MEANS OF INCREASING RICE PRODUCTION

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CENTRE D'ETUDE DE L'AZOTE - GENEVA

Frontispiece: *Cutting rice in Egypt*

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FOREWORD

West European Nitrogenous Fertilizer Manufacturers have felt, for many years that the quantity of world food production could be greatly improved by intelligent application and increased consumption of nitrogen fertilizers, and by these means contribute to a higher standard of living for the world's population in general.

In order to further this nitrogen producers in Austria, Belgium, France, Germany, Italy, the Netherlands, Norway, Switzerland and the United Kingdom founded in April 1953 the Centre d'Etude de l'Azote *in Geneva, with the object of making a scientific and practical study of the methods which may assure rational and increasing use of nitrogenous fertilizers in the world.*

The Centre d'Etude de l'Azote *endeavours to realize this object by collecting relative data and issuing publications concerning improved and increased production of human food and animal feeding stuffs. The book* Means of Increasing Rice Production *is one of its first publications.*

This book does not claim to be a complete handbook for the rice grower, but it stresses the possibilities of increasing rice production by means of efficient fertilizing without neglecting or underestimating the importance of so many other factors that contribute greatly to larger yields and that often form the basis for maximum fertilizer response.

The subject of this book was chosen, not because the production of rice is more closely connected with nitrogen than any other crop — as a matter of fact there are many crops that respond much more to nitrogen fertilizers than rice — but because rice is the principal food for more than half of the world's population, and the wellbeing, standard of living, and prosperity of so many countries are dependant on this commodity.

May Means of Increasing Rice Production *fulfil the purpose for which it was written.*

Geneva, 42 Rue du Rhône.
June 1954

CENTRE D'ETUDE DE L'AZOTE

C. BOUDEWIJN, Chairman
A. LANG, Secretary

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I am greatly indebted to Dr. H. L. Richardson, I.C.I. London, not only for his most interesting contribution to this book concerning fertilizing results on paddy in China, but also for his kind and valuable help in so many other ways.

I also wish to thank Dr. G. Watts Padwick of I.C.I. for having revised the English phraseology and particularly the chapter dealing with pests and diseases and their control.

J. G. DE GEUS

Measures and weights are usually expressed in hectares and kilograms, except for those countries where acres and lb. are customary.

The following photographs are reproduced bij courtesy of the Koninklijk Instituut v/d Tropen, Amsterdam: p. 13 H. Bongers, p. 16, p. 18 H. Bongers, p. 19 A. d'Angremont, p. 23 (above) Thio Piek, p. 23 (below) Mr. F. A. Brusse, p. 25, p. 41 N.V. Stoomvaartmij. „Nederland", p. 46 Dr. W. v. d. Sleen, p. 52 and p. 70 Thio Piek, p. 94 and p. 103 Resident van Steenis.

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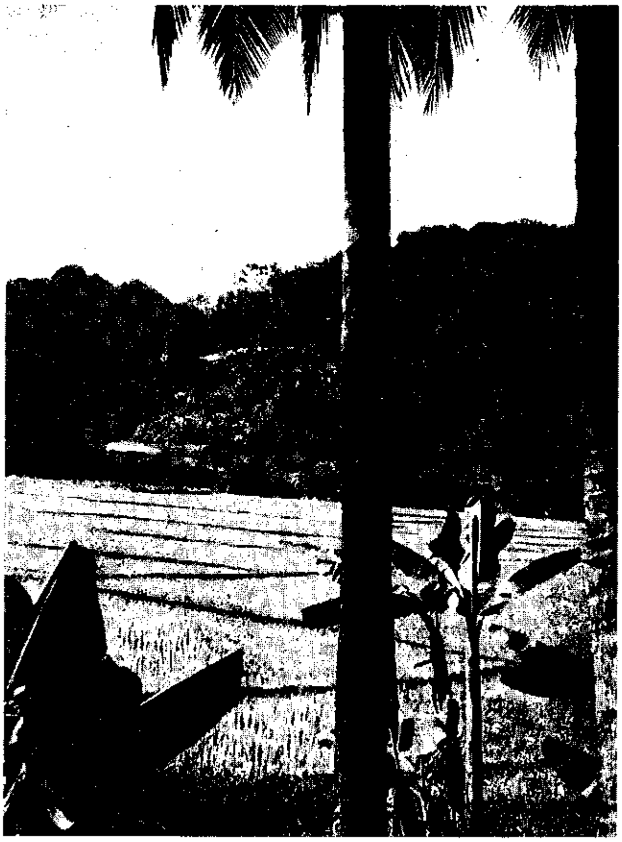
SOME PARTICULARS ABOUT WORLD RICE SHORTAGE

NO COUNTRY in the world can enjoy the blessings of peace and tranquillity, let alone the most primitive form of prosperity, as long as its inhabitants are forced to live in the state of hunger or under-nourishment prevalent today in very many Asiatic countries with rice-eating populations.

In prewar years the world rice production amounted to a figure of about 150 million tons of paddy, equivalent to about 100 million tons of milled rice from a total area of about 85 million hectares (210 million acres).

As by far the greater part of this rice is consumed by the producing countries themselves, not more than about 8.5 million tons of milled rice entered world trade. The most important exporters of rice were:

	Average exports 1934-38 (million tons of milled rice)
Burma	3.07
Thailand	1.39
Indo-China	1.32
Korea	1.16
Taiwan	0.68
Total main exporting countries	7.62



Western Java. Paddy fields in the plains, forests on the slopes against import requirements for Asiatic countries of:

	Average imports 1934-38 (million tons of milled rice)
India/Pakistan	2.16
Japan	1.76
Malaya	0.72
China	0.70
Ceylon	0.53
Indonesia	0.28
Philippines	0.04
Others	0.72
Total	6.91

Under pre-war conditions Korea and Formosa (Taiwan) were parts of the Japanese Empire and thus forced to meet the Japanese demands for rice.

The demand for rice in India was met by Burma, but during the second world war significant changes occured in the rice production pattern, one of the most important being the considerable decrease in production in the rice exporting countries, Burma and Indo-China. This is demonstrated by the following figures:

	Rice area in 1000 hectares	
	Average 1934–38	*1946–47*
Indo-China	5,590	3,950
Burma	4,931	3,018

	Production of paddy (rough rice) (in million tons)	
	Average 1934–38	*1946–47*
Indo-China	6.50	4.30
Burma	6.97	3.84

According to an official estimate some 25% of the rice land in Thailand was lying fallow at the end of the war.

As a result of these instances of decrease in production, the pre-war rice-exporting countries had, at the end of the war, hardly any supplies available for export. This is well illustrated by the following export figures for 1946:

	Export in 1946 (in 1000 tons)	*Prewar average*
Burma	480	3,070
Indo-China	109	1,320
Thailand	492	1,390
Total	1,081	5,780

Moreover, as Korea had changed from a surplus to a deficit area, the natural consequence was that in the immediate postwar period rice became one of the most important world food commodities in short supply.

Substitute foods, such as wheat, barley and coarse grains had, therefore, to be imported to make up this shortage, although rice still is, and will remain, by far the most popular food in Eastern countries.

There has recently been a gradual increase in production and exportable surplus of rice in the former exporting countries, although, owing to unsettled political conditions, the total rice production in and export from Indo-China and Burma are far below pre-war level. Moreover, as acreage under rice production has expanded considerably in North and South America, total world production has by now even surpassed that attained before the outbreak of the last war. This increase of production, however, having been accompanied by a much greater rate of increase of population, the world is still, and is likely to be for many years to come, faced with a rice shortage because, as a result of the excessive increase in the population of rice-consuming areas, the demand steadily increases.

Special efforts should be directed, therefore, towards increasing world rice stocks by means of expanding the areas of production and increased yields per unit area, if for no other reason than that there is no factor more important for world peace and prosperity than a sufficiency of rice supplies in Asiatic countries.

As far as the expansion of rice acreage is concerned, this could to a large extent be achieved by the reclamation of cultivable wasteland in some of the less densely populated countries of Southeast Asia, such as Burma, Siam and Indo-China. As mechanised rice cultivation in those countries is still in the experimental stage, labour and available draft animals often limit the desired increase in area under cultivation.

Many regions in the Western Hemisphere still provide great possibilities for an expansion of rice production in areas that are at present largely wasteland devoted to the limited cultivation of other crops or under cattle grazing, but in which future expansion will depend, not only on available labour supply, but also on the relationship between the prices offered for rice and other products.

Although possibilities thus exist for expanding acreage under rice in certain areas, they cannot provide the solution of the problem confronting very many Eastern countries where these potentialities for expansion do not exist and which are not in the financial position to purchase rice from abroad, apart from other disadvantages of forcing such countries to depend on foreign sources of rice supply. Even more important, therefore, than the expansion of rice acreage will be the problem of increasing yields in existing rice areas by the following means:

(1) Extending irrigation facilities and improving the regulation of water supply.
(2) Judicious fertilizing schemes.
(3) Wider use of green manuring.
(4) Improved soil preparation and general cultural practices, combined with improvements in the supply and types of implements normally used in rice growing.
(5) Production of higher yielding varieties of improved quality by plant breeding.
(6) More efficient control of pests, diseases and weeds.

All these steps towards yield increase must be supplemented by attention to the conservation of available supplies through improved storage conditions, including effective control of insects and rodents, and the highest possible efficiency in the milling process.

Before discussing in more detail many of the yield improvement factors already mentioned, the important characteristics of the different forms and varieties of rice will be described.

THE DIFFERENT FORMS AND VARIETIES OF RICE

IN ADDITION to the many wild species of the genus *Oryza* there are two cultivated species, viz. *O. sativa*, found in all the rice-growing areas of the world, and *O. glaberrima,* which is confined in its distribution to tropical West Africa.

O. sativa comprises a wide range of forms and the fact that the diversity in this species is nowhere as great as it is in India might indicate that India and Indo-China should be considered as the countries of origin of this species. More or less as a consequence wild rice, *O. sativa* var. *fatua,* whose natural hybrids with cultivated rice occur in cultivated fields and are undistinguishable from cultivated forms until the ears appear, constitutes a great nuisance in India and more especially in the states of Madhaya Pradesh, Bombay, Orissa, Bihar and Punjab. The most promising method of control consists in introducing to the local variety a pigment gene, originating from specially pigmented varieties, so that hybrids with wild rice can easily be identified by this anthocyanin-factor in the early stages and removed by weeding.

O. sativa can be further sub-divided into two geographical races, *O. sativa* var. *japonica,* cultivated in Japan, Korea, China and other rice-growing areas in the subtropics and *O. sativa var. indica,* cultivated in India and the rice belt of the tropical Asian countries.

Japonica rices are characterized by high yields, good response to intensive manuring, short non-lodging straw, a round coarse or bold type of grain and higher percentage of rice to unhulled grain, whereas the Indica rices, with a longer type of grain, are generally much lower in yield and cannot stand such heavy manuring because of a relatively stronger vegetative growth, but are hardier and more resistant to unfavourable conditions.

Japonica varieties are definitely less suitable than Indica varieties for the Indica zone of cultivation and vice versa, but Japonica rice may be crossed with Indica varieties to increase the yields of the Indica zone. This hybridization work has been undertaken on a large scale at the well-known Cuttack Rice Research Institute under the auspices of the International Rice Hybridization Project.

O. sativa exhibits striking variability also in the following respects:

(a) Early maturing varieties with a growing period of less than 80 days as compared with late maturing varieties with a vegetation period of as many as 200 days.

(b) Varieties adapted to salty water inundation as compared with others that require fresh water.

(c) Deep water or floating rice that has the capacity to grow as much as a foot a day if flood waters rise at that rate, up to a height of 15 feet or more. When the water level falls, the plant stalks trail along the soil surface and eventually become embedded in the mud. From each node of the elongated, tender stem a secondary stalk sprouts and the new stand grows and matures on the moisture and nutrients in the mud obtained from the receding flood.

(d) Upland rice, dependent on rain and growing like other cereals without irrigation, as compared with lowland or wet rice, grown under irrigation or sometimes in natural swamps where there is standing water during the growing season.

(e) Varieties which are time limited in growth, signifying those which take approximately the same period to mature irrespective of when they are sown or transplanted, as compared with those which are season limited, coming to maturity at a particular season of the year, irrespective of the time of the year at which they were sown or transplanted, by extending or reducing their life periods. Most of the short-lived varieties of rice which take less than 120 days to mature belong to the time limited class.

(f) Common varieties, comprising those whose kernels remain well separated after cooking as compared with the far less important glutinous varieties, which produce a gluey, sticky mass when boiled and are used for special foods, such as pastries and confections.

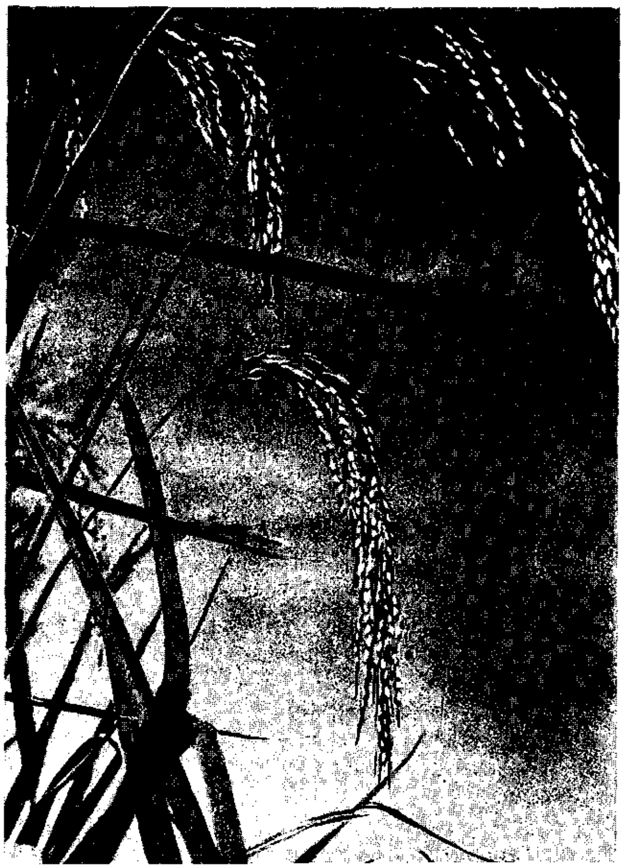
Varieties which are well adapted to growing in salty concentrations may be very useful in coastal areas containing brackish water, where, as in Egypt, they are used in the reclamation of salty soil along the coast by leaching out the salt with the large quantities of fresh water required for rice growing. When sufficient salt has been removed, the soil is sown with bersim *(Trifolium alexandrinum)*.

As long as this crop shows a reddish appearance and yields remain low, the salt content of the soil is still too high and rice growing should be continued until there is a low enough salt content in the soil to enable it to support other crops.

The yields of such salt resistant varieties are considerably below the average, but the main purpose for which they are grown is soil improvement.

World production of wetland rice is much more important than that of upland rice, because the total area under the former is many times greater and the average yields of upland

Paddy



rice are much lower, often only half as much or less. The distinction between upland and wetland rice is not an absolute one, for although the latter can practically never be grown on upland areas, the reverse is possible in the case of certain upland varieties.

All of the upland varieties are characterised by a relatively short growing period, fluctuating from 3 to 4 months in the wet monsoon in tropical areas to 6 months or more in more temperate regions. The grains of the upland varieties are usually somewhat coarser and in less demand commercially.

For wet rice growing monoculture, that is, rice planted after rice in successive seasons, is not uncommon, but in the case of upland rice a well-planned rotation scheme with crops like maize, groundnuts, cassava, soyabeans, etc. alternating with rice is of primary importance.

Upland rice is often grown as the first crop in a system of shifting cultivation because immediately after the burning process soils are still sufficiently rich to give good yields of rice. Later on, when the soils have become more exhausted, less exacting crops should be grown.

Rice fields near Tjiwidej (Java)

CULTURAL PRACTICES IN RICE GROWING

CULTURAL PRACTICES contributing to higher yields will now be discussed:

(1) Improved water supply in the form of extended and better regulated irrigation facilities. Adequate and timely supply of water is a factor that has an extremely great influence on yields.

(2) Greater use of fertilizers, which is undoubtedly one of the most effective means of increasing rice yields so as to obtain larger supplies of rice for the Asiatic countries which are deficient in this commodity and where many food producing areas are cultivated as intensively as circumstances permit. Double cropping is quite common in these regions, some areas producing even three crops annually. Unless, therefore, some provision is made for maintaining soil fertility by means of chemical fertilizing, the constant and intensive use of the land must inevitably exhaust the soil and is reflected in declining rice yields.

Up to the present, however, inorganic fertilizers have been applied to rice on a relatively small scale in most of the Asiatic countries. Before the second world war Japan, Korea and Formosa were practically the only Asiatic countries in which significant quantities of commercial fertilizers were employed. As far as other rice growing regions of the world were concerned the fertilization of rice was practiced only in the U.S.A., Egypt, the rice growing countries of Europe and Australia. It is clear from information available that one of the most promising methods of increasing rice yields in the tropics is the extension of the practice of intensive manuring, judiciously combining the use of green manure with local fertilizing materials and commercial fertilizers. The high rice yields of Japan should be considered to be the result of the judicious combination of fertilizers with the natural manures employed there for centuries. Nitrogen is the most important element in which the soil is deficient, although in many areas phosphates are needed in addition to nitrogen. In some areas, e.g. Java, Thailand and Indo-China soils respond even more to phosphates than they do to nitrogen. Most rice soils contain sufficient potash for the requirements of the crop, although in some countries symptoms of potash deficiency have been observed on sandy soils.

(3) The more extensive use of green manure crops grown in rotation with rice.

(4) More intensive tillage of the soil, im-

Weeding operation in paddy fields in Eastern Java

proved cultural practices in general, adopting the practice of transplanting seedlings from nurseries instead of broadcasting the seed and more attention to the important operation of weeding.

In addition light and warmth should be mentioned as the more or less uncontrollable factors affecting rice growing, the limitations of which, however, can to a certain extent be overcome by selecting suitable varieties for different environmental conditions.

On account of its heat-loving characteristics rice is a crop most suitable for the tropics and sub-tropics, although it is also grown during the summer in warm temperate regions.

The great intensity of light and the solar energy found in sub-tropical and warm temperate areas might even constitute an especially favourable factor in rice growing and is, next to the excellent cultural treatment of the crop, perhaps responsible for the high average yields obtained in countries like Japan, Italy and Spain. In these countries yields of 3000 kg. per ha. of milled rice are not uncommon, in comparison with the yields of very many tropical countries that do not even reach 1000 kg. per ha. Under the conditions of cloudy weather during the wet monsoon, light deficiency might be the limiting factor in tropical areas.

WATER SUPPLY FOR RICE GROWING

RICE needs an abundant supply of water, upon which depends the success of all intensive methods of cultivation, such as manuring, rotation and growing of improved varieties.

Rice is seldom grown in an area with a rainfall of less than 40 inches during its vegetative period, unless irrigation water from an outside source is available. The minimum water requirements of paddy are estimated at about 10,000 m^3 of water per hectare.

In Egypt, where the rice crop is wholly dependent on irrigation, it is estimated that 7000 m^3 of water per feddan, or 16,000 to 17,000 m^3 per hectare, are needed during the whole period of the crop's growth. This is a much greater volume of water than is required for any other crop, so that in years of water scarcity the rice area is the first to receive a restricted supply. The excessive water requirements of rice explains why the cultivation of this crop is almost entirely confined to Lower Egypt, as it is only in this part of the country that an ample and regular water supply can be assured. In Upper Egypt cotton growing with the aid of well water is possible, but this source of water supply does not meet the demands of rice growing.

Egypt. Lifting water for irrigation by means of a „sakieh" and blindfolded oxen

In India too rice growing is almost entirely limited to the coastal territories and other areas with a rather high rainfall as far as Indian conditions are concerned, which should be at least 50 inches (125 cm.) pér annum. Other cereals are grown in areas with a more deficient rainfall.

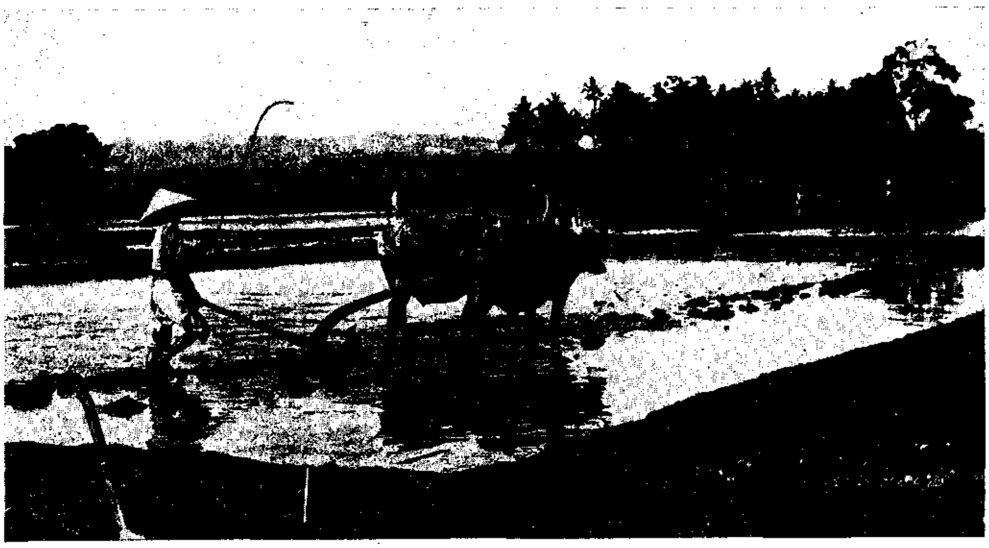
A large supply of water is needed for wet tillage alone. In heavy soils this may amount to approximately 30 per cent and over of the total water requirements of the crop. Immediately after sowing or transplanting a comparatively small quantity of water is consumed. This increases with the growth of the crop up to maturity. At the start of the growth of the crop the depth of water should be at least 5 centimeters (2 inches) — and preferably more — to check weed growth. The depth is gradually increased to 10 cm. (4 inches) and later on to 20 cm. (8 inches).

SOIL TILLAGE FOR RICE GROWING

Soil tillage for wet rice growing. Garut, Java

INTENSIVE TILLAGE of the soil is as essential for wet rice growing as it is for dry crops, though the end in view is somewhat different. For dryland crops soil tillage aims primarily at the improvement of physical conditions and a better water-air ratio in the soil. For wetland rice growing on the other hand the presence of oxygen in the soil is of less importance as the crop is adapted to waterlogged soil conditions.

The upper layer of the soil, to a depth of about 2 cm. under the water layer, is in an aerobic condition. At a greater depth the soil medium is completely anaerobic and deeper still it again contains oxygen. This peculiar condition influences both the root system of the rice and the soil itself. The roots in the upper soil layer are whitish in colour and well supplied with root hairs. This horizontal root system developing during the tillering stage is comparable with that of cultivated cereals such as wheat, barley and similar crops. It is presumably this part of the root system that absorbs nitrogen in the form of nitrates. The roots which penetrate more deeply into the anaerobic layer are coarser, less branched and mostly brown in colour.



Java. Plowing of the wet rice field

The anaerobic soil layer causes a mobilization of iron and manganese, which are leached to the subsoil and there deposited in the forms of more highly oxidized insoluble iron and manganese salts. This eventually causes the development of a hard pan, consisting of an iron bearing deposit over one containing manganese, at the bottom of the paddy field.

With regard to the supply of oxygen to the root system of paddy it must be assumed that part of the necessary oxygen is supplied by means of an air-canal system in the plant tissues themselves. The aerobic portion of the root system seems to be provided with oxygen in the normal way, an appreciable part of it being derived from the result of the photosynthetic processes of several kinds of algae living in the paddy field water.

The chief object of intensive soil tillage in wet rice growing is to create the so-called puddled condition, which involves working up the soil to the consistency of a fine, soft mud, by means of ploughing, harrowing and trampling. The whole of the upper layer of the soil should be in this smooth, soft muddy condition, permitting the roots to ramify freely in the medium without being obstructed by hard layers or spots. To achieve this a great deal of time and care should be devoted to intensive tillage, especially in the cases of the heavier types of soil.

In other respects heavy soils are especially suitable for wet rice growing as they produce more easily the more or less impervious layer favourable to rice growing and prevent the leaching of plant nutrients.

Careful preparatory cultivation of the soil is, however, even more important for heavy soils than for lighter types. Neglect of this is apt to cause decreased yields or increase in the incidence of pests and diseases.

Inadequate soil tillage may be a consequence of lack of time between two rice crops under a system of double cropping.

Soil tillage may be carried out under dry soil conditions or in flooded fields. When abundant water is available, however, the latter method is preferable so that the puddled soil condition may be created.

According to VAN DE GOOR [32] inadequate water application in the preparation of the soil might be responsible for the frequent crop failures in East Java following a late start of the rainy season. Heavy margalite soils appear to be especially sensitive to moisture content at the time of preparation.

One of the diseases induced by inadequate tillage of heavy soils is the so-called bambang or mentek disease in Java, the principal symptoms of which are retarded growth, stiff weedy appearance and yellowish green leaves. This disease appears 3 to 5 weeks after transplanting and farmers suppress it by trampling the soil.

15 to 20 cm. (6 to 8 inches) should be regarded as a good standard depth of the puddled layer as a furrow slice of less than 15 cm. (6 inches) may cause food deficiency symptoms in the later stages of growth and, according to Japanese investigations, exceptionally deep soils retard ripening.

In any case it should be remembered that wet rice growing is quite different from rice growing in swamps or inadequately drained areas. Drainage of both irrigated areas and of those dependent on rainfall is almost as important as irrigation itself. Available evidence indicates that irrigation without adequate drainage has actually caused a reduction in yield in some countries. Where, however, suitable drainage was subsequently provided yields increased substantially.

A period of drainage and aeration of the soil before the start of wet rice growing should, therefore, be regarded as essential. According to Japanese investigations this practice exerts its influence on the nitrogen supply of a soil also as the time at which nitrogen becomes available is quite different in well and poorly drained paddy soils. In well drained paddy soils the nitrogen released from organic materials by aerobic decomposition processes is generally supplied to the plant in its early and middle stages of growth when it is most in need of nitrogen. In poorly drained soils, on the other hand, most of the nitrogen is released by anaerobic decomposition under the influence of high summer temperatures. When it becomes available to the plant so late in the growing season it results in lodging, late ripening and the outbreak of diseases. Moreover, some of the decomposition products may be injurious to the rice plants.

The primary importance of good and intensive soil tillage in wet rice growing must again be stressed.

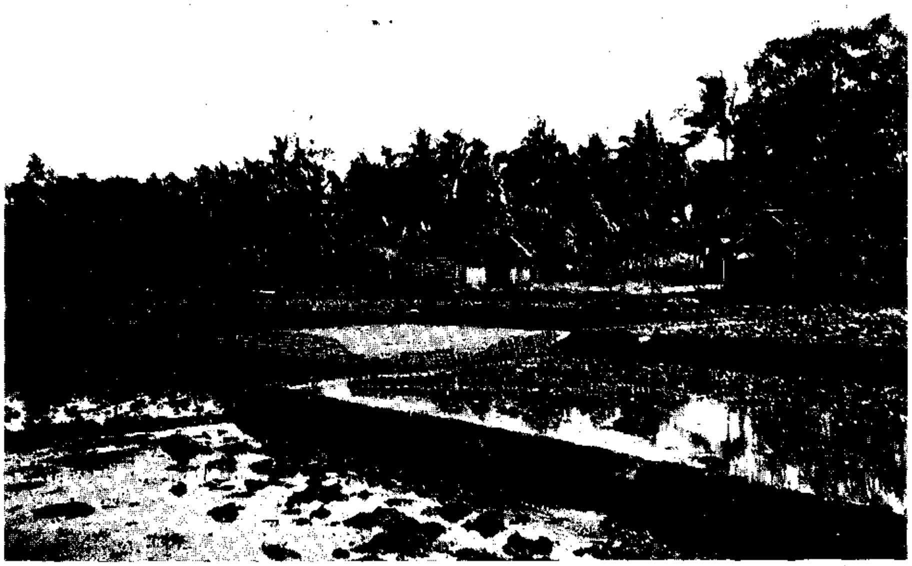
Paddy fields in Western Java, waiting for soil tillage

TRANSPLANTING VERSUS BROADCASTING AND WEED CONTROL

ONE OF THE WAYS of obtaining increased yields is the practice of transplanting seedlings instead of broadcasting the seed in the field.

In addition to the methods of broadcasting seed by hand and transplanting seedlings from a seed bed there are the use of seed-drills and sowing from the air, practiced especially in the U.S.A., where flooded fields are sown from aeroplanes and seed-drills are used on dry fields that are subsequently flooded, as, of course, they cannot be used for sowing seed in flooded fields.

Transplanting is generally preferable to broadcasting as the former, though an arduous practice requiring a large amount of manual labour, has a direct beneficial effect on yield and results in saving in the amount of seed required. In transplanting not more than 25 to 30 lb. of seed per acre is used, whereas 75 to 100 lb. is required for broadcasting. In addition transplanting results in



Paddy fields near Bandung, Java. In the middle seedbeds more effective weed control, not only because it facilitates weeding, but also because it is possible to start with a thicker water layer. Much greater attention to the question of weed suppression is called for in many rice growing countries.

Other advantages of transplanting are the extra time available for the necessary intensive soil tillage, while permitting more time for the preceding crop to ripen and, in Egypt, the extra cut of bersim obtainable, where this crop is followed by rice.

The transplanting process also calls for somewhat less water, as for some weeks irrigation is required only for the comparatively small area devoted to seed beds until soil tillage operations require the greater quantity of water.

One of the countries which would benefit considerably from the replacement of the now customary method of broadcasting by transplanting is Ceylon, especially as far too much seed is generally sown there. The result of this is an excessively dense growth of seedlings which crowd each other out, inadequate tillering and frequent lodging, all leading to greatly deficient yields. Very often the typical yellow colouration due to nitrogen deficiency can be seen. This is partly caused by overcrowding of seedlings. With transplanting, on the other hand, the plants are well spaced so that each gets an opportunity for optimum development. This results in better growing conditions for the whole field and increased yield.

As already mentioned transplanting facilitates weed control. The seedlings are quickly established in the field, develop, tiller and keep so much ahead of weed growth that the latter is unable to compete effectively with the crop.

Weeds are also effectively controlled as a result of a scheme of rotation with other crops in areas where such a practice is possible, and by continuous submergence of fields.

The use of modern selective herbicides, such as the several 2,4-D formulations, has proved useful against many broadleaved plants but ineffective against the many grasses that often constitute the main weed flora. In many cases, therefore, hand weeding will remain essential.

→

Above: *Java. Pulling out rice seedlings for transplanting*
Below: *Planting of rice in the plantfield in Central Java*

As stated before the application of fertilizers is one of the most promising methods of increasing rice yields in the world. This extremely important cultural practice will now be discussed, with nitrogen application taking first place, and phosphate following.

THE IMPORTANCE OF NITROGEN FOR WETLAND RICE GROWING

ALTHOUGH NITROGEN is the most important soil element in deficient supply responses to nitrogen vary considerably. In most countries nitrogen applications increase yields substantially, but there are some areas, e.g. in some soils of Indonesia, where responses to this element have been unexpectedly small.

This may be explained by differences in natural nitrogen supply as a result of the following:

(1) A very low nitrogen content of rain- and irrigation water.
(2) Liberation of nitrogen as a result of decomposition of organic material under wetland rice growing conditions.
(3) Fixation of atmospheric nitrogen by bacteria and algae in the irrigation water.

One of the best known investigators of nitrogen fixation by blue-green algae is P.K. DE.

According to investigations by WATANABE, NISHIGAKI and KONISHI [81], 13 species were able to fix atmospheric N out of 643 samples of blue-green algae collected from rice fields in East and South-East Asia. These N-fixing species belonging to the genera *Tolypothrix, Nostoc, Schizothrix, Calothrix, Anaboenopsis* and *Plectonema* are plentiful in tropical and semi-tropical regions but scanty in more temperate areas like Japan, North China, Manchuria, Korea and Sakhalin.

The most active of all these species proved to be *Tolypothrix tenuis,* which fixed 9.6 mg. N in 2 months and in 1 l. of culture medium.

In other experiments *T. tenuis* increased leaflength bij 17% and number of ears by 30% in watercultures, leaflength by 11% in potcultures and yields in field experiments by 15% in well drained paddy fields and by 25% in badly drained paddy fields.

The subject of nitrogen fixation by soil and water inhabiting bacteria also is receiving considerable attention at the present time and DERX [63] has quite recently found in Indonesian water and soils some nitrogen fixing species, demonstrating further that nitrogen fixing bacteria are common and plentiful in tropical soils of both acid and alkaline reaction, while natural waters also appear to contain these organisms in surprising abundance.

