16. THE PRESENT STATUS OF FERTILIZER PRODUCTION IN JAPAN AND CHARACTERISTICS OF NEW FERTILIZERS

Tatsuo HAYASE*

The Present Status of Fertilizer Industry in Japan and its Problems

(1) Increase of fertilizer consumption in the world.

The total fertilizer consumption in the world is estimated at 50,700,000 tons during the period of '66/67 which is an increase of 10% over the previous year. In additon, approximately 3,000,000 tons of rock phosphate was used as fertilizer in the whole world. The total fertilizer consumption is made up of 21,830,000 tons of nitrogen fertilizers (N), 15,810,000 tons of phosphate fertilizers (P_2O_5), and 13,100,000 tons of potash fertilizers (K_2O). All of these figures show 15, 7, and 7% increase respectively over the previous year. As shown in Table 1, during the next 10 years following, i.e. until '76/77 the average increse rate is estimated as 10% for N, 7% for P_2O_5 6.5% for K_2O, and 7.5% for the average of these three elements.

Table 1. 3 Nutrients Consumption Trend in the World

(in 1,000 Tons)

Elements	'62/64	'63/64	'64/65	'65/66	'66/67	Increase rate against last year (%)			
						'63/64	'64/65	'65/66	'66/67
N	13,163	15,015	16,370	19,007	21,826	14	9	16	15
P_2O_5	11,430	12,680	13,900	14,750	15,810	11	10	6	7
K_2O	9,290	10,080	11,170	12,190	13,096	9	11	9	7
Total	33,883	37,775	41,534	45,947	50,732	12	10	11	10

Table 2. Nitrogenous Fertilizer Consumption Trend in Each Area

(in 1,000 Tons)

Area	'62/63	'63/64	'64/65	'65/66	'66/67	Increase rate against last year (%)			
						'63/64	'64/65	'65/66	'66/67
Europe	4,958	5,405	5,897	6,490	7,049	9	9	10	8
U.S.S.R.	1,070	1,360	1,759	2,282	2,656	27	29	30	16
North, Middle America	3,959	4,502	4,807	5,557	6,328	14	7	16	14
South America	224	270	292	327	348	21	8	12	7
China Mainland, North Korea, North Vietnam	773	965	1,040	1,447	1,961	25	8	39	36
Another Asia	1,755	2,002	2,023	2,264	2,804	14	1	12	24
Africa	381	445	492	555	583	17	11	13	5
Oceania	47	67	64	86	97	43	- 4	34	13
Total	13,163	15,015	16,370	19,007	21,826	14	9	16	15

* Divisin of Chemical Fertilizers,
National Institute of Agricultural Sciences, Nishigahara, Kita-ku, Tokyo, 114 Japan

Table 3. Nitrogenous Fertilizer Production Trend in Each Area

(in 1,000 Tons)

Area	'62/63	'63/64	'64/65	'65/66	'66/67	Increase rate against last year (%)			
						'63/64	'64/65	'65/66	'66/67
Europe	5,791	6,361	7,110	7,917	8,759	10	12	11	11
U. S. S. R.	1,414	1,759	2,099	2,712	3,100	24	19	29	14
North, Middle America	3,916	4,520	5,049	5,793	6,237	15	12	15	10
South America	318	297	341	340	286	-7	13	—	-16
China Mainland, North Korea, North Vietname	298	541	590	595	895	82	9	1	50
Another Asia	1,588	1,819	2,020	2,272	2,593	15	11	12	14
Africa	180	184	205	235	240	2	11	15	2
Oceania	26	24	29	33	39	-8	21	14	18
Total	13,528	15,501	17,440	19,895	22,149	15	12	14	12

Table 4. Nitrogenous Fertilizer Production Rate in the World (%)

Fertilizer	'62/63	'63/64	'64/65	'65/66	'70/71 (Presumption)
Ammonium Sulphate	21	19	18	18	12 (Including Ammonium Nitrate Sulphate)
Ammonium Nitrate (Amm. Nitrate Sulphate)	29	29	30	28	22 (Not including Amm. Nitrate Sulphate)
Na. Nitrate	2	—	—	—	1
Ca. Nitrate	4	3	3	3	2
Ca. Cyanamide	2	2	2	2	1
Urea	9	10	10	11	14
Others					6 Ammonium Phosphate
Solid	14	15	15	16	7 Compound Fertilizer
Liquid	19	20	20	20	8 Liquid Ammonia

