.	Although soil productivity is high, good drainage is necessary to avoid strong soil reduction. Application of organic matter such as decomposed compost, etc. is effective in promoting fertility.
2	Glei	Diversified into humic gray soil and gray hydromorphic soil. If shows clear longitudinal specialization as well as remarkable graying. Generally exists under bad drainage conditions. Upper layer is a dark inorganic matter zone in humic gray soil and a bright gray leaching zone in gray hydromorphic soil. Lower layer consists of heavy clay in many cases. Chemical composition is moderate.	As this soil develops under bad drainage condition, every effort to ensure good drainage is important to keep the soil oxidative.
3	Regosol	Sandy volcanic and porous soil. Cultivation is easy because of its good physical properties. Areas where new volcanic soil exists are recognized as the most important fertile land. Soil productivity is variable depenting upon the degree of weathering. In initial and medium stages of weathering, *the available nutrients* are sufficient, but subsequently N and P gradually run short.	In areas where weathering has developed, the potential soil fertility is low and sufficient fertilization is required. It is desirable to enrich the soil organic matter by applying compost to extend the life of the fertilizer.
4	Grumosol	Calcium and humas accumulated soil, black or dark gray incolor. Recognized as heavy clay soil containing 40-80% clay. Air conductivity is low. Extreme swelling with sufficient water, cracking and hardening when dried. In many cases, pH ranges from 6 to 8, showing the low P content. Deficient in K, Mg and Mn. Abnormal soil reduction is apt to occur. There is a tendency for Mentek to break out frequently.	As water management is very difficult for this soil, care is required in the dry season so that the soil does not become excessivery dry. P, together with K, has to be applied sufficiently, if possible. Introduction of upland crops in the crop rotation system is used to recover soil reduction.
5	Latosol	Formed as a result of strong weathering and leaching. Low in organic matter contents, base-saturation percentage and plant nutrient contents. pH is in region of 4.5-6.5 Red brown clay is easily broken exists over an extensive area. Parent material is ejecta, with a high *water permeability. Plant roots can reach the* deeper layers. Because of the high iron content, the P absorption coefficient is great and it is to liable to be deficient in P. Nitrification even under flooded conditions is considered as great.	Soil productivity is lower than a luvial soil. Sufficient fertilization is required to obtain high yields especially by supplementing the organic matter by straw or compost, and supplying large amounts of P. *care is necessary concerning loss of* fertilizer through continuous irrigation flow.
6	Andosol	Upper layer is black and rich in organic matter. pH range is 5-7. Parent material is ejecta, very similar to Latosol. Distributed in volcanic areas which have cool weather and heavy rainfall. It has good water permiability and is easily attacked by erosion. Light and porous soil. Physiochemical properties are generally good.	This soil is considered to have comparatively few special problems in fertilizer application. One of the highly productive soils, along with aluvial.
7	Red-Yellow Podsolic Soil	On reddish yellow accumulated layers attacked by heavy leaching and consequently showing heavy clay block structure, there is a gray-yellow upper layer. Low contents of organic matter and plant *nutrients. pH is in region of 3.5-5.0.* Consists of acidic deposits. Permeance of water, as well as root stretching, is limmited owing to the extremely specified layer. It is effective to apply some minor elements.	Sufficient fertilization is required to procure high yields. Application of plant and wood ashes is especially effective. In order to promote the *physical properties of the soil, deep* plowing is necessary.
8	Red-Yellow Mediterranean Soil	Attacked by strong weathering, it shows a heavy clay block structure. Not very rich in organic matter and low in base-saturation percentage. pH range of 6.0-7.5 Red soil. Viscostity is high in lower Layer. Parent material consists of ejecta limestone, calcareous sandstone, etc.	As organic content is small, it is desirable to apply straw and compost. Precautions against run-off of N and K are required. When fertilizing, sufficient mixing with the soil is important.

Remark : Spelling of soil names follows the Indonesian language except for No. 7 and No. 8 in which English spelling is used.