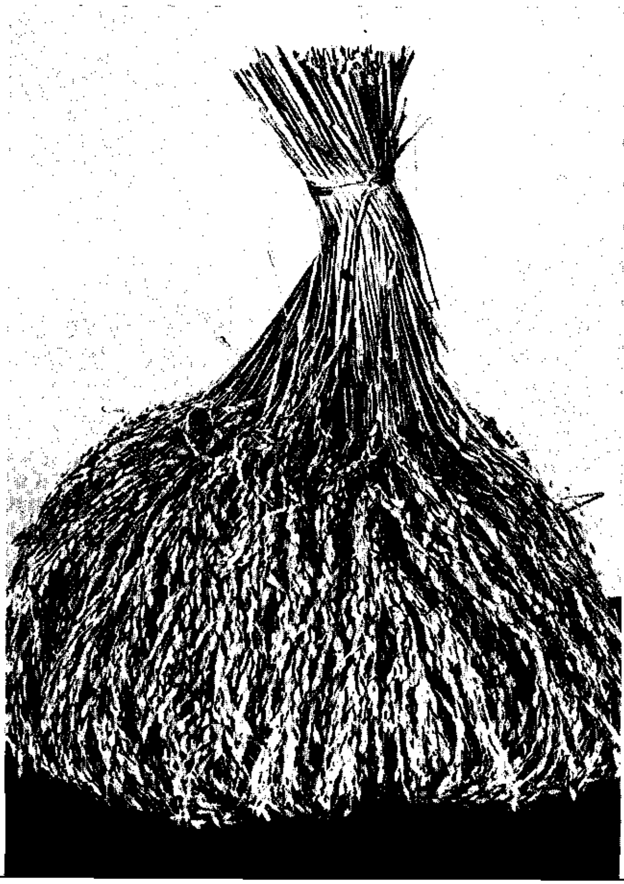
Species of bacteria known to be capable of fixing atmospheric nitrogen are as follows:

Name	*Occurrence*	*PH*
Azotobacter chroococcum Beyerinck	soil	> 6
Azotobacter vinelandii Lipm.	soil, water	> 6
Azotobacter agile Beyerinck	water	> 6
Azotobacter insigne Derx	tropical, calcareous waters	> 6
Azotobacter proteus Derx	Deli soils	> 6
Beyerinckia indica Derx (syn. *Az. indicum* Starkey & De)	tropical, waterlogged soil	< 6
Beyerinckia indica var. alba		< 6
Beyerinckia mobile Derx	tropical soil	< 6

The small response to nitrogen applications to wetland rice frequently experienced in Indonesia is undoubtedly associated with the great activity of the abovementioned nitrogen fixing micro-organisms.

Under certain circumstances all the natural sources of nitrogen mentioned together seem able to supply paddy with practically all the nitrogen it requires, but in general these sources are quite inadequate, with the consequence that in most rice growing countries, e.g. India, Ceylon, Japan, China, the Philippine Islands, Egypt, etc., the application of nitrogenous fertilizers is one of the most effective means of increasing rice production.

The phenomenon of nitrogen fixation by biological means may play its part in these countries as well, however, in that moderate nitrogen applications will suffice, having, as they do, a more supplementary character when applied to wetland rice than when used on dry land crops. A normal rate of nitrogen dressing for wetland rice is 30-60 kg. N per ha. Only seldom are applications higher than 60 kg. N per ha. needed.



Stalk paddy

THE MOST SUITABLE FORM IN WHICH N SHOULD BE APPLIED FOR PADDY GROWING

NITROGEN in the ammonium form is most effective for application to paddy fields. As demonstrated by experiments nitrates give definitely inferior results owing to losses from denitrification in the paddy soils with their reducing qualities. In the first place Indian experiments have shown that sulphate of ammonia was the most effective of all the inorganic nitrogenous fertilizers tested. Poor results were obtained from nitrates and calcium cyanamide, while applications of ammonium nitrate, ammonium phosphate and urea gave results that compared favourably with those obtained from the use of sulphate of ammonia.

In spite of the fact that all the results were not strictly comparable as the experiments with different fertilizers were carried out at different localities and there was, in addition,

considerable variation in the relative effects of various fertilizers from one year to the next, these results were considered to be reliable enough to point to certain definite conclusions and to enable the following relative efficiency rating for the abovementioned fertilizers to be established.

RELATIVE EFFICIENCY OF VARIOUS NITROGENOUS FERTILIZERS
(taking sulphate of ammonia = 100)

Fertilizer	*Relative rating*
Sulphate of ammonia	100
Ammonium nitrate	92
Ammonium phosphate	86
Urea	82
Calcium cyanamide	64
Potassium nitrate	44
Sodium nitrate	40

The figures show the undoubtedly greater efficiency of the ammoniacal forms of nitrogen than the nitrate forms.

The same tendency can be deduced from the results of similar experiments in other countries, a summary of which is presented in the following table:

RELATIVE EFFICIENCY OF VARIOUS NITROGENOUS FERTILIZERS FOR WET RICE GROWING

Location	*Level of N used lb./acre*	*Relative efficiency Yield from sulphate of ammonia = 100*			
		Ammonium nitrate	*Urea*	*Cyanamide*	*Sodium nitrate*
INDIA					
Pattambi, Madras	30	54			
(2nd crop)	30	91			
	30				57
Aduturai, Madras	30				28
Coimbatore, Madras	30				45
Mareteru, Madras	30	90			
Irwinfarm, Mysore	15	111			
Naganetally, Mysore	15	77			
Nagina, U. P.	30	103			
	60		76		
Cuttack, Orissa ave.	20 & 40	71	71		
U. S. A.					
California ave.	21, 31.5 & 42		81	76	91
Louisiana	80	71 (split-appl.)			
JAPAN					
Tokyo	67.5				75.9
Tokyo	48.2				91.3 (top dress)
Yamagata	54.0	91	95		
Shiga	57.3	87	100		
Hiroshima	63.0	90	98		
Ehime	47.2	80			
	(15.5 basal	80			
	(31.0 top dress)	91			
Saitama	50.6		102		
Akita	33.7		93		
Fukushima	67.5		105		
Toyama	(31.0 basal				
	(21.2 top dress)		98		
Ishikawa	(67.5 basal				
	(16.9 top dress)		100		
Shimane	50.6			103.4	
Nara	60.7			101.1	
Niigata	101.1			100.8	
Hukushima	67.5			106.1	
Okayama	54.0			100.6	
Hyogo	91.0			104.0	

According to these figures, sodium nitrate is an inferior nitrogenous fertilizer for wet rice growing owing to losses by denitrification and possibly by leaching. If, however, nitrates are applied to the surface layer of the soil after the crop is established and when it is growing actively, that is, when the aerobic superficial root system has been fully developed, these fertilizers can be absorbed by the plant before they reach the reducing layer.

Nitrates should never, therefore, be used as a basal dressing, but only as a later top dressing.

In general ammonium nitrate has proved to be only slightly less efficient than sulphate of ammonia. The former might, therefore, be a useful substitute for sulphate of ammonia when its hygroscopic character is not a drawback.

Urea has been shown to be fairly effective especially in the Japanese tests, in which the results with this fertilizer were practically equal to those with sulphate of ammonia. One of the advantages accruing from the use of urea in areas with high transport costs is its high nitrogen content (about 45 % N).

Calcium cyanamide, which proved to have little effect in the Indian experiments, was very efficient when tested by means of the deep placement technique in Japan. It is definitely less suitable as a top-dressing, however, because of harm to the plants. Calcium cyanamide, when used as a basal dressing, should be applied at least one week before transplanting, in order to avoid the harmfull effects of some of its decomposition products on the young rice plants.

In Formosa calcium cyanamide proved to be somewhat more effective than sulphate of ammonia on acid soils, but a little inferior on neutral and alkaline soils.

The following precautions are recommended in Japan if calcium cyanamide is, nevertheless, sometimes used as a topdressing:

(a) About 50-100 parts of soil are mixed with one part of calcium cyanamide, piled into a heap and moistened with water. The soil-calcium cyanamide-mixture is applied after the decomposition of calcium cyanamide is completed, indicated by the cessation of heat evolution.

(b) Mix several parts of soil, which may be wet, with one part of the calcium cyanamide. The mixture is applied immediately between the plant rows and care is taken that none falls on the leaves of the plants. Even though the mixture does not touch the plants, this treatment may result in the burning of some leaves, but if applications are made early in the growing season the plant recovers before heading with no ill effects.

Liquid ammonia has been tried in the U.S.A. Experimental results showed that in general it is less effective than sulphate of ammonia.

At the present time, therefore, sulphate of ammonia must be classed as the most suitable form of nitrogenous fertilizer for wet rice growing.

Long term experiments have not up to the present shown any deleterious effects from sulphate of ammonia applications, and it is indeed to be expected that in many instances the calcium content of the irrigation water will successfully counteract the acidifying effect of sulphate of ammonia.

In Burma repeated applications of sulphate of ammonia have resulted in declining yields of rice. This, however, could not be explained by the acidifying effect of the chemical because the phenomenon was observed on calcareous as well as on acid soils. It is assumed that the primary cause of the trouble is phosphate deficiency, which is becoming the limiting factor in successful rice growing there more and more as time goes on.

The effect of continuous applications of sulphate of ammonia on the physical and chemical properties of the soil is being studied at two centres, the Central Rice Research Institute, Cuttack, Orissa and the Rice Research Station, Chinsura, West Bengal. The experiments in progress include treatments which should be able to counteract the harmful effects, if any, of the continuous use of sulphate of ammonia. Plots have been treated with dressings of sulphate of ammonia with and without the addition of lime and with and without basal dressings of organic matter in the forms of cattle manure and compost.

For the so-called „degraded" or Akiochi paddy soils in Japan, a peculiar soil type comprising about 18% of the total rice acreage, ammonium chloride (NH_4Cl) has proved to be a more suitable fertilizer than ammonium sulphate $(NH_4)_2SO_4$. This may be explained by the fact that these soils are extremely leached and impoverished, so that not only practically all of the bases, but all free iron as well has disappeared into the subsoil. When sulphate of ammonia is used under wet rice growing conditions, the sulphate is reduced to H_2S, harmful to the root system, but, under normal conditions, with free iron present, the sulphate is converted to and inactivated in the form of the harmless FeS. Where no free iron is present, this H_2S is not neutralized, however, and has a poisonous influence on the root system of the rice plant, causing serious damage. When NH_4Cl is used instead of $(NH_4)_2SO_4$ under these conditions no H_2S is formed and thus there is no poisonous effects on the plants. After deep ploughing, an operation that restores the iron to the topsoil, sulphate of ammonia may eventually be again used.

Rice growing in Western Java

TIME AND METHOD OF N APPLICATIONS

Paddy fields in Western Java

AS SULPHATE OF AMMONIA is rapidly oxidized to nitrate when applied to the aerobic surface layer of paddy soils at the time of or before transplanting, it follows that sulphate of ammonia is thus subject to loss of nitrogen by denitrification if it is applied in this manner. This fertilizer should therefore be applied in such a way that its nitrification to nitrate is prevented, which is accomplished by putting the sulphate of ammonia directly into the chemically reducing soil layer, where it remains more or less unchanged until it is taken up by the plants.

The Japanese, with their deep placement technique, were the first to practice this method of application.

According to Japanese reports, superficial application of sulphate of ammonia has often resulted in losses of more than 50%. PEARSALL[57] and JONES even report losses as great as 70% and 80% as a result of the superficial application of this fertilizer.

The summary on the following page gives some additional results of experiments of this nature.

According to these results deep placement of

SUMMARY OF SOME FIELD EXPERIMENTS ON DEEP PLACEMENT OF SULPHATE OF AMMONIA FOR LOWLAND RICE IN JAPAN

Location of the experiment	*Method of application*	*Yield index unhulled rice*
Hokkaido Agr. Expt. Sta.	shallow dressing deep placement	100 118
Aomori Agr. Expt. Sta.	shallow dressing deep placement	100 110
Chiba Agr. Expt. Sta.	shallow dressing deep placement	100 111
Shiga Agr. Expt. Sta.	shallow dressing deep placement	100 128
Hiroshima Agr. Exp. Sta. I	shallow dressing deep placement	100 110
Hiroshima Agr. Exp. Sta. II	shallow dressing deep placement	100 123
Kumanoto Agr. Exp. Sta.	shallow dressing deep placement	100 126
Kanto Tosan Agr. Expt. Sta. Agri-Forestry Ministry (Saitama Pref.)	shallow dressing deep placement	100 110

sulphate of ammonia gives an increase in yield of at least 10% over that resulting from surface application.

Deep placement is carried out in Japan by means of ploughing under the sulphate of ammonia, followed immediately by irrigation. The period between the application of fertilizers and commencement of irrigation should be as short as possible because, if the field is left for any lengthy period under upland rice conditions after fertilizing, nitrification sets in and denitrification losses subsequently occur when conditions favourable to such a reaction arise after irrigation. The fields should, therefore, be irrigated not more than three to four days after ploughing.

As a general rule only a part of the nitrogen required is applied before transplanting and some of it may be applied in the form of pellets or balls consisting of the fertilizers (sulphate of ammonia and often also superphosphate) cemented with peat, mud or gypsum into the form of a small ball which is pushed down into the chemically reducing layer. The effectiveness of this method may be illustrated by the following figures:

SUMMARY OF SOME FIELD EXPERIMENTS ON THE MANURIAL EFFECT OF BALL FERTILIZERS FOR LOWLAND RICE IN JAPAN

Location of the experiment	*Method of application*	*Yield index unhulled rice*
Fukushima Agr. Expt. Sta.	deep placement	100
	ball fertilizer	109
Saitama Agr. Expt. Sta.	shallow dressing	100
	ball fertilizer	106
Niigata Agr. Expt. Sta.	deep placement	100
	ball fertilizer	114
Okayama Agr. Expt. Sta.	shallow dressing	100
	deep placement	107
	ball fertilizer	107
Tottori Agr. Expt. Sta.	shallow dressing	100
	deep placement	123
	ball fertilizer	122
Tokushima Agr. Expt. Sta.	shallow dressing	100
	deep placement	108
	ball fertilizer	115
Kumamoto Agr. Expt. Sta.	shallow dressing	100
	deep placement	104
	ball fertilizer	113
Miyazaki Agr. Expt. Sta.	shallow dressing	100
	ball fertilizer	109

The usual practice in Japan is to apply two-thirds of all nitrogen in the form of sulphate of ammonia as a basal dressing to the dry soil by ploughing it in to a depth of 2-3 inches a day before the water is run into the field for puddling and transplanting. The other third is applied later in the form of pellets or balls, also buried to a depth of 2 to 3 inches.

A supplementary top dressing is advisable in cooler regions owing to the comparatively slow root growth retarding the intake of nitrogen from ball fertilizers.

Top dressing should be carried out at the commencement of tillering or somewhat later, when the growth rate is rapid and nitrogen requirements heavy.

The plant should be provided with an ample nitrogen supply more especially during the tillering phase. As nitrogen deficiency in the growth stage between tillering and heading may result in less grains in the ear, a diminished grain weight and ultimately a reduced yield, nitrogen applications should be adapted to the demands of the plant for this element over this critical period, care being taken however to prevent harmful lodging.

RAMIAH[60] reports that according to experiments in Madras, the protein content of the grain can be increased by judicious manuring of the rice crop.

In most countries fertilizers are usually applied by means of top dressing after draining the field and irrigating again as soon as possible after the fertilizer is applied.

The usual method of applying sulphate of ammonia to rice all over India consists of spreading the chemical on the surface of the wet soil. Experiments at the Cuttack Institute, however, showed that application by means of the Japanese deep placement method should be beneficial under Indian conditions, as indicated by the following figures illustrating yield responses:

AVERAGE RESPONSE OF GRAIN IN LB. PER ACRE FOR EVERY LB. OF NITROGEN APPLIED

	Deep (dry) application	*Surface (wet) application*
Medium land	14.2	9.4
Lowland	19.3	11.4
Mean	16.8	10.7

These figures show that the dry deep placement method of applying sulphate of ammonia is more effective than the application to wet soil usually practiced.

Further experiments to compare the effect of sulphate of ammonia application by means of pushing pellets 2-3 inches deep in the soil one month after planting with that of the usual surface application have given the following results, according to RAMIAH[60].

YIELD PER ACRE FOR DEEP PLACEMENT AND SURFACE APPLICATION
(Yield in lb. per acre)

	grain	*straw*
No nitrogen (control)	1575	1926
Surface application	1698	2089
Deep placement by means of pellets	1895	2395

These results show a definite increase in yield following deep placement of fertilizers by means of pellets. Experiments in Louisiana (U.S.A.) have shown that applying the fertilizer two inches below the seed resulted in an increase of rice yield by 8½ bushels per acre over that obtained when the fertilizer was drilled into the soil with the seed.

In Indonesia it is unusual to apply nitrogenous fertilizers before transplanting. The common practice is to apply a fertilizer of this kind in two equal portions, 3 to 4 and 6 to 8 weeks respectively after transplanting. The timing of the dressings usually coincides with the weeding of the drained fields. The fertilizer is broadcast between the rows or applied in small quantities per hill and trodden into the soft mud, thus pushing the sulphate of ammonia in the chemically reducing soil layer.

When nitrogenous fertilizers are applied 6 to 8 weeks after transplanting the root systems of the plants are considered to be sufficiently developed for a rapid intake of nitrates as well as ammonium-ions.

GREEN MANURE AND RICE GROWING

LIKE DRYLAND CROPS the paddy crop derives much benefit from the incorporation into the soil of large quantities of organic matter, by no means the least benefit being the rapid liberation of nitrogen as a result of the decomposition of this material under submerged conditions. With fertilizing, green manuring is, therefore, one of the readiest means of increasing rice yields. One of the greatest drawbacks of this practice, however, is that green manure production often involves sacrificing a food crop and in Far Eastern Countries especially it is usually preferable to grow a food crop as long as sufficient water is available. It follows, therefore, that water is most often the limiting factor in the growing of a green manure crop in rotation with rice. The water requirements of the green manure crop can be met to some extent by the careful selection of a crop suited to the prevailing conditions. In parts of India, for example, where the water is limited and a rice crop will not be sown for four or five months, a leguminous crop such as *Tephrosia purpurea* should be used. This legume, which requires very little moisture and is slow growing, is sown between the rows of the standing crop of rice and remains on the land for four or five months before being turned under. In Ceylon *Tephrosia purpurea* seed is sown with the rice, the green manure seed remaining dormant until the rice crop is harvested, after which it germinates and grows well under dry land cropping conditions.

Crotalaria juncea, which is used in Indonesia, has the advantage of a short vegetative period and produces a rather large quantity of organic matter within a period of 2 or 2½ months.

One of the chief difficulties encountered in the cultivation of this legume is the production of seed, owing to the attacks of insect pests. *Crotalaria usaramoensis* produces rather higher yields than *C. juncea,* but it remains in the field for about five months before being turned under.

The fertilizing value of *C. usaramoensis* on a light volcanic, young andesitic lateritic Indonesian soil, responsive to N applications, is demonstrated by the following figures (right above):

These figures demonstrate not only a significant increase in yield but also a gradual increase in protein content following the in-

Treatment	N-content in kg.	Dry paddy q./ha.			Protein content of polished rice
		yield	increase		
A. Control	0	27.7	—	—	7.1
B. 100 q./ha. *Cr. usar.*	44	38.4	10.7	—	7.7
C. 200 q./ha. *Cr. usar.*	88	47.0	19.3	8.6	9.8
D. 300 q./ha. *Cr. usar.*	132	47.3	19.6	0.3	10.9
Significant (P = 0.05) = 2.48					
Highly significant (P = 0.01) = 3.89					

corporation of an increasing quantity of green manure with the soil.

The undermentioned figures, also recorded by VAN DE GOOR [33] show that the increases in yield of paddy are more or less proportional to the total weight of the green manure turned under.

Although leguminous crops are especially suitable for green manuring owing to their nitrogen fixing characteristics, non-leguminous crops may, under certain conditions, be as useful. This is demonstrated by the results of an experiment in which *Crotalaria usaramoensis* was compared with *Eupatorium pallescens,* a well-known shrub-like weed of Java attaining a height of 2-6 meters and with *Tithonia diversifolia,* another shrub which grows to a height of 2 meters. This experiment was laid out on rather young andesitic lateritic soil and recorded by VAN DE GOOR [33]. None of the plants used in this experiment was grown in situ, all the material having been transported from elsewhere and applied at the rate of 25 tons per ha. (figures next page).

Treatment	YIELDS IN QUINTALS PER HA.			
	first year		second year	
	dry paddy	dry straw	dry paddy	dry straw
Control	24.4	50.4	24.9	65.9
50 *Cr. usaramoensis*	29.5	67.8	29.0	80.0
100 *Cr. usaramoensis*	34.2	73.0	30.6	92.4
150 *Cr. usaramoensis*	35.0	79.7	34.7	103.1
200 *Cr. usaramoensis*	39.5	81.7	38.3	103.6
250 *Cr. usaramoensis*	40.4	91.0	43.5	128.3
300 *Cr. usaramoensis*	39.7	98.3	43.0	129.2
350 *Cr. usaramoensis*	47.2	117.2	46.1	146.0
400 *Cr. usaramoensis*	46.6	123.5	45.9	141.3

TREATMENT PER HA. IN TONS	YIELDS AND INCREASE IN QUINTALS PER HA.							
	Dry stalk paddy				*Dry straw*			
	1941		*1942*		*1941*		*1942*	
	Yield	*Increase*	*Yield*	*Increase*	*Yield*	*Increase*	*Yield*	*Increase*
A. Control 0	24.2	–	24.9	–	73.1	–	40.7	–
B. *Cr. usaramoensis* 25	35.9	11.7	41.8	16.9	110.2	37.1	77.5	36.8
C. *E. pallescens* 25	31.9	7.7	39.9	15.0	105.7	32.6	80.8	40.1
D. *T. diversifolia* 25	33.0	8.8	43.2	18.3	104.5	31.–	79.3	38.6
Significance:	P 0.05 = 6.23 P 0.01 = 10.27		P 0.05 = 3.05 P 0.01 = 5.38		P 0.05 = 16.24 P 0.01 = 26.75		P 0.05 = 11.91 P 0.01 = 20.98	

The general conclusion to be drawn from these figures is that there was an active response to green manure, irrespective of whether a leguminous or non-leguminous crop was employed.

Wherever it is possible and economically justified to introduce organic matter in the form of wild vegetation from outside sources as, according to DR. RICHARDSON, is often done in the hilly parts of China, this practice should contribute greatly to the desired increase in production.

All organic material is considered capable of stimulating Azotobacter activity in the soil.

The results of experiments recorded by VAN DE GOOR [37] relating to the time of application have shown that no significant difference was obtained in wet land rice fields by turning under the green manure crops 1 to 60 days before transplanting. In these experiments it was found that the yield of the unmanured variety Untung varied from 20.8-28.3 quintals dry paddy per ha. By the application of 250 quintals of *Crotalaria usuramoensis*, at an average age of five months, the increase in yield obtained was 14.9-18.2 quintals of dry paddy (an average increase of 67 %).

The method of application from which the best results were obtained consists of digging in the green manure crop under wet conditions, as demonstrated by the results of an experiment carried out on the young andesitic lateritic soils of the experimental farm „Muara" near Bogor in Indonesia recorded by VAN DE GOOR [37] (figures next page).

Although laying the green manure crop on the soil surface two weeks or one week before transplanting also resulted in a significant increase, by far the best results were obtained from digging the material into the soil.

It is remarkable that in Malaya best results were obtained by leaving the green manure to rot on the surface. This difference might be explained by the fact that in Indonesia the irrigation water was flowing slowly, while in Malaya it was stagnant.

→

Transplanted paddy near Bogor (Western Java)

TREATMENT	*Quintals/ha. dry paddy*		*Quintals/ha. dry straw*	
	yield	*increase*	*yield*	*increase*
A. Control	20.9	–	53.6	–
B. 250 *Cr. us.* incorporated 2 weeks before transplanting	42.4	21.5 (102.8 %)	123.1	69.5 (129.7 %)
C. 250 *Cr. us.* on the surface 2 weeks before transplanting	32.2	11.3 (54.1 %)	91.0	37.4 (69.8 %)
D. 250 *Cr. us.* on the surface 1 week before transplanting	31.3	10.4 (49.8 %)	88.4	34.8 (64.9 %)
Significant (P = 0.05)	1.77		6.48	
Highly significant (P = 0.01)	2.77		10.17	

AVERAGE YIELD OF RICE PER ACRE IN LB. AFTER APPLICATION OF SULPHATE OF AMMONIA WITH AND WITHOUT COMPOST. CHINSURAH FARM 1946/47 — 1948/49

Sulphate of ammonia applied as top dressing

Basal organic dressing	*0*	*30*	*60*	*90*	*120*
No compost	2001	2489	2386	2352	2242
Compost at 4 tons per acre	2252	2629	2585	2156	1937
Mean	2132	2559	2486	2254	2090

The problem of growing a greenmanure crop without sacrificing a food crop has been solved in some parts of Indonesia where rice is grown in a rotation with maize by sowing the green manure between the maize rows when the maize is half grown or even before this, and digging it in two or three weeks after the maize is harvested. The maize as well as the rice crop benefits from this practice. Mixed culture of this kind can be practiced in the case of some other crops also.

Another method of soil improvement is to alternate rice cultivation with that of a crop used partly for forage or for human consumption and partly as green manure.

In India where relatively good moisture conditions prevail *Sesbania aculeata* (Dhaincha) and *Crotalaria juncea* (sunnhemp) are grown for two months. The yield from each is from 8,000 to 10,000 lb. organic material containing about 40 lb. N per acre. *Sesbania* is unpalatable to cattle, which is a great advantage in India and some other countries where the loss of the green manure crop by animal grazing is an important problem.

Compost and cowdung seem to be less effective than green manure in India, comparing them on the basis of equal nitrogen content. There is evidence that these materials can be most satisfactorily used as basal dressings, with sulphate of ammonia as a top dressing. This is demonstrated by the figures in the abovementioned table obtained in experiments conducted at Chinsurah (West Bengal).

It will be noted that the yield increases from applications of N up to 30 lb. per acre, declining thereafter. The highest yield obtained in the experiment, 2629 lb. per acre, was the result of the application of 4 tons compost per acre plus 30 lb. N in the form of sulphate of ammonia, with a decrease in production following higher N applications.

Statistical examination of the results obtained produced the following figures showing the average production of lb. of grain per acre for every lb. of nitrogen supplied in the different quantities of sulphate of ammonia applied.

PRODUCTION OF LB. GRAIN PER ACRE FOR EVERY LB. OF NITROGEN SUPPLIED

Sulphate of ammonia N per acre	*No compost*	*With compost at 4 tons per acre*
10	10.1	14.4
20	9.3	12.8
40	7.7	9.6
60	6.1	6.4
80	4.5	3.2

PHOSPHATE FERTILIZING FOR WET RICE GROWING

NITROGEN has been the only rice yield increasing factor so far discussed, but in certain areas, Indonesia and Thailand in particular, phosphate is relatively even more important than nitrogen in view of the facts that in Indonesia not less than 800,000 to 1 million hectares are deficient in phosphorus and that there has seldom been a greater response to phosphate than that observed in some rice fields in the environment of Bangkok.

A quickly available form of phosphatic fertilizer like superphosphate or dicalcium phosphate is preferable, as rice requires its P_2O_5 within a short period. Phosphorus is usually applied to rice in the form of superphosphate, often in the more concentrated form of double superphosphate (D.S.P.). Because of the effectiveness of watersoluble phosphate in wet rice soils, moderate applications suffice. In Indonesia, for instance, the optimum dosage for many phosphate deficient soils seems to be scarcely more than 50 kg. D.S.P. or 18 kg. P_2O_5 per ha. Higher applications, it is true, often resulted in slightly higher yields but seldom enough to pay for the increased fertilizing costs. An average rate of application sufficient for all Indonesian soils has been found to be 1 quintal of D.S.P. or 36 kg. P_2O_5. This may perhaps be partly explained by the fact that the rice plant itself has a low P_2O_5 content compared with that of N and K_2O.

The effectiveness of watersoluble phosphates is probably strongly influenced by the chemically reducing soil layer that prevents the formation of trivalent iron-phosphate compounds and thus increases the availability of this food material.

Comparatively small annual applications are more effective than larger applications at less frequent intervals. This is demonstrated by the results of a phosphate fertilizing experiment on the more or less alkaline margalite soils*) of the Tjihea and Tjiandjur plain, one of the most important rice producing centres of West Java (figures next page).

In the first place there is an increase in yield of almost 100 % to phosphate manuring as the result of an application of not more than 50 kg. per ha. of D.S.P. There is little or no further increase following higher applications,

*) Margalite soils have been developed under the influence of high base concentrations during weathering and are characterised by montmorillonite as the main clay mineral.

RESULTS OF AN EXPERIMENT ON ORIGINAL AND RESIDUAL EFFECT OF D.S.P. IN TJIRANDJANGHILIR

	Quintals per hectare dry stalk paddy				
	Increase in yield as a result of a dressing of				*Yield of control plots*
	0.5 q./ha. dsp	*1 q./ha. dsp*	*1.5 q./ha. dsp*	*2 q./ha. dsp*	
Original effect	22.2	23.2	22.6	24.0	24.5
First residual effect	3.3	6.8	14.6	22.0	33.8
Second residual effect	2.2	2.9	6.9	8.7	30.2
Total increase over 3 years	27.7	32.9	44.1	54.7	

which, however, influence the first and, to some extent, the second residual effect.

When the total increase over a period of three years is taken into account, it is clear that a small annual dressing of not more than 0.5 q. per ha. of D.S.P. is most economical and greatly preferable to a quantity of 1½ to 2 quintals of D.S.P. every three or four years. The fact that heavy dressings are less effective may be partly attributed to greater losses in irrigation water when they are applied in spite of the fact that even water soluble phosphate was considered to be little subject to losses as it reacts immediately with the excess of calcium in these soils to form insoluble dicalcium phosphate or tricalcium phosphate. The following experimental results recorded by VAN DE GOOR[34] prove, however, that the rice grower has to reckon with the possibility of phosphate losses in the outflowing irrigation water.

The experiments were carried out in the ex-

Thailand. Rice on heavy Bangkok clay; unfertilized spot surrounded by rice fertilized with N and P_2O_5

perimental garden at Ngale (in the middle of Java) where heavy margalite soils exist, and the following treatments were applied:

A. Control
B. 1 quintal/ha. D.S.P. } each plot with separate intake and outlet of water

C. Control
D. 1 quintal/ha. D.S.P. } common intake and outlet for all plots.

The fertilizer was applied one day before transplanting and water re-admitted to the field five days after fertilizing. Analysis of water samples taken for determination of P_2O_5 content revealed that the water flowing from the D-plots to the adjacent C-plots contained 20 mg. P_2O_5 more than the water entering the plots, demonstrating a movement of the fertilizer from the D to the C plots. This was further confirmed by the following yield figures:

RESULTS OF EXPERIMENTS IN THE GARDEN "NGALE"

Year	*Yields in q./ha. dry paddy (variety Untung)*			
	A	*B*	*C*	*D*
1st	34.8	42.3	37.1	40.9
2nd	33.4	41.8	31.1	38.2
3rd	32.1	43.3	35.7	42.5
4th	25.8	34.4	27.1	32.1
Average	31.5	40.5	32.8	38.4

The mean difference between the yields from A and B is 9 q. paddy per ha., and that between the yields from C and D only 5.6 q., while the yield from the control plots, C, was 1.3 q. per ha. higher than that from the A plots. This phenomenon can be explained in no other way than by assuming a movement of P_2O_5 from the D to the C plots. The heavier

Planting of rice from seedbeds in the island of Bali

the dressing the more it will be removed by outflowing water, making comparatively small dressings more economical.

Attention will now be directed to the question of the usefulness of other forms of phosphate for application to wet rice.

Dicalcium phosphate is about as effective as monocalcium phosphate in many soils. The P_2O_5 in bonemeal is also quite readily available. The advisability of using ground rock phosphate in wet rice growing depends not only on the fineness of the material but also on the physical and chemical nature of this rock phosphate and on the nature of the soil. The more acid the soil the quicker will P_2O_5 become available from rock phosphate. One of the most readily available rock phosphate forms is the Indonesian Cheribon phosphate which, in the first year, produced half the response obtained from the use of D.S.P. in some excessively weathered acid lateritic soils and also in the acid dacitic soils in the province of Banten. In other soil types, the direct response was even less, while in neutral or alkaline margalite soils there was no response at all. Most of the other forms of raw phosphate are even less readily available than Cheribon phosphate, producing only a small response during the first year, which explains, therefore, why e.g. in Vietnam and Burma, hardly any response to phosphate fertilizing was observed during the first year by using Gafsa phosphate and ground apatite even on very acid soils, and also why the later effects were considerable.

In general, therefore, the rice grower cannot depend on a reliable response to phosphate from the use of rock phosphate, although its after effects are greater than in the case of D.S.P.

Another rock phosphate form, aluminium phosphate, should in theory be able to produce definite results in some neutral and alkaline soils only. In accordance with this assumption this form of phosphate produced no response on acid lateritic soils but gave some results in the margalite soils in the Bodjonegoro area, to a somewhat smaller extent in the margalite soils in the Koelon Progo area and in the so-called "gesik" soils of Bangkalan area. Aluminium phosphate also produced a response in the acid dacitic soils in the province of Banten, the acidity of which is closely connected with its silicic acid content.

In general the immediate response to aluminium phosphate applications was one third of that produced by D.S.P., although the after effect of the former was greater.

The best guarantee for a quick response, therefore, is the use of superphosphate and equivalent phosphates, although, under favourable conditions, raw phosphate forms also may give some immediate response.

Besides contributing greatly to higher production, phosphate asserts its influence in several other ways:

(a) It stimulates root development, making plants more drought-resistant.

(b) It promotes earlier flowering and ripening, by means of which the unfavourable influence of late transplanting is eventually reduced or neutralised.

(c) It encourages more active tillering, which enables rice fields to recover more rapidly and more completely after a borer attack.

(d) It gives a higher feeding value to the rice, owing to the higher phosphorus content of the grain.

In addition, the possibility that the advantages derived from phosphatic fertilizing are in some cases due to an improved nitrogen supply should be taken into account. Phosphates stimulate the growth of algae and so, indirectly, nitrogen fixation.