Table 5. Nitrogenous Fertilizers Export Rate in the World (%)

Fertilizer	'62/63	'63/64	'64/65	'65/66
Ammonium Sulphate	35	31	31	34
Ammonium Nitrate (Including Amm. Nitrate Sulphate)	22	20	17	14
Na Nitrate	6	5	4	4
Ca Nitrate	8	7	7	5
Ca Cyanamide	—	—	—	—
Urea	18	22	23	25
Others (Including Amm. Phoshate)	11	15	18	18

As long as any new project for plant extension is not drawn up, over-production of fertilizers will come to its peak during the period of '68/69 to '69/70, and production is expected to be well balanced with the demand for the year '74/75 on.

Nitrogen fertilizer consumption by each region is listed in Table 2, which shows an outstanding increase rate in Asia. This is due to the 40% increase of nitrogen fertilizer imported mainly by Mainland China and India.

(2) **Increse of nitrogen fertilizer production in foreign countries**

Changes in nitrogen fertilizer production by each region of the world are seen in Table 3. Remarkable thing is the considerable increase of production rate in Mainland China and North Korea, and also the facts that Kuwait started production in their own country and European countries are included among the fertilizer exporting countries. In the same table, decrease of Chili saltpetre export from South America also attracts our attention.

When itemized, production of urea is steadily increasing as seen in Table 4. Urea is the most important for its high rate among the ni trogen fertilizers appeared on the inter-

Table 6. Fertilizer (2 Elements) Production and Demand in Japan (1955—1967)

Nitrogenous Fertilizer (N, P_2O_5 1,000 Tons)

Year	Output	Domestic demand	Export	Stock
'55/56	713.4	567.2	129.6	64.5
'56/57	781.6	589.9	192.6	63.6
'57/58	886.2	592.8	248.2	108.8
'58/59	993.9	613.2	311.2	178.3
'59/60	928.6	680.8	297.7	91.4
'60/61	1,064.7	693.2	297.4	165.5
'61/62	1,121.0	667.6	398.8	195.3
'62/63	1,165.7	698.5	508.8	153.7
'63/64	1,298.4	736.9	581.9	133.3
'64/65	1,392.9	721.3	634.2	170.7
'65/66	1,635.1	769.2	775.5	261.1
'66/67	1,789.3	842.0	930.6	277.8
'67/68	2,034.7	889.4	1,051.6	371.5
Phosphate Fertilizer				
'55/56	461.1	391.6	59.6	46.6
'56/57	479.1	412.9	51.3	61.5
'57/58	426.9	392.6	33.0	62.8
'58/59	433.4	406.8	31.4	58.0
'59/60	496.8	464.3	26.3	64.2
'60/61	540.3	493.2	27.5	83.8
'61/62	519.4	470.3	49.1	74.7
'62/63	531.1	493.4	34.7	77.7
'63/64	569.2	532.2	37.9	76.8
'64/65	622.7	534.7	69.2	95.6
'65/66	637.7	574.3	54.4	104.6
'66/67	648.8	619.9	34.0	99.5
'67/68	715.3	670.7	31.2	111.2

national market. Although export of ammonium sulphate is also taking an upward tendency (Table 5), whether or not the increasing tendency can continue in future is a question when the manufacturing conditions are taken into consideration.

Referring to price of fertilizer, AID data predict that with the decline in price maintaining power, fertilizer prices may drop generally in the free market. If production becomes stagnant despite of the enormous latent demand for fertilizer, as a consequence it is feared that the world famine problem will become acute.

(3) Ferftilizer production in Japan

At present, demand and supply of fertilizer in Japan are both increasing every year as seen in Table 6. Although Japan's fertilizer industry has been enjoying speedy growth during the past twenty years, it is far inferior to that of the western countries in the scale of business. Moreover, partly because the number of enterprises is large, excess competition within the industry tends to be intensified and there is an indication that various kinds of products are manufactured in small quantities in each enterprise. These unfavorable factors sometimes bring forth the decline of earning rate or deterioration of capital composition, and weaken the enterprise in the ability to develop new technology, to cultivate new market, or to raise business funds. In order to meet keen competition in the international market, both modernization of outdated factory setup including abandonment of superfluous facilities, and expansion of plants must be attempted.