Part II : Fertilization Techniques

II-1. Outline of Field Trial Results

Various kinds of field trials using the high-yield rice variety, *Pelita-I, have been conducted in Cihea since the 1971/1972* wet season.

The results concerning fertilization techniques obtained from these trials, are summarized as follows.

(1) Optimum amount of N fertilizer to be applied to seedling beds is usually 10g/m^2 in the form of urea.

Either too little or too much N retard the germination and decrease the rate of healthy seedlings.

In both cases, the rooting activity weakens, so that sound seedlings are not obtained.

(2) N rate required for the 1st half of growth during which the basic fertilizer and 1st additional fertilizer after transplant-*ing are applied, is 65-75% of the total N according to* existing recommendations.

In contrast to this common method, a new fertilization method in which more fertilizer is applied during the 2nd half of growth, i.e. 40-50% for the 1st half and 50-60% for the 2nd half, can bring about higher yields and far better quality rice plants.

(3) Trials of integrated effects combining various factors in an overall plan showed the highest yield in the case of a combination of heavy fertilization (N 135 kg/ha), the application of more fertilizer in the 2nd half of growth (2nd of half growth: N 60%), close spacing (22.2 hills/m^2) and the use of matured seedlings (31-day old seedlings).

However, with light fertilization (N 72 kg/ha), the quantity of fertilizer is a limitting factor to dice the yield, and the effects of the other factors are masked.

Compared with the fertilizer application standards adopted to date, it is evident from the above-mentioned conclusions that applying more N fertilizer in the 2nd half of growth is effective.

The significance of applying more N fertilizer in the 2nd half of growth is considered to be great because this method can avoid the quick degradation of the rice plant after the ear-primordia stage, which the short-culmed new varieties such as Pelita-I are susceptable to.

In Muara also, some trials concerning fertilizer application using Pelita-I have been conducted since the 1972/1973 wet season.

The following is an outline of the results of the trials.

1 When applying a total of 200 kg/ha of urea, the top-dressing method of 20 kg/ha (basic fertilizer) – 60 kg/ha (15 days after transplanting) – 100 kg/ha (ear-primordia stage) – 20 kg/ha (20 days after ear-primordia stage) is superior in growth and yield to that of 60 kg/ha (basic fertilizer) – 70 kg/ha (15 days after transplanting) – 70 kg/ha (ear-primordia stage).

In the former method, 40% of the N is distributed in the 1st half of growth (basic fertilization + 1st top-dressing 15 days after transplanting) and 60% of the N in the 2nd half (2nd top-dressing at ear-primordia stage + 3rd top-dressing 20 days after that).

In the latter method, however the percentage of N distribution for the 1st and 2nd halves is 65% and 35%, respectively.

As mentioned above, better results are gained by applying more N fertilizer in the 2nd half of growth, showing the same tendencies as obtained in Cihea.

2 In comparison with the application of a tatal of 200 kg/ha of urea, higher yields are obtained by applying either 250 kg/ha or 300 kg/ha of urea, although the rice plants

become more susceptible to such diseases as bacterial leaf streaks on account of the heavy application of N.

Under heavily fertilized conditions, sufficient care is required to prevent attack of the rice plants by diseases and insects.

Regarding the effectiveness of newly recommended method of applying more N fertilizer in the 2nd half of growth, it has now been confirmed through simple field trials conducted at the Extension Centers of 7 Kabupatens in West Java Province.

II-2. Improved Fertilization Standards

1. General Concept of Fertilization Standards

Suitable fertilization standards should be determined comprehensively taking into consideration not only the technical background, but also the various farm management factors such as effects of fertilizer investment.

Especially in countries such as Indonesia where the price of rice is low, the economic efficiency of fertilizer application is very important.

The following explanation is based upon the intention of presenting an improved method compared with the existing plan exemplified by the BIMAS program recommendation which has been nationally accepted by farmers.

Some results obtained through project activities are added to the existing recommendation.

2. Kind of Fertilizer

Urea is the most suitable N fertilizer at the present time in Indonesia from the technical background and circulation status of the fertilizer. Ammonium sulphate is not always considered to be safe since it sometimes generates H_2S in degraded paddy fields which is very harmful to rice plants since it can cause root rot.