The investigations recorded by VAN DE GOOR[38] were remarkable in that they showed that the breeding of fish in wet rice fields had an effect on yield similar to that of the application of 1 q. per ha. of D.S.P. to phosphate deficient soils. This phenomenon, which has not yet been explained, is illustrated by the following figures:

Preceding 3 months	*Variety*	*Manure*	*Yields in quintals per ha. dry paddy*
A. Fish	Chingfow	No fertilizer	25.0
B. Fish	Chingfow	1 q./ha. D.S.P.*	27.7
C. Fish	Djintung	No fertilizer	18.5
D. Fish	Djintung	1 q./ha. D.S.P.*	22.0
E. Fallow	Chingfow	No fertilizer	11.0
F. Fallow	Chingfow	1 q./ha. D.S.P.*	28.4
G. Fallow	Djintung	No fertilizer	4.8
H. Fallow	Djintung	1 q./ha. D.S.P.*	19.0

* Applied one day before transplanting.

POTASH, LIME AND TRACE ELEMENTS FOR WET RICE GROWING

MOST of the world's paddy soils contain sufficient potash for the needs of the crop, partly as a result of the potash contents of the irrigation water and partly because rice is nearly always grown on heavy soils, which usually have a high potash content.

VAN DIJK[19] has calculated the quantities of potash supplied in a west monsoon irrigation at:

16-38 kg. K_2O per ha. for Western Java, and
21-25 kg. K_2O per ha. for Middle and Eastern Java.

The average consumption of potash for grain production is 12 kg. per ha., and for straw production, 51 kg. per ha., so that in each of the abovementioned regions the K_2O requirements for grain production are completely covered by the supply in the irrigation water. When, however, the straw is also removed from the fields for industrial purposes, there is a potash deficiency which must be made up from soil reserves of this plant food material.

There are, however, exceptions to the general rule that rice soils normally contain sufficient potash. Sandy soils especially have proved to be more or less deficient in potash in several countries e.g. in Vietnam, where on light, sandy soils potassium applications result in yield increases.

Another example is Ceylon, where more recently potash deficiency has been diagnosed in paddy growing on light soils. It is estimated that 25 % of the total rice area is affected by this deficiency.

In Ceylon potash deficiency symptoms have been observed also in tea growing in the mountain areas which are the sources of the irrigation water and silt. These areas, therefore, must supply little potash.

In Malaya potash applications are recommended as next in importance to those of nitrogen and phosphate for the sandier soils of the eastern part of the country. In the U.S.A. also, more particularly in Arkansas and Texas, soils are reported to respond well to potash fertilizers.

In Japan the so-called degraded paddy soils, of an extremely leached and poor type, respond so well to potash that on these soils an increase in crop yields of 20 to 30 per cent can be expected as a result of the use of this plant nutrient.

In dryland rice growing, when there is no irrigation water to supply potash, the possibility of a potash deficiency is much greater than in the case of wetland rice cultivation.

Calcium applications are also usually unnecessary as rice grows well in acid soils and, moreover, calcium is very often supplied in the irrigation water. The calcium content of irrigation water also neutralises the acidifying effect of sulphate of ammonia and in Indonesia, where rice is grown in rotation with sugarcane, the latter crop has been heavily fertilized with sulphate of ammonia for decades without any harmful effect on the soil. Occasionally, however, calcium application has been found to be advantageous where the soil is too acid or where the element benefits nitrogen fixing organisms. In addition, calcium may have an indirect influence on the nitrogen content of a paddy soil by accelerating the decomposition of organic matter in that soil.

Before liming a soil consideration should be given to the influence of this cultural practice on the availability of trace elements. Lime and pH are important factors in this essential supply of plant nutrition.

As far as trace elements and their importance in rice growing is concerned no outstanding results were obtained in experiments with many of these elements in several countries e.g. Ceylon and Malaya.

In Malaya, trials were carried out on arsenic, because it is associated with alluvial tin in that country and the effluents from mining operations often reach irrigation canals. Pot experiments showed that arsenic, when applied to an arsenic-free paddy soil at the rate of 10 to 15 p.p.m., exerted a pronounced favourable influence on rice growth. Heavier applications were found to be toxic.

Pot experiments in Indonesia have demonstrated the very favourable effect of copper sulphate applied at the rate of 25 kilograms per hectare to a very acid oligotrophe Borneo peat soil, while from India there have been reports of definite responses to manganese sulphate and zinc sulphate.

In Japan most of the so-called "degraded" paddy soils are manganese deficient, but these soils have been leached and impoverished to such a degree that many other nutrients, e.g. potash, together with special cultural treatment, are needed for their improvement. But in contrast to the question of manganese deficiency consideration should be given to the possibility of manganese toxicity from too high a concentration of this element in the soil. This may occur on very acid soils, especially after the application of acidifying fertilizers, and is the possible explanation of the harmful effect of even small quantities of acid fertilizers in some very sandy, acid soils in North Eastern Thailand.

Aluminium is another element that may be toxic when present in large amounts and in acid soils. Aluminium toxicity may occur on very acid rice soils in Vietnam and is controlled by heavy rock phosphate applications.

Iron deficiency may exist in calcareous soils where it can be overcome by spraying with, but scarcely ever by applications of $FeSO_4$. Symptoms of B and Zn deficiency have been demonstrated in culture solutions but have not apparently been observed in the field. These elements too are toxic when present in more than minute quantities in the soil.

Mo deficiency has not produced any definite symptoms in culture solutions.

It has been reported from Japan that the application of 1 oz. of Na F per acre has a stimulating effect, but that amounts over 1 lb. are toxic.

In conclusion it can be stated that insufficient experiments have been conducted on paddy with these trace elements and there is need for more intensive investigation of this subject.

PRE-TREATMENT OF SEED AND SEED BED MANURING

APART FROM the effects of direct application of manures to the field the effects of pre-treatment of seed with nutrient solutions and of seed bed manuring have been investigated in many countries. As far as the pretreatment of seed with nutrient solution is concerned various results have been reported. In Vietnam, for example, soaking seed in solutions of sulphate of ammonia and ammonium nitrate, produced yield increases in certain soil types and depressed yields in others. Further investigations indicated that the effects varied with different rice varieties, $MgSO_4$ having produced an increase in yield of all the three varieties tested. It is also apparent that the effect varies from one year to another. In Indonesia, seed treatment with phosphate produced a marked increase in seedling vigour, which, however, was not reflected in the ultimate yield.

In Ceylon, significant and striking increases in the yield of both grain and straw were obtained in pot experiments on soaking seed in 5 % and 20 % Na_2HPO_4 and K_2HPO_4. These yield increases were, however, not reproduced in field trials.

From India definite results have been reported from pot as well as field experiments. In pot experiments conducted at Coimbatore, soaking seed in 10 % and 20 % solutions of K_3PO_4 resulted in significant yield increases of 21 % and 39 % respectively over the controls.

Field experiments at the Central Rice Research Institute during 1949/50, based on pretreatment with solutions of K_2HPO_4, K_3PO_4, $(NH_4)H_2PO_4$, NaH_2PO_4, $(NH_4)_2SO_4$ and $(NH_4)NO_3$, gave significant yield increases of 14, 12, 9, 13, 12 and 11 per cent respectively with comparable results for 1950/51. Further investigations have revealed that seed pretreatment gave yield increases of this order only on soils well supplied with nutrients, indicating that the pre-treatment of seed with nutrient solutions cannot be considered a substitute, complete or partial, for standard fertilizer dressings to the crop in the field. The quantities of nutrient taken up as a result of pre-treatments of this nature are very small indeed. In the case of phosphate, for example, it was calculated that the quantity absorbed amounted to not more than 30 gr. P_2O_5 per hectare, as compared with a requirement for a normal rice yield of about 20 kg. P_2O_5 per

Rice terraces with seed beds in the foreground near Bandung (Java)

hectare. Pre-treatment of seed only would, therefore, provide not more than about 0.15 % of the total requirements of phosphate.

Pre-treatment of seed should be regarded only as a possibly stimulating factor for vigour in the young stages of growth of the plant. This may have a beneficial effect on final yield provided that there are other contributing factors. Most of the reports indicate, however, a depressing effect of seed treatment on germination. Pre-treatment of seed may be of value in the supply of trace elements, which are needed in small quantities only and might possibly be applied by this means.

Seed bed manuring is a practice that should be recommended unconditionally because close sowing in combination with the high demand for nutrients in the early stages of growth frequently results in a shortage of nutrients in a few weeks. The typical yellow-green colour, indicating nitrogen deficiency, is, therefore, a normal characteristic of rice seed beds. In many cases this results in the rather poor quality of the transplanting material and the degree of fertility of the rice field will largely determine whether it will be possible to overcome this disadvantage or whether the weakened condition of the seedlings will continue throughout the growing period of the crop and be reflected in the final yield.

Seed bed manuring should aim primarily at the production of sturdy, healthy plants, which can be transplanted early and resume growth rapidly.

Seed bed manuring is the more advisable as it costs little and the extra work entailed in the treatment is negligible and of a simple nature. It is not a substitute for direct fertilization of the fields, however, as in many instances the practice of nursery fertilization has completely failed to produce increased yields. Where these have been obtained the results have not been comparable with the increases resulting from direct fertilization of the crop in the field.

Seed bed manuring should always be supplemented by direct fertilization of the crop in the field. This combined practice gives promise of optimum yields as demonstrated recently by HOMANS[46]. He compared the difference in yield between plots which had been given identical soil treatment but were planted out alternatively with previously treated and untreated seedlings. The soil of the plots was of a young andesitic lateritic type, rather poorly supplied with plant nutrients and were situated in the experimental garden, Muara, at Bogor in Indonesia. A three-year trial indicated that it was possible to increase yields by about 500 kg. per hectare as a result of fertilizing seed beds and the crop in the field as compared with fertilizing the crop in the field only. Furthermore, there was a definite and remarkable response in the seed beds to treatment with K in combination with N while there was no response to K applied in the field. This indicates a differential response to K_2O of young and older rice plants. The same phenomenon occurs in tea plantations in Assam, where mature tea exhibits no response to K_2O, whereas there is a definite response of the very young plants to this nutrient.

Careful consideration should, therefore, be given to the possibility of different nutritional requirements for very young and for older plants respectively.

Paddy complex near Bandung, partly planted

PLANTBREEDING AS A FACTOR IN INCREASED PRODUCTION

AT THE Central Rice Research Institute at Cuttack, India is participating with eight other rice-growing countries in a hybridization scheme, aimed at improving the rice crops of these and other producing areas by a programme of breeding, selection and seed exchange, which has been worked out on an international basis.

As already mentioned, the programme aims at combining the high yielding quality of the round grained japonica rice with the adaptability of the long grained indica type to the varying climatic and soil conditions as well as to the cultural practices of the Indian subcontinent and South East Asia.

Although the chief aim of the breeding programme is undoubtedly the production of high yielding varieties adapted respectively to differences in soil, climate and other conditions of growth, breeding should, however also aim at:

(a) Good quality involving the desirable characteristics of translucency, hardness, size and shape of the grain, as well as good milling and cooking qualities and good nutritive value.

(b) Resistance to lodging (which means that attention should be paid to growth habits and strength of straw) and freedom from shattering.

In view of the harmful effect of lodging on quantity as well as on quality of the yield, breeding should aim at the production of lodging resistant varieties which may have an influence on N fertilizing as varieties with short firm straw may be able to utilize greater quantities of N economically.

In order to make full use of the yield-increasing possibilities offered by fertilizers, it will probably even be necessary to breed varieties especially for their ability to utilize heavy applications of nitrogen, which has been done in the cases of other cereals in Western Europe.

(c) Early maturity. Although maximum yields are usually obtained from late maturing varieties, equally good yields can be obtained from varieties with a shorter growing period, provided that seasonal and other conditions are favourable. In Madras and Bengal yields of 3,000 lb. of grain per acre from some improved early varieties are not uncommon.

Some of the Chinese varieties are considered to show great promise of early maturity and high production. Two Chinese varieties, which have done well at Cuttack, are reported to yield as high as 5000 to 6000 lb. per acre in the Kashmir Valley, although they do not mature there so early as at Cuttack, owing to the high altitude and cooler climate. Another early maturing high yielding selection from rice of Chinese origin has become popular in Uttar Pradesh and is reported to yield over 3000 lb. per acre.

(d) Adaptability to special environments, such as deep water, and resistance to salt and drought in areas where such conditions may occur.

(e) Resistence against pests and diseases. Control of pests and diseases should be subject of breeding in spite of the present extensive assortment of fungicides and insecticides.

In Indonesia breeding solved the problem of controlling the so-called mentek or bambang disease. This disease, to which only certain varieties are highly susceptible, retards growth about 3 to 5 weeks after transplanting and produces a typical stiff, weedy appearance of the plants and a yellowish-green colour of the leaves.

DR. KUILMAN's investigations[49] showed that the type of root system possessed by the plant is the predisposing factor in the disease. Plants with a dense system of strongly branched, fine rootlets proved to be much more resistant, possibly owing to the greater potentialities for absorption of nutrients possessed by such a root system.

In India and Japan resistance to blast *(Piricularia oryzae)* is an important item in the breeding programme. In this sphere of work remarkable results have been obtained from the new varieties C.O. 25 and C.O. 26, both of which have proved to be resistant even under intensive manuring with nitrogen. As these varieties are rather late maturing, however, they cannot be cultivated everywhere.

Teaching the search for higher-yielding strains of rice at Cuttack Rice Research Institute to students from all parts of Asia assembled there under the auspices of the International Rice Commission of F.A.O.

As far as breeding for resistance to insect pests is concerned mention should be made of the attempts made in India to produce strains resistant to the attacks of the rice bug *(Leptocorisa varicornis)* by crossing heavy yielding susceptible varieties with a very early maturing variety called Sathi, which has enclosed ears. These crosses have produced strains with partially enclosed ears resistant to the rice bug somewhat later maturing than Sathi and yielding 20 % tot 25 % more than this parent.

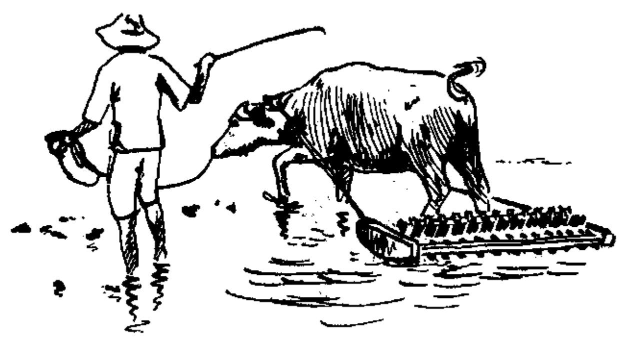
From Bombay reports have been received of high yielding varieties moderately resistant to *Pachdiplosis oryzae* and resistant to *Leptispa pygmea* (blue beetle) and to *Sitotroga cerealella* (store moth).

Breeding for insect resistance is not easy, however, and large differences between varieties in their respective reactions to insect attacks are rather uncommon. Modification of cultural practices must, therefore, be the chief means of reducing losses due to the incidence of such insect pests as the stemborer *(Schoenobius)*, rice ear fly *(Leptocorisa acuta)* and rice gall fly *(Pachdiplosis oryzae)*.

The fact that the cultivation of better quality higher yielding rice varieties requires little or no cash expenditure is, to the Eastern farmer, with his lack of capital, a big advantage when compared with the use of fertilizers, which have to be purchased and for which lack of money is frequently the limiting factor to their employment, even in those cases where their application would lead to considerable yield increases.

It should be remembered, however, that higher yielding varieties also make greater demands upon the plant nutrient reserves of the soil. This means that in general the cultivation of improved varieties must be accompanied by fertilization.

In any attempt to increase production, therefore, the question of credit facilities must be given full consideration. The establishment of suitable agricultural credit organisations well adapted to the existing circumstances and the establishment and extension of village agricultural co-operative societies will be essential to provide the solutions to these credit problems in many tropical countries, where there are very small holdings and rice farmers have very limited financial resources of their own. Establishment and extension of credit facilities will also be of primary importance as incentives towards the increased use of fertilizers in those areas.



PESTS AND DISEASES AND THEIR CONTROL

BEARING IN MIND that the rice plant is susceptible to the attacks of insect pests at every stage of its growth and the large number of pests and diseases that may attack this crop, it is remarkable that seldom has there been recorded a pest or disease of this crop of a really disastrous nature. Pests and diseases may, however, be severe locally and the damage done is great enough to call for every effort in the application of control measures, thus increasing yields considerably.

The worst pests are stem borers, plant bugs, caterpillars and grasshoppers, of which stem borers and plant bugs cause the greatest damage.

The greatest difficulty encountered in the control of stem borers results from the fact that the larvae of the moths bore into the paddy stems shortly after hatching and remain there for most of their life. Insecticides are, therefore, of little use in combatting this pest because the chemicals cannot come into contact with the larvae. Nevertheless VAN DER LAAN reported promising results against *Scirpophaga innotata,* the white stem borer, one of the worst paddy pests in Indonesia, by spraying seed beds with 0.04 % DDT emulsion at thirteen to twenty days after sowing. This treatment resulted in a reduction of 25 to 30 per cent of the damage. In general, however, it is only right to say that in the present state of knowledge cultural methods offer the best chances of reducing crop losses from stem borers, although no really effective method of control of *Proceras polychrysus,* a serious pest of paddy in Malaya, has yet been discovered.

Borer damage can be especially severe in those areas where there is overlapping of paddy cropping throughout the year. One of the most effective methods of control of *Schoenobius bipunctifer,* the yellow stem borer, therefore, is by ploughing the land immediately after harvest and submerging it for as long a period as possible so as to avoid the overlapping of successive paddy crops which would provide a continuity of host plants for the pest. Other means of control are (a) light traps for catching the moths, the proportion of which that are caught however being seldom great enough to reduce the number of the pest considerably, (b) hand collection of eggs and of injured plants, a slow and costly procedure and (c) the herding of young ducks in the affected paddy fields to consume exposed

Storage of stalk paddy in Java

larvae. Cutting out infested stems before the larvae have emerged and submerging young paddy plants are means of control against the striped stem borer, *chilo suppressalis.*

Although there are undoubtedly better prospects for the control of paddy bugs than stem borers by means of modern insecticides such as DDT, BHC, Chlordane, Toxaphene, Aldrin, Dieldrin, Parathion, T.E.P.P. etc., much research remains to be done in this field, the more so because some of them such as parathion and T.E.P.P. are extremely poisonous and thus dangerous to handle by inexperienced persons. Cultural methods will remain very important means of keeping these pests as well in check. One of the most effective precautions against the attacks of these insects is keeping the bunds and banks in the vicinity of the fields as clean as possible between two successive crops so as to deny to the pest the wild grasses which are their alternative hosts in the absence of paddy. Other useful control methods are uniformity of date of planting to avoid any extension of the growing season, catching the insects, egg collection, and shaking the nymphs into water on the surface of which there is a film of kerosene.

The most harmful plant bugs, which suck the sap from the developing grain, belong to the genera *Leptocorisa, Nephotettix, Scotinophara, Nezara* and *Moridea.*

Leptocorisa which is particularly prominent in parts of India and Ceylon has been clearly demonstrated to be satisfactorily and economically controlled with a 5 % BHC dust, whereas *Nephotettix* is better controlled with DDT.

Leaf caterpillars can be controlled by several insecticides and by cultural practices, such as flooding the nursery beds against *Spodoptera mauritia, Borolia venalba* and *Laphygma frugiperda,* or draining the beds or fields against *Nymphula depunctalis.* Collecting and destroying cocoons is also effective.

There are other insects, e.g. leaf beetles and grasshoppers, which cause damage to the rice crop and which have been also succesfully controlled with BHC.

Next in importance to these are several other pests such as birds, crabs and rats. The last mentioned can be a serious menace and should be controlled by means of poison baits.

In addition to all these pests there are a large number of diseases, caused by fungi, which may infect the rice plant. Examples of these are:

Blast, caused by *Piricularia oryzae* Cav.,
Brown spot, caused by *Helminthosporium oryzae,*
Narrow brown leaf spot, caused by *Cercospora oryzae,*
Bakanae disease (*Gibberella fujikuroi* (Saw) Wr),
as well as several stem- and foot-rots and diseases of the grain.

As some varieties of paddy have proved to be more susceptible than others to many of these diseases, the cultivation of resistant varieties is one of the most promising control methods. Straw and stubble from diseased crops should be burnt. Seed treatment with an organo-mercurial seed dressing is effective against brown spot, bakanae disease and miscellaneous footrots.

It has been clearly demonstrated in Japan and India that heavy nitrogen applications on soils deficient in other plant nutrients predispose rice to blast disease.

In Japan where *Helminthosporium* leaf spot is common on the extremely leached and poor Akiochi paddy fields, potash applications have been found to be effective in the control of the disease. Fertilizers containing silica and manganese were also helpful in this connection.

Both brown spot and blast tend to be worse in nursery beds where the soil has been excessively dry.

From Eastern Bengal, Malaya and Burma there have been reports of a disease caused by a nematode, *Ditylenchus angustus,* the only known means of control against which is to avoid planting paddy on the area for a certain period, so that the nematode is deprived of its source of food.

Insect pests of stored paddy and rice such as the rice weevil *(Sitophilus oryzae),* the lesser grain borer *(Rhizopetha dominica F.),* the sawtoothed grain beetle *(Oryzaephilus surinamensis L.),* the angoumois grain moth (*Sitotroga cerealella* Oliv.) and the mediterranean flour moth (*Ephestia Kuehniella* Zell.) are controlled by means of fumigants like hydrogen cyanide, carbon disulphide, chloropicrin, ethylene oxide, methylbromide, methylformate etc. or by means of smoke generators.

The subject of pests and diseases and their control is a very comprehensive one. Its discussion here, however, must be restricted to these general remarks. For further information we refer our readers to a recently published book on rice-growing by D. H. GRIST [42] which includes a great deal of valuable and detailed information.

A discussion of rice growing in the main rice producing countries of the world will now follow, commencing with consideration of production in Asia.

This continent supplies 93.2 % of world rice production at the present time. Percentages supplied by other areas are as follows:

South America	*2.5 %*
Africa	*2 %*
North America	*1.5 %*
Rest of the world	*less than 1 %*

RICE AREA AND PADDY PRODUCTION

Continent	Area in 1000 hectares		Production in 1000 metr. tons of paddy	
	average 1934-38	1951	average 1934-38	1951
Asia	82,000	87,500	144,800	140,200
South America	1,190	2,360	1,820	4,100
Africa	1,850	3,000	2,180	3,200
N. & C. America	540	1,190	1,180	2,550
Europe	220	320	1,140	1,370
Oceania	10	30	50	70
World total	85,810	94,400	151,170	151,490

Rice growing in Japan will be considered first because this country is outstanding among the large producing areas for the intensive character of its rice growing and for the extent to which fertilizers and manures are used to reach optimum yields.

RICE GROWING IN JAPAN

IN pre-war days Japan, with about 6 million hectares of arable land to provide food for 85 million people, provided about 85 % of its food requirements. This was made possible partly by growing more than one crop a year on much of the acreage, the total area cropped annually being thus about 1.4 times the arable area, that is, about 8.5 million hectares, and partly by the intensive nature of crop cultivation in Japan, resulting in an average paddy yield of about 36 quintals per hectare. The rice crop takes up about 53 % of the total cultivated area, with about 30 % devoted to wheat and barley together.

In spite of the intensive rice cultivation in Japan and an average annual home production of about 8.5 million tons of milled rice over the period 1935-39, this country was forced to import more than 1.5 million tons annually to satisfy the local demand. These imports originated in prewar years from Korea and Formosa, both included in the Japanese Empire at that time. After the war, however, Korea became independent and Formosa was returned to China, with the result that both these sources of supply are no longer available to Japan except on an exchange basis. The food situation has, therefore, become a very serious problem for Japan, the more so as there are fewer possibilities of a further increase in production in that country than in other rice producing countries.

The present rice area of 3.18 million hectares in a total of 6 million hectares of cultivated land, cannot be substantially expanded without damaging the interests of other no less essential crops like wheat, barley and tea. Moreover, the degree of intensity of cultivation is closer to its optimum in Japan than in any other country. It can be expected, therefore, that in the future Japan will continue to be dependent on large quantities of imported food. The programme of agrarian reform. dictated by the Allied occupation forces with the object of transferring land from landowners to those who actually farm it and of re-allocating big farmholdings, can result in hardly any improvement in this situation. Only about 16 % of the total area of Japan is cultivated, but any large-scale expansion beyond this limit does not appear possible. With about 6 million hectares of cultivated land worked by about 5.5 million farm households the average size of a farm unit in Japan is only about 1.1 hectares, though two-thirds of the farm households each cultivate less than 1 hectare, frequently divided into scattered patches. With so many people on so little land the fields of Japan are cultivated intensively. Double cropping is customary when climatic conditions permit, with rice following rice in some southern areas. Rice is, however, generally followed by naked barley, common barley or wheat as the winter crop. In localities where the climate does not permit the growth of winter grain, a green manure crop may be cultivated on the paddy fields instead.

The intensive character of crop growing in Japan involves the ample use of manures and fertilizers.

About half of the required plant food is applied in the form of farm manures including all the bulky organic matter such as compost, night soil, green manure, farmyard manure, woodashes, seaweed, etc., supplied by the farm itself or by local outside sources. The other half consists of commercial fertilizers, both organic (chiefly oil cake and fish meal) and inorganic (chiefly sulphate of ammonia and superphosphate).

The total quantity of farm manures applied in prewar years averaged about 70 million tons per annum, of which 60 % was compost, over 20 % night soil and 8 % green manure. The quantity reached a peak of nearly 100 million tons per annum during the war, equivalent to almost 17.5 tons per hectare per annum. The peak of commercial fertilizer application occured in the late thirties when an amount of nitrogenous fertilizers equivalent to about 1.8 million tons of sulphate of ammonia, an amount of phosphatic fertilizers equivalent to 1.5 million tons of superphosphate (16 %) and up to 200,000 tons of 50 % potash fertilizers were used.

Nearly all the Japanese paddy soils are deficient in nitrogen, and although the quantities of nitrogenous fertilizer applied vary with different regions, soils and cropping methods, 60 kg. N per ha. can be taken as an average rate as far as commercial fertilizers are concerned. This is supplemented by an average rate of application of about 35 kg. N in the form of farm manures. In many cases even higher quantities of nitrogen are recommended. Application of nitrogenous fertilizers results in an average increase in yield of 30 % over the untreated plots.

By far the greatest proportion of nitrogen for rice growing in Japan is applied in the form of sulphate of ammonia, with urea, calcium cyanamide and ammonium nitrate as alternatives.

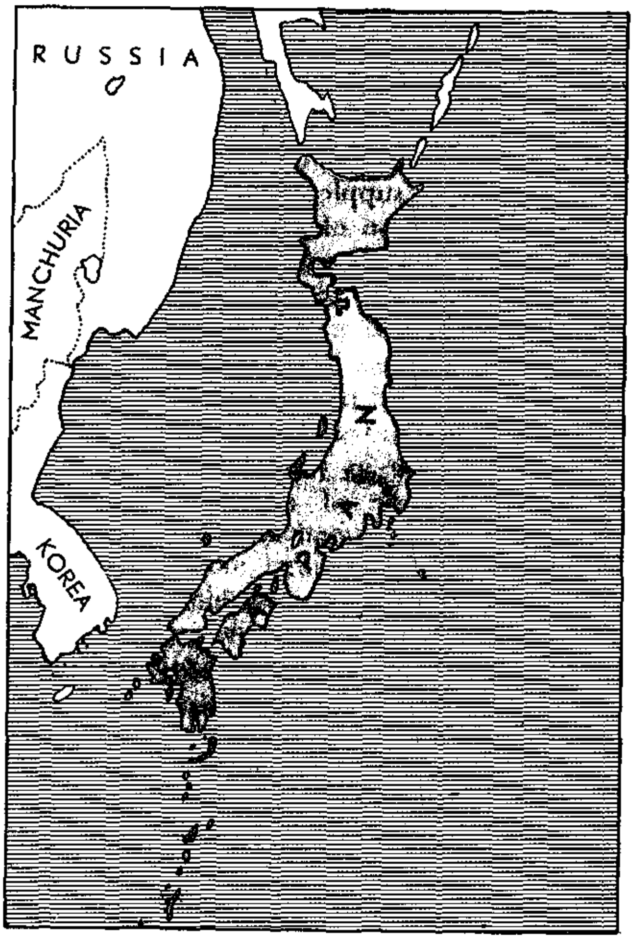
Calcium cyanamide, of which Japan produced up to about 300,000 tons in prewar years, is normally used in basal applications only, as special precautions are required to prevent damage to the plants when this chemical is used as a top dressing. Ammonium nitrate may, however, be safely used as a top dressing.

In three experiments in Japan, urea, when substituted for sulphate of ammonia as a basal dressing was nearly as effective as the latter. Ammonium nitrate as a basal dressing was about 10 % less effective, but as a top dressing proved nearly equal to sulphate of ammonia.

Ammonium chloride is another form of fertilizer very suitable for paddy especially when growing in degraded soils, where sulphate of ammonia may cause a harmful accumulation of H_2S.

For the normal paddy soil type the fertilizing value of NH_4Cl may be considered equal to that of $(NH_4)_2SO_4$.

Deep placement of nitrogenous fertilizers has been recommended in Japan since about 1940. This is effected by ploughing in a basal



dressing of sulphate of ammonia just before irrigation, and by the use of pellet or ball fertilizers, incorporated in the chemically reducing layer, for the young rice. As in the cooler regions of Japan a considerable number of days may elapse before the rice roots reach the fertilizer balls or pellets, early growth being thus retarded, it may be preferable in such circumstances to apply a small part of the fertilizer as a normal top dressing, together with the pellets.

The Japanese Ministry of Agriculture and Forestry recommends that about 70 % of the nitrogen should be used in the initial application before the seedlings are transplanted.

In general basal applications of fertilizers for the rice crop begin early in April and end early in July, with earlier applications in southern than in northern districts.

Top dressing with N fertilizers normally takes place 24-25 days before the formation of the rice ears. On a fertile paddy field the application is sometimes delayed until 14-15 days before heading. Most of the top dressing is applied in July. In warm districts the application may begin in early June and continue to the end of July or early in August. In colder districts the period for top dressing is much shorter and the fertilizer is usually applied during the first half of July.

Lime applications have an indirect N fertilizing effect. When slaked lime is added in large quantities to rice soils (500 mgr. CaO per 100 gr. dry soil), the quantity of NH_3-nitrogen is greatly increased owing to an accelerated decomposition of organic matter. Sufficient lime must be added to raise the pH of the top soil up to 8.5 to 9 and keep it at that level for 1 to 2 days. Field experiments with rice gave an increase in yield up to 20 % when slaked lime in sufficient quantities was applied to the soil. This practice was recommended during the war when there was a shortage of nitrogenous fertilizers.

The total requirements of sulphate of ammonia equivalent for all crops can be estimated at about 2 million tons in the not too distant future.

Owing to the gradual build-up of a phosphate reserve in the soil as a result of the application of phosphate dressings over a long period, a definite response to phosphate is uncommon with rice. Omitting phosphate applications may lead, however, to P_2O_5 deficiency symptoms and to a decline in yield within 3-8 years. Phosphate fertilizing is, therefore, generally recommended on the average basis of about 40 kg. of P_2O_5 in the form of commercial fertilizers, supplemented by about 30 kg. of P_2O_5 per ha. in farm manures.

Soils derived from volcanic ash receive larger quantities of phosphate than do sandy or alluvial types. Applications of 70 to 100 kg. of P_2O_5 per ha. are not unusual on soils derived from volcanic ash, compared with about 20 to 40 kg. of P_2O_5 per ha. applied to alluvial soils.

Maintaining the phosphate level of rice soils is important if only because a phosphate deficiency, by suppressing the propagation of blue-green algae, lowers the nitrogen content level also. Phosphate applications may therefore aid in increasing the nitrogen content of the soil as well.

When the phosphate deficiency is not acute it is possible that the effect of a retardation in growth during the early stages is overcome later without a final decrease in yield. But if, on the other hand, phosphate deficiency is acute, with a resulting decrease in yield, a long time may elapse before the yield is restored to a normal level in spite of phosphate applications.

Phosphate fertilizing should be continued, therefore, even where no direct responses to the applications are experienced.

In some parts of Kyushu, where the soils have been derived from volcanic ash and have a strong tendency to fix phosphates, the farmers prepare a thin mud paste by mixing one part of superphosphate with about five parts of soil and dip the roots of the seedlings into the superphosphate mud immediately before transplanting. This practice of concentrating phosphates around plant roots tends to compensate partially for the loss of phosphates through phosphate fixation.

Most Japanese paddy soils are moderately well supplied with potash. As the reserve of this nutrient in the soil is, moreover, supplemented by further supplies from manure applications and irrigation water, commercial potash applications can be omitted altogether or kept at a very low rate except in the so-called degraded soils, comprising about 20 % of the total paddy area of the country.

These degraded or Akiochi paddy fields are leached to such a degree that, in addition to many other soil constituents such as silica, manganese, iron, magnesium, and calcium, potassium has also disappeared from the top soil and must be supplied in the form of KCl. K_2SO_4 is a less suitable potash fertilizer for soils of this kind, as all sulphates increase the risk of harmful H_2S accumulations.

Manganese deficiency is another rather common characteristic of these degraded paddy soils. The treatment of Akiochi, or degraded paddy soils, therefore, presents the rice grower with a very difficult problem.

RICE GROWING IN KOREA

MOST of the cultivated land in Korea is found on the southern and western side of the peninsula. This is the region most favoured by nature for the culture of rice as well as other crops, such as barley, naked barley and soyabeans. In the northern and central regions of this country soil and climatic conditions do not favour rice.