The chemical fertilizer industry of Japan has been producing mainly ammonia nitrogenous fertilizers and phosphate fertilizers. When they to expand plants, caution is being taken against superfluous over-equipment by balancing supply with demand through scrap-and-build system, and by joining their efforts in investment and business management.

These attempts are being made mainly in the production of ammonia and phosphoric acid which are intermediate materials for chemical fertilizer production.

Despite a considerable number of enterprises, such attempts mentioned above have not been made in manufacturing final products. This is due to the proper guidance provided from the govenment authorities concerned for export and domestic sales, resulting in less competition among the trade during the past years in the case of ammonium sulphate production.

(4) Ammonium industry

Ammonia production in Japan ranks the third following U.S.A. and U.S.S.R. until 1967 as seen in Table 7. However, such large production is supported by small plants which belong to 63 enterprises. One company has a capacity of 150 t/day production on the average. Among these 63, are included 6 which were built after the spring of 1965, and has productivity of 500 t/day. Those other than big 6 are far smaller in production capacity than the average.

In Europe and America, backed by the increase in the demand of nitrogen all over the world and also by technical innovation, expansion of facilities for ammonium produc-

Table 7. Production Capacity of Ammonia

Country	Capacity (t/d)
U. S. A.	40,000
U. S. S. R.	15,000
Japan	9,000
West Germany	9,000
France	7,000

Table 8. **Strengthening Capacity (>500 t/d) Rate of Producing Ammonia in Each Country**

Country	$\frac{\text{Strengthening Capacity}}{\text{Total Capacity}}$ (%)
U. S. A.	45
Japan	33
West Germany	15
France	35
Holland	52
United Kingdom	75
Canada	50
Belgium	28

tion has been in progress, and brilliant result is being obtained. A comparison between Japan and western countries is shown in Table 8.

Production of ammonia nitrogenous fertilizers (like ammonium sulphate, ammonium chloride, ammonium nitrate, and urea), has remarkably increased since the latter half of 1950's in Japan. Such increase in production was attributable to the increase of exported fertilizers rather than the increase of domestic demand as seen in Table 6. Thus, Japan's nitrogenous fertilizer industry can be said to have switched over to an export industry. This conversion was made possible under the conditions that utilization of lowcost hydrogen source as raw material for ammonia synthesis, including crude petroleum, natural gas, naphtha, butane, COG, or waste gas of petro-chemical industry, has been faciliated. All these progress and changes in chemical engineering have urged to expand factory facilities which have productive capacity of 1,000 t/d or even 1,500 t/d.

These technical changes reduced the difference in cost between the products of western countries and Japan to be 3 dollars per ton. Our geographical advantage in shipping products to South-East Asia or to Mainland China can make up for the difference in the high cost of raw materials.

Especially in the case of urea, prices in the markets of Mainland China and India are lower, by 6 dollars per ton and 3-4 dollars per ton respectively, than those shipped from Europe or America due to the advantageous freight. The total export to these two countries amounts to 165 million dollars during '67/68 period.

However, NITREX, Japan's great competitor, gave a shock to the fertilizer industry in this country by quoting prices as low as 28 dollars per ton for ammonium sulphate and 59 dollars per ton for urea for export to Mainland China. This fact indicates the further expansion of industrial facilities in Europe which allows price reduction of urea lower than 60 dollars per ton with sufficient profit.

The average export prices in Japan are :

Year	Ammonium sulphate \$ / t	Urea \$ / t
'65/66	48	92
'66/67	39	78
'67/68	34	72

Table 9. Scrap-and-Build Equipment Plan of Ammonia (1967, Aug.)