TSP and DSP, including super phosphate, are appropriate as fertilizers.

Diammonium phosphate (DAP: $(NH_4)_2HPO_3$) containing both N and P in the same compound is also effective as a P source.

The necessity of applying K fertilizer is in general low since the natural supply of this element is greater than that of N and P.

However it must be remembered that some soils need K fertilizer. When applying K fertilizer, potassium ohloride is recommended.

With regard to compound fertilizers, a detailed explanation is omitted here since their general applicability with rice plants is still in doubt. Greater use in the future is expected for compound fertilizers which have many merits such as enabling the effective and simultaneous application of N-P or N-P-K elements, a decreased loss of fertilizer components, and relatively cheap transportation.

3. Quantity of Fertilizer

(1) According to the field trial results in Cihea, 10 g/m^2 of urea is the optimum amount. The fixed amount is decided in the region of 5-15 g/m^2 by investigating the soil fertility.

The same amount of TSP may be applied. When the suitable rate of fertilizers has not yet been decided in the area concerned, 10 g/m^2 each of urea and TSP is suggested.

(2) Paddy fields

From the trial results in Cihea and Muara, the fertilizer quantity and the yield generally show a positive corelation up to the level of approximately 300 kg/ha of urea.

However, since the rice plant becomes more sensitive to diseases and insect damage as fertilization increases, sufficient care should be taken to ensure higher yields.

It is very dangerous to increase the quantity of fertilizer without sufficient after-care.

Taking the BIMAS-packet into consideration, the minimum amount of urea for high yield varieties is considered as 200 kg/ha.

As the utilization rate of fertilizer generally has a tendency to become greater in the dry season than in the wet season, there should be no trouble if 10% more fertilizer is applied in the dry season.

The minimum amount of TSP is considered to be 70 kg/ha. As mentioned before, the natural supply of K is larger than that of N and P, so that there is little necessity to apply this element except in some special soils.

In principle, fertilization requirements have to be decided from the results of analyses of the soil and irrigation water.

The results of K analysis for some rivers in Indonesia show higher values than the world average.

Supposing the total water requirement for rice plants for one season is 15,000 ton/ha, and the plant is submerged in irrigation water containing 3 ppm of K_2O throughout the growth period, the total amount becomes equivalent to 45 kg/ha of K_2O.

Assuming that the utilization ratio of K from irrigation water by rice plants is 1/3, the above figure is reduced to be 15 kg/ha.

From the standpoint of soil conservation, sufficient amounts of P and K fertilizers should be applied before the deficiency symptoms occur.

To determine the optimum amount of N, P and K by means of a technically correct methodology, the field trials on natural supplies of the three primary elements mentioned later have to be conducted together with the soil analysis.

4. Method of Top-dressing

A well known and tested basic principle of the timing of fertilizer application is that the efficiency of the three primary elements in production of rice, or more precisely, the degree of influence of N, P and K applied at various stages of rice production, is highest at the starting stage of growth and the ear primordia-stage in case of N, and also at the starting stage in the cases of P and K.

The suitable amounts of fertilizer, the ratio of N and P, the ratio of basic and additional application rates of fertilizer and the frequency and timing of top-dressing, etc. differ with varieties of rice and soil fertility. Therefore, there should never be one universal fertilization standard.

It is desirable to apply the proper amount of fertilizer at the proper time, by observing carefully the actual form of rice plant.

Therefore it is recommended to prepare the various fertilization standards from among which the best one is to be selected (local recommendation).

According to the trial results from in Cihea and Muara, the method of applying more N fertilizer in the 2nd half of growth, i.e., the method in which the quantity of N fertilizer top-dressed in the ear primordia stage and the following stage reaches 50-60% of the total amount of N fertilizer, has been shown to be superior.

In Table 5, some examples of desirable fertilization plans are given, in conformity with the above-mentioned new method.

The proper plan should be chosen after taking into consideration the various conditions of rice cultivation in the area concerned.