During the period of annexation to Japan, from 1910 to 1946, rice production in Korea increased considerably through improvements in irrigation works, an increased and more efficient use of fertilizers, higher yielding varieties and more efficient control of pests and diseases.

For the whole of Korea the average area devoted to rice cultivation during the period 1934 to 1938 amounted to 1,645,000 hectares per annum with a total production of 3,700,000 metric tons of paddy.

All these improvements were not without a selfish basis, as Japan needed the rice to supplement her own home production.

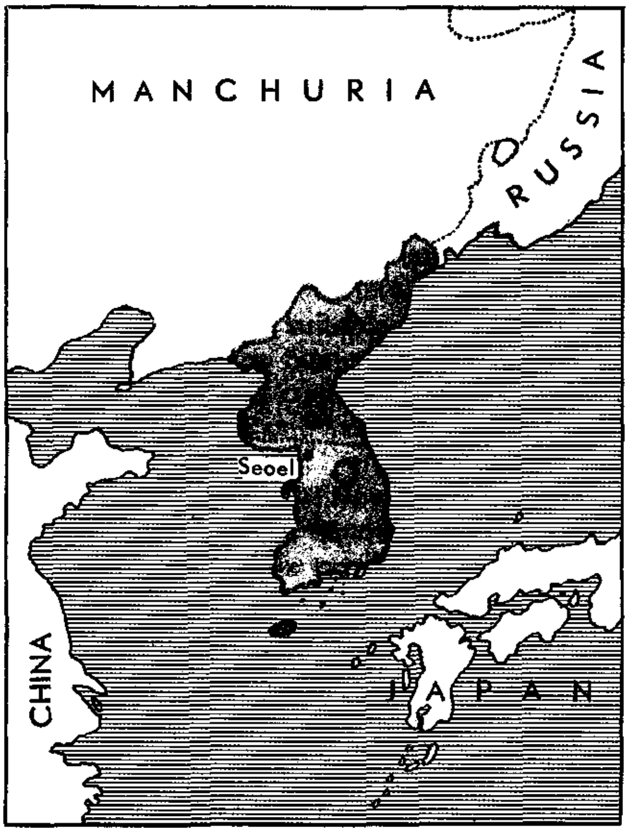
Partly as the result of an ample fertilizer supply from the more industrial north and of imports from Japan, partly by limiting the rice consumption of Korea itself through the substitution of imported foodstuffs — mainly millet and soyabeans from Manchuria — for rice, Korea had an export surplus of more than a million tons of milled rice annually available for Japan.

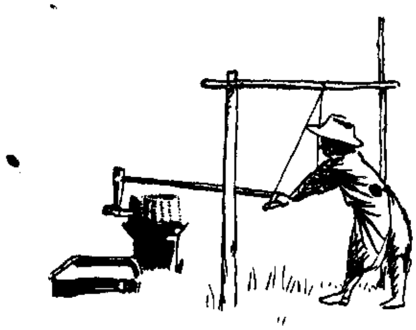
The situation was completely changed after the war when Korea became independent and an overpopulated agrarian South Korea was separated from a much less densely populated and more industrial North. This state of affairs forced South Korea to import 440,000 short tons of food (in terms of brown rice equivalent) in 1947 and 250,000 short tons during 1948-49 to supplement domestic production.

This situation was caused partly by an unusual increase in the population and partly by the fact that rice exports could no longer be substituted by food imports from Manchuria. Another very important factor was, however, the interruption in supplies of fertilizers. This caused a decline, not only in yields of rice, but also in the area under cultivation, because a great proportion of the fields remained fallow after the reaping of the rice crop instead of being planted with wheat or barley, which practice was no longer profitable without sufficient fertilizers. The U.S.A. tried to provide South Korea, therefore, with the urgently needed fertilizers as quickly as possible, and some hundreds of thousands of tons of nitrogenous and phosphatic fertilizers were imported and distributed among the farmers at reduced prices. This device proved to be an effective aid in restoring the volume of rice production in South Korea to a point approximating prewar levels.

Production level and food supplies will depend also in the future upon the ability of the government of Korea to continue its imports of fertilizers and the practice of distributing them, against subsidised and reasonable prices, among the poor Korean farmers, who are sadly lacking in capital and whose holdings each average about 1.1 hectare in area.

Korea no longer possesses potentialities for expanding its rice area, any more than does Japan, and more intensive rice growing, involving the use of at least 200,000 tons of nitrogenous fertilizers annually, will be the only practicable solution for satisfying an ever increasing demand.





RICE GROWING IN CHINA

AS already mentioned, the intensive nature of rice growing in Japan, involving the liberal application of fertilizers as well as many other kinds of manure, results in an average annual production level of about 36 quintals of paddy per hectare.

In China also rice growing is characterised by the use of large amounts of many kinds of manures, chiefly of the organic type, but up to the present hardly any inorganic fertilizers are used for this crop.

This omission is mainly responsible for the average annual production in that country of about 25 quintals of paddy rice per hectare as compared with 36 quintals in Japan.

The efficient use of inorganic fertilizers, therefore, coupled with the existing intensive cultivation of rice and use of ample supplies of organic manure, could undoubtedly bring about a marked increase in production in China.

In that country rice is one of the dominant crops only in and south of the Yangtze Valley. In the north, the dominant grain crops are wheat, millet and kaoliang (a grain sorghum). In the Yangtze Valley one crop of rice is grown each year. In the extreme southern areas, which are favoured by abundant rainfall and high temperatures, two or even three annual crops may be produced successfully. A comparison of the acreage production figures for rice in India and China will reveal a much larger area under cultivation in India (26 million hectares as compared with 18 million in China) but a considerable higher annual production in China (50 million tons of paddy as compared with 35 million in India). This is due to the much higher yields per hectare in China as a result of the intensive character of rice cultivation there.

In addition to the reaping of two consecutive crops, it is a common practice in China to transplant into the field alternate rows of early and late varieties of rice, or to transplant late varieties into the flooded field where early varieties are already growing and maturing, so as to utilize the rice growing season and the available water to the greatest possible extent.

In China what are known as „natural" manures have been used in rice growing for countless generations. Night soil, animal excreta, garbage and organic material in the form of weeds, grass, straw and leaves are carefully conserved, mixed with wood ashes and mud dug out from nearby streams and applied at the proper season. In addition other organic fertilizers, such as peanut cake and soyabean cake, are utilized, but inorganic fertilizers have not, up to the present, been extensively applied. The judicious use of nitrogenous, and for certain soils also, phosphatic fertilizers could, however, further increase yields economically, according to RICHARDSON,*) who gave the following survey of the results of nearly 300 fertilizer experiments conducted in a series of years by Messrs. Imperial Chemical Industries (China) Ltd., the National Agricultural Research Bureau, the Provincial Agricultural Improvement Institutes and the Colleges of Agriculture of various Universities.

After converting the results of all these experiments, which differed in layout, kinds of treatment and rates of application, into crop responses to a standard rate of application of 60 kg. of nutrient per hectare, RICHARDSON [61] compiled the data in two categories:

(1) Soil test experiments, in which fertilizers were used without local manures and either the experiments were each those for a single year, or else the data for the first year only of a continuous experiment were used. Consequently the fertilizer response was almost entirely directly due to the nutrient status of the soil when growing paddy rice. The amount of response indicates the degree of deficiency of the nutrient concerned.

(2) The much greater number of all field experiments on paddy fertilization, including those which covered a variety of subjects and were, therefore, not suitable for inclusion in the „soil test" series. Some of the experiments had been conducted continuously on the same site for more than one year, while others involved the use of local organic manures as basal applications or as one factor in an experiment.

The all-China average responses to the standard applications of 60 kg. per ha. of N, P_2O_5 and K_2O in the 82 „soil test" experiments are shown below as kg. per ha. of paddy or rough rice. Each figure for mean yield in the table is that resulting from the application of a particular nutrient.

*) H. L. Richardson. The Fertilizer needs and manuring of paddy rice in China.

AVERAGE RESPONSES TO PLANT NUTRIENTS
(in kg./ha.)

Nitrogen		*Phosphate*		*Potash*	
Response	*Mean Yield*	*Response*	*Mean Yield*	*Response*	*Mean Yield*
		First crop rice			
+ 660	2870	+ 295	2890	+ 45	2955
		Second crop rice			
+ 460	2490	+ 260	2535	0	2535
		Both crops			
+ 620	2805	+ 290	2830	+ 40	2880

As only one crop of paddy per annum is grown over most of China the number of second crop experiments is only a small fraction of the number of first crop experiments. The results for „both crops" are, therefore, not the simple means of „first" and „second" crop averages respectively.

The experiments show that the paddy soils of China are most deficient in nitrogen, moderately deficient in phosphate, but well supplied with potash.

RICHARDSON [61] points out that this is true also for China's dryland crops, including both winter and summer crops. In these cases also nitrogen responses are generally greater than those following phosphate applications, which in turn exceed those relating to potash fertilizing.

The relative richness of the soil in potash can be explained by the traditional use of local manures, the available potash content of which is relatively great, but in which available phosphate is relatively lacking in quantity. Nitrogen, on the other hand, does not accumulate at all but is readily lost in gaseous form as well as by leaching.

Partly owing to the favourable influence of the continuous use of local manures the level of rice production in China is considerably higher than that in countries like India, where, in the past, rice was hardly ever manured at all.

In a comparison of the „soil test" results with paddy rice on the wide alluvial plains, where the crop is extensively grown every summer, with the compiled results from the hilly land areas where paddy rice is grown in terraced fields on the valley floors and on the lower slopes of the hillsides, RICHARDSON [61] obtained the undermentioned figures representing responses to 60 kg. per ha. of N, P_2O_5 or K_2O.

As might have been expected, the mean yield figures in the table below show that the alluvial plain paddy soils were on the whole more fertile than the hilly land paddy soils, though only moderately so, owing to the fact that the hilly land paddy fields have also benefitted from soil enriching materials washed down from the upper slopes.

The decidedly greater responses to both phosphate and potash in the hilly lands illustrates the superior mineral nutrient status of the alluvial plain soils. The average response to potash on the alluvial plain soils was actually a negative one, showing that potash fertilizers, except the ashes and other locally available materials traditionally used, are quite unnecessary.

A remarkable result of the experiment, however, was the higher average nitrogen response on the paddy soils on alluvial than on those of hilly lands.

An explanation of this phenomenon may be obtained by classifying the results of these

ALLUVIAL PLAIN AND HILLY LAND PADDY SOILS
in kg./ha.

	Nitrogen		*Phosphate*		*Potash*	
	Response	*Mean Yield*	*Response*	*Mean Yield*	*Response*	*Mean Yield*
Alluvial plain	+ 645	2930	+ 225	3000	− 20	3060
Hilly land	+ 585	2625	+ 375	2570	+ 120	2640

RESPONSES OF PADDY SOILS, BY GREAT SOIL GROUPS
in kg./ha.

Soilgroup	*Response to*			*Mean Yield*	*No. of experiments*
	Nitrogen	*Phosphate*	*Potash*		
Calcareous Alluvial:					
Hwang Ho	+ 1000	+ 170	− 195	3170	3
Yangtze	+ 1150	+ 160	− 105	3190	5
Purple Soil	+ 700	+ 240	− 15	3225	7
Brown Earth	+ 670	(+ 45)*	(+ 375)*	3420	2
Yellow Earth	+ 480	+ 165	+ 100	2890	4
Red Earth	+ 540	+ 630	+ 190	2180	15
Podzolized Red Earth	+ 620	+ 270	+ 75	2595	7
Paddy Alluvial:					
Hwai & Yangtze	+ 600	+ 150	− 10	2750	12
Chengtu Plain	+ 675	+ 200	+ 80	3570	9
S. of Yangtze	+ 470	+ 310	− 20	2670	18

* Brackets indicate values derived from only one experiment. The mean yields and numbers of experiments were those for nitrogen.

„soil test" experiments on the basis of the chief soil groups, as abovementioned.

According to these figures the characteristics of low nitrogen, moderate phosphate and high potash contents appear to hold true for not only Chinese soils in general but most of the individual groups as well.

The average N status of Chinese paddy soils appears to be low regardless of soil type. The phosphate status is more variable, ranging from moderate to low and the potash status is generally high, except in the cases of a few soil groups.

The most fertile soils are those which are constantly supplied with mud-containing irrigation water originating from fertile areas. Mud originating from more strongly weathered red earths and allied soils is poorer and is unable to contribute as much to a high production level.

It was also found that some of the largest responses to nitrogen were given by the most fertile soils. This may be explained on the assumption that these soils are so well supplied with all other nutrients that nitrogen is the only one which controls the production capacity and thus yield. It follows, therefore, that fertile soils often need more nitrogen, than less fertile ones.

The biggest responses to phosphate should be expected from strongly leached soils which have been more or less exhausted, through continuous cropping, represented by the red earth and podzolized red earth soils of southern China and by the alluvial paddy soils derived from the above-mentioned types. These soil types undoubtedly need phosphate fertilizing.

Practically all of the alluvial soils were found to be amply supplied with potash. Up to the present responses to potash have been experienced on some of the older and more strongly leached soil types only.

The average results of the „soil test" experiments, classified according to the statistical significance of the responses in individual experiments, were as follows:

Paddy soils	*Percentage of significant responses*		
	nitrogen	*phosphate*	*potash*
Positive	85	48	14
Negative	6	0	1
Non-significant	9	52	85

These figures show that:

(1) By far the greater number of Chinese paddy soils (85 %) are deficient in nitrogen. The negative responses (6%) were probably the results of lodging in fields where nitrogen was applied to soils already rich in that nutrient.

(2) About half of the Chinese paddy soils showed significant phosphate responses, but the other half did not, and for efficient fertilizing the paddy soils which need phosphate will have to be separated from those which do not. A detailed study of the results showed that phosphate deficiency exists chiefly in the more leached soil types of central and south China, especially among the red earths.

(3) In agreement with the small average response to potash mentioned previously, only 14 %, about one-seventh, of the Chinese paddy soils are significantly deficient in potash. These are chiefly the strongly weathered and leached soil types.

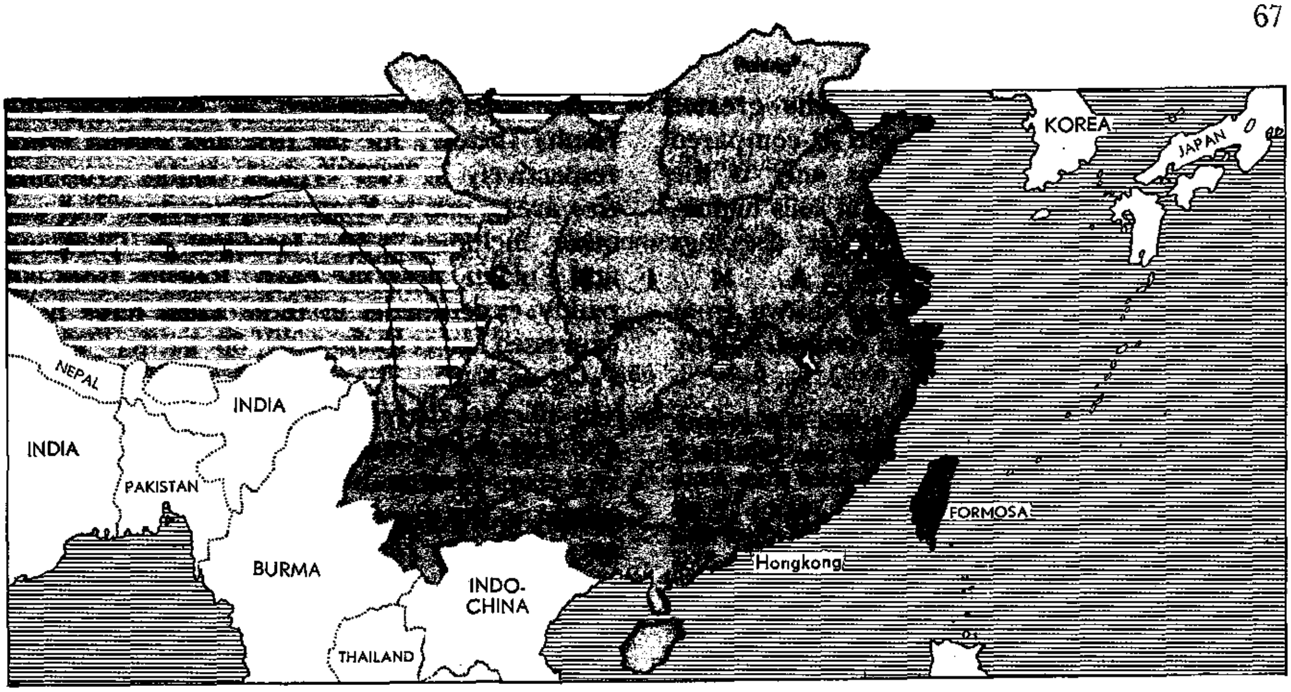
These experimental results indicate therefore that practically all Chinese paddy soils need some nitrogenous fertilizer, and that some soils require a regular supply of phosphate, while for others occasional applications of this nutrient will suffice.

According to RICHARDSON[61], small regular phosphate applications, in addition to nitrogen, might be given to paddy on both the alluvial plains and the hilly land of Szechwan, and on the alluvial plains and the podzolized red earths of south China. Only on the red earths of South China would the regular application of fertilizers equally rich in both nitrogen and phosphate be justified.

Potash fertilizers are not needed on most Chinese paddy soils as long as the traditional use of local manure and plant ashes continues;

PADDY RICE: ALL CHINA RESPONSES AND YIELDS

Nitrogen			*Phosphate*			*Potash*		
Response	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*
			First crop Rice					
+ 670	2770	(177)	+ 240	2805	(139)	+ 30	2860	(108)
			Second crop Rice					
+ 370	2790	(58)	+ 180	2805	(54)	+ 20	2710	(31)
			Both Crops					
+ 590	2775	(235)	+ 225	2805	(193)	+ 30	2830	(139)



a little potash might be added to N and P for red earths, or occasional potash applications might be given to individual paddy soils known to respond to this nutrient, e.g. red earths, podzolized red earths, yellow earths, brown earths and the alluvial soils of the Chengtu Plain.

Besides the rather limited number of „soil test" experiments RICHARDSON [61] summarised also the average results, in kg./ha. of paddy, for all the Chinese rice experiments in which nutrient responses could be measured and calculated at application rates equivalent to 60 kg./ha. of plant food *(see p. 66 below)*.

In general these results bear a surprisingly strong comparison to those given earlier for the much smaller number of „soil test" experiments. The fact that the mean responses to nitrogen, phosphate and potash are somewhat lower here, may be attributed to the use of local manures besides fertilizers for many of the objects included in these experiments.

The compiled results obtained on alluvial plain soils as compared with those on hilly land soils in the full series of experiments were as follows:

	Nitrogen			*Phosphate*			*Potash*		
	Response	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*
Alluvial plain soils	+ 570	2900	(157)	+ 170	2960	(130)	− 15	3090	(82)
Hilly land soils	+ 640	2520	(78)	+ 330	2480	(63)	+ 90	2445	(57)

These figures again demonstrate the greater fertility of the alluvial plain soils as compared with those on hilly land, as not only is the mean yield level for alluvial plain soils higher, but also the responses to fertilizer dressings are lower.

The practical conclusions to be drawn from the foregoing results have been summarised by RICHARDSON[61] als follows:

> In China, somewhat smaller yields and greater responses to the chief fertilizers are obtained from paddy rice grown on hilly land than from that grown on the wide alluvial plains. With nitrogen the difference in response is small and nitrogenous fertilizers should be used for rice on any type of land. The difference in response to phosphate is greater and, therefore, more phosphatic fertilizer should be used on rice in hilly land than on the plains.
> Potassic fertilizers should not be used on the plains, except in particular localities known to need them. Potash is rather more effective on hilly land, but potassic fertilizers need be applied only where they are known to produce a good response.

It is a noteworthy fact that, as indicated by some of the figures in the foregoing tables, the second crop tends to show smaller responses to fertilizers than the first.

This was demonstrated by comparing the results (below) for the first and second crops respectively in two typical double cropping rice areas, one in Kwantung province and another, including a few localities in Chekiang and Fukien, near the coast. Results from all paddy experiments in these areas have been expressed as responses to 60 kg./ha. of N, P_2O_5 or K_2O.

In all cases there are a lower mean yield level and higher responses to fertilizers in the first rice crop. Presumably the explanation must be sought in the more rapid mobilization of nutrients from the reserves in the soil during the hot summer weather experienced throughout the growing period of the second crop.

The first crop in those double cropping localities should, in consequence, receive most of the manuring. In the Chekiang-Fukien area a top dressing of nitrogen alone would be sufficient on the second crop, while in the Kwantung area soils are deficient not only in nitrogen but in phosphate as well.

As far as the responses at different rates of application are concerned, the average nitrogen response curve for paddy in China is almost a straight line, in which the proportionate

PADDY RICE-COMPARISON OF FIRST AND SECOND CROPS

	Nitrogen			*Phosphate*			*Potash*		
	Response	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*
				Chekiang & Fukien					
1st crop	+ 620	2480	(40)	+ 220	2360	(32)	+ 45	2480	(29)
2nd crop	+ 495	3090	(19)	+ 70	3150	(17)	+ 10	3410	(16)
				Kwantung					
1st crop	+ 630	2280	(57)	+ 315	2280	(47)	+ 100	2025	(27)
2nd crop	+ 310	2650	(39)	+ 230	2650	(37)	+ 40	2235	(15)

RESPONSES WITH AND WITHOUT LOCAL MANURE

Local Manure	*Nitrogen*			*Phosphate*			*Potash*		
	Response	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*	*Response*	*Mean Yield*	*No. of Expts.*
Absent	+ 570	2775	(103)	+ 285	2800	(88)	+ 40	2830	(89)
Present	+ 615	2775	(132)	+ 165	2815	(105)	+ 15	2815	(50)
Difference	+ 45	0		− 120	+ 15		− 25	− 15	

responses to higher rates of application showed a slight decrease. The average phosphate response curve, however, was a strongly flattened one in which fairly large responses to the lower rates of application were shown, the higher rates securing little further increase.

This may be illustrated by the average responses to 30 and to 120 kg./ha. of nutrient, calculated as percentages of the responses to 60 kg./ha. For nitrogen the corresponding values were 55 % and 168 %. For phosphate they were 92 % and 101 %, which means that 30 kg./ha. gives over 90 % of the response to 60 kg./ha. and that in practice, except for soils very deficient in phosphate, the rate of 30 kg./ha. P_2O_5 will generally be more efficient and economical than heavier applications.

As an all China average, the response to 1 kg. of N may be estimated to be somewhat more than 10 kg. of paddy. In general straw gave an even greater response to nitrogen than did grain.

As far as the fertilizing value of slow-acting bulky local manures like compost in addition to fertilizers is concerned, the use of such material resulted usually in a smaller response to phosphate and potash, but an even greater response to nitrogen. This is well illustrated by the general comparison of responses to fertilizers with and without local manure. Results are again given as responses (kg. paddy per ha.) to 60 kg. per ha. of N, P_2O_5 or K_2O *(see figures above)*.

It can be seen that the use of bulky local manure decreases the response to phosphate and potash, but increases the response to nitrogen. This may be explained by the relatively low nitrogen content of this material as compared with its soil improving influence, which often makes a soil more responsive to nitrogen fertilizing and increases the effect of N. Active organic materials on the other hand, like oil-seed cakes, night soil and also leguminous green manures decreased not only the responses to phosphate and potash, but to nitrogen as well. Such material has a pronounced nitrogen fertilizing value, therefore, whereas that of the slow-acting bulky local manure is negligible.

The difference in nitrogen fertilizing value between active and slow-acting local manures may be demonstrated by the average responses to 60 kg. N per ha., using both kinds of local manure as well as without local manure, expressed as kg. of paddy rice per ha.:

No local manure	+ 570 kg. per ha.
Active local manure	+ 470 kg. per ha.
Inactive local manure	+ 850 kg. per ha.

It thus appears that active local manures tend to reduce the response to nitrogenous fertilizers while the slow acting local manures have the opposite effect.

Although characterised by the liberal use of organic material rice production in China could be considerably increased by the efficient use of inorganic fertilizers, mainly nitrogen, supplemented by some phosphoric acid for about half the area and some potash for the most strongly weathered and leached paddy soils. Based on the very moderate application of not more than 30 kg. per ha. of N and on a total area of about 18 million hectares of land under paddy cultivation in China, there would be a total N requirement of not less than 540,000 tons, equivalent to 2.7 million tons of sulphate of ammonia. In many cases, however, as already noted, an application of 60 kg. of N per ha. would be needed. This would increase proportionally the total quantity required.

Paddy fields in Java with Tangkuban Prahu vulcano in the background

RICE GROWING IN FORMOSA (TAIWAN)

BEING a sub-tropical island with an adequate rainfall, Formosa is very suitable for rice-growing, and two crops can be produced annually on most of the rice land. The first crop is sown between February and March and harvested between May and July, while the second is sown between July and August and harvested between November and December.

As in Korea and for the same reason, rice production increased considerably in Formosa under Japanese rule, with 1938 a maximum year of production, when the area under cultivation amounted to 625,398 hectares, the total production of paddy was 1,402,414 metric tons, the average yield of paddy 2,243 kg. per ha., the total quantity of fertilizer used 389,334 tons and the average quantity of fertilizer applied per ha. was 623 kg.

The exports of rice from Formosa varied during that period from 600,000 to 700,000 metric tons of paddy per annum. The high production was due to the use of fertilizers, the total output of paddy and average yield per hectare in Formosa being closely connected with the quantities of fertilizers used.

The total fertilizer consumption for all crops in 1938 reached a peak of 648,800 tons, consisting of 177,995 tons of soyabean cake, 169,642 tons of sulphate of ammonia and 233,213 tons of mixed fertilizer.

The consumption in terms of elements was 76,793 tons of N, 24,649 tons of P_2O_5 and 5,552 tons of K_2O.

After 1938 the consumption of fertilizers steadily decreased to no more than 325,702 tons in 1943, and in 1945 it dropped to a figure of not more than 10,000 tons of chemical fertilizers.

The manner in which this sharp decline in fertilizer consumption affected crop yields, in spite of a considerable increase in compost consumption (from 4.6 million tons in 1939 to 16.9 million tons in 1943), is illustrated by the figures for rice production, which fell from 1,100,000 tons per annum during 1940-43 to 630,000 tons in 1945. The decline in yield of the first crop was from 2000 kg. to 1400 kg., and of the second from 1600 kg. to 1000 kg. per hectare.

All soils in Taiwan respond to nitrogen fertilizing. The productive soils apparently respond to N even more than do the less productive ones.

It was shown that the available P_2O_5 con-

DEFICIENCY STATUS OF N, P_2O_5 AND K_2O IN THE SOILS OF DIFFERENT PREFECTURES IN TAIWAN (CHU)

Name of Prefecture	*Increase of rice yield from the application of 80 kg./ha. of N, P_2O_5 and K_2O in %*					
	1st crop			*2nd crop*		
	N	*P_2O_5*	*K_2O*	*N*	*P_2O_5*	*K_2O*
Hsinchu (native rice)	20.7	6.0	7.5	16.5	4.5	8.2
Taipei (Horai rice)	20.4	7.4	4.3	18.1	7.2	6.1
Taichung (Horai rice)	23.8	5.0	2.4	16.6	3.7	7.5
Tainan (Horai rice)	19.1	–3.5	–4.1	23.9	10.7	–2.6
Kaohsiung (Horai rice)	23.0	5.4	4.4	16.5	5.9	5.9
Hwalien (Horai rice) / Taitung (Horai rice)	25.4	4.3	–2.0	8.0	–1.4	–0.12
Average of six prefectures except that of Hsinchu	22.3	5.0	1.7	17.2	5.8	3.9

tent of the soil varied inversely with the soil acidity. On acid soils, the available amount of P_2O_5 is very low and it increases continuously with the rising of the pH values. Field experiments showed the red and yellow earths to be most responsive to P_2O_5.

As far as potash is concerned, it was shown by the field experimental results that the yellow and red earths are the soils most responsive to K_2O fertilizers. The slightly acid, neutral and slightly alkaline soils are usually not deficient in potash.

The figures above show that the soils of this island are most deficient in nitrogen, P_2O_5 deficiency is next, and K_2O deficiency least.

According to results recorded by RICHARDSON in China, soils show a greater N deficiency in the early or first rice crop than in the second or late crop, P_2O_5 deficiency is about equal for each crop, while that of K_2O seems to be more pronounced in the late than in the early crop.

More or less in accordance with these findings the standard of fertilizer allocation in kg. per ha. under the Japanese regime was as follows:

	1938—1941		
	N	*P_2O_5*	*K_2O*
1st crop of rice	66	28	10
2nd crop of rice	52	21	16

Although Formosa produces fertilizers locally, domestic production does not cover the requirements. The following amounts of fertilizers had, therefore, to be imported during the period 1947—1951:

Year	*Metric Tons*
1947	59,446
1948	65,152
1949	105,148
1950	225,103
1951	274,906

The allocation to the farmers by the Department of Fertilizer Transportation and Allocation of the Taiwan Food Administration was made on the principle of barter, by which farmers obtained fertilizer from the government and paid for it in the form of paddy.

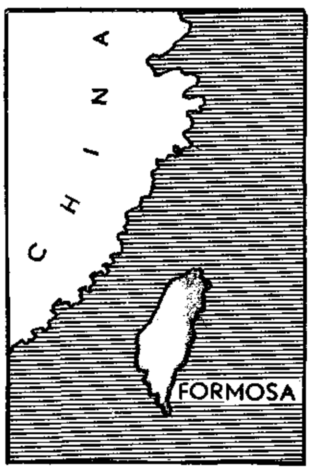
The following figures illustrate the rates of barter, the supply of one kilogramme of any kind of chemical fertilizer being repayable in the form of the following quantities of paddy:

Year	*Sulphate of ammonia*	*Calcium cyanamide*	*Ammonium nitrate*	*Chilean nitrate*	*Ammonium phosphate*	*Super phosphate*
1948 2nd half	1.50	—	2.00	—	1.90	—
1949 1st „	1.50	—	2.00	—	1.90	0.50
1949 2nd „	1.50	—	2.00	0.80	1.80	0.50
1950 1st „	1.20	—	1.60	0.70	1.50	0.40
1950 2nd „	1.00	1.00	1.40	0.60	1.30	0.40
1951 1st „	1.00	0.90	1.40	0.60	1.30	0.40
1951 2nd „	1.00	0.90	1.40	0.60	1.30	0.40
1952 1st „	1.00	0.90	1.40	0.60	1.30	0.40

For example, as one kg. of sulphate of ammonia can increase paddy production by 3 kg. and from this increase the borrowers take 1 kg. to repay their fertilizer debt to the government, leaving a balance of 2 kg. as their gain, the great benefit accruing to the farmers from barter of this kind can be appreciated. Moreover, the Formosan authorities gave financial aid to farmers in other ways also. Partly as a result of these rice growing incentives, and partly because the rice area has increased at the expense of that under sugar-cane, the total area under rice cultivation in 1952 amounted to 790,000 hectares, producing 1,600,000 metric tons of paddy.

Owing to the increasing quantities of fertilizers available for rice growing, the average production in kg./ha. over the period 1947—1952 has increased as follows:

1947	1474	*1950*	1845
1948	1407	*1951*	1882
1949	1624	*1952*	2025



RICE GROWING IN INDIA

WHEN in 1947 prewar British India was partitioned into the Dominions of India and Pakistan, India was left with about 80 % of the prewar population, but with a disproportionately smaller share of the agricultural resources and especially of land under irrigation. This aggravated the problem of food deficiency.

Based on a food requirement of 1 lb. of grain a day per head of population, the total annual requirements at present are:

	59 million tons	of grain per year, supplemented with
	3,5 million tons	of grain lost in storage
+	2,5 million tons	of seed grain
Total	65 million tons	against an average production
of	60 million tons	which means at present a shortage
of	5 million tons	of grain annually.

As the population increases, however, at a rate of more than 5 millions a year, food requirements will, within about 10 years, amount to:

67 million tons +
3 million tons lost in storage
3 million tons seedgrain

Total 73 million tons

which means that the deficit will have gone up to 13 million tons if yields per unit area are not substantially increased.

Apart from the financial consequences and difficulties connected with foreign exchange, existing harbour and railway facilities could not handle such a volume of imported rice. The figure illustrates convincingly, therefore, the urgency of increasing domestic grain production in India, involving an increase in rice production chiefly, rice being by far the most important food grain in India as the following figures prove:

ACREAGES OF DIFFERENT GRAIN CROPS IN INDIA

Rice	70 million acres
Wheat	24 million acres
Sorghum or Jowar (Sorghum vulgare)	31 million acres
Millet or bajra (Pennisetum typhoides)	18 million acres
Finger millet or ragi (Eleusine coracana)	5 million acres
Barley	7 million acres
Maize	7 million acres

The average rice yields in India, amounting to 800 to 900 lb. per acre, are extremely low and could be substantially increased by:

(1) better irrigation facilities through improvement of existing irrigation systems and establishment of extensive new irrigation projects;

(2) fertilizing, including the judicious use of

farmyard manure, compost, green manure and other available organic material as well as inorganic fertilizers;

(3) an improvement in other cultural practices;

(4) a more extensive use of higher yielding varieties.

The dependence of rice on water and rainfall is strikingly illustrated in India where rice is almost entirely grown in areas with an average annual rainfall of not less than 50 inches, that is, along the western coast and in the north-eastern part of the country. The most important rice-growing states of India are Madras, West Bengal, Bihar, United Provinces (Uttar Pradesh), Central Provinces (Madhya Pradesh), Assam and Orissa.