(NH_3 Tons/Day)

Maker	New Capacity	Cap. of Abolishable Equipment		Increased Cap.
Mitsubishi Chemical	1,000	Kurosaki	483	517
Mitsui Toatsu (Toa Gosei)	1,000	Ōmuta Hokkaido Nagoya	113 216 135 464	536
Nippon Kasei	1,000	Tōhoku Nissui	283 224 507	493
Asahi Chemical	800	Chisso Asahi Chem.	86 102 188	612
Kashima Ammonia	1,000	Nitto Chem. Yokohama Mitsubishi Petro Chem.	170 187 153 510	490
Showa Denko Nissan Chemical	1,000	Showa Denko Nissan	150 65 215	785
Ube Industries	1,000	Ube	676	324
Sumitomo Chemical Seitetsu Chemical	1,000	Seitetsu Beffu Himeji	181 177 358	642
Japan Gas Chemical	600	Niigata	306	294
Toyo Gas Chemical	750	Toyo Gas Muroran Mitsui Toatsu	284 147 226 657	93
Total	9,150		4,364	4,786

For price reduction, plant expansion became the first requirement to meet the international competition. Table 9 shows the expansion plan mapped out in August of 1967.

In contrast with the expansion of ammonium industry, production of synthetic ammonium sulphate decreased year after year owing to the decline in the domestic demand and also to the economical disadvantage when compared to both recovered and by-produced ammonium sulphates. By 1966, its production had already been decreased to be less than half of the total ammonium sulphate production. Recovered ammonium sulphate, being easily recovered from ammonia or sulphuric acid which have been used for other industrial purposes, has an advantage over others in the production cost. Its recovery is possible from those industries of caprolactam, methylmethaacrylate, sulfamic acid, titanium dioxide, or melamine.

By-produced ammonium sulphate is produced by collecting ammonia contained in the coke oven gas with sulphuric acid. The amount is proportional to the coke production. It is naturally influenced by the production of major products in city gas works, coke works or iron mills.

Recently, production of recovered ammonium sulphate through desulfulization of waste gas and by-produced ammonium sulphate through desulfulizaton of crude oil have been started. These production methods are serving as a countermesure against air pollution at the same time.

(5) **Phosphate fertilizers**

Rationalization of phosphate fertilizer production has been quickened since 1967.

The principal raw material of phosphate fertilizers is phosphoric acid which is produced from phosphate rock and sulfuric acid. In recent years, about 2,500,000 tons of phosphate rock has been imported annually at the freight of around 11 dollars per ton.

Although the number of sulphuric acid enterprises and factories are 20 and 23 respectively, their production scales are all strikingly small. For instance, productivity is only 77 t/d in one factory and 59 t/d in one enterprise on the average as of April 1, 1968. These are far smaller when compared with the average capacity of 386 t/d (1967) in 43 factories of the U.S.A.

The total production of phosphoric acid in Japan is 455,000 tons in 1967, 82% of which is utilized for fertilizer and the rest, mainly for the production of sodium tripoly phosphate and feed stuff. Out of the phosphate used for fertilizer production, 88% becomes raw material for high analysis compound fertilizer. The annual 20% increase of phosphate porduction during the past few years, is attributed to the remarkable increase in demand of high analysis compound fertilizer.

Export of phosphate fertilizers from Japan does not account for 5% of the total produced in the country. This indicates that most of the products are for domestic use. In comparison with that of the U.S.A., the cost of phosphate production is higher, for such reasons as small manufacturing scales, dependence on the imported raw phosphate, and relatively high cost of sulphuric acid.

If the production cost of ammonium phosphate is as high as 36,000 yen per ton in Japan, imported products is lower in price by 20% on CIF base.

In order to meet the competition, all the production process of sulphuric and, phoshoric acid, ammonium phosphate should be expanded in scale. Although 500 tons per day is the minimum production to be comparable to the foreign competitors, the present target is over 200 tons per day for phosphoric acid and 400 tons per day for ammonium phosphate due to the difficulty in by-produced gips.

Phosphate fertilizer production involves other problems like location of factory or selection of the kind of product mostly needed in the area.

The present capacity of phosphoric acid production is shown in Table 10. Those enterprises which are expanding plants and have plans for expansion are :

Name of Enterprise	Phosphoric acid t/d	Amm. phosphate t/d	Sulf. acid t/d
NIHON RINSAN	200	400	1,000(1969)
Sun Chemicals	200	300	·········(1970)
RASA Industries	100	120	·········(1968) (Oct)
TOHOKU Chemical Fertilizers	148	120	·········(1968) Dec)

In the case of RASA Industries, price of sulphuric acid is low because refined gas from their own factory is being used for its production. Tohoku Chemical Fertilizer is utilizing low cost sulphuric acid obtained from the refined gas of Akita Refinery of Mitsubishi Mineral, Ltd. adjacent to the factory. Utilization of sulphuric acid from such source is showing an upward tendency in wider area.