For reference, some plans for the improved traditional varieties such as Syntha, etc. are also included.

Table 5 : Fertilization standards

Variety	No.	Fertilizer	Total amount of fertilizer (Product weight)	Basic fertili-zation	1 st top-dressing 15 days after transplanting	2 nd top-dressing ear-primordia stage	3 rd top-dressing(1) 15 days after ear-primordia stage	3 rd top-dressing(2) uniform heading stage	Remarks
	1	Urea	200	20	60	1001	20	or	N; 1st half 40%, 2nd half 60%
		TSP	70	70	–	–	–		
High	2	Urea	200	30	60	90	20	or	N; 1st half 45%, 2nd half 55%
		TSP	70	70	–	–	–		
yield	3	Urea	200	40	60	80	20	or	N, 1st half 50%, 2nd half 50%
		TSP	70	70	–	–	–		
variety	4	Urea	250	40	80	100	30	or	N; 1st half 48%, 2nd half 52% Because of increased N application, good pest control required.
		TSP	100	100	–	–	–		
	5	Urea	250	50	80	100	20	or	N; 1st half 52%, 2nd half 48% Because of increased N application, good pest control required.
		TSP	100	100	–	–	–		
				1st half of growth			2nd half of growth		
Improved	6	Urea	120	20	40	40	20	or	N; 1st half 50%, 2nd half 50%
		TSP	50	50	–	–	–		
traditional	7	Urea	120	20	40	60	–		N; 1st half 50%, 2nd half 50%
		TSP	50	50	–	–	–		
variety	8	Urea	150	30	45	55	20	or	N; 1st half 50%, 2nd half 50% Because of increased N application, good pest control required.
		TSP	70	70	–				

Remarks:

(1) As a rule, the 3rd top-dressing is conducted 15 days after the ear-primordia stage. However, if the leaf colour is still dark enough at this time, the top-dressing should be postponed until the uniform heading stage.

(2) The amount of TSP is the minimum value. TSP may be increased up to the same level of urea if economically beneficial.

(3) The reason why K is not included in the above standards is not because the application of K is technically not necessary, but because the economic effect of K application and the conformity with existing recomendations are taken into consideration.

Potassium chloride may be applied up to the same level of urea if economically beneficial. Equivalent amounts as K_2O in the form of plant and wood ashes may be applied instead of potassium chloride.

II-3. Important Points for Fertilizer Application

The practical methods of applying fertilizer at each working stage at the site and the important points in fertilization work are as follows.

1. Seedling Beds

(1) Fertilization of seedling beds is conducted 1-2 days before sowing. After leveling the soil surface and applying the fertilizer evenly, the surface of the soil is lightly pressed down by a banana stem or board.

Fertilizer and soil are mixed well to prevent seeds from direct contact with fertilizer.

After applying the fertilizer and mixing it well with the soil, the surface of the seedling bed is leveled again by a banana stem or board prior to sowing.

(2) Additional fertilization for seedling beds is not required in general. However, if the leaf color is remarkably pale about 2 weeks after sowing, a little of urea, approximately 5 g/m^2, may be applied.

When the fertilization is very uneven, a small amount of additional fertilizer may be applied only in the bad spots. Seedlings can also be activated by a foliar spray using a 1% aqueous solution of urea 1-2 days before transplanting.

Is this case, special care must be taken not to spray excessively.

2. Paddy Fields

(1) Plowing back of straw

When applying fertilizer to paddy fields, the first job to be done is to plow back the straw.

In Indonesia, we often see farmers burning the straw of the previous cropping season or throwing it out of paddy fields after cutting, not realizing that the removal of straw causes a decrease of organic matter in the soil and the lowering of soil fertility.

If a power tiller is used, the straw has to be cut into 1 or 2 pieces by sickle, or be cut to pieces by a cutter, so that it will not wind around the tiller and can be plowed back evenly.

Although the period required for complete decomposition of straw is not constant and varies according to the soil temperature, soil type and especially the activity of soil micro-organisms, the plowing back should be completed at least one month before transplanting.