Uneven and irregular seasonal distribution of rainfall creates a problem for India and also makes rice production more hazardous than it is in most other rice producing countries. Water supply is generally the principle limiting factor for rice production in India. Extension of irrigation facilities is, therefore, of prime importance.

The area under irrigation during 1935-1936 amounted to:

	million acres
irrigated from government canals	26.7
irrigated from private canals	4.6
irrigated from wells	15.3
irrigated from tanks	7.6
irrigated from other sources	5.7
Total	59.9

Owing to many extensive new irrigation projects, now under construction or planned, a much larger total area can be assured, however, of a better water supply in future.

Rice fields along the western coast of India →

The manner in which rice yields are influenced by irrigation facilities may be demonstrated by some figures for average yields of rice under irrigated and non-irrigated conditions over the period 1901-1936.

State	*Irrigated*	*Non-Irrigated*
	Yields in lb. per acre	
Madras	1,100	800
Bombay	—	1,200
Sind	1,300	—
U.P.	1,070	850
Punjab	900	650
N.W.F.P.	1,030	—

The exceptionally high yield of non-irrigated rice in Bombay is the result of abundant rainfall in the rice-growing areas concerned. Under existing conditions only about 20% of the rice crop is provided with canal irrigation facilities, the remaining area being dependent more or less solely on the rainfall, mostly from the south-west monsoon.

Although in India, as well as in other rice growing countries, transplanting results in an increase in yield of from 15 to 30 per cent, an appreciable proportion of the rice area is still sown broadcast at the rate of about 80 lb. per acre, due to the scarcity of water.

Fields are usually ploughed and prepared for sowing in a dry condition, sowing being done with the first monsoon or pre-monsoon showers in May-June. When the monsoon is delayed so also is planting of the seed, which, for most varieties, results in decreased yields.

Another factor towards decreased yields is the fact that dry soil preparation by means of bullock-drawn implements is seldom or never thorough enough, and water scarcity, moreover, causes a stronger weed growth.

Transplanting is practiced in areas of assured regular water supply.

Fertilizing, more especially with N, has proved to be a promising cultural practice, as Indian soils are generally deficient in N, the application of which, therefore, either in organic or inorganic form, has invariably resulted in an appreciable increase in yield. According to the initial fertility status of the soil, results obtained showed an optimum rate ranging from 20 to 60 lb. of nitrogen per acre. On the average there was an increasing response up to 40 lb. of N per acre applied as sulphate of ammonia, beyond which rate the response declined. Following a rate of application of 20 tot 30 lb. of N per acre, a yield increase of about 300 to 500 lb. of grain may be expected. This is equivalent to about 15 to 16 lb. of grain for every lb. of nitrogen applied.

YATES, FINNEY and PANSE [85] record in the following table the results of a survey of response by paddy to sulphate of ammonia, standardized to 20 lb. of N per acre.

Sites	*State*	*Years*	*Number of Experiments*	*Yield without nitrogen*	*Response*
				in lb. per acre	
Exp. farms	various	1937/49	75	1563	353
Exp. farms etc.	various	1936/38	27	?	329
Cultivators	Bihar	1948/49	117	1316	337
Cultivators	Bihar	1949/50	576	1234	387
Cultivators	Bihar	1951/52	1245	1152	247
Cultivators	Bihar	1952/53	624	1399	206
Cultivators	W. Bengal *	1951/52	46	1728	206
Cultivators	Madhya Pradesh	1950/51	78	1316	123
Cultivators	Madhya Pradesh	1951/52	133	?	230
Cultivators	Madhya Pradesh	1952/53	48	1316	329
Cultivators	Madras	1950/51	159	1810	337
Cultivators	Madras	1951/52	273	1892	329
Cultivators	Madras *	1951/52	46	2221	197
Unweighted mean					279

* Two districts only in each State; in Madras basal dressing of green manure applied.

Fertilizing experiments on rice in North-East India (Burdwan farm)

Though an increase in yield of 500 to 600 lb. per acre has frequently been obtained, the extensive trials conducted at 60 locations on cultivators' fields in Orissa, with an application of 100 lb. of sulphate of ammonia per acre, gave an overall average increase of 275 lb. of paddy per acre over a no-manure control plot yield of 1,521 lb. per acre, an increase of about 18 %.

Phosphate fertilizing also produced responses in many cases, although the results were not so uniform. Thus phosphate fertilizing showed distinct responses at Bihar, Assam and Richhai (Central Provinces) but not at Nagina (Central Provinces), Berhampur (Orissa) and Pattambi (Madras).

YATES, FINNEY and PANSE [85] give, in the following table, the results of a survey of responses to superphosphate, standardized to 20 lb. P_2O_5 per acre.

The responses to phosphate are substantially less than those to nitrogen.

Sites	*State*	*Years*	*Number of Experiments*	*Yield without phosphate*	*Response*
				in lb. per acre	
Exp. farms etc.	Madhya Pradesh	Before 1950	19?	987	345
Exp. farms etc.	various	Before 1950	120?	2222	107
Cultivators	Bihar	1949/50	576	1810	197
Cultivators	Bihar	1951/52	1245	1646	165
Cultivators	Bihar	1952/53	624	1563	156
Cultivators	W. Bengal *	1951/52	46	1975	99
Cultivators	Madras *	1951/52	46	2468	82
Unweighted mean (excluding Madhya Pradesh)					132

* Two districts only in each State; in Madras basal dressing of green manure applied.

Classification of responses of paddy to N and P_2O_5 according to soil type in experiments on cultivators' fields in Bihar in 1949/50, gave the following results according to YATES, FINNEY and PANSE [85].

Soil	Number of Experiments	Yield without fertilizer	Response to 20 lb. N/acre in lb. per acre	Response to 20 lb. P_2O_5/acre in lb. per acre
Alluvial				
Clays *	168	1317	403	156
Loams	76	1070	428	288
Sands *	136	1070	362	107
Non-alluvial				
Clays *	63	1476	444	337
Loams	46	1317	411	362
Sands *	46	1317	222	173

* including clay loams.
* almost entirely light loams and sandy loams.

All soils show similar responses to N except non-alluvial sands, which produce a lower response. Responses to phosphate are decidedly more variable, this variability being apparent also in the results from individual experiments on experimental farms. It is clear, however, that response to phosphate, especially on non-alluvial clays and loams, can be as great as those to nitrogen.

Potash fertilizing seldom produced responses. Indications of a response to potash were noticed only on some sandy soils and some strongly leached old lateritic soils. Thus potash produced somewhat positive responses on the sandy loam soils of Richhai and Adhartal (Central Provinces) but no result at all at Nagina (United Provinces), Sabour (Bihar), Waraseoni (Central Provinces) and Hyderabad (Deccan).

One series of experiments on cultivators' fields in the province of Bihar, however, showed appreciable responses to potash, by paddy and maize. In the 1952/53 experiments in Bihar, where the effect of 40 lb. K_2O per acre (as KCl) was tested on paddy in the presence of N and P_2O_5, the mean response in 624 experiments was 214 lb. per acre. Every one of the 17 districts showed some response and though the magnitude varied from district to district no clear association with soil type could be seen.

Lime sometimes produced a definite response, e.g. at Pattambi (Madras), sometimes showed no effect at all and sometimes proved harmful, e.g. at Travancore and on the Dacca highlands lateritic soils.

A final conclusion reached from all these experimental results is that a moderate dressing of N, e. g. 30 lb. N per acre, supplemented by a basal dressing of 5000 lb. of green manure, can be regarded as highly profitable and be safely recommended to cultivators to their ultimate advantage.

In 1952, as in 1951, India imported 700,000 tons of rice at a total cost of Rs. 43 million in

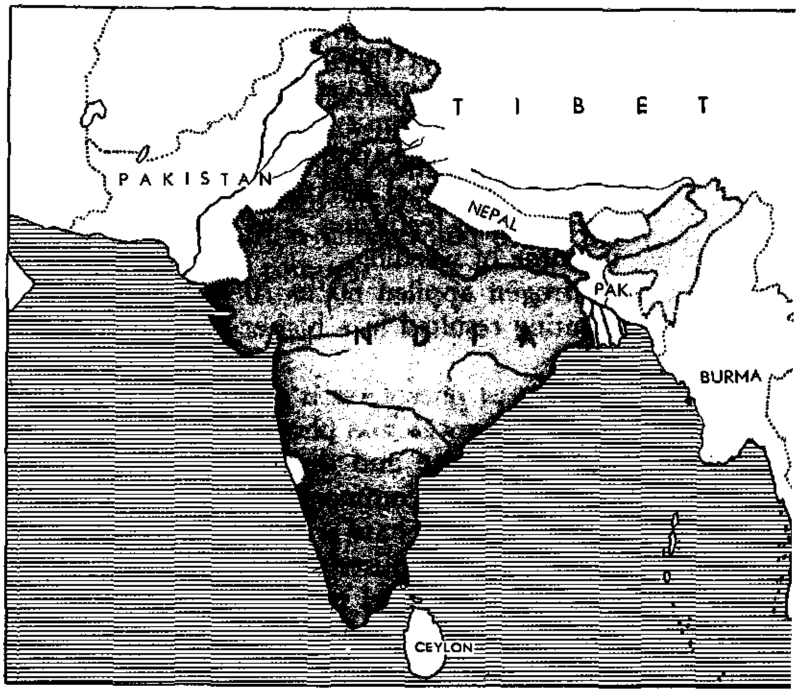
1951 and Rs. 50 million in 1952. If one half of the rice acreage was fertilized at a rate of not more than 20 lb. N per acre, an additional yield of about 3 million tons of rice would be obtained, a 15 per cent increase on the present yield of rice for the whole country. This would require 1.6 million tons of sulphate of ammonia, when the present home production of this chemical amounts to about 360,000 tons annually.

Planning a fertilizing scheme for phosphate on paddy is more difficult, as a general recommendation for the use of superphosphate would clearly be unprofitable to many farmers. Generally speaking one may say that on the 15 million acres of lateritic soils a phosphate application of 30 lb. P_2O_5 or more may be considered necessary or advisable, while also on the 5 million acres of sandy coastal plain soils good responses are obtained to phosphate. For most of the 55 million acres of alluvial paddy soils, phosphate does not give a yield increase, however, and in view of the scarcity of capital it would seem possible to fertilize these soils with nitrogen only, at least until signs of phosphate need begin to appear. Often, however, an application of 30 lb. of P_2O_5 is officially recommended for soils of this type also.

In the first place, therefore, areas that are at present suffering from phosphate deficiency must be determined. When this has been done, it may well be found that an additional half a million tons of superphosphate can be utilized in a profitable way to give an additional 750,000 tons of rice or 3½ per cent of the present total yield.

These figures do not represent the limit of what can be expected from the use of fertilizers, as the introduction of improved varieties and improvement of cultural practices will lead also to an increase in the use of fertilizers. It is estimated that less than 1 % of the rice area actually receives fertilizer at present.

Up to the present sulphate of ammonia has proved to be the most suitable form in which nitrogen can be applied to paddy soils. Leguminous crops too should be utilized as much



as possible.

The usual method of applying sulphate of ammonia is by means of spreading the fertilizer on the wet soil's surface after planting. According to DR. VACHHANI [79] however, experimental results indicate that the application of sulphate of ammonia to the dry soil and ploughing it in 2 to 3 inches deep immediately before the pre-planting inundation of the land with water, produces higher yields than the customary practice of broadcasting the fertilizer on the surface after planting. The fertilizer can be evenly applied in plough furrows and covered up when the next furrow is cut. Trials conducted on cultivators' fields during 1951-1952 have shown that the dry application of sulphate of ammonia at 100 lb. per acre gives increased yields of 466 lb. of paddy per acre as compared with 304 lb. per acre in the case of the customary wet application. The common practice of applying the entire quantity of sulphate of ammonia immediately after transplanting is less efficient, according to VACHHANI[79], than the application of the entire quantity one month after transplanting or application in two equal doses, one at planting time and the other one month after by ball-fertilizing, 2 to 3 inches deep, at the time of weeding.

Nitrogen applied 60 to 70 days after transplanting resulted in a higher N content of the grain.

As far as phosphate is concerned, the water soluble monocalcium phosphate, in the form of superphosphate and double or triple superphosphate, is commonly favoured, although dicalcium phosphate is just as useful and bonemeal may be utilized where it is available at a low cost. Ground rock phosphate is used on phosphate fixing, free iron containing, strongly weathered lateritic soils.

Ploughing under the phosphate, together with a green manure crop before broadcasting or transplanting is one of the best methods of application.

Fertilizing the rice seed beds often results in stronger plants with better developed roots at transplanting time, but has practically no influence on final yields.

The practice of growing leguminous crops for green manuring, although strongly advocated by the Agricultural Departments, still meets with great opposition owing to the difficulty of introducing a green manure crop without sacrificing a food crop. The practice is gradually extending, however, particularly in Madras and the southern rice regions, where it has been widely adopted in the deltaic alluvial areas. *Sesbania* and *Crotalaria juncea* are two of the most suitable forms of green manure crops for rice growing in India. In addition, maximum use is at present being made of the available sources of organic material provided by green manure grown on the bunds or by the leaves of jungle trees, which are applied wherever possible. Cattle manure is applied chiefly to the dry crops. Little is used for paddy.

In certain areas quick growing leguminous crops, such as green gram *(Phaseolus aureus)*, black gram *(Phaseolus mungo)*, gram *(Cicer arietinum)*, or Khesari *(Lathyrus sativum)* are grown after harvesting the rice crop, but as the yields of such crops are low, and since they are grown for seed, their value as soil enrichers is rather small.

Where conditions permit, a crop of groundnuts *(Arachis hypogaea)* can be rotated with rice. This practice causes a considerable increase in the succeeding crop of rice.

In conclusion, some figures are here presented relating to the results of a large scale trial with paddy on 27 acres of channel irrigated private land in Mysore and fertilized on a basis of 12 lb. N and 18 lb. P_2O_5 in addition to 1 to 1½ ton of farmyard manure per acre per annum, which implies a very moderate application of fertilizers.

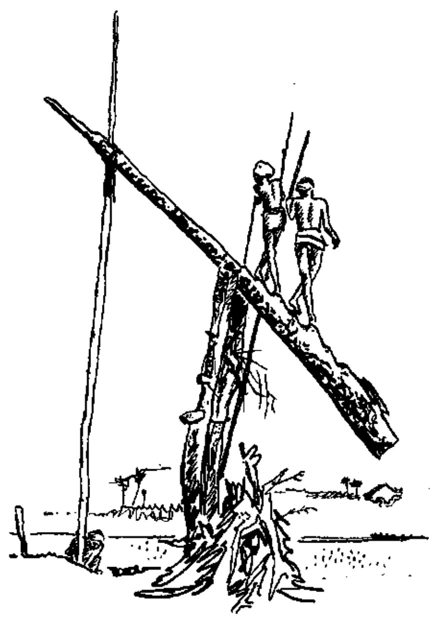
Season	*Average Yields in lb./acre*
1924/25	1480
1925/26	1663
1926/27	1735
1927/28	2281
1928/29	2466
1939/40	2950
1940/41	2776
1941/42	3071
1942/43	3148
1943/44	3186

These figures show the possibility of increasing rice yields up to 3500 lb. per acre by means of fertilizing and better cultural practices.

From crop competitions, a very valuable means of propaganda and strongly encouraged by the Government, there have been reports of yields even as high as 8,000 to 10,000 lb. of rough rice per acre, whereas the present average yield for the whole of India amounts to not more than 800 tot 900 lb. per acre.

India is aiming also at the expansion of its food growing area by the reclamation of large tracts of land infested with *kans*-grass *(Saccharum spontaneum)* by deep ploughing with heavy state-owned tractors equipped with root cutters, stumpers etc..

A country wide tree planting programme has been organised. This may in time augment the fuel supply in rural areas and, in this way, preserve farmyard manure for fertilizing. Nowadays only 40 % of this farmyard manure is used for crop production, large quantities being used as fuel. Furthermore, the Government is energetically encouraging compost making projects in which cattle dung, urine and night soil are used in conjunction with waste and refuse from villages and towns for the preparation of compost.



RICE GROWING IN PAKISTAN

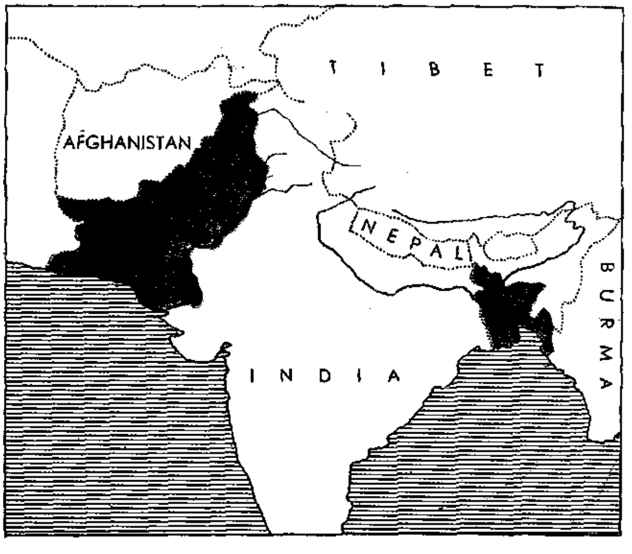
PAKISTAN consists of two quite distinct areas, Eastern Pakistan and Western Pakistan, separated by more than 1000 miles of India territory.

While Eastern Pakistan is a large rice producing area, West Pakistan grows comparatively little of this crop but large quantities of other grains such as wheat, bajra (millet), jowar (sorghum), maize and barley.

The area under rice in Pakistan totalled in 1951/52 about 22,480,000 acres (of which 20,300,000 acres were in East Pakistan), with a production of 11,800,000 metric tons of paddy.

West Pakistan, with an area of about 923,000 sq. km. and a population of 33.5 millions, should be grouped with the semiarid regions of the Near East. Large portions of it have a climate approaching even that of a desert, as a result of which irrigation is a vital necessity for large-scale agriculture. At the present time, wide areas are under irrigation in the Punjab, Sind, Bahawalpur and Khairpur and smaller areas in the N.W. Frontier Province and Baluchistan. New irrigation schemes, such as the Thal Desert project and the lower Sind Barrage, are under construction and several others are projected.

A serious menace to many of the irrigated soils of West Pakistan is the increasing degree of salinity which is developing in them. Rice growing is considered to be one of the most effective means of reclaiming these saline soils, as experiments have shown that it is possible to grow rice after reducing the salt content of the soil by leaching.



As reclamation proceeds the rice yield increases and is a reliable indication of the stage to which reclamation has reached. In addition, while the land may be suitable for rice only at the beginning of an irrigation scheme, this land improves to such an extent as time goes on that it eventually becomes capable of producing excellent crops of cotton, wheat, sugarcane, etc.

In areas where the excessive salt content of the soil is a problem, therefore, the cropping system should be altered temporarily so that rice can be included in the rotation.

East Pakistan, on the other hand, with an area of about 54,000 sq. km. only, but with a population of 42.5 million, has an average annual rainfall of over 80 inches with the rainy season extending from the end of May until mid-October. The other months of the year are very dry, with practically no rainfall at all during December to March.

Most of East Pakistan is a flat deltaic plain built up by the rather fertile silt of three huge rivers, Ganges, Brahmaputra und Meghna. The southern part of the area is swampy with tidal forests and in the north the land rises to an elevation of about 100 feet above sea level. In May the rivers rise rapidly by about 20 feet, flooding almost one third of the country, and descend again in October.

Owing to the density of population in East Pakistan, this region does not produce sufficient rice for its needs in most years, but as West Pakistan often has a small surplus of food, there is more or less self-sufficiency in food production over the country as a whole.

In favourable years Pakistan may even have small quantities of food grains available for export, but in years with unfavourable growing conditions the country may be confronted with a food shortage. This occurred during 1952-53, when the shortage amounted to 400,000 tons. Pakistan is forced, therefore, to increase production, especially as the population is increasing at a rate which makes greater demands upon the food supply from year to year. An extremely valuable contribution to the much needed higher level of food production will be the execution of the ambitious VAN BLOMMESTEIN plan.

This project involves the irrigation of wide areas and some flood regulation — affecting a total area of nearly 15 million acres — with the generation of hydro-electric power, and improvements of waterways for inland navigation.

This is a long term project, which will possibly not be completed for 30 years. In the meantime certain stages can be put into effect as they are developed.

The extension of irrigation facilities will increase production considerably as cultivation during the dry season is now limited to those areas with reserve soil water, comprising only about 30 % of the total cultivated area.

By means of continuous irrigation it will be possible to grow two crops a year, over the whole area, and three crops in some places.

For the Surma Valley there is a project to regulate the rise of the river's level in such a way that it will be possible to grow one crop of long stem paddy over wide areas. At the present time the area in question is a vast inundated basin, in which the water level rises at the end of May about 20 feet in three weeks. This is such a rapid rise that it is quite unsuitable for the cultivation of even long stem paddy. When the water level falls again after about seven months, only small patches of land are available for the cultivation of short term crops. The greater part of the area is now, therefore, regarded as being unsuitable for cultivation.

RICE GROWING IN CEYLON

IN Ceylon, as in Malaya, attention is mainly concentrated on export crops, tea, rubber and coconuts in the case of the former country, more or less at the expense of rice growing.

By far the greater part of Ceylon's rice area is situated in the south-central region and the south-west lowlands, both of which regions have ample rainfall.

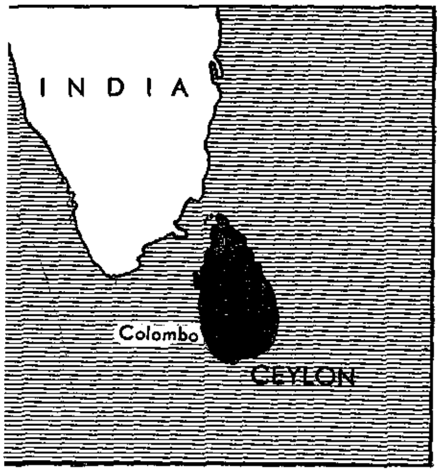
The total rice area is estimated to be 900,000 acres in extent, but yields are low and total production probably does not greatly exceed 200,000 tons of milled rice. This has to be supplemented by the importation of about 500,000 tons of rice to meet all requirements. Dependence on imports to such an extent may be very dangerous in time of war. It means, moreover, that a large part of the income accruing from exports has to be spent on the importation of rice. In 1949, 1950 and 1951 the value of rice imports represented 22 %, 23 % and 15 % respectively of the total value of all imports. Increasing the domestic production of rice is, therefore, a matter of prime importance. This may be effected by an extension of the rice growing area or by means of more intensive cultivation of the existing area.

Great possibilities of extension of rice cultivation exist in northern Ceylon. The climate is here characterised by a long period of complete drought but in ancient times there used to be intensive cultivation of rice in those areas dependent on an extensive system of storage reservoirs, called tanks, varying in size from tiny ponds, belonging to single cultivators respectively, to large lakes several square miles in area, which could supply water to the paddy fields of a whole village. The total number of tanks probably exceeded twelve thousand.

Invasions and infiltrations by Tamils from India subsequently occurred. The original inhabitants were pushed back more and more as time went on, the tanks and waterworks were destroyed or neglected and the population decimated by war and malaria. The jungle again took possession of the fields and covered the ruins and remnants of a great old civilization with dense vegetation. Almost the only form of agriculture practiced subsequently was shifting cultivation, called there *Chena* cultivation, by which method the *Chena* culti-

Working on soil tillage in the paddy fields of Ceylon →

Paddy soils in Ceylon



Paddy fields in Ceylon

Ceylon. Paddy fields drained after soil tillage vator burns down and roughly clears a portion of the jungle in order to sow or plant his food crops, which are cultivated for a few years until the soil is exhausted.

Government has now under consideration a big rehabilitation scheme to return as much as possible of this area to rice cultivation, for which extensive irrigation works are under construction.

The chief means by which rice cultivation can be intensified are:

(1) replacing the existing method of broadcasting by transplanting and
(2) fertilizing.

Despite the undoubted advantage of transplanting as compared with broadcasting the latter method is still that usually practiced in Ceylon. With this method far too much seed grain is used, resulting in an overdense growth of seedlings with all its attendant disadvantages. The population still adheres to the broadcasting method because transplanting calls for more manual work, which is distasteful to the Ceylonese.

Nitrogen is undoubtedly the most important fertilizing element. Practically all paddy soils in Ceylon are deficient in nitrogen and thus respond well to dressings of this type of fertilizer in the inorganic form or as green manure. At present, however, less than 20% of the paddy soils of the islands are receiving a sufficient supply of nitrogen in either form.

According to the results of experiments on plots scattered over the whole country production could be increased from 50 % to 100% by applying nitrogen.

Approximately 50% of the paddy soils respond to phosphate also. Up to the present only about half the area concerned receives any fertilization with phosphates. Recently a potassium deficiency has been discovered in paddy soils of the light sandy type. Approximately 25% of the rice area is thought to be subject to this deficiency but in spite of the fact that experimental applications of potassic fertilizers resulted in increases of 20% to 40%, this nutrient has not so far played an important part in the rice fertilization programme.

There are indications that in some soils sulphur deficiency may also exist. Work on this problem is proceeding.

The supply of organic materials to paddy fields in Ceylon is very limited, owing to the difficulty of introducing a green manure crop into a programme based on two rice crops a year. Moreover, the transport of organic material to the paddy fields from outside sources requires an excessive amount of labour and is too expensive.

In addition to the substitution of broadcasting by transplanting and an efficient fertilizing scheme, better weed control must be mentioned as a third factor towards an increase in rice production.

The most favourable time for applying nitrogenous fertilizers is considered to be about 3 weeks after sowing or transplanting. This generally coincides with the correct time for weeding the fields. Harrowing is sometimes carried out to decrease the number of plants after broadcasting. This practice results in yields intermediate in magnitude between those obtained after broadcasting and after transplanting.

Just before sowing the fields are almost completely drained of all water to encourage the germination of the rice grains. Preparatory cultivation of the soil requires abundant water, however, to facilitate puddling. The fields should, therefore, be carefully levelled so that the subsequent drainage may be efficiently carried out.

RICE GROWING IN INDONESIA

THE rice situation in Indonesia can be roughly illustrated by the following data:

	Tons of milled rice
Rice production Java	4,000,000
Rice production areas outside Java	2,400,000
Total production	6,400,000
Total requirements	7,000,000
Rice shortage	600,000

The shortage of 600,000 tons has to be made up by imports which, in addition to other disadvantages, implies that a considerable amount of foreign exchange, obtained from exports, must be used for the importation of foodstuffs, with a diminished amount remaining, therefore, for the importation of greatly needed raw materials and machinery for industry. Increasing the domestic production of rice is, therefore, a vital necessity for Indonesia, the more so as imports have continued to increase in postwar years. This is illustrated by the following figures.

Quantities of rice imported

1947	97,000 tons
1948	206,300 tons
1949	333,700 tons
1950	346,100 tons
1951	402,700 tons
1952/53 import requirements	600,000 tons

In prewar years about 250,000 tons of milled rice had to be imported annually, but the construction of additional irrigation facilities, the distribution of improved and higher yielding varieties and more intensive culture together contributed to a decrease in import requirements, until Indonesia actually had a small quantity of rice available for export immediately prior to the outbreak of the second world war.

Now again the primary aim should be increased rice production so as to make Indonesia as far as possible independent of external sources of supply. This is all the more vital as the increase in population produces a demand for an extra 100,000 tons of milled rice annually.

In addition to being the principal food of the inhabitants rice plays other important parts in the economy of Indonesia:

(1) Rice is generally the main source of revenue for the farmer. Increased yields therefore, mean a better livelihood for him.

(2) The price of other foodstuffs depends on the price of rice and abundant food at a low and stable price contributes to the more effective competition of Indonesian exports in the world's markets.

An increase in rice production may be effected in different ways:

(a) The rice acreage, especially that under wet rice, should be extended as much as possible. More extensive rice cultivation in Java and Madura is hardly possible, however, except at the expense of other interests, e.g. the protective forest area. The other islands are sparsely inhabited and with great scope for an extension of the rice area. Many of their soils are, however, less fertile than those in Java and the first requisite will be the provision of irrigation facilities.

(b) Improvement of irrigation facilities and water distribution by repairing the old neglected irrigation works or those that are not operating efficiently, by building new irrigation works and/or increasing the irrigation capacity. An important consideration is, moreover, the maintenance of the requisite area of protective forests above a certain minimum figure on account of their vitally important influence on water supply.

(c) Plant breeding for the production of higher yielding varieties well adapted to the various soil types and to existing water conditions.

(d) Judicious fertilizing.

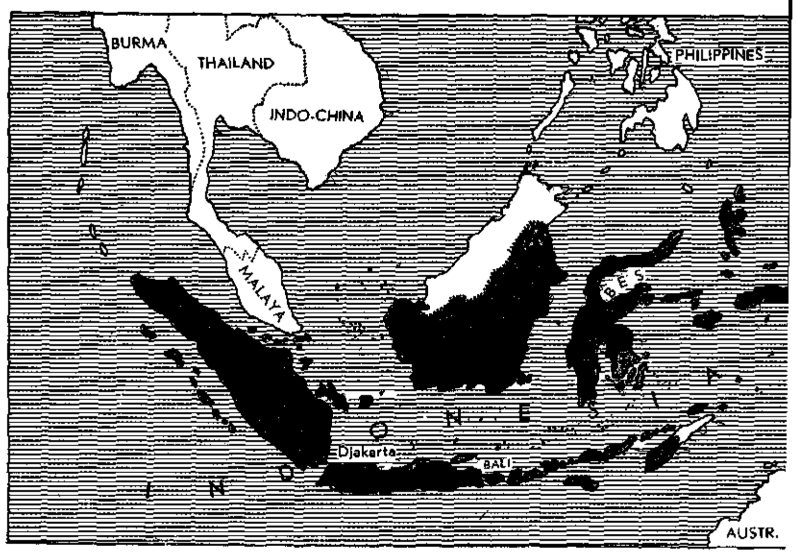
(e) More extensive use of green manures.

(f) Greater efficiency in pest and disease control.

(g) Improvements in soil tillage, and other cultural practices. Improvements in the supply and types of implements normally used in rice growing, would also be great aids towards maximum agricultural production.

More or less contrary to the situation in Ceylon, India, China, Japan, etc. where nitrogen is by far the most important element in the fertilizing programme, phosphate occupies this position in Indonesia, where phosphate deficiency is chiefly found in the rice fields of Java and Madura. The phosphate deficient rice soils in Java belong to the margalite, lateritic and bleached dacitic groups. Increases in yields following phosphate applications were experienced also on sandy quartz soils scattered over the central and eastern parts of the country.

The total area of rice soils in Java responsive to phosphate fertilizing amounts to 800,000 to 1,000,000 ha. and the use of phosphates on this area could increase total rice production by at least 400,000 tons of rough rice annually. The fact that in many cases a dressing of not



more than 50 kg. of D.S.P. (double superphosphate) per ha. has proved to be the most economical rate of application is undoubtedly an advantage. Higher rates of application increase yields to a certain extent but not enough to justify the extra expense involved. They may however, exert a beneficial residual effect.

Although the use of 40,000 to 50,000 tons of D.S.P. over the whole of Java would be economical and result in a yield increase of at least 400,000 tons of rough rice annually, the quantity of D.S.P. used in pre-war years for rice growing never exceeded 2000 tons.

The figures in the following table illustrate to

Paddy fields Western Java

some extent the degrees of responses to phosphate fertilizers (at 1 q. D.S.P. per ha.) by a series of late and medium late *tjereh* varieties on a heavy margalite soil at Grobogan (Central Java). These *tjereh* varieties are characterised by the absence of an awn on the outer glumes and are moderately hardy, as shown by the fact that they give satisfactory yields even on rather poor soils, on which bearded, so-called *bulu* varieties, are hardly capable of producing any crop at all.

Varieties (*Late and mid-late*)	*Yields in q./ha. dry stalk paddy*	
	Average of the unmanured fields	*Average of fields with an application of 1 q.D.S.P./ha.*
Utri Suwiri	30.3	43.0
Brondolputih T 43	31	45.4
Untung	43.9	59
Andel bluluk	29.4	41.9
Bogo	29.7	43.2
Kelasar	26.9	43.5
George Sail	30.6	46.7
Emata	35	51.5
Tuntang	36	53
Teran 1131	29.3	43.1

It can be seen from the table that an application of 100 kg. D.S.P. per ha. has increased the average yield of all varieties considerably. These figures moreover illustrate clearly the high yielding character of Untung, a variety well adapted to poor or relatively poor growing conditions.

Similar responses to phosphates may be expected on the bleached dacitic soils in the Banten residency. Although the water soluble monocalcium phosphate form of D.S.P. is undoubtedly the most suitable form for wet rice manuring, the value of the available native rockphosphates, Cheribon phosphate and aluminium phosphate, has also been a subject of investigation. Cheribon phosphate (a raw tri-calcium phosphate) has produced a response on strongly weathered acid lateritic soils and on the acid dacitic soils in the province of Banten, but not on the generally neutral or alkaline margalite soils. Cheribon phosphate has, however, to be applied at rates at least double those for D.S.P. in order to obtain the same direct response, but the residual effect of this rockphosphate seemed to be somewhat better than that of D.S.P.

Provided, therefore, the soil type and the slower and more gradual response resulting from its application is considered, Cheribon phosphate may be used to good effect, when the residual response is often greater than the direct effect of the fertilizer. Aluminium phosphate, also a native fertilizer, produced a response on certain neutral and alkaline soils, but was without effect on acid soils, with the exception, however, of the previously mentioned typical dacitic soils, the acidity of which is closely connected with their high silicic acid content. The best results from aluminium phosphate applications were obtained on the bleached dacitic soils of Western Java and the margalite soils in the province of Bodjonegoro, but even under those conditions the response to this fertilizer was in the first year only one-third that produced by D.S.P., though the residual effect of aluminium phosphate was considerable.