Table 10. Capacity of Phosphoric Acid Production

(P_2O_5 Tons/ Year) (1968, Apr.)

Maker	Apr. 1, 1968		Apr. 1, 1968-June 30 1969 Capacity of Increase		Factory
	Tons/Day	Tons/Year			
Mitsui Toatsu	42 110 31	13,600 36,900 10,800			Hokkaido Hikoshima Omuta
Nitto Chemical	81	26,000			
Rasa Industries	67	23,000	56,900	1968, Oct.	
Tohoku Fertilizer	188	63,200			
Nippon Suiso	39	12,800			
Niigata Ryusan	81	26,900			
Toyo Gas Chemical	31	10,200			
Nissan Chemical	51 115	17,300 39,000	0	1969 Apr.	Ōji Toyama
Nippon Godo	43	15,000			
Asahi Glass	—	—	24,000	1969, May.	
Nippon Rinsan	—	—	68,000	1969, Apr.	
Nippon Kokan	56	19,300			
Ishihara Sangyo	40	13,400			
Tagi Seihi	55	18,800			
Kōnoshima Chem.	35	12,200			
Toyo Soda	—	—	33,000	1969, May	
Ube Industries	46	15,100	24,700	1968, July	
Central Glass	193	66,600			
Sumitomo Chemical	145	48,600			
Kyushu Chemical	33	10,700			
Mitsubishi Chemical	106	36,000	39,200	1968, Oct.	
Chisso	85	29,000	32,400	1968, July	
Onoda Chemical	87	24,400			
Total	1,760	588,800			

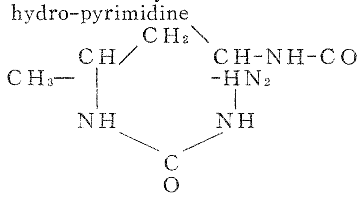
Characteristics of New Fertilizers

(1) Slowly available nitrogen fertilizers

There are four kinds of newly developed fertilizers that are placed on the market and proved effective (Table 11).

Table 11. Slowly Available Nitrogen Fertilizers

(Commercially available)

Name and abbreviation	Raw material	Constitution, structure, chemical formula	N%	Solubility g/100 ml H_2O
Ureaform UF	Urea+Form-aldehyde	Mixture of methylene urea U-CH_2-U	40—43%	2—0. 1
IBDU IB	Urea+Isobutyl-aldehyde	Isobuthylidene diurea $(U)_2$>CH—CH<$(CH_3)_2$	32.16	0. 1—0. 01
Crotonilidene diurea CDU	Urea+Acetal-dehyde	2-Oxo-4-methyl-6-ureido-hexa-hydro-pyrimidine 	32.54	0. 12
Guanylurea GU	Calcium Cyanami-de→Dicyandiamide →	NH_2—C(=NH)—NH—CO—NH_2 Phosphate Sulphate	ab 28 ab 37	2—4

Among them, Uraform and CDU generally become available in the soil with the aid of soil micro-organisms. IB is absorbed by plants mainly through hydrolysis. GU presumably becomes available after being decomposed by soil micro-organisms.

Although there are various characteristics as fertilizers in both hydrolysis-type fertilizers and the ones utilized after decomposition by soil micro-organisms, the latter is generally slow in the ferilizer effectiveness.

However, in the case of hydrolysis-type fertilizers, the time when they gain the effect can be controlled by changing the size or hardness of the fertilizer granules, while those of the other type are hard to control the time of release.

In hydrolysis-type fertilizers, if only one kind of fertilizer is applied, sometimes decomposition completes in a comparatively short time once it is started. In this respect, advantage of the fertilizers which are decomposed by microorganisms is to prevent salt injury caused by high fertilizer concentration.

Under the name of slowly available nitrogen fertilizer, there are various kinds which differ each other in caracteristics. It becomes necessary to choose an application method that suits the purpose best.

GU is now being used exclusively for rice in paddy field, IB for rice, wheat and barley, and both Ureaform and CDU are being used for vegetables and flowers.