(2) *Basic fertilization*

Basic N fertilizer promotes the start of growth to assure the number of tillers required to achieve the yield goals.

Since basic N fertilizer is more effective in obtaining higher yields if it is applied in the deep layers of the soil, where it can prevent denitrification and promote nutrient absoption, the fertilizer should be broadcast before plowing.

When the period between plowing and transplanting is comparatively long, and there might be N loss by nitrification under upland conditions, the basic fertilizer may be evenly applied just before puddling, and after that, be mixed well so as not to cause the uneven fertilization.

When fertilizer is applied just before transplanting, which is often observed, the fertilizer easily runs off with the continuous irrigation flow. Application of fertilizer just after transplanting should also be avoided.

Only the required amount of urea as basic fertilizer is applied together with the total amount of P and K fertilizers. Compost is to be applied at the same time as or just before basic fertilization.

As mentioned in the last section, compost containing fertilizer components is highly effective in increasing the yield because of its excellent characteristics not only in improving the physical properties of the soil, but also in adsorbing the applied fertilizer components so as to reduce the (run-off) loss of fertilizer.

(3) Top-dressing

Fertilizer should be applied after regulating the field water to a depth of 2-3 cm by closing the water inlet prior to any additional fertilization.

When the leaf color or growth is not uniform, supplementary fertilization may be conducted to achieve uniform growth in spite of the initial plant, but only at the spot where leaf is discolored or growth seems delayed. For about 3 days after fertilization, the water inlet is closed to prevent the fertilizer from running off.

When closing the water inlet, the depth of water should be as low as possible, to increase adsorption of fertilizer by the soil. After top-dressing, soil and fertilizer are to be mixed well using hand weeder not only to exterminate weeds but also to make the fertilizer be adsorbed well by the soil.

However, the hand weeder must not be used at the 3rd top-dressing because after the ear-primordia stage it will damage the root, and delay the growth of the rice plant.

1 1st top-dressing

In order to promote effective tillering, N is top-dressed 15 days after transplanting.

In general, top-dressing 25-50 days after transplanting leads to in effective tillering, as well as the elongation of lower innernodes which causes lodging.

2 2nd top-dressing

The 2nd top-dressing is conducted at the ear-primordia stage which is more pricesely defined as the late stage of spikelet primordium differentation, approximately 18-20 days before heading.

(This definition is applicable throughout this textbook).

Since the number of days from transplanting to the ear-primordia stage differs with the varieties of rice and also with the seasons even when the same variety is used, actual inspection is necessary to determine the correct date of the ear-primordia stage the method is pull a sample plant and cut its stem vertically with a knife when the stage thought to be approaching.

When conducting the top-dressing during this stage, optimum timing for applying the fertilizer is especially important. Care should be taken to avoid deciding on the ear-primordia stage earlier than the actual date when the length of the young ears becames about 5 mm as average for one hill.

In case of Pelita I/1, the ear-primordia stage is estimated as approximately 60 days after transplanting in the wet season and 5 days earlier than that in the dry season.

Top-dressing in the ear-primordia stage increases the number of grains and the percentage of ripened grains to give a higher yield.

This effectiveness is greater for the panicle weight type variety. As the ear-primordia stage approaches, the leaf colour becomes less pale. Even though the top-dressing might be done earlier because of this symptom, fertilizer must not be applied until the ear-primordia stage comes.

3 3rd top-dressing

When the leaf color is still pale in color even after 15 days of 2nd top-dressing, the 3rd top-dressing is required because the discoloration of the leaf means an increase in empty grains and the degradation of grain content.

If the leaf colour is still dark 15 days after the 2nd top-dressing, the 3rd top-dressing is postponed until the uniform heading stage.

If leaf color is remarkably dark all through by the end of the booting stage, a 3rd top-dressing before and after the heading stage is rather dangerous because bacterial leaf blight might occur.

For the 3rd top-dressing, as mentioned in Table 5, It is advisable to consider the timing and quantity of fertilizer appled, as flexible according to the growth conditions indicated esoecially in respect to leaf color.