Although D.S.P. seems, therefore, the most suitable and reliable phosphate form for wet rice growing, Cheribon phosphate, because it is locally produced, may be used on certain soils and for building up reserves of nutrients in the soil (stock manuring).

The dicalcium phosphate appeared equal in

Transplanted paddy near Bandung (Java)

value to the monocalcium phosphate form.

Although in Indonesia most rice soils are less responsive to nitrogen fertilizing than rice in most of the other rice growing countries of the tropics and although the results with double superphosphate are usually more conspicuous than those obtained from nitrogen fertilizing, there are some areas in which significant increases in yield have been obtained from the application of sulphate of ammonia. According to the results of experiments recorded by VAN DE GOOR [32], the best results from the use of sulphate of ammonia can be expected on light soils, more particularly on those overlying a more or less permeable subsoil, which promote leaching of plant nutrients, including nitrogen. The best results from N applications are obtained, therefore, on young volcanic andesitic ash soils, on the very light so-called "gesik" soils and on permeable lateritic soils, although a definite response to N was also often obtained on heavy margalite and bleached dacitic soils.

Sulphate of ammonia added to a basic dressing of phosphate may, therefore, contribute considerably to higher rice yields. This is illustrated by the results, presented in the following table, of a long-term experiment on the effects of a continuous annual application of double superphosphate as a basic dressing, with other fertilizers, sulphate of ammonia and sulphate of potash, added.

year	*Yield in q./ha. dry stalk paddy* [1])						
	A = *100%* *(Control)*	B *1 D.S.P.* [2])		C *1 D.S.P. + 1 S.A. 4 + 8* [3])		D *1 D.S.P.+1 S.A. 4+8 + 1 S.P.* [4])	
		Yield	*Percentage*	*Yield*	*Percentage*	*Yield*	*Percentage*
1929/30	16.2	22.7	140.2	32.6	201.2	31.7	195.6
1930/31	18.9	25.8	136.5	29.4	155.5	29.8	157.6
1931/32	17.5	27.5	157.1	28.7	164.0	29.3	167.4
1932/33	20.9	29.0	138.7	32.2	154.0	33.4	159.8
1933/34	16.2	27.1	167.2	32.1	198.1	33.5	206.7
1934/35	18.7	32.3	172.7	32.5	173.7	33.7	180.2
1935/36	19.8	29.0	146.4	34.1	172.2	34.6	174.7
1936/37	20.4	31.4	153.9	34.1	167.1	34.8	170.5
1937/38	21.9	28.9	131.9	34.8	158.9	36.6	167.1
1938/39	15.3	25.3	165.3	32.0	204.1	32.2	210.4
1939/40	13.8	21.8	157.9	28.1	203.6	25.5	184.7
1940/41	16.1	30.1	187.5	35.4	219.8	37.5	232.9
1941/42	14.9	28.0	189.5	31.0	208.1	31.6	213.5
1942/43	18.6	32.1	172.5	32.8	176.3	34.7	186.5
Average	17.8	27.9	156.7	32.1	180.3	32.8	184.2

1) Stalk paddy is paddy with about 15 inches of stalk, in which form it is usually harvested in Java.
2) 1 D.S.P. means 1 q. double superphosphate per hectare.
3) 1 S.A. 4 + 8 means 1 q. sulphate of ammmonia per hectare, applied in two equal portions 4 and 8 weeks after transplanting.
4) 1 S.P. means 1 q. sulphate of potash per hectare.

The variety used was Tololawejan, a local mid-late *tjereh* (unbearded) variety.

These figures demonstrate the increasingly favourable effect on yield of annual applications of double superphosphate. Significant responses to nitrogen dressings was also noted in most years. The addition of potash to phosphate and nitrogen resulted in slight and insignificant increases.

Owing to the potash supplying effect of the irrigation water rice soils in Indonesia are seldom deficient in potash and up to the present potash has produced responses only in exceptional cases, e.g. on some strongly weathered, very old lateritic soils.

According to VAN DIJK [19] the position with regard to potash may be expressed as follows:

Supply by means of continuous west monsoon irrigation

16-38 kg. per ha. K_2O for Western Java

and 21-51 kg. per ha. K_2O for Central and Eastern Java

as compared with requirements of about

12 kg. per ha. K_2O for the grain,

and about 51 kg. per ha. K_2O for the straw.

As long as the present usual method of harvesting is continued, which involves leaving the straw on the fields, there is, therefore, under normal conditions hardly any risk of potash deficiency developing on wet rice soils. Only if and when the straw is removed from the fields, for industrial or some other purposes, would the possibility of a potash deficiency arise in the future. Of course this state of affairs holds good for irrigated rice fields only. Dry rice fields may be really de-

Top: *Rice fields near Bandung.* Center: *Rice terraces, Western Java.* Below: *Rice and sugarcane (background to the left) in Eastern Java.*

ficient in potash and will usually require a greater quantity of nitrogen.

For wet rice soils as much as 150 kg. of sulphate of ammonia may be used per ha. The highest yield increases from dressings of 150 kg. per ha. amounted to an average of 11 quintals of dry paddy per ha. for *tjereh* varieties (unbearded) and 9 quintals dry paddy per ha. for *bulu* (bearded) varieties.

Another cultural practice which may greatly contribute to an increased rice production is the more extensive use of green manure crops on rice fields, as illustrated by the results of a series of experiments with different rice varieties on volcanic Klut sandy soils and recorded by VAN DE GOOR [35].

The results are listed in the following table:

Variety	*Yield unmanured*	*Yield manured*
Oewen (awned)	44.3	76.0 dry stalk paddy
Gropak (awned)	44.1	90.6 dry stalk paddy
Godril	35.8	66.1 dry paddy
Untung	41.7	46.1 dry paddy
Menter	32.8	45.0 dry paddy
Average 9 other var.	36.1	61.3 dry paddy
Godril	33.2	60.4 dry paddy
Untung	44.3	50.5 dry paddy
Menter	25.8	39.1 dry paddy
Dorowati	26.8	49.5 dry paddy

There are marked and significant responses to green manure by all varieties. They do not all react to the same degree, however. For instance, the variety Untung, adapted to poor or relatively poor soil conditions, shows less reaction to green manuring than does any other variety.

Terraced rice area in the island of Bali

Rice harvest (stalk paddy) near Bandung (Java)

RICE GROWING IN THAILAND

AS mentioned before, Thailand has become in postwar years the most important rice exporter of the world, exports from Burma and Indo-China having declined considerably because of the unrest and political troubles in those areas.

In view of the importance of these rice exports for the food situation in the whole Far East and therefore for political relations in this part of the world, not only these countries themselves, but other countries as well, are very interested in the possibilities of increasing Siamese rice production and export, an interest that has brought the question of fertilizing also more to the fore. This has increased in importance as available statistical data indicate that, while the area under rice has steadily increased, the total production has remained more or less unchanged over the last two decades, which means that a decline in yield per acre has accompanied the increase in acreage. An increasing population in the presence of a stable production level, results in gradually decreasing quantities available for export.

The total area of paddy fields in Thailand has risen to more than 5.5 million ha. and total production to about 7 million tons of paddy.

In the greater part of Thailand the rainy season is between May and September. Most of the produce, consisting of long duration varieties of rice, is harvested in December/January and reaches the market in the months of January/February.

The rice area of Thailand lies in 4 zones:

- the Central Plain,
- the Northern Region,
- the North-Eastern Region and
- the Southern Regions.

The Central Plain, which contributes about 60 per cent of the total production and provides most of the rice for export, is by far the most important rice area of Thailand. Except for very fine sandy soil and silty soils close to the banks of the larger rivers, this plain consists of heavy dark clay soils, very well suited for rice growing.

In view of its leading position in the production and export of rice, this Central Plain should receive the greatest attention towards increasing the existing rate of production by means of:

- improving water control,
- application of manures and fertilizers,
- improvement of varieties,
- better cultivation and
- control of pests and diseases.

The greatest requirement for increasing rice production is the proper control of water. At the present time 10% to 20% or even more of the total area is often seriously damaged or is unable to reach maturity on account of floods or droughts.

The amount of rainfall in Thailand is by itself not sufficient to raise a satisfactory crop of rice in the Central Plain and the same may be said of most districts, so that rainfall must be supplemented by irrigation. Although part of the Central Plain is provided with irrigation, it is not, however, adequately controlled. Of prime importance for increased rice production within the Central Plain is, therefore, the completion of the Chao Phya project, which has for its object not only the improvement of water supply for existing rice areas but also the provision of water for a second crop in part of the area. Up to the present the land of the Central Plain has never been utilized for double cropping, that is, two crops of rice or one crop of rice plus another crop.

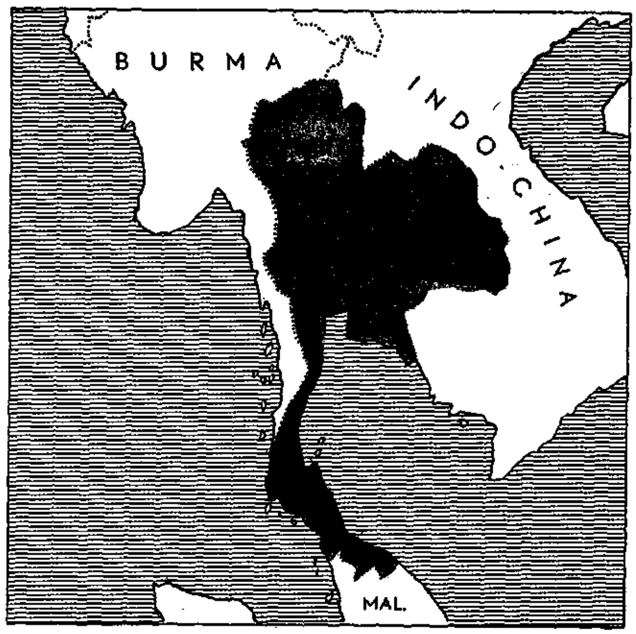
Nearly 1/3 of the rice area in the Central Plain is under floating or deepwater rice, which is grown mainly in the low lying lands of the Central Plain, where the water may be as deep as 2 to 3 meters. The farmers' main task here is to get the crop well established before the fields are flooded.

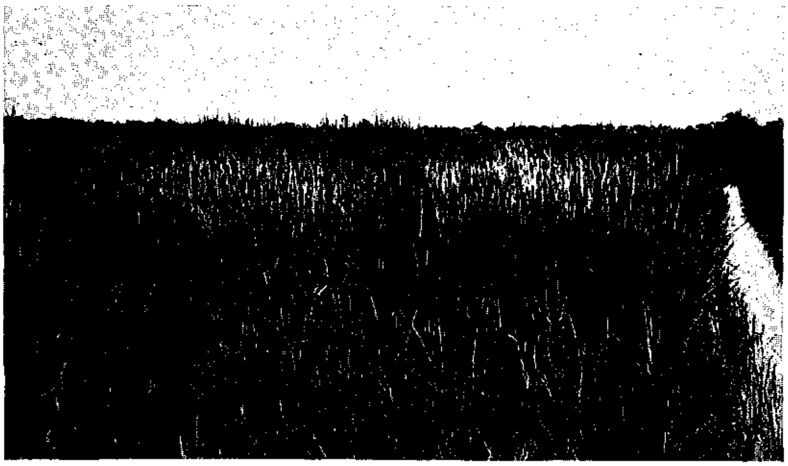
Only in the Northern region, the Chiengmai area, are there soils and water supplies which permit double cropping. The farmers here are more enterprising than those on the Central Plain. Moreover they have the advantages of better soil and better water control. In many places farmers here have co-operated in building irrigation systems which make possible two crops of rice a year or one of rice followed by one of soyabeans or peanuts. As this region makes only a relatively small contribution to the total production, and transport of the produce southward is difficult and expensive, it is of practically no significance as far as exports are concerned.

The North-Eastern region, comprising an area of approximately 1/3 of the whole Kingdom, consists of a large plateau. It is a region bristling with problems, is mainly dependent on rainfall and has very poor sandy soils, low in waterholding capacity. A better water control (for many areas by means of the construction of small reservoirs or irrigation tanks) and fertilizers will provide the solution to the problem of increasing rice production here. In addition, the possibilities of growing other and less water consuming cereals or crops, like millet, should be investigated.

In Southern Thailand, the Chantaburi region as well as in the Southern part of peninsula Thailand, where rainfall is more plentiful, rice is grown on all the low flat lands on which water can be conserved.

More or less in contrast to the situation in most rice producing countries, where nitrogen





Thailand. Rice on heavy Bangkok clay; foreground without fertilizers, background fertilized with N and P_2O_5

is the main constituent of the fertilizing programme, but similar to that in Java, phosphate is the most important plant nutrient for application to the soil in Thailand. Field experiments at Bangkhen Experimental Station under the supervision of the well-known soil scientist DR. PENDLETON resulted in a remarkable phosphate response. Prime attention should, therefore, be given to phosphate, although in many cases nitrogen also produces a distinct response. The nitrogen effect is characterised by much bigger variations, however. Potash seldom or never produced a significant result, neither did lime although many of the soils in the Central Plain are definitely acid. Phosphate and nitrogen comprise therefore, the basis of the fertilizing scheme.

Rice and sugarcane near Sriracha (Thailand)

With regard to the quantities which should be applied, 25 kg. N in the form of sulphate of ammonia and 50 kg. P_2O_5 in the form of superphosphate may be considered as an approximately correct amount per ha., although there may be rather big variations in the rates of application, dependent on differences in soil type. About 10 % of the best rice soils do not produce any response to nitrogen, and the middle part of the Central Plain reacts much less to fertilizing than does the eastern part.

The rates of application may fluctuate considerably in the case of N especially, as in one trial a quantity of not more than 20 kg. N caused lodging, whereas in other experiments quantities of 80 and even 100 kg. N per ha. proved profitable. The increase in yield must, however, be considerable for economical application of fertilizers, as these materials, because of high transport costs, are rather expensive in most areas.

There was a remarkable discovery that on certain very sandy soils in North-East Thailand, even a moderate rate of fertilizer application was deleterious to the growth of rice plants. A harmful manganese mobilization under the influence of an acid fertilizing programme (sulphate of ammonia + superphosphate), and reducing conditions on soils high in manganese might be the cause. This explanation is still hypothetical, however, and should be further investigated.

Fertilizers for the benefit of rice growing are now subsidized in Thailand.

RICE GROWING IN BURMA

BY far the most important rice growing areas of Burma are found in the southern part of the country, namely in the Irawaddy Delta and the lower valleys of the Sittang and Salween, together with parts of the Arakan and Tenasserim coasts. In prewar days these comprised an area of over ten million acres of rice out of a total of somewhat more than 12 million for the whole of Burma. The monsoon is so reliable here that only relatively unimportant marginal areas are in danger of crop failure through lack of water.

Rice is also grown, next in importance to several other crops, in rather extensive irrigated areas in the dry zone; as well as in the Upper Burma wet zone, but these areas are either barely selfsufficient or have to import rice from other parts of the country. All the rice-exporting areas are, therefore, confined to Southern Burma.

Over most of the country, the rainy season starts about the latter part of May, and continues until September/October in Lower Burma. The abundant and reliable rainfall makes Burma the country best suited for rice growing in the world, with existing possibilities of great expansion of the cultivated area.

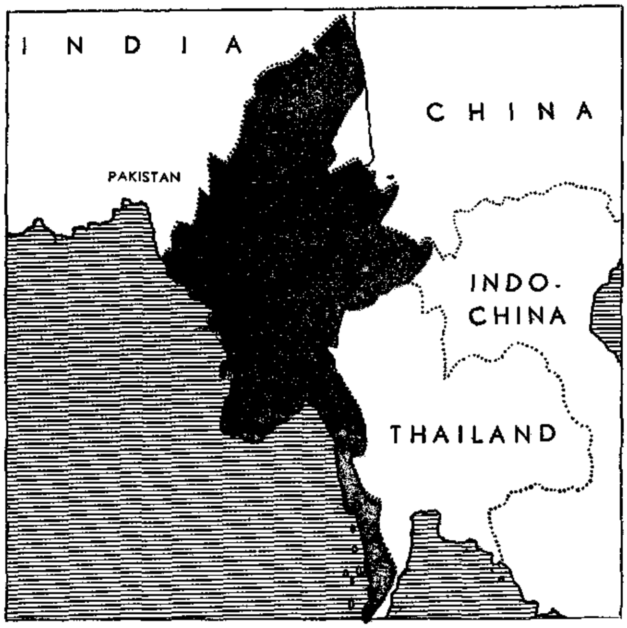
Very little land is planted with rice twice in the same year.

Before the war Burma was the largest exporter of rice in the world, exporting more than 3 million tons a year. Over 12 million acres of her agricultural land was cultivated with paddy, which resulted in an average total yield of about 5 million metric tons of milled rice a year.

As a result of war damage and civil disorders rice production and rice export decreased greatly after the war. The total area shrunk to less than 8 million acres and an appreciable proportion of the two million acres of paddy land, lying fallow in lower Burma and more or less reverted to jungle, will have to be reclaimed.

Rehabilitation of Burma's rice production to its prewar level and more, if possible, is, however, one of Government's main targets, rice exports and prosperity of this country being closely connected.

This increase in rice production can be achieved by means of a) enlarging the prewar area by adding existing potentially excellent rice land that has not so far been cultivated, b) increasing the rice yield per acre by im-



proved cultural practices and fertilizing. Experiments carried out by the Agricultural Department of Burma have clearly demonstrated the practicability of increasing yields by the application of fertilizers in appropriate quantities.

As the clay-loam soils of Burma are fairly well supplied with potash, nitrogen and phosphate will have to form the basis of such a fertilizer programme.

All of Burma's rice soils respond to phosphate, and both superphosphate and bonemeal give immediate and residual effects.

Superphosphate proved somewhat superior to bonemeal, however, in a 5 year experiment based on a dosage of 20 lb./acre of P_2O_5; 32 % increase in production was obtained with superphosphate compared with 23 % in the case of bone-meal.

Sulphate of ammonia also gave large yield increases, although its continued use without a phosphate fertilizer in the form of superphosphate, bone meal or large quantities of organic materials lead to a rapid decline in this response. Thus 30 lb. N in the form of sulphate of ammonia applied for 5 years gave an increase of 630 lb. of paddy per acre during the first year and only 200 lb./acre the fourth year, whilst in the fifth year it caused a decrease of 180 lb./acre. The average responses for two successive 5 year periods respectively was a positive response of 29.6 % over the control during the first period but a negative response of 22.8 % during the second five year period.

The initial response, as well as that obtained in combination with phosphates, indicates, however, a strong nitrogen deficiency, so that in general the fertilizer program should contain nitrogen in addition to phosphate.

A fertilizer experiment with different quantities of NP 20/20 gave the following results:

NP 20/20 in lb. per acre	*Increase in paddy lb. per acre*	*Increase in grain per lb. of fertilizer applied*
50	400	8
100	650	6,5
200	1100	5,5
300	1400	4,6
400	1600	4

During 1951, however, only 20 tons of P_2O_5 in the form of bone meal was used and the total import of N fertilizers did not exceed 20 tons of sulphate of ammonia, while other sources of nitrogen are negligible in importance. The practice of rice fertilization may therefore be considered as being non-existent in Burma up to the present.

Practically the only form of fertilizing is green manuring with the weeds that grow up during the dry season and are turned under before flooding, eventually supplemented with organic material collected from adjacent forests.

RICE GROWING IN INDO-CHINA

IN a total area of about 741.000 km², about 6,5 million hectares are cultivated, of which more than 5,5 million hectares are included in the rice area.

The most important rice growing areas of Indo-China are concentrated in the Red River delta of Tonkin and the Mekong delta of Cochinchina and Cambodia, with other concentrations in the countless smaller deltas of Annam and in the paddy fields bordering the Great Lakes in Cambodia.

The acreages for the different States were estimated in pre-war years at:

Tonkin (North Vietnam) . .	1,200,000 ha.
Annam (Central Vietnam) . .	760,000 ha.
Cochinchina (South Vietnam) 2,000,000 to	2,300,000 ha.
Cambodia 900,000 to more than	1,000,000 ha.
Laos	400,000 ha.

The total area in mountain rice, that is, dryland rice, is estimated at no more than 400,000 ha. for the whole of Indo-China.

The alluvial rice fields of the Red River delta are protected from floods by dikes, which has the advantage that floods cannot interrupt the cultivation periods, but the disadvantage that drainage of many of the low lying soils is hampered, whereas sandier soils situated at high altitudes may suffer from a water deficiency. Much attention is being devoted, therefore, to the construction of works for the more efficient drainage of the low lying area during the wet monsoon and the irrigation of those areas that are in need of water. This will bring about a gradual increase in the area suitable for double cropping.

The main rice growing season of Tonkin is during the wet monsoon, which necessitates sowing in May/June, transplanting in July and harvesting about November. Where enough water is available another rice crop is grown during the „dry" season, which is not entirely dry here. This crop is sown in October/November, transplanted between December and February and harvested in May/June.

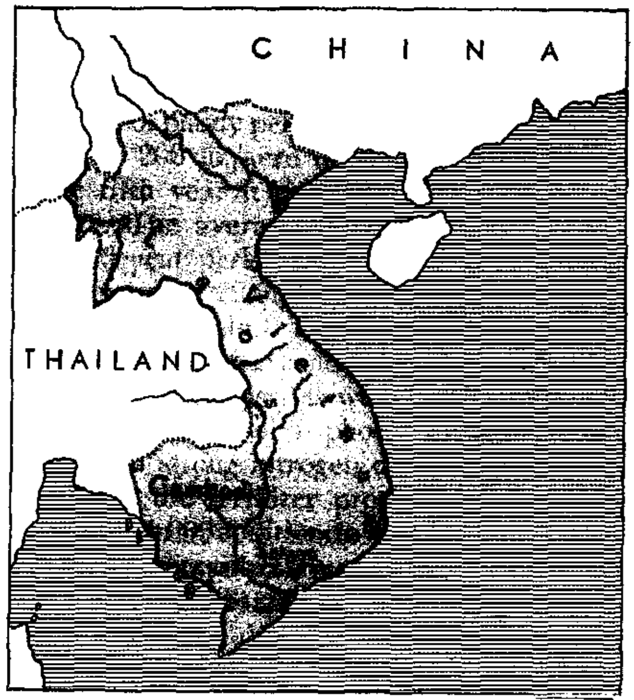
Over a restricted area of about 20,000 ha. even a third rice crop of very short duration is grown between the dry and the wet season crop.

Owing to the dikes, rice fields in the Red River delta cannot profit by the fertilizing action of the silt deposits. Despite the fact that cropping practices are relatively satisfactory here, it is to be expected, therefore, that fertilizers would contribute a great deal to improved yields and higher production level. This is all the more important as the Red River delta is the most densely populated area of Indo-China, where about 9 million inhabitants have to live on 1.2 million ha. of rice fields. The food problem is therefore a serious one. Owing to its very dense population, this area has practically no rice available for export.

In the Centre and the South of Annam the planting of rice coincides with the beginning of the rainy season in those areas where the rains are not too heavy, but especially in the Centre of Annam planting has to be postponed until the heaviest rains are over, which results in a planting season from November until March/April.

Owing to its pronounced dry season, rice growing in Cambodia and Cochinchina generally remains restricted to one rice crop a year. The seedlings are transplanted from July until the end of August, with a second transplanting at the end of September in certain areas, and a harvesting period accordingly extending from the end of October for short term varieties until February for long term varieties. As there are no dikes along the Mekong, extensive areas of Eastern Cambodia and Western Cochinchina are devoted to the growing of floating-or deep water rice.

Experiments conducted by the Rice Bureau showed that in many soils of Northern Vietnam there were responses of about 10 kg. paddy per kg. N; sometimes responses even as high as 20 kg. paddy per kg. N were observed; 25-30 kg. N per ha. can often be considered a suitable rate of application. In Southern Vietnam responses to N were much more variable and sometimes nitrogen applications even proved to be harmful by over-stimulation



of vegetative activity, resulting in decreased yields. In Cambodia nitrogen fertilizing again proved very effective resulting in an average response of about 14 kg. of paddy per kg. N applied.

Many of the rice soils of Southern Vietnam are particularly deficient in phosphate, however, so that fertilizing with phosphate is a prime recommendation. This is often applied in the form of the indigenous rockphosphate of which large deposits are available in Indo China. Rather high applications of rockphosphate (100-150 kg. of P_2O_5 per ha.) are often recommended, but primarily it has a considerable residual effect in addition to a favorable effect on the whole soil condition. Moreover this phosphate application counteracts the toxic aluminium present in many of these soils.

For Indo-China the fertilizing scheme should, therefore, include nitrogen and phosphate, with the accent on nitrogen for many of the soils in Northern Vietnam and on phosphate for Southern Vietnam. For part of the sandier soils this should be supplemented with potash.

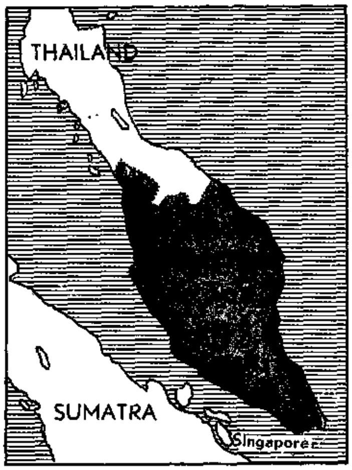
Practically all of the heavier soils contain sufficient potash of their own.

Up to the present the use of fertilizers has been on a very limited scale, however.

Average yields, with 1.35 tons of paddy per ha. for Tonkin, 0.94 tons for Annam, 1.39 tons for Cochinchina and 0.9 tons for Cambodia, are still low and could undoubtedly be substantially increased by a judicious fertilizing programme.

The average total annual production in pre-war years fluctuated around 6.5 million tons of paddy, with a maximum of more than 8 million tons in 1938.

Rice harvest in the island of Bali



RICE GROWING IN MALAYA

THE main interests in Malaya being concerned with its rubber growing and tin mining, rice is a more or less neglected culture and although in normal times the exploitation of the country's principal export industries may be preferable economically, this is a dangerous practice in abnormal times, e.g. in times of an economic depression or when a war is being waged and imports are restricted or come to a standstill completely.

Government is therefore making strenuous efforts to increase local rice production, but without conspicuous results so far. However, there still exists a big reserve in potential paddy lands and yields could be increased by better and more intensive cultural practices.

All paddy is grown during the monsoon or rainy season, including the months of September to January, with harvest taking place during the first quarter of the year.

At present Malaya has to import more than 500,000 tons of rice a year compared with a local production of about 350,000 metric tons of milled rice. The rice area amounts to approximately 900,000 acres of which 700,000 acres in Western Malaya and 200,000 in Eastern districts.

The paddy fields of the western side of the Peninsula are for the most part found on fairly deep coastal plain soils, with little if any response to manuring. Cultivators use some bat guano and bone meal only. Problems concerning drainage and irrigation are considered more important here than those relating to fertilizing.

The situation regarding the approximately 200,000 acres of light paddy soils in the Eastern region is quite different. As a result of more than 20 years' trials, this region was discovered to be deficient primarily in soluble phosphates and in nitrogen, with a potash deficiency on most of the sandy soils.

More than 300 fertilizer demonstrations have confirmed the value of a mixture consisting of sulphate of ammonia, double superphosphate and potassium chloride, composed of 11.3 % N, 10 % P_2O_5 and 12.6 % K_2O. This mixture is being distributed and, when used at 200 lb. per acre, results in about a 20 % increase in paddy yields.

At present approximately 3000 tons of this mixture are being used, while requirements are estimated at 40,000 tons. The great benefit to be derived from fertilizing is suggested by the estimate that 1 dollar spent on fertilizers will yield 6 or 7 dollars worth of rice.

RICE GROWING IN THE PHILIPPINES

IN the Philippine Islands rice growing is especially concentrated in the provinces of central and northwestern Luzon and in the western parts of the islands of Mindoro, Panay, Negros and Palawan. All these areas are characterized by pronounced wet and dry seasons and only a single crop of rice is grown, except in a few places provided with artificial irrigation. The total rice area was about 2 million hectares before the war and amounts to 2.4 hectares at the present time, with a total production of about 1.5 million tons of milled rice before the war and 1.8 million tons now.

Before the war, rice production in the Philippines was slightly deficient for the needs of the islands which were forced to import about 50,000 tons of rice a year. Immediately after the war, rice production was found to have decreased considerably because of war damage and a diminished area, partly due to a shortage in draught animals, which had been slaughtered in large numbers during the war. In the meantime production has increased to such an extent that now the production level is higher than it was in prewar years, but as the population has increased even more, there is still a considerable rice shortage.

Government is striving therefore to increase home production as much as possible by means of

a) replacing low yielding varieties of rice by those giving higher yields, which could result in a production increase of 10 %,
b) by encouraging an improved seed supply of high yielding varieties well adapted to the environmental conditions in the different areas,
c) by better ploughing and preparation of the paddy fields,
d) by more efficient control of pests and diseases,
e) by an extension and improvement of irrigation facilities, and
f) by encouraging the use of manure and fertilizers and the growing of green manure crops.

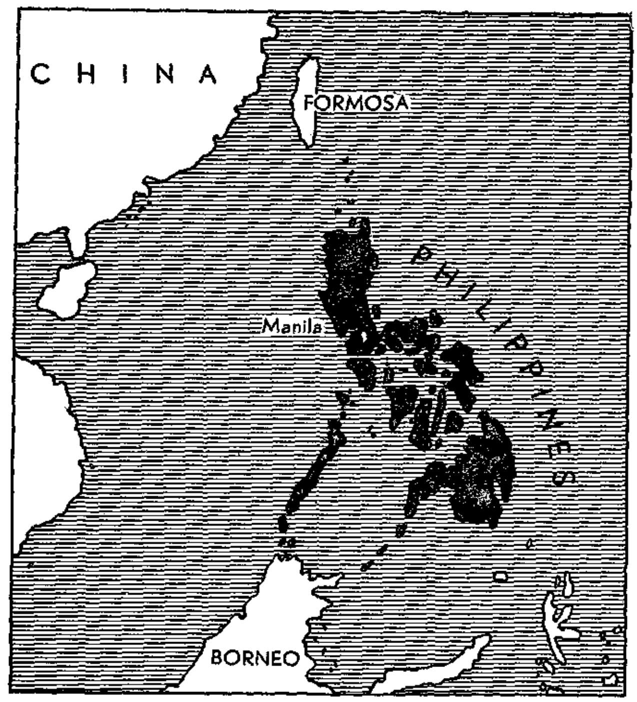
Commercial fertilizers and manure are used to some extent in the Philippines, but experiments have been carried out to indicate the general benefits to be derived from the application of fertilizers. Some of the soils are apparently not in urgent need of fertilizers, but the older and over-cropped lands especially have often been found to be deficient in nitrogen and phosphoric acid. Both constituents should therefore be included in a fertilizing programme, according to BAUTISTA, at rates of 30 to 40 kg. N and 30 kg. P_2O_5 per hectare, depending on soil conditions. These applications should eventually be supplemented by 40 kg. K_2O.

The Philippine Bureau of Plant Industry recommends the use of green manures or the planting of secondary crops in rotation with rice, when conditions of soil and water permit, and the gradual introduction of mineral fertilizers. The pronounced wet and dry seasons and the absence of adequate irrigation facilities, however, very often prevent the growing of green manure crops that might be ploughed under for soil improvement.

Another means of increasing rice production, strongly encouraged by Government, is the extension of rice growing into the Southern Islands, more especially Mindanao and Palawan, where thousands of hectares of idle land are still available for rice cultivation.

Increasing home production and thus ending dependence on rice imports is all the more important in view of the changes that are to be expected in the structure of Philippine Agriculture when several of the present export crops can no longer be marketed at competitive prices as a result of the abolition of the preferential duties on the U.S.A. market.

At present 45 % to 50 % of the total crop area is still planted with typical export crops like coconuts, sugarcane, abaca and tobacco, while 50 % to 55 % is used for food crops, mainly rice. It is expected, however, that in the future the latter percentage figure will increase at the expense of that relating to export crops.



RICE GROWING IN SOUTH AMERICA

RICE is grown in all of the countries of South and Central America. Most of them are more or less self-sufficient in this commodity although some of them have some import requirements and others have smaller or larger quantities available for export.

The chief region of this area with a deficiency in rice production is Cuba, with British West Indies, Venezuela and Peru as secondary importers.

By far the largest rice producer and rice exporter in this part of the world is *Brazil,* with a total acreage of about 1,850,000 hectares, an area about twice that in the U.S.A. and twice as large as the prewar average area of production. The average yield is 15 to 16 quintals of paddy per hectare, with a total yield of about 3 million tons of paddy per annum.

The average annual prewar acreage (1934-1938) was 956,000 ha., with an average total production of 1,365,000 tons of paddy.

Rice exports from Brazil vary considerably in quantity, but amounted to 165,000 tons of milled rice during 1951.

The three major producing states are Rio Grande do Sul in the South and Sao Paulo and Minas Gerais in Central Brazil. In the rather densely populated and more or less industrial Central States practically all of the rice production is consumed locally, with some imported from southern Brazil. Rio Grande do Sul is, therefore, the only State with an important export surplus.

As about 80 % of the total rice area is planted to dryland rice and only 20 % is irrigated, Brazil is the largest producer of the former type of rice in the world.

Upland rice is grown in the central and northern parts of the country especially, 90 % of the rice area here being non-irrigated, while in Rio Grande do Sul, which possesses larger and more mechanized farms, the reverse holds true, and 90 % of the rice is of the irrigated type.