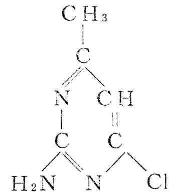
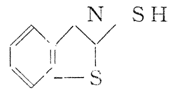
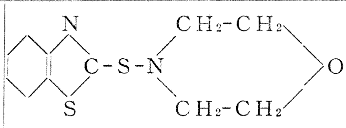
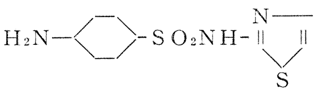
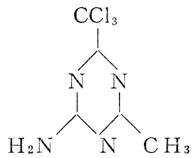
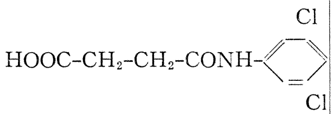
(2) **Nitification inhibitors**

Nitrification inhibitors which are put on the market and proved effective are listed in Table 12.

All the nitrification inhibitors must have at least the following four properties :

(1) To maintain its inhibiting effect for a certain period of time
(2) To be harmless to human beings, animals, and to fish
(3) Not to react within the components of the mixture when it is mixed with fertilizer
(4) Not to cause disorder in the plant at its early growth stage

Table 12. Nitrification Inhibitors

Common Name	Chemical Name	Chemical Formula	Solubility
Thiourea	thiourea	NH_2-CS-NH_2	12.1 g (20°C)
Dd	dicyandiamide	NH_2—C(=NH)—NH—CN	4.1 g (25°C)
AM	2-amino-4-chloro-6-methyl-pyrimidine		12.7mg(20°C)
MBT	2-mercapto-benzothiazole		<100mg
KN	2-benzothiazole-sulfene-morpholine		
ST	sulfa-thiazole		60mg(26°C) pH6 235mg(37°C) pH7
MT	2-trichloro-methyl-4-methyl-6-amino-triazine		
DCS	n-2, 5-dichloro-phenyl-succinamide		26mg(40°C)
ASU	guanylthiourea	NH_2-C(=NH)-NH-C(=S)-NH_2	

There are other special requirements than those listed above. For example, N-Serve made in U.S.A. has stronger inhibiting effect than Japanese products in Table 12, but when mixed with fertilizer, it acts on mucosae in the eyes and nose of human body. Also its sublimation is so rapid that it volatilizes very quickly even when mixed in granular fertilizers. Therefore, it must be injected directly from an air-tight container into the soil over 10cm below the surface. For these reasons, it was not been put to practical use in Japan.

Among those listed in Table 12, both MBT and KN are chemicals which have a benzothiazol radical and are effective to increase number of tillers and shorten the grass height. Although the mechanism is not elucidated yet, such nitrification inhibitors with chemical properties which can control physiological changes in plant seem to increase in number and variety of products.

(3) **Other new fertilizers**

Among others, coated fertilizer, condensed phosphate, and slowly released potash fertilizer are being investigated as new promising fertilizers.

Discussion

M.W. Thenabadu, Ceylon : Please comment on ammonium chlolide as a fertilizer. Is it a by-product of any other industry? Has it any nitrification inhibiting properties?

Answer : The production method of ammonium chloride in Japan is a modification of the Solvay ammonia-soda process used for producing sodium carbonate (soda-ash). This method can be said to be more economical through salting out the ammonium chloride and recovering all the sodium bicarbonate. Thus, ammonium chloride is the cheapest nitrogen fertilizer in Japan, and in my opinion, is not a by-product but main product in the glass industry. The nitrogen efficiency of ammonium chloride for rice plants is the same as ammonium sulphate according to the tremendous field experiments. Of course, it is superior to ammonium sulphate in degraded paddy field or of Akiochi soil because of no content of of sulphate. Furthermore, when applied at top dressing for paddy rice, ammonium chloride appears to have a slow availability as compared to ammonium sulphate. It is observed in some cases that the elongation of No. 3-5 internode of rice stem from the top is controled by the application of ammonium chloride at "Hogoe" stage, resulted in the increasing resistance for lodging.

Y. Takijima, Japan : Let me know the future possibility of the production of slowly available K fertilizers, in view of some prevalency of K deficient soils is the tropics such as bronzing-sick soils and expectable effect of top-dressing of K.