3. Important Points in Fertilizer Application

(1) Firstly it is important to determine carefully the kind and quantity of fertilizer to be applied and also to pay a *special attention to whether the designated amount is indicated* as the component or as the product itself.

Urea contains 46% N and TSP usually contains 46% of P_2O_5 although the P_2O_5 content is variable according to the specifications of the product.

The component of phosphate is in many cases indicated by P *but in the* P_2O_5 *oxide form.*

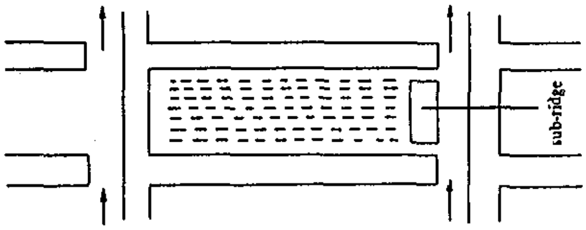
For potassium, indication as K_2O is common.

(2) An iron-bound rule for fertilizer application is to mix the fertilizer well with the soil and scatter it evenly, taking the greatest possible care. Basic fertilizer especially should be broadcaset uniformly in 10 cm of top soil.

However, somewhat heavier fertilization on some spots is sometimes necessary to make the growth uniform. One means of basic fertilization is to increase the total volume of fertilizers by mixing urea and TSP in a pail prior to application to facilitate the uniform application.

(3) Because it is difficult to stop water flow only in one's own field during top-dressing owing to the continuous irrigation, a sub-ridge, approximately 20 cm high, is to be made at the sacrifice of a row of rice plants at one end of the field as shown in Figure 5 to release the excess water.

Figure 5 : A method of water control



(4) If possible, it is advisable to apply compost, the various effects of which can be listed as follows.

1. Imporvement of physical properties ofthe soil (increase of water retaining power and fertilizer retaining power)
2. Supply of fertilizer components (source of N, P, K, Ca, Mg and other elements)
3. Improvement of chemical properties of the soil (buffer action for soil acidity, increase of P fertilizer)
4. Improvement of microbial properties of the soil (increase in population of useful micro-organisms).
5. Biochemical improvements (increased resistance to drought and heavy fertilization, etc.)

Although compost does not have strong and rapid effects like those of chemical fertilizer, its application is highly significant from the viewpoint of supplementing organic matter in the soil.

An example of analysis data of compost is shown in Table 6.

Table 6 : Analysis of compost

H_2O	Ash	C	N	C/N	P_2O_5	K_2O	CaO	MgO
61.4	14.0	11.0	0.6	17.9	0.2	0.4	0.9	0.1

For reference, the practical method of preparing the compost is given below:

1) Material (amount required for preparing 2 tons of compost, which is the standard amount applies per ha)

Straw of rice plants	1 ton (cut 20-30cm long)
lime	10 kg
water	a little
TSP	5 kg
urea	3 kg

2) Prepartion procedure

1 Location: $2m^2$ in area, with good drainage conditions
2 Pile up about 100 kg of cut straw
3 Trample and press down the pile
4 Scatter 1 kg of lime evenly on the pile
5 Water with 4-5 pails of water, until water cozes out in large amounts from the straw.
6 Repeat steps 2 to 5 ten times (for 10 layers)
7 Cover the top surface with long bundled straw, mat-rush or plastic film in order that rain may not enter.
8 Invert (turn over) the pile after one week Spraying evenly with 5 kg TSP and 3 kg urea in aqueous solutions while building up the pile.
9 Cover the top surface again as in 7
10 Invert the pile againa after one week, adding water if nečessary and covering the top surface as in 7

Compost can be prepared in 3 weeks.
Far longer preservation is possible.

(5) Plant and wood ashes are well known as a convenient sources of K fertilizer.

K included in the ashes is almost all available for crops and the content is 5-10% on the average although it varies with the kind of plant and wood.

These ashes can be prepared from fuel used in every household for cooking.