Because of the dependence on rainfall of by far the greater part of the crop, rice yields show wide variations from year to year.

Dryland rice is usually the first crop planted after clearing virgin land, when soils are still well supplied with accumulated plant food materials. Trees and brush are cut and burned during the latter part of the dry season and rice is sown in shallow holes when the rains start in September/October; the harvest sea-

Brazil. Workers hoeing the rice growing in land reclaimed from Amazon-flooded jungle and now yielding first-class crops

son is February/March. Many of these fields are planted with cotton or coffee at a later date. Most of these family-farms are relatively small, growing no more than 10 acres or 4 hectares of rice each.

In Rio Grande do Sul there is a total area of between 500,000 and 600,000 acres (between 200,000 and 250,000 hectares) of rice, divided between about 6,500 farms, of which 50 % cultivate less than 15 acres (6 ha.) of rice per farm and the remainder up to 500 acres (200 ha.) each.

The rotation scheme here generally consists of rice for one year and fallow land, pastured with beefcattle, for two years.

About 40 % of the producers in Rio Grande do Sul use some fertilizers in the form of 90 to 180 lb. of bonemeal per acre (100 to 200 kg. per hectare).

Other countries in South and Central America which produced in postwar years greater or smaller quantities of rice available for export are Ecuador, British Guiana and Uruguay. In practically all of Latin American countries great possibilities exist for extending their rice areas, provided sufficient labour is available.

RICE GROWING IN THE U.S.A.

THE main rice growing areas in the U.S.A. are situated:

(1) in those areas of southwestern Louisiana and southeastern Texas bordering the Gulf of Mexico,

(2) the Grand Prairie section of eastern Arkansas and scattered delta areas in southeastern Arkansas,

(3) the Sacramento and San Joaquin Valleys of California.

Both the area under rice cultivation, about 2 million acres (800,000 ha.), and production, about 2.2 million tons of paddy (1952) are now about double the prewar annual average for each figure, so that, with an export figure of more than 500,000 tons of milled rice, the U.S.A. has become one of the most important rice exporters in the world after Thailand and Burma.

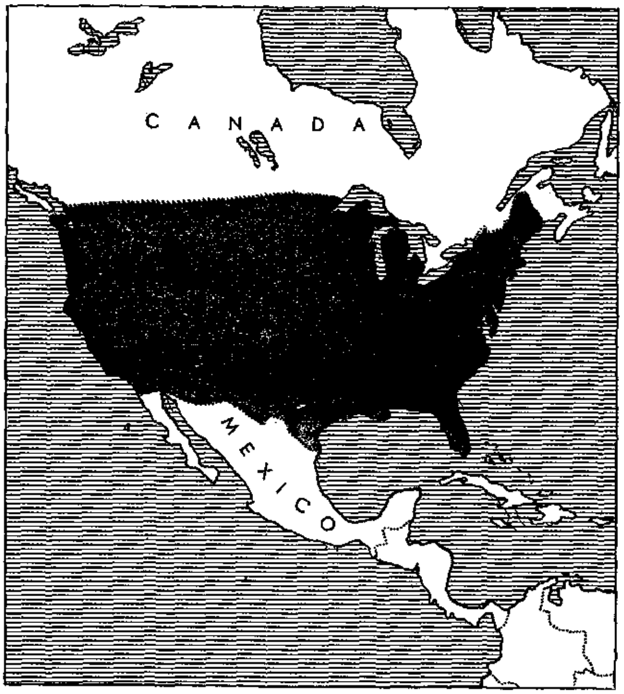
Because of the characteristic hardpan, typical for most of the soils, and relatively poor drainage, due to the heavy soils and level terrain, the above mentioned soils of Louisiana, Texas and Arkansas are particularly well suited to rice growing. Moreover, the rainfall is favourable with an average annual precipitation ranging from about 36 to 56 inches, well distributed during the growing season, which means that one fourth to one half of the total water requirements are normally supplied by rainfall, leaving 30 to 40 inches to be supplied by irrigation.

In California, where water requirements, varying from 60 to 90 inches, are somewhat higher, about 80 % of total water needs must be supplied by irrigation.

In the U.S.A. rice is cultivated in essentially the same way as wheat, oats or barley, except that the crop is irrigated. Whereas rice growing in the Orient makes excessive demands on manual labour, it is highly mechanized in the U.S.A. Farm machinery is used extensively and even the aeroplane is employed to a greater extent than for any other crop, for seeding, fertilizing and applying chemicals to control weeds.

Preparatory cultivation of the soil consists of ploughing, with either disc- or mouldboard ploughs, to a depth of generally 4 to 6 inches, after which the land is worked into an even, well-pulverized seedbed by the use of discs, harrows and floats.

All of the ploughing and other preparatory



operations are carried on while the land is still dry.

Immediately before, or soon after preparatory cultivation, the land is prepared for irrigation by building levees and cutting drainage gaps.

In the greater part of the southern area sowing is done by seed drills, often provided with a fertilizer distributor mounted directly in front, by means of which the seed is sown and the fertilizer is applied in the same operation.

Practically the whole of the rice area in California and a small part of that in the southern area is sown by aeroplanes. For sowing by aeroplane the field is flooded to a depth of 2 to 3 inches and pre-soaked seed is used, which sinks immediately. Dry rice seeds would float on the surface of the water and be liable to be blown about by the wind, which would cause uneven stands. The sowing season is usually in April and May.

Because of frequent rainfall in the spring months, it is usually not necessary to flood rice fields sown by dry methods. The first irrigation, to a depth of 1 to 2 inches, takes place as soon as the majority of the plants have reached a height of 6 to 8 inches. As the plants grow taller, the depth of water is gradually increased until it reaches 5 to 6 inches.

In Arkansas and in some other areas, fields are drained after the plants have been flooded for about three weeks, which facilitates control of certain pests and top dressing.

In California and Arkansas, where short season varieties are most widely grown, the fields are kept flooded for 80 to 100 days, whereas in Louisiana and Texas, where there are mostly long season varieties, the irrigation season may be as long as 120 days. The only cultural practices during the irrigation season are top dressing with fertilizers and weed control by means of 2,4-D. Fertilizers as well as 2,4-D are usually applied by aeroplane.

Harvesting is done either by means of the binder-thresher method, which involves cutting first and threshing later or with a combine which cuts, threshes and sacks the rice in one operation. The success of the combine method has been due to the development of practical mechanical dryers to remove the excess moisture from the grain.

The most intensive rice growing areas in the U.S.A. are those in California, with 300,000 acres out of a total of 2,000,000 acres, but producing about 28 % of the total crop of the U.S.A.

In the Sacramento Valley of California, rice is produced on a single, rather uniform soil type. The only deficiency here is nitrogen, so that sulphate of ammonia is the principal fertilizer used, with calcium cyanamide, urea and anhydrous ammonia as minor sources of nitrogen.

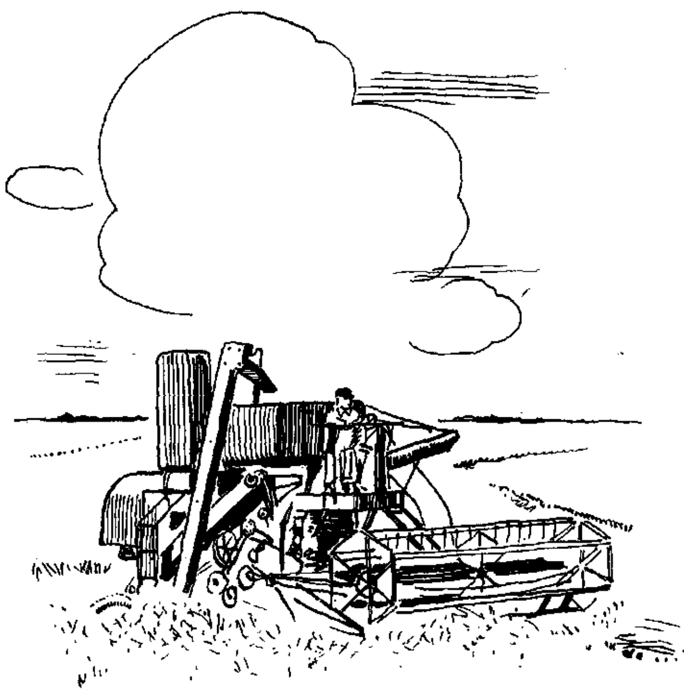
The average rate of application is about 30 lb. of N per acre, with recommendations varying from none on the richest land and about 20 lb. on soils not quite so rich, up to 45 lb. on the poorest soils.

It is estimated that, without fertilizers, the average rice yield of the valley would fall about 20 %, while a 50 % increase in fertilizer consumption would only increase yield by 3 %. At present, the yield is about 3300 lb. of rice per acre.

Although the use of green manure crops produces excellent yield increases, the only type employed up to the present is a clover, which produces naturally sown seedlings when winter conditions are favourable.

In the states of Arkansas, Louisiana and Texas, with a total acreage of about 1.5 million acres of rice, soils show a rather wide variability and consequently with wide variations in fertility requirements, including phosphate and potash as well as nitrogen. The over-all average rate of application of fertilizers is 11 lb. of N, 8 lb. of P_2O_5 and 4 lb. of K_2O per acre, the average yield being about 2,000 lb. of rice per acre.

As the present yield amounts to 54%, slightly more than half of the maximum obtainable with optimum applications on all soils, the present rates of fertilizer applications are considerably below desirable levels. The fertilizer is applied at two distinct periods. Approximately half is applied on the prepared seedbed at the time of sowing and the remainder broadcasted after flooding at any time up to 60 days after sowing.



RICE GROWING IN EGYPT

THE continent of Africa at present contributes 2 % of the world's rice production. Due to climatological conditions there is no country in the continent which does not grow rice, but the most important and most interesting rice growing area here is Egypt, which, together with Madagascar, forms the only rice exporting area of Africa and will be discussed therefore in greatest detail.

The extent of the rice area of Egypt fluctuates from year to year, but was about three times greater during the period 1947/49 than it was 20 years earlier.

The intensive character of rice growing in Egypt can be illustrated by the fact that Egypt did not grow more than 295,000 hectares of rice during 1950, compared with a total area of about 3,000,000 hectares for the whole of Africa, but produced about 1,242,000 tons of paddy out of a total of 3,750,000 tons. This means that the average rice yields in Egypt are about 4 times the average yields of tropical Africa.

In Egypt the cultivated area consists of a relatively narrow strip along the upper Nile and in the broad Nile Delta. Rice growing is concentrated in the Northern Delta provinces of Lower Egypt and more than 95 % is found in the four provinces Gharbieh, Béhéra, Dakalieh and Charkieh.

Since there is practically no rainfall in Egypt, all crops have to be irrigated and rice, therefore, must compete with many other crops such as cotton, sugarcane, corn, oilseed crops and vegetables for the available water. Water supply is the limiting factor, therefore, and because of the high water requirements of the crop, the maximum rice acreage to be planted is determined each year by the Ministry of Public Works of the Egyptian Government. Double cropping, including winter crops of wheat, barley, legumes, onions and vegetables, followed by summer crops of cotton, rice, millet, corn, sugarcane and summer vegetables, is the normal practice.

In the rotation scheme rice generally follows either bersim *(Trifolium alexandrinum)*, wheat or barley. When rice follows bersim, the second or third cut of which is usually ploughed under and utilized as a green manure, there is generally sufficient time for an intensive preparatory soil cultivation by means of ploughing twice. When rice follows wheat, which is not harvested before May/June, there is often not

Cutting rice in Egypt

sufficient time available for the necessary soil tillage when rice is broadcast. Transplanting from a seedbed is therefore preferable under these circumstances, as this leaves more time for the required soil cultivation.

After ploughing, the fields are carefully levelled, because the water layer should be equally deep over the whole field. Due to the relative scarcity of water, all preparatory soil cultivation, including the first levelling, is done under dry conditions. A second levelling is subsequently carried out under water. Broadcasting is generally done in April/May.

Early maturing Japanese varieties can be sowed somewhat later than varieties such as *„El Nabatat"* and *„El Fino"*, which produce low yields after late sowing.

Because of the relative scarcity of water, irrigation of the crop throughout the growing season is carefully controlled and much less water is used than is usual in many other rice growing countries. The fields are drained several times during the season, retaining just enough water to cover the soil during the first part of the season and increasing the quantity as the rice grows. Increasing the depth of the waterlayer results in improved weed control.

As far as the use of nitrogen fertilizers is concerned, a quantity of 75 to 150 kg. sulphate of ammonia or NH_4Cl per feddan*, or 175 to 350 kg. per ha., is recommended in Egypt.

The ammoniacal nitrogen form of fertilizers are most beneficial for wet rice growing in Egypt.

The abovementioned higher rates of application, 150 kg. sulphate of ammonia per feddan or 350 kg. per ha., is seldom employed. In areas where rice follows bersim, or where for some other reason higher N-applications are less desirable, a quantity of 75 kg. sulphate of ammonia per feddan, or 175 kg. per ha., will suffice.

After broadcasting, sulphate of ammonia is generally supplied in two applications, the first 30 to 40 days after sowing, when the plants are 15 to 20 cm. high, and the second 20 days later, after weeding.

The Advisory Service of the Ministry of Agriculture recommends even three applications, namely, ¼ of the total quantity mixed with superphosphate just before sowing and the other ¾ in two applications at the times previously mentioned.

When the transplanting method is practised, the seedbed is first of all fertilized at the rate

* 1 feddan = 0.42 ha = 1,038 acre.

Threshing by means of an old-fashioned „norag" drawn by a tractor in front of an Egyptian village

of 100 to 150 kg. of sulphate of ammonia per feddan, in two applications at sowing time and 15 to 20 days later. After transplanting in the fields N is applied at the same rate as that recommended for broadcast rice and also in two applications, viz. 10 to 12 days after transplanting and about 20 days later.

The usual method of fertilizer application here involves draining the field 2 or 3 days before fertilizing and then closing the drains. Sulphate of ammonia is then broadcast. The next day the fields are carefully irrigated again and kept just submerged without opening the drains for about 15 to 20 days. After this period irrigation and drainage can be executed normally.

Egyptian soils generally are considered to be rather well supplied with total phosphate, but the quantity of available phosphate may be rather low. More particularly is this true in the cases of the soils of Lower-Egypt, the main rice growing area, and this explains why phosphate fertilizing is a more common practice for rice than for most of the other crops.

Phosphate stimulates root development of the very young rice plant but an ample phosphate supply is also important for the period between tillering and flowering.

Phosphate accelerates ripening, increases the yields, and corrects nitrogen excess by counteracting harmful lodging.

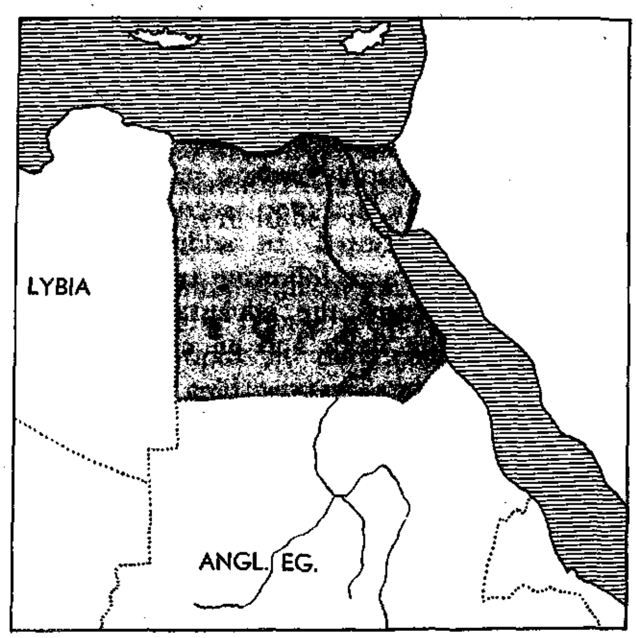
The optimum dosage of phosphate varies from 100 to 200 kg. of superphosphate 18 % per feddan. This superphosphate is often worked into the soil during preparatory soil cultivation and before sowing. When transplanting is carried out phosphate is generally applied at the rate of 100 kg. of superphosphate per feddan on the seedbed, supplemented with 50 kg. per feddan in the fields whenever there is also an application of nitrogen.

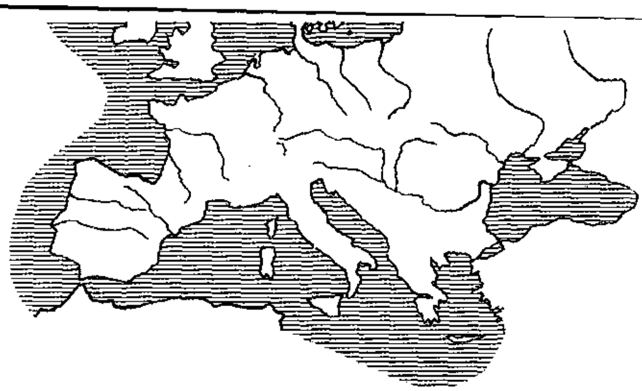
As most Egyptian soils are rich in potash and also in view of the rather high potash content of the Nile water, potash fertilizing is not necessary.

As far as the economics of fertilizing generally are concerned, it is estimated that there is a response of 20 tot 25 % by using 150 kg. sulphate of ammonia + 200 kg. superphosphate.

Each rice grower should, however, determine the most profitable quantity required in each instance as a result of his own experiments and observations.

Based on a rice area of 750,000 feddans and an average application of 100 kg. sulphate of ammonia and 100 kg. superphosphate 18 % per feddan, Egypt would require, for rice growing only, a quantity of 75,000 tons of each of the abovementioned fertilizers.





RICE GROWING IN EUROPE

ALTHOUGH rice is grown in all the countries of Southern Europe, *Italy* with a production of 750,000 metric tons of paddy on an area of 140,000 hectares as a prewar annual average, has been for a long time by far the most important rice producing country of Europe. Acreage and production are now even higher.

The main rice growing area of Italy is in the Po Valley, including the plains of Lombardia and Piedmonte, with the town of Vercelli as a centre. The river Po and its tributaries, with an extensive system of canals, supply an ample amount of irrigation water. The Experimental Station for Rice, established in 1908, has contributed much to the improvement of rice growing in this area.

Both the transplanting and direct broadcasting methods are used. Because there is an abundant labour supply in most parts of Italy, 30 to 80 % of the rice crop, according to the region, is transplanted. In addition to the higher yields per acre following transplanting, the method permits the advantage of later ploughing of the fields and an extra cutting of hay.

For broadcasting, the usual procedure is to plough, cultivate and fertilize the land in March and April. For the transplanted crop the nursery beds are planted early in June, the transplanting being carried out in June and July.

By means of a circulating system, much of the irrigation water is warmed up early in spring before it enters the paddy fields. Harvesting starts late in August and extends until late October.

Rice growing in Italy is characterized by unusually high rates of production and thus is a subject of great interest throughout the whole rice world. Only in Spain are higher yields obtained. This is illustrated by the average annual prewar production figures in the following table.

Average yield of paddy per hectare over the period 1934/35—1938/39 according to F.A.O. reports

	Quintals		Quintals
Spain	62.3	Pakistan	14.8
Italy	53.0	Brazil	14.3
Japan	36.3	Burma	14.1
Egypt	35.0	India	13.3
China	25.3	Thailand	12.9
British Guiana	24.8	Indochina	11.6
U.S.A.	24.7	Philippines	10.9
Indonesia	15.8		

Although favourable climatic conditions, including a greater length of day, greater light intensity and more solar energy as in tropical countries, which favour the physiological activities of the plant, may contribute to Italy's high production level, other contributary factors undoubtedly are:

(1) an intensive fertilizing scheme, and

(2) an effective rotation scheme.

As rice farms here are predominantly diversified rice-dairy-farms, the general practice in the Po Valley is the growing of rice for some successive years, followed by a series of years of grass and legumes for hay making and pastures to feed dairy cattle. This has proved to be such an excellent rotation scheme that the practice has now been extensively adopted in the Rice Belts of Louisiana and Texas in the U.S.A.

The fertilizing scheme is based on an ample use of farmyard manure before planting (20 to 60 tons per hectare), supplemented by applications of chemical fertilizers, including a mixture of sulphate of ammonia, superphosphate and potassium chloride, at an average rate of 750 to 1,000 kg. per hectare. Two thirds of the fertilizer is applied before seeding or transplanting and one third as a topdressing early in the growing season.

Spain, has also been producing rice for many years especially in the provinces of Valencia and Tarragona. The total area is 48 to 50,000 hectares, and the total production 180 to 200,000 metric tons of rice, which is almost entirely consumed in the country itself.

The fact that average yields in Spain are higher than anywhere else in the world, proves that extremely great care is given to rice culture, including the use of fertilizers (mainly nitrogenous fertilizers) on a large scale.

The nitrogenous fertilizers are allocated to the Federation of Ricegrowers by the Ministry of Agriculture, and are further distributed via the local Rice Syndicates.

The following quantities of nitrogenous fertilizers have been distributed during the following years to the members of those Syndicates:

Years	*Hectares in cultivation*	*Nitrogenous fertilizers in metric tons*
1939	41,876	16,155
1940	47,357	15,812
1941	47,008	19,557
1942	47,279	26,238
1943	47,673	29,856
1944	48,001	24,118
1945	48,068	19,944
1946	50,047	16,545

Sulphate of ammonia is considered the most suitable fertilizer, followed by ammonium nitrate and calcium cyanamide.

In *Portugal,* where the average yields per ha. are somewhat lower than in Italy and Spain, the rice area amounted to an average of 21,000 ha. and the production to 66,000 metric tons of paddy per annum in prewar years, but these figures are higher now.

In *Greece,* rice growing is expanding and previously uncultivated estuary soils are being reclaimed for this crop. About 10,000 hectares have already been planted with rice, compared with a prewar area of not more than 2,000 hectares. The estimated total production amounts to 20,000 tons of milled rice per annum.

Another country with an increasing interest in rice growing is *Hungary.* Because of the climatic conditions in that country, with its rather long cold winters and its dry warm summers, search is being made in the first place for rice varieties well adapted to these environmental conditions. As much of the crop as possible should be harvested in September, before the rains start.

In 1948 the rice area amounted to 13,886 hectares yielding 30,000 tons, an average of 2,175 kg. per ha. In 1951 about 17,000 ha. of rice were harvested, but it is intended to expand this area considerably by means of improved irrigation facilities.

The rice area of the *U.S.S.R.* amounted to about 125,000 ha. in 1932 and 195,000 ha. in 1938, with production varying from 200,000 to 380,000 tons. According to the fourth five-year plan, however, production must exceed 500,000 tons of rice in 1950.

Rice growing in *France* has expanded considerably as a consequence of postwar high rice prices. The centre of rice growing in France is in Camargue, the low lying flat area of the Rhone mouth.

In 1860 dykes were built in this area to protect the land from floods, but this caused increasing salination because salts were no longer leached from the topsoil by those floods. Owing to this saline character, many soils here were almost entirely uncultivated but have been reclaimed by means of efficient systems of irrigation and drainage and made suitable for rice growing.

Very much capital is, of course, needed for these reclamation works including the building of irrigation facilities and drainage canals. This capital has been provided partly by the cultivators themselves and partly by other institutions and organisations, like Le Crédit Agricole.

Early maturing, high yielding varieties, that are resistant to lodging and do not shatter seeds are preferred.

All the soil tillage is carried out before flooding. Sowing is effected either by a grain-drill, or broadcast before flooding, or broadcast by hand or plane thereafter. Very little of the rice is transplanted.

For machine harvesting the fields should be drained in good time. A large part of the crop is still mown by hand, however.

Owing to the present favourable price level for rice there is hardly any rotation practised, rice normally following rice. Establishment of a satisfactory rotation scheme is, however, very important, the more so as this practice provides one of the most effective means of weed control.

The rice area in France has expanded from about 250 hectares in 1942 to 11,000 hectares in 1950, as shown by the following figures:

Year	*Area in ha.*	*Paddy production in metric tons*
1942	250	500
1945	500	1125
1949	8000	25000
1950	11000	44000

Not only has the area expanded considerably since the war but yields have also doubled owing to better cultivation methods, the more widespread use of varieties better adapted to environment and improved weed control and fertilizing schemes.

The following fertilizing scheme may be considered a general guide:

$$\left.\begin{array}{l}\text{300 kg. sulphate of ammonia}\\ \text{600 kg. superphosphate 16\%}\\ \text{200 kg. muriate of potash}\end{array}\right\}\text{per hectare}$$

Sometimes nitrogen applications are increased up to about 100 kg. N per ha.

It is estimated that the rice area in France could be further increased to a total of 20 to 30,000 hectares.

The above mentioned production of 44,000 tons of paddy satisfies about one third of the total requirements of France.

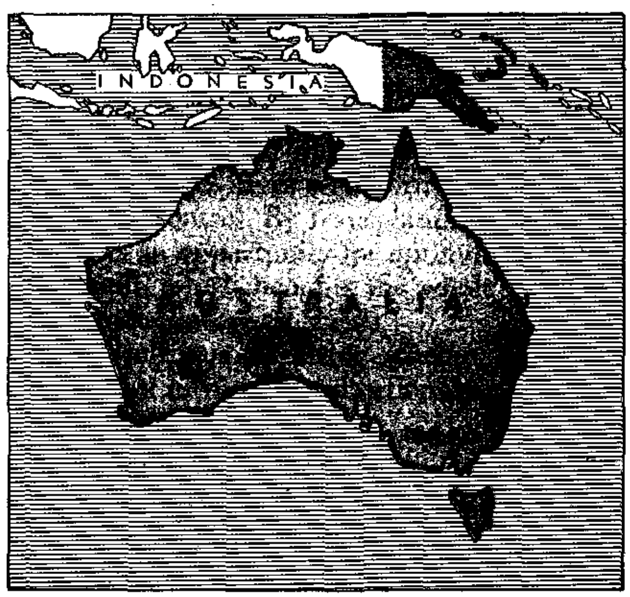
RICE GROWING IN AUSTRALIA

RICE has been grown on a commercial scale in New South Wales only since the 1924-1925 season, when a little more than 150 acres were put under this crop on the Murrumbidgee Irrigation Area.

Before that time the impossibility of controlling weed growth and other adverse factors had made it quite evident that upland rice growing could not be considered a commercial proposition in this State.

Since then the irrigated rice area on the Murrumbidgee Irrigation Area has extended to about 25,000 acres, with a production of about 35,000 tons of paddy during 1939-1940.

The average yield per acre over a period of 8 years amounted to 1.75 tons of paddy. Rotational cropping with other cereals and the use of temporary pastures are, next in importance to fertilizing, practiced here as a means of maintaining and increasing soil productivity. Such a rotation scheme, with rice cultivation only once every three years, is undoubtedly one of the most effective and one of the cheapest methods of weed control. This method should be assisted to such a degree by water control that weeds succumb and rice is little harmed or not at all.



As far as fertilizing is concerned, an application of about 200 kg. of sulphate of ammonia per acre has proved to be most economical on clean land, that is, land without a N-reserve resulting from legume growing. Portions of land with a N-reserve may need only a reduced quantity of fertilizer per acre or may even not require any fertilizer at all. On the other hand it may be advisable to apply somewhat higher quantities of N-fertilizers to soils that are very deficient in this constituent.

The normal practice of applying this fertilizer is as a basal dressing during the operation of drilling the seed. Sometimes, however, part of it is given as a top dressing during the early growing stage of the rice plants.

The practice of adding 100 kg. per acre of superphosphate to the abovementioned quantity of sulphate of ammonia is recommended.

Rice growing in Australia is mechanised as much as possible, including not only soil tillage and sowing, but harvesting as well, mainly by means of the combine-method, which involves cutting, threshing, winnowing, cleaning and bagging the paddy all in one operation.

The occurrence of empty glumes may be caused by extreme daily changes in temperature, chiefly as a result of hot drying winds alternating with cold spells at some stage of the flowering period.

According to DARGIN [15] other factors contributing to the production of empty glumes in rice crops are a lowered vitality of rice plants, overseeding, sowings made too late in the season, an absence of sunlight and an excessive amount of nitrogen.

SUMMARY

FOLLOWING the serious decline during the war years world rice acreage and production have again increased to such an extent that their levels are even somewhat above the pre-war annual average. Nevertheless, the increase in the number of rice-eating people has been so much greater in the meantime that there is still a considerable world shortage in rice. Production of rice should, therefore, be increased, especially by those countries which still depend on imports. This is the more important because on the results of these efforts will depend the maintenance of peace, order and prosperity in most of the areas concerned.

In this connection various cultural methods are discussed that are of definite importance for the increase of rice production, and in particular that of wet rice, which includes by far the greater part of the world's rice production.

Thereafter a short survey is given of the situation in each of the main rice growing countries.

The above mentioned cultural methods comprise:

(1) An abundant water supply, not only because the rice itself requires an abundance of water, but also for the essential puddling operation in wet rice soils.

(2) Very intensive soil tillage, which also contributes to the necessary puddled condition.

(3) The substitution of transplanting from seedbeds for broadcasting where the latter is practised. Transplanting often allows more time and opportunity for intensive soil tillage, saves seed corn and facilitates weed-control. By transplanting each plant gets an opportunity for optimum development, which benefits the whole field and produces highest yields.

(4) A judicious fertilizing scheme, which includes nitrogen application as a primary consideration.

Owing to an intensive biological nitrogen fixation, in which blue-green algae *(Cyanophyceae)* as well as bacteria play their parts, moderate nitrogen applications will, in many cases, suffice.

A normal nitrogen application for paddy is 30-60 kg. N/ha. Seldom need more than 60 kg. N/ha. be applied.

The ammonium form is undoubtedly most suitable for paddy. Nitrates are definitely less effective for basal dressings because of denitrification losses from the chemically reducing soil layer.

Methods of basal dressing should be adapted

to these extraordinary circumstances by deep placement, which involves putting the sulphate of ammonia directly into the chemically reducing layer, where no nitrification is possible and where the nitrogen remains available for the plants in the NH_4-form. This may, as in Japan, be effected by ploughing under the sulphate of ammonia, directly followed by irrigation, or by pressing fertilizers in the form of tablets or big pellets into the reducing zone of the paddy field.

In Indonesia sulphate of ammonia is sometimes introduced into the reducing zone by trampling it in with the feet, which has the same effect as the abovementioned method.

Partly owing to its influence on the nitrogen content of the soil, green manuring is also a practice of great benefit to paddy soils and in nearly all rice producing countries extremely favourable results are reported as a result. The main difficulty is often, however, that of introducing green manure crops into a rotation scheme without sacrificing a food-crop.

Although in most countries nitrogen constitutes the main element in the fertilizing scheme, phosphate also is often a necessary constituent. In some cases, as in Indonesia and in Thailand, phosphate is even more important than nitrogen.

As paddy absorbs its P_2O_5 within a short period, a quickly available phosphate form like superphosphate, or dicalciumphosphate is preferable. The suitability of other phosphate forms depends on such factors as soil type, soil reaction etc.

In view of the effectiveness of water soluble phosphate in paddy soils, moderate applications will suffice. This effective character is probably closely bound up with the reducing layer of soil, which prevents formation of trivalent iron-phosphate compounds and increases availability.

Small annual phosphate applications are preferable to heavier applications over a longer period, partly because of the possibility of phosphate losses in the outflowing irrigation water.

Besides contributing greatly to higher production, phosphate asserts its influence in several other ways e.g.

(a) A stimulating influence on root development, making plants somewhat more resistant to drought.
(b) Somewhat earlier flowering and ripening, by which the eventually unfavourable influence of late transplanting is reduced or neutralized.
(c) Better tillering, which affords to rice fields the ability of recovering more rapidly and more completely from a borer attack.
(d) Higher feeding value of the rice owing to its higher phosphate content.

Furthermore consideration should be given to the possibility that in some cases the favourable effect of phosphate fertilizing is partly due to an improved nitrogen supply, because phosphate fertilizing stimulates algae growth and thus nitrogen fixation.

Although many of the lighter soils have proved to be more or less deficient in potash, practically all of the heavier soils, comprising by far the greater part of the world's rice area, are still rather rich in potash. Potash is also very often supplied as a constituent of the irrigation water.

The same may be said of lime, and liming experiments have, therefore, seldom produced positive responses. Moreover, consideration must be given to the influence of lime on the minor elements' circulation. Liming may decrease the availability of several of these trace elements and may cause typical deficiency symptoms.

Results of experiments with the minor elements have not so far been striking.

In Indonesia positive results are reported from pot experiments with copper sulphate in a very acid oligotrophe Borneo peat soil, while in India favourable results have been obtained with manganese sulphate and zinc sulphate. In Japan a marked response to manganese was observed on the so-called degraded or Akiochi paddy soils, a very poor and leached soil type often also deficient in potash.

Apart from this the possibility of poisoning plants with surpluses of some minor elements should be considered.

Pre-treatment of seed with plant nutrients and seedbed manuring has often produced a marked increase in seedling vigour, which has not always been reflected in increased yields.

The conclusion to be drawn is that seed treatment and seedbed manuring are possibly stimulating factors for active development of the young stages of the plant, which may maintain its influence till harvest if other beneficial influences act sufficiently on the plant in its later stages of growth. This means that seed treatment or seedbed manuring cannot be considered a complete or partial substitute for paddy manuring after transplanting. Seed bed manuring combined with an efficient fertilizing scheme afterwards should give the best results.

Selection should not only aim at a high level of production, but at other characteristics as well. New varieties should be of a good quality, more resistant to pests and diseases, resistant to lodging, early maturing, etc.

More efficient control of pests and diseases will also contribute to higher yields.

Japan is outstanding among the large producers for the intensive character of its rice growing and for the extent to which fertilizers and manures are used to reach optimum yields. The average N-application is about 60 kg. N per ha., supplemented with some superphosphate. Potash responses have been observed in the so-called degraded — or „Akiochi" paddy soils — an extremely poor and leached soil type.