Answer : The more promising slowly available potassium fertilizers are : potassium metaphosphate, fused product of mixture of rock phosphate and potassium sulphate, and materials treated Liparite with KOH. These materials are hardly water-soluble, but soluble in 2 % citric acid solution. In addition, controlling of K availability can be achieved by the coatings of granular water soluble potassium fertilizers. The results obtained upto the present time show that slow availability of these materials is observed, but there is no clear-cut benefits in view of economical basis. At any rate, further studies will be needed about this problem.

S. K. De Datta, IRRI : In how many places the slow release fertilizers have been proved to be superior to other ammonium sulphate or urea for rice, in term of increasing the grain yield? If superior in grain yield production, what level of increases were obtained?

Answer : In the past several years, the nation-wide field experiments were conducted with every slowly available nitrogen fertilizer. IBDU and GU are more promising nitrogen for rice cultivation. These nitrogen efficiency is obviously superior to urea and ammonium sulphate. I will show you an example in regard with IBDU. IBDU compound fertilizer (10-10-10) for rice plants is approximately 8 mm in granular size, and nitrogen consists of 80% IBDU and 20% Urea. The cost is approximately 50% higher than that of usual compound fertilizers. According to many field experiments in Japan, brown grain yields with only basal application of the IBDU compound fertilizer are almost the same as or more than those with the split application of usual nitrogen fertilizers. When compared with the only basal application, grain yields are about 10% higher than those with usual compound fertilizer. In this case, average grain yields are about 5.5 ton/ha. Furthermore, top dressing at panicle formation stage is recommended to increase the yield, even if applied with IBDU as a basal application. Thus, the utilization of IBDU for rice cultivation is concluded to eliminate the top dressing in many cases, but to be necessary to expect higher yield. The similar results are obtained with GU fertilizer.

(Comment) S. **Mitsui**, Japan : In connection with the presentation I made an additional comment on the specific configuration of fertilizer production of Japan. Historically, the research on acid soil and its improvement and on the so-called AKIOCHI soil and its amelioration have been the two main incentive to result in a remarkable increase of urea fertilizer, set up ammonium chloride industry and fused magnesium phosphate (all non-sulphatic fertilizers). The nitrate nitrogen problem was also discussed.

Soebijanto, Indonesia : What is the N-content of the slow releasing N-fertilizer, what is the per by N compared with urea?

Answer : The nitrogen contents ars shown in Table 11 in my paper. As for the price of these fertilizers, I have already answered.

S. **Yoshida**, IRRI : We have tested effects of potassium metaphosphate, potassium silicate, KCl, and K_2SO_4 on rice in calcarious soils in Philippines. The results were that potassium metaphosphate and potassium silicate are as fast and releasing as KCl or K_2SO_4.

Answer : The slowly availability of potassium metaphosphate is closely related to its granule size. If applied with the pulverant KPO_3 any slow availability may not be expected. This may be attributed to the easy exchange reaction of K in KPO_3 with cations in soil solutions.

S. C. Hsu, Taiwan : Will you please tell me the market price of the slowly available nitrogen fetilizers and the nitrification inhibitors which are popular in Japan at present?

Answer : All the slowly available nitrogen fertilizer listed in Table 11 have a cost of twice as much or greater than N per unit from usual nitrogen fertilizer such as urea. Nitrification inhibitors can be only commercially available with the form of compound fertilizers. In this case, the compound fertilizers containing nitrification inhibitors are 10-20% more expensive than the usual compound fertilizers. These two materials are not so popular in Japan, but the production and consumption increases with a high rate year by year.

Y. Ota ; Japan : I was very much interested in nitrification inhibitors from the point of plant growth. Is there any data that show direct effect of the materials on plant growth?

Answer : As mentioned in my presentation, nitrogen inhibitors having benzothiazol radicals have obviously a direct (not indirect) effect on plant growth, I think. These data were presented in our Ann. Report of the Division of Chemical Fertilizers, No. 114(1967). As nitrogen inhibitors have the similar structures to herbicides and plant hormones, further extensive studies will be necessary to elucidate their direct effect on plant growth from the standpoint of plant physiology.

(Comment-to question of Dr. De Datta) H.R. von Uexkull, Germany : The main reasons for the development of slow release fertilizer have not been to obtain a higher yield, but rather to simplify fertilizer application, reduce labor cost and to make nitrogen application less risky. Slow release fertilizers are slso less hygroscopic.