After collecting the ashes, they should be stored so as *not to be exposed to rain.*

Ashes as are produced from the residue of sugar care processing in sugar factories are better fertilizers which contain not only K but also a lot of Si and P.

(6) In addition to compost and plant or wood ashes, the application of green manure is also effective in supplementing the organic matter in the soil.

Since it has been used in some regions, application of Crotolaria juncea, a leguminous grass, is suggested 4-5 weeks before transplanting.

Part III : Nutritional Diagnosis and Fertilizer Trials

III-1. Nutritional Diagnosis of Rice Plants

For effective fertilization, nutritional diagnosis by inspection of the actual form of the rice plant is essential.

As a technique for nutritional diagnosis, it is useful to learn how to distinguish the nutrient deficiency symptoms.

It is requested that agricultural officials train themselves to increase their ability to judge accurately the diseases which are summarized in Table 7.

The methods for diagnosis by inspecting root conditions and soil improvement are as follows:

After removing the rice plant carefully and washing the root well, the color of the old root is inspected.

Rust or yellowish brown color indicates the healthy condition while white and black suggest a unsound root and a rotten root respectively.

A yellowish-brown root indicates that there is sufficient air in soil.

This is the color of ferric oxide which is a reaction product between iron and air in the soil.

The white root indicates the formation of the reduced form of iron on account of insufficient air in the soil.

When there is generation of hydrogen sulphide (H_2S) the plant root becomes black.

If root of the rice plant is white, soil aeration is required. Methods of providing oxygen in the soil include good drainage, dressing of soil containing oxydized iron and intertillage.

In case of black roots, the application of S containing fertilizers such as ammonium sulphate must be stopped.

III-2. Method of Fertilizer Trials

1. Purpose of Fertilizer Trials

The fertilizer trial is an important means of soluing the technical problems concerning fertilizer usage.

Table 7 : Element deficiency diseases of rice plants

Locations of symptoms	Development of symptoms	Characteristics of symptoms	Type of disease	How to distinguish from other diseases
Appearing in all parts	Growth decreases in all parts, more quickly in old leaves	Elongation or tillering retarded. Yellow appears starting from lower leaves.	N-deficiency	*Method of distinguishing N and S deficiencies* 1. After applying ammonium sulphate and ammonium chloride independently, N is deficient if both treatments cause growth recovery, and if only ammonium sulphate results in recovery, S is deficient.
		Elongation not very retarded. Yellow appears in leaves.	S-deficiency	
		Tillers become small in number, leaves in become narrow and, dark green. Lower leaves, leaf sheathes and stems become purple.	P-deficiency	2. *Leaf analysis for N and S.*
Appearing from old leaves	Occurs more at the beginning of growth	Lower leaves become yellow. Leaf blade lodges from the ligula part at right angles the maximum tillering stage.	Mg-deficiency	Very similer to N deficiency. K point of Mg-deficiency is that the leaf blade deoops from the ligula at right angles.
	Occurs more in *the middle or* end of growth	Leaves become dark green at the *heading stage, then elongation is* delayed and leaves become yellowishbrown or die from tip of lower leaves	K-deficiency	Point distinguishing it from Mg-deficiency is *that leaf becomes deep green.*
Appearing not in new and old leaves, but in middle ones		Leaf becomes wider and yellow along the veins. *Brown dead parts appear in* yellowed arears.	Mn-deficiency	This deficiency occurs more often when the content of available Mn or Fe in the soil is small and the reaction of the soil is neutral or alkaline.
Appearing in new leaves		New leaves become yellowish white, *which do not develop in the worst* cases. Old leaves remain green.	Fe-deficiency	Same as above.

For the time being, the fertilizer trials which are an essential step especially for establishing fertilization standards in the area concerned are expected to be conducted at the site in each Extension Center, making effective use of past experience from a series of field trials already carried out at the Extension Center under the name of "Observation Field".

2. Kinds of Fertilizer Trials

(1) Three element trial

The puspose of this trial is to clarify the natural supply of N, P and K. The natural supply means the quantity of nutrients which the soil itself and irrigation water can supply to crops, in addition to the artificially applied fertilizer components.