Most of the nitrogen is applied in the form of sulphate of ammonia, except for the above mentioned degraded paddy soils, in which the use of sulphate of ammonia may lead to harmful H_2S concentrations. SO_4-free fertilizers are, therefore, preferable in such cases.

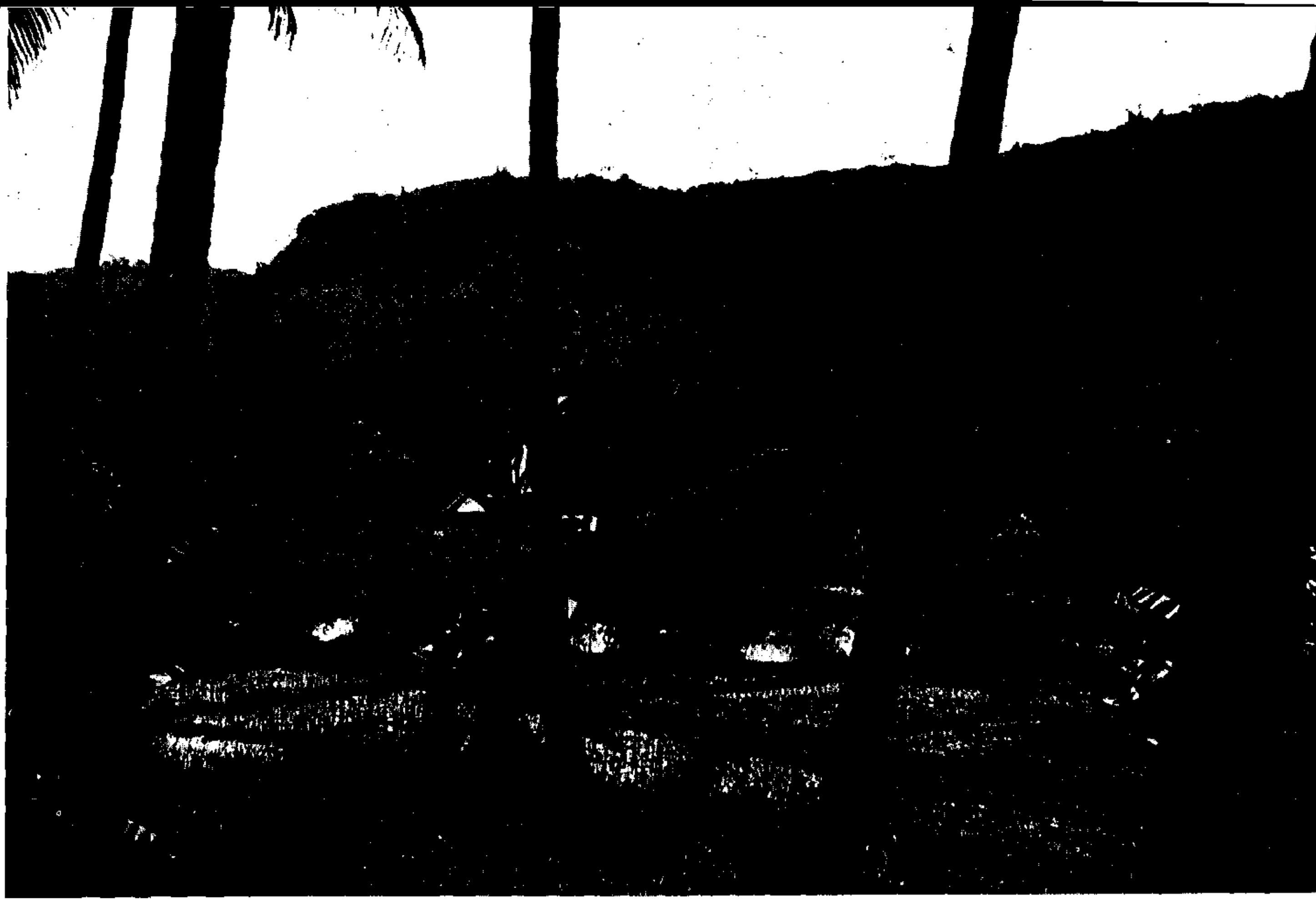
Production level and the food supply of *Korea* are dependent on the question as to whether or not this country can provide itself with sufficient fertilizers at a moderate price level for the benefit of the poor, capital-lacking, small Korean farmer.

Practically all soils in *China* show a big response to nitrogen, about half of them a definite reaction to phosphate and not more than about 15 % (for the greater part, lateritic strongly weathered and related soils) a distinct response to potash.

The degree to which yields in *Formosa* are affected by fertilizing was shown during the war when lack of fertilizers caused average rice yields to fall from 2000 kg./ha. to 1400 kg./ha. for the first crop and from 1600 kg./ha. to 1000 kg./ha. for the second crop.

For *Indian* rice soils a moderate N-dressing, e.g. 30 lb. N/acre, will be highly profitable. This should be supplemented with some phosphate for the lateritic soils and sandy coastal soils.

For *Pakistan,* where rice growing is concen-



Western Java, River plain utilized for paddy soils, hill sides forested

trated in East Pakistan, the completion of the ambitious plan VAN BLOMMESTEIN will prove an extremely valuable contribution to a higher production level.

Ceylon is still one of the big rice importers, but will be able to increase its home production considerably by

(a) extending the rice area into the dry zone, where big irrigation projects are under construction;

(b) increasing yields of the existing rice fields by

 (1) replacing the now customary method of broadcasting by transplanting from seedbeds;

 (2) a judicious fertilizing scheme with nitrogen as the main component, supplemented with phosphate and, for many of the lighter soils, also with potash.

For *Indonesia,* where on the island of Java at least 800,000 ha. are deficient in phosphate, this nutrient is the main component of the fertilizing scheme. Next in importance to it, nitrogen will be able to contribute in many cases to a higher production level. The nitrogen effect is less uniform, however, which makes it difficult to issue reliable recommendations for its use. Further trials are needed to determine the correct rate of nitrogen application for each case.

Thailand, the world's main rice exporting country in post-war years, provides another example of a fertilizing scheme based on phosphate, supported by nitrogen. Responses to nitrogen are much more variable, however.

Rice soils in *Burma,* by far the most important rice exporter in pre-war years, show a definite response to nitrogen and phosphate, but hardly any fertilizers have been used up to the present.

For *Indo-China* the fertilizing scheme should include nitrogen and phosphate, with the accent on nitrogen for many of the soils in Northern Vietnam and on phosphate for Southern Vietnam. For part of the sandier soils this should be supplemented with potash.

In *Malaya,* with its heavy import requirements, paddy fields of the western side of the peninsula have rather rich soils, but in the eastern region yields could be increased considerably by a fertilizing scheme based on nitrogen and phosphate, with potash for the most sandy soils.

In the *Philippines,* Government is attempting to increase rice production by means of better varieties and of reliable seed. supply, by extending the use of fertilizers, irrigation improvement, more efficient control of pests and diseases and extension of the rice area in the Southern Islands.

Brazil, the greatest rice producer of the Western Hemisphere, grows mainly dry rice. Of the three principal rice producing states, Rio Grande do Sul, Sao Paulo and Minas Gerais, only Rio Grande do Sul, with bigger, somewhat more mechanised farms, produces mainly wet rice.

Bonemeal is practically the only fertilizer used.

Rice growing in the *U.S.A.* is highly mechanised, especially in California, where sowing, fertilizing and weed control by means of herbicides is done from aeroplanes.

The fertilizing scheme in California consists of nitrogen only, with an average application of about 30 lb. of N per acre.

In Arkansas, Louisiana and Texas, where soils are less uniform than in California, nitrogen is supplemented with phosphate and potash; the over-all average application in these areas is 11 lb. of N, 8 lb. of P_2O_5 and 4 lb. of K_2O per acre.

In *Egypt,* where rice growing is concentrated in the Northern Delta provinces of Lower Egypt, nitrogen applications should be based on quantities of 175 to 350 kg./ha. of sulphate of ammonia, dependent on the natural nitrogen content of the soil, preferably supplemented with a phosphate application.

In *Europe,* Italy is the main rice producer and the only rice exporter. Spain is also a rather important rice producer but generally without an export surplus. The production level is much higher here than in tropical areas partly owing to favourable natural conditions for vegetative activity, but chiefly owing to excellent cultural methods, including an efficient rotation scheme and the judicious use of fertilizers. In Southern France also rice growing has expanded considerably in the post-war years.

Rice growing in *Australia* is highly mechanised. An average application of about 200 kg. of sulphate of ammonia per acre has proved to be most economical, supplemented with 100 kg. of superphosphate per acre.

SOMMAIRE

METHODES POUVANT AUGMENTER LA PRODUCTION DU RIZ

APRES avoir subi une sérieuse diminution pendant la guerre, l'extension de la culture et la production mondiale du riz se sont rétablies à des niveaux légèrement supérieurs à leurs moyennes d'avant guerre. Toutefois, le nombre des consommateurs de riz s'est tellement accru dans l'entretemps qu'il subsiste un déficit mondial considérable. Il en résulte que la production du riz doit être augmentée, particulièrement dans les pays qui sont toujours tributaires de l'importation. Cet objectif est fort important car, dans nombre de cas, la paix, l'ordre et la prospérité de ces pays en dépendent.

Dans cet ordre d'idées, une série de méthodes culturales susceptibles d'exercer une influence décisive sur la production du riz à été passée en revue en s'attachant en particulier à la culture irriguée, laquelle assure de loin la plus grande partie de la récolte mondiale.

Un court aperçu de la situation dans les principaux pays producteurs est donné ensuite.

Parmi les méthodes culturales en question, il y a lieu de citer:

(1) De l'eau en abondance, pour assurer non seulement les besoins propres du riz mais également pour améliorer les propriétés physiques et obtenir la structure de boue nécessaire pour la culture irriguée du riz.

(2) Un labourage énergique du sol, également pour effectuer la structure de boue nécessaire pour une culture rémunerative du riz.

(3) Pratiquer de préférence le repiquage plutôt que le semis à la volée. Le repiquage laisse plus de temps disponible pour effectuer les labours, il permet d'économiser de la semence et facilite le désherbage. Le repiquage place chaque plante dans les conditions de développement optima; il en résulte une influence bénéfique sur l'entièreté du champ et qui se traduit par des rendements meilleurs.

(4) Une fertilisation judicieuse comprenant avant tout de l'azote.

Etant donné qu'il se produit une fixation biologique intense de l'azote dans laquelle interviennent les algues bleues (Cyanophycées) ainsi que des bactéries, des applications modérées d'azote suffiront dans de nombreux cas.

Pour le paddy, une fumure azotée normale comportera 30-60 kg N/ha, rarement plus.

La forme ammoniacale est incontestablement la meilleure. Les nitrates sont moins efficaces pour les fumures de fond à cause des pertes par dénitrification dans le milieu réducteur. Il faudra en tenir compte lors de l'application de la fumure de fond en apportant le sulfate d'ammoniaque directement dans la couche réductrice dans laquelle aucune nitrification n'est possible et où l'azote restera à la disposition des plantes sous la forme ammoniacale.

Ceci peut se faire comme au Japon, en enfouissant le sulfate d'ammoniaque par un labour suivi directement par une irrigation ou bien en introduisant les engrais sous forme de tablettes ou de grosses boulettes par pression dans la zone réductrice.

En Indonésie, on introduit parfois le sulfate d'ammoniaque dans la zone réductrice par piétinnement, ce qui produit des effets analogues.

L'enfouissement d'engrais verts est également un facteur important, en raison, entre autres, de son influence favorable sur l'enrichissement du sol en azote. Cette technique a donné des résultats extrêmement favorables dans pratiquement toutes les régions productrices. Toutefois, il est difficile d'introduire les cultures d'engrais verts dans l'assolement sans sacrifier une récolte principale.

Bien que dans la plupart des régions l'azote soit l'élément principale de la fertilisation, souvent le phosphore est également nécessaire. Dans certains cas même, comme en Indonésie et en Thaïlande, la fertilisation phosphatée est relativement plus importante que la fumure azotée.

Etant donné que le paddy doit absorber le P_2O_5 pendant une courte période, il faut donner la préférence à un engrais phosphaté rapidement assimilable, tel que le superphosphate ou éventuellement le phosphate bicalcique. La possibilité d'utiliser d'autres phosphates dépend des circonstances tels que nature et réaction du sol, etc..

En raison de l'efficacité des phosphates à solubilité aqueuse dans les terres à paddy, il suffira d'appliquer des doses modérées. Cette efficacité résulte probablement du millieu réducteur qui empêche la formation de phosphate de fer trivalent.

Il est préférable d'appliquer les phosphates par petites doses annuelles plûtot que par doses plus massives et plus espacées car il faut compter avec les possibilités de pertes en phosphates par l'eau d'irrigation.

Outre qu'ils contribuent à l'augmentation de la production, les phosphates:

a) favorisent le développement radiculaire, ce qui rend les plantes un peu plus résistantes à la sécheresse;
b) hâtent quelque peu la floraison et la fructification, ce qui a pour effet de réduire ou d'annuler les dommages éventuels d'une plantation tardive;
c) favorisent le tallage du riz, ce qui permet aux plantes de se rétablir plus rapidement et plus complètement après une attaque du charançon;
d) accroissent la teneur du riz en phosphore et, par conséquent, sa valeur alimentaire.

Il y a lieu de tenir compte également que les phosphates stimulent la croissance des algues et ainsi la fixation de l'azote. Il s'ensuit que, dans certains cas, il est possible que les manifestations favorables de la fumure phosphatée ont en partie pour cause un accroissement indirect des apports d'azote.

Sauf certains sols, assez légers, qui se sont révélés plus ou moins déficients en potasse, les sols, plus lourds, qui constituent la plus grande partie de l'aire mondiale du riz, sont plutôt riches en cet élément. En outre, trés souvent, la potasse est apportée par l'eau d'irrigation.

Il en est de même pour la chaux et les essais de chaulage ont rarement donné des résultats positifs.

De plus, il faut tenir compte de l'influence de la chaux sur le circulation des éléments mineurs car le chaulage peut réduire les disponibilités en plusieurs éléments mineurs et provoquer l'apparition de symptômes typiques de carences.

Les essais effectués avec les oligo-éléments ou éléments mineurs n'ont pas donné, jusqu'à présent, de résultats bien évidents.

On a signalé d'Indonésie des résultats positifs obtenus avec le sulfate de cuivre en vases de végétation sur un sol tourbeux de Borneo, très acide et oligotrophe, tandis que de l'Inde on signale des résultats favorables avec le sulfate de manganèse et le sulfate de zinc. Au Japon, on a observé un bon résultat avec le manganèse sur des terres à paddy dégradées d'Akiochi, un type de sol lessivé, très pauvre, manquant aussi souvent de potasse.

On doit tenir compte, en outre, qu'un excès en éléments mineurs peut exercer un effet toxique sur les plantes.

Le traitement préalable des semences avec des éléments phytogéniques et l'application de fumures au lit de germination produit assez souvent une augmentation de la vigueur des jeunes pousses qui cependant ne se reflète pas toujours dans les rendements. L'impression finale est à peu près la suivante: le traitement de la semence et l'application de fumures au lit de germination peut exercer sur le développement juvénile des plantes une action stimulante, laquelle pourra se maintenir jusqu'à la récolte si, au cours du développement ultérieur, ne se manifestent pas des causes adverses. Il s'ensuit que le traitement de la semence et la fumure au lit de germination ne peuvent pas être considérés comme pouvant se substituer totalement ou partiellement à la fertilisation après transplantation. Les résultats les plus prometteurs résulteront d'une combinaison de la fumure au lit de germination avec l'application ultérieure d'une fertilisation efficiente.

La sélection doit viser à améliorer non seule-

High producing rice field in Egypt

ment la production mais également d'autres propriétés. Les nouvelles variétés doivent être de bonne qualité, plus résistantes aux parasites et aux maladies, résistantes à l'engrenage, caracterisé par une maturation précoce, etc..

Une lutte plus efficace contre les parasites et les maladies contribuera également à élever les rendements.

Parmi les gros producteurs de riz, le *Japon* se distingue par le caractère intensif de sa culture et l'emploi étendu des engrais en vue d'obtenir des rendements optima. On utilise en moyenne 60 kg N à l'ha et un peu de superphosphate en supplément. La potasse réagit dans les terres à paddy dégradées d'Akiochi, un type de sol lessivé, très pauvre.

L'Azote est généralement appliqué sous forme de sulfate d'ammoniaque, sauf dans ces terres dégradées où il risquerait de se former des concentrations nuisibles en H_2S, de sorte qu'on préfère y appliquer des engrais exempts de radical SO_4.

En *Corée,* les niveaux de la production et de l'alimentation sont étroitement liés aux possibilités de ce pays de se procurer des engrais en quantités suffisantes et à des prix modérés appropriés à la situation des petits fermiers coréens, pauvres et dépourvus de capitaux.

En *Chine,* pratiquement tous les sols réagissent fortement à l'azote, environ la moitié des sols montrent une réaction sérieuse aux phosphates et pas plus de 15 % d'entre eux (pour la plupart des sols latéritiques ou analogues) ne réagissent d'une manière nette à la potasse.

A *Formose,* la mesure dans laquelle les rendements sont influencés par la fertilisation est apparue pendant la guerre, quand le manque d'engrais a fait tomber les rendements moyens de riz de 2000 kg/ha à 1400 kg/ha en 1ère coupe et en seconde coupe de 1600 kg/ha à 1000 kg/ha.

Dans *l'Inde,* une application à dose modérée de par ex. 30 lb. N/acre sera hautement profitable. Eventuellement, on appliquera un supplément phosphaté dans les sols latéritiques et dans les sols sablonneux de la côte.

Au *Pakistan,* la culture du riz est concentrée dans l'Est. L'exécution du plan ambitieux VAN BLOMMESTEIN doit apporter une contribution extrêmement importante à l'accroissement du niveau de production.

Ceylan est toujours un des plus gros importateurs de riz mais sera en mesure d'accroître considérablement sa production indigène:

a) en étendant la culture au riz dans la zone sèche où de vastes projets d'irrigation sont en exécution;
b) en adoptant un plan de fertilisation judicieux basé, en ordre principal, sur l'azote complété par des phosphates et aussi, pour la plupart des sols légers, par de la potasse.

En *Indonesie,* dans l'Ile de Java, où 800.000 ha manquent de phosphore, les phosphates sont à la base du plan de fertilisation bien que, dans beaucoup de cas, l'azote est également apte à contribuer à l'élévation du niveau de production.

Cependant, l'action de l'azote est moins uniforme de sorte qu'il est plus difficile de donner des directives générales. Il sera nécessaire de faire des essais pour déterminer les applications d'azote à faire dans les différents cas.

La *Thaïlande,* le plus gros exportateur de riz de l'après-guerre, est un autre exemple d'une fertilisation basée sur les phosphates et complétée par l'azote. L'effet de l'azote est cependant encore plus variable.

En *Birmanie,* de loin le plus gros exportateur de riz de l'avant-guerre, les terres à riz réagissent nettement à la fumure azotée et phosphatée mais jusqu'à présent on utilise à peine les engrais.

En *Indochine,* la fertilisation doit porter sur l'azote et sur les phosphates avec prédominance du premier dans beaucoup de sols du Nord du Vietnam et une prédominance du second dans le Sud du Vietnam. Dans certains sols plus sablonneux, cette fumure sera complétée par de la potasse.

La *Malaisie* est fortement tributaire de l'importation. Les terres à paddy situées dans l'Ouest de la péninsule sont assez riches mais dans les terres situées dans l'Est les rendements pourraient être augmentés considérablement par une fumure azotée et phosphatée complétée par de la potasse dans les terres les plus sablonneuses.

Aux *Philippines,* le gouvernement essaie d'augmenter la production par l'emploi de meilleures variétés et un bon approvisionnement de semences, en propageant l'emploi des engrais, le perfectionnement de l'irrigation, par une lutte plus efficace contre les maladies et les parasites et l'extension de l'aire du riz dans les îles du Sud.

Le *Bresil* est le plus gros producteur de riz de l'hémisphère occidental. On y cultive principalement le riz sec. Parmi les trois états principaux producteurs du riz: Rio Grande do Sul, Sao Paolo et Minas Gerais, seul dans le Rio Grande do Sul, où l'on rencontre des fermes plus importantes, quelque peu plus mécanisées, on cultive, en ordre principal, le riz irrigué.

La farine d'os est pratiquement le seul engrais utilisé.

Aux *Etats-Unis,* la culture du riz est fortement mécanisée, particulièrement en Californie où le semis et l'épandage des engrais et des herbicides se font par avion.

En Californie, la fumure est exclusivement azotée et comporte, en moyenne, l'application de 30 lb. de N par acre.

Dans l'Arkansas, la Louisiane et le Texas, où les sols sont moins uniformes qu'en Californie, la fumure azotée est complétée par une fumure phospho-potassique. La dose moyenne pour l'ensemble de ces trois états est de 11 lb. de N, 8 lb. de P_2O_5 et 4 lb. de K_2O par acre.

En *Egypte,* la culture du riz est concentrée dans les provinces septentrionales de la Basse Egypte, riveraines du Delta. Suivant la teneur naturelle du sol en azote, la fumure comportera l'application de 175 à 350 kg/ha de sulfate d'ammoniaque, complétée de préférence par une application de phosphates.

En *Europe,* l'Italie est le plus gros producteur et seul exportateur de riz. L'Espagne est également un gros producteur mais ne dispose généralement pas de surplus exportables. La production y est beaucoup plus élevée que dans les pays tropicaux en raison des conditions naturelles plus favorables à la végétation et surtout de la mise en oeuvre d'excellentes méthodes culturales, dont une rotation appropriée et un emploi judicieux des engrais. Dans le midi de la France également, la culture du riz s'est étendue considérablement pendant les années d'après-guerre.

En *Australie,* la culture du riz est hautement mécanisée. Il s'est avéré fort économique d'appliquer une fumure moyenne d'environ 200 kg/acre de sulfate d'ammoniaque, complétée, par exemple, avec 100 kg/acre de superphosphate.

ZUSAMMENFASSUNG

MASSNAHMEN ZUR ERHÖHUNG DER REISERZEUGUNG

OBWOHL die Reisanbauflächen und die Produktion nach dem starken Absinken während der Kriegsjahre wiederum so weit zugenommen haben, dass sie etwas über dem Vorkriegsdurchschnitt liegen, so hat die Anzahl der reisessenden Bevölkerung in der Zwischenzeit so viel stärker zugenommen, dass noch ein erheblicher Reismangel in der Welt besteht. Die Reiserzeugung sollte daher gesteigert werden, insbesondere von den Ländern, die noch von Einfuhren abhängig sind. Dies ist umso wichtiger, weil in vielen Fällen die Ergebnisse dieser Anstrengungen entscheidend sein werden für die Ruhe, die Ordnung und den Wohlstand in den betreffenden Gebieten.

In diesem Zusammenhang wird eine Reihe von Anbaumethoden besprochen, die von ganz entschiedener Bedeutung sind für die Erhöhung der Reisproduktion und insbesondere der Reisproduktion auf Ueberschwemmungsland, auf die bei weitem der grösste Teil der Weltreisproduktion entfällt.

Anschliessend wird ein kurzer Ueberblick über die Situation für jedes der hauptsächlichen Reisanbauländer gegeben.

Die oben erwähnten Anbaumethoden umfassen u.a.

(1.) Eine reichliche Wasserzufuhr, nicht nur weil der Reis selbst reichlich Wasser benötigt, sondern auch für die Puddelarbeit von nassen Reisböden.

(2.) Eine sehr intensive Bodenbestellung, auch im Hinblick auf das erförderliche Puddeln.

(3.) Bevorzügung des Umpflanzens aus Saatbeeten gegenüber dem Ausstreuen des Saatgutes. Die Umpflanzung lässt häufig mehr Zeit und Gelegenheit übrig für eine intensive Bodenbearbeitung, sie erspart Saatgut und erleichtert die Unkrautbekämpfung. Durch die Umpflanzung erhält jede Pflanze die Gelegenheit zu einer optimalen Entwicklung, die das ganze Feld begünstigt und die besten Ertragsergebnisse liefert.

(4.) Einen wohlabgewogenen Düngungsplan, der an erster Stelle Stickstoff umfasst.

Infolge einer intensiven biologischen Stickstoffbindung, bei der sowohl Blau-Algen (Cyanophyceae) als auch Bakterien eine Rolle spielen, werden in vielen Fällen mässige Stickstoffdüngungen ausreichen.

Eine normale Stickstoffdüngung für Reis beträgt 30-60 kg N/ha. Relativ selten werden mehr als 60 kg N/ha gedüngt.

Die Ammoniumform ist zweifellos für Reis sehr geeignet. Nitrate sind für Grunddüngungen entschieden weniger wirksam wegen der Denitrifizierungsverluste aus dem reduktiven Reismilieu.

Die Methoden der Grunddüngung sollten diesen aussergewöhnlichen Umständen angepasst werden durch tiefe Unterbringung, d.h. durch direkte Verbringung des Ammoniumsulfates in die reduktive Schicht, wo keine Nitrifizierung möglich ist und wo der Stickstoff für die Pflanzen in der NH_4-Form verfügbar bleibt.

Dies kann, wie z.B. in Japan, erfolgen durch Unterpflügen des schwefelsauren Ammoniaks, unmittelbar gefolgt von der Bewässerung, oder durch Einpressen der Düngemittel in der Form von Tabletten oder grossen Körnern in die reduktive Zone des Reisfeldes.

In Indonesien wird das Ammonsulfat zuweilen dadurch in die reduktive Zone gebracht, dass man es mit den Füssen eintrampelt, was in derselben Weise funktioniert.

Teilweise infolge ihres Einflusses auf den Stickstoffgehalt des Bodens ist die Gründüngung auch ein Faktor von grosser Bedeutung für Reisböden, und aus praktisch allen reiserzeugenden Ländern werden im Zusammenhang mit dieser Praxis äusserst günstige Ergebnisse verzeichnet. Die Hauptschwierigkeit besteht jedoch häufig darin, die Gründüngungskulturen ohne das Opfern einer Nahrungsmittelkultur in ein Fruchtwechsel-Schema einzubauen.

Obwohl der Stickstoff bei den meisten Ländern das Hauptelement des Düngeplanes bildet, ist Phosphor häufig auch ein erforderlicher Bestandteil. In einigen Fällen wie in Indonesien und Thailand ist Phosphat sogar relativ wichtiger als Stickstoff.

Da der Reis seine Phosphorsäure (P_2O_5) innerhalb eines kurzen Zeitraums benötigt, ist eine schnell verfügbare Phosphatform wie Superphosphat oder gegebenenfalls Dikalziumphosphat vorzuziehen. Die Eignung anderer Phosphatformen hängt von Umständen wie Bodentyp, Bodenreaktion u.s.w. ab.

In Anbetracht der wirksamen Eigenschaft wasserlöslicher Phosphate für Reisböden werden mässige Düngungen ausreichen. Diese wirksame Eigenschaft hängt wahrscheinlich eng zusammen mit dem reduktiven Milieu, das die Bildung von dreiwertigen Eisen-Phosphatverbindungen verhindert und die Verfügbarkeit erhöht.

Kleine jährliche Phosphatdüngungen sind stärkeren Düngungen über einen längeren Zeitraum vorzuziehen, teilweise, weil man mit der Möglichkeit von Phosphatverlusten über das herausgehende Irrigationswasser rechnen muss.

Neben dem Beitrag zu einer höheren Produktion übt Phosphat seinen Einfluss in verschiedenen anderen Richtungen aus, z.B.

(a) Stimulierender Einfluss auf die Wurzelentwicklung, der die Pflanzen etwas widerstandsfähiger gegen die Trockenheit macht.
(b) Eine etwas frühere Blüte und Reife, wodurch ein eventueller ungünstiger Einfluss einer verspäteten Umpflanzung verringert oder neutralisiert wird.
(c) Eine bessere Bestockung, die eine Möglichkeit bietet, dass sich die Reisfelder rascher und vollständiger nach einem Befall durch Bohrer erholen.
(d) Ein höherer Nährwert des Reis infolge eines höheren Phosphatgehaltes.

Weiter sollte man die Möglichkeit berücksichtigen, dass die günstige Wirkung der Phosphatdüngung teilweise auf eine bessere Stickstoffversorgung zurückzuführen ist, weil die Phosphatdüngung das Wachstum der Algen und somit die Stickstoffbindung fördert.

Obwohl es sich herausgestellt hat, dass verschiedene leichtere Böden mehr oder weniger unter Kalimangel leiden, sind praktisch alle schwereren Böden, die bei weitem den grössten Teil der Weltreisgebiete ausmachen, noch ziemlich reich an Kali. Ausserdem wird Kali sehr oft zugeführt als ein Bestandteil des Irrigationswassers.

Dasselbe kann man von Kalk sagen, und Kalkdüngungsversuche haben deshalb selten positive Ergebnisse gezeigt. Ueberdies muss man mit dem Einfluss von Kalk auf die Zirkulation der Spurenelemente rechnen, da eine Kalkdüngung die Verfügbarkeit verschiedener Spurenelemente verringern und typische Mangelsymptome verursachen kann.

Die Ergebnisse von Versuchen mit Spurenelementen waren bisher nicht deutlich.

Aus Indonesien berichtet man über positive Ergebnisse des Kupfersulfats in Topfversuchen mit einem sehr sauren oligotrophen Borneo Torfboden, während aus Indien günstige Ergebnisse mit Mangansulfat und Zinksulfat berichtet werden. In Japan beobachtete man eine gute Manganwirkung auf sogenannte „degradierte" oder Akiochi Reisböden, ein sehr armer und ausgelaugter Bodentyp, der oft auch unter Kalimangel leidet.

Abgesehen hiervon sollte man sich die Möglichkeit einer Vergiftung der Pflanzen durch Ueberschüsse an einigen Spurenelementen vor Augen halten.

Eine Vorbehandlung des Saatgutes mit Pflanzennährstoffen und Saatbeet-Düngung rief nicht selten eine merkliche Steigerung der Stärke des Sämlings hervor, was sich jedoch nicht immer bei den Erträgen bemerkbar machte. Der letzte Eindruck ist mehr oder weniger der, dass eine Saatgutbehandlung und Saatbeetdüngung als ein die Jugendentwicklung möglicherweise fördernder Faktor angesehen werden sollten, der seinen Einfluss bis zur Ernte aufrecht erhalten kann, wenn andere Faktoren während der weiteren Entwicklung einen ausreichenden Beitrag leisten. Dies bedeutet gleichzeitig, dass solch eine Vorbehandlung oder Saatbeetdüngung nicht als ganzer oder teilweiser Ersatz für die Reisdüngung nach der Umpflanzung angesehen werden kann. Eine Saatbeetdüngung in Verbindung mit einem späteren wirksamen Düngeschema verspricht die besten Ergebnisse.

Eine Saatgut-Auslese sollte nicht nur hohe Erträge erstreben, sondern auch andere Eigenschaften. Neue Sorten sollten von guter Qualität sein, widerstandsfähiger gegen Schädlinge und Krankheiten und gegen das Umlegen, während Frühreife vorteilhaft sein kann.

Eine bessere Kontrolle von Schädlingen und Krankheiten wird auch einen Beitrag zu höheren Erträgen leisten.

Japan ragt unter den grossen Reiserzeugern besonders heraus wegen des intensiven Charakters seiner Reiskultur und wegen des Ausmasses, in dem Handelsdünger und Mist zur Erreichung optimaler Erträge verwendet werden. Die durchschnittliche N-Düngung beträgt etwa 60 kg N je ha, die durch etwas Superphosphat ergänzt wird. Das Ansprechen auf Kali ist bekannt bei sogenannten degradierten — oder „Akiochi" Reisböden, einem äusserst armen und ausgelaugten Bodentyp.

Der grösste Teil des Stickstoffs wird in Form von schwefelsaurem Ammoniak gedüngt mit Ausnahme der obengenannten degradierten Reisböden, wo die Verwendung von schwefelsaurem Ammoniak zu schädlichen H_2S-konzentrationen führen kann und SO_4-freie Dünger vorzuziehen sind.

Die Höhe der Produktion und die Nahrungsmittelversorgung *Koreas* hängen eng zusammen mit der Frage, ob es gelingt, dieses Land mit ausreichend Düngemitteln zu gemässigten

Preisen zum Nutzen des armen, kapitalschwachen, kleinen koreanischen Bauern zu versorgen.

Im Falle *Chinas* reagieren praktisch alle Böden sehr gut auf Stickstoff, etwa die Hälfte von ihnen zeigt eine zuverlässige Phosphatwirkung, und nicht mehr als etwa 15 % (zum grössten Teil lateritische, stark verwitterte und verwandte Böden) eine deutliche Kaliwirkung.

In welcher Weise die Erträge in *Formosa* durch die Düngung bestimmt werden, zeigte sich während des Krieges, als der Düngemittelmangel ein Absinken der Reiserträge von 2000 kg/ha auf 1400 kg/ha bei der ersten Ernte und von 1600 kg/ha auf 1000 kg/ha für die zweite Ernte verursachte.

Für *Indische* Reisböden ist eine mässige N-Düngung, z.B. 30 lb. N/acre, sehr vorteilhaft, die eventuell ergänzt werden muss durch etwas Phosphat bei den lateritischen und sandigen Küstenböden.

Für *Pakistan,* wo der Schwerpunkt des Reisanbaus in Ostpakistan liegt, wird die Durchführung des hochgesteckten VAN BLOMMESTEIN-Planes einen äusserst wertvollen Beitrag zu einer höheren Produktion bedeuten.

Ceylon ist noch eines der