In most cases, this natural supply involves in particular N, P and K, which are known as three major elements for plant growth. In this trial, the yield gained from a one-component-free treatment is compared with that from complete treatment including N, P and K.

From this trial, it comes clear which of the three primary elements is most deficient.

Natural supply varies with the soil, climate, crop and cultivation methods. Since this is the most important and basic fertilizer trial for establishing fertilization standards adaptable to every area concerned, it is strongly advised to begin with this trial at Extension Centers which have no technical data on natural supply.

Basic design of this trial is as follows.

1 no fertilizer	5 N + P + K
2 − N	6 + N
3 − P	7 + P
4 − K	8 + K

Steps 6, 7 and 8 are not always necessary.

(2) Fertilization Method Trial

This trial is performed to establish a rational fertilization method in which the quantity of fertilizer, the timing of top-dressings, the frequency of fertilization, etc. are included as test parameters, aimed at increasing the yield or raising the quality.

The previously mentioned trials in Cihea and Muara are included in this trial. Along with the three elements trial, this trial is also basic in establishing the fertilization standard.

(3) Fertilizer response comparision trial

In this trial, the effects of various fertilizers are compared, including newly developed fertilizers and the fertilizers for which responses are still unknown.

(4) Economical fertilization trial

This trial is aimed at investigating economical methods of fertilizer application, or more precisely, at determining what kind of fertilizer is most beneficial or how much fertilizer should be applied per ha to obtain greatest benefits.

(5) Continuous application trial

This trial is intended to determine how the continuous application of the same kind of fertilizer for several seasons influences yield or quality of crop and soil.

(6) Residual effect trial

The aim of this trial is to estimate how much of the fertilizer components remain in the soil unabsorbed by the crop.

Some kinds of fertilizer components are not absorbed completely in one cropping season, but remain in the soil with some partion becoming available for the crop in the following season.

3. Basic Principles of Fertilizer Trials

(1) In all types of fertilizer trial, all conditions must be Rept constant in one trial except for the conditions which to be compared and investigated.

(2) It is necessary to include a basic standard, i.e. a control, with which the other trial results can be compared.

It is not scientific to evaluate fertilizer effects without comparing with a control.

(3) *Each trial should only have one objective*

Except in the case of factor analysis, it is not desirable to include, for instance, the three-element trial and the fertilization method trial smultaneously in one trial because such a diversified method often causes confusion and leads to unsatisfactory results.

4. Field Trial Procedure

(1) Selection of the field

It is first important to select a field uniform in geographical position and soil fertility.

Virgin land where no crop and no fertilizer have been introduced is most convenient for conducting the fertilizer trial.

If there is no unclutivated land in the area concerned, it is desirable to select land where fertilizer has been applied evenly and the same kind of crop has been cultivated.

When soil fertility is uneven, the field may not be used for trial purposes until the field becomes completely uniform in fertility by cultivating a crop which can easily grow uniformly under non-fertilized or evenly fertilized conditions.

Needless to say, the field must not be shaded.

(2) Area and shape of plot

In case of rice plants, a rectangular area of 15-30 m^2 per plot is adequate for the trials.

Repetition of the trials can be performed by dividing plots into sections of 10 m^2 to obtain correct data.

In paddy fields, it is necessary to prevent the fertilizer elements from funoff with irrigation water, by dividing every plot with ridge.

The intake and outlet of water must be independent *in each plot to prevent the intermixing of fertilizer from* other plots.

(3) *Method of collecting and evaluating the data*

The error becomes smaller as repetition increases.

When evaluating the results, data obtained from only one plot may never be used, together with those from the plots heavily damaged by disease or insects.

Important conclusions should be derived from data for at least 2 or 3 seasons, rather than only one season.

Strictly speaking, biological statistics, a mathematical *method, should be applied to determine significance.*

However, when trial is conducted only for the purpose of obtaining a rough trend, such as on one farmer's farm in the form of a "simple trial", statistical data processing is not always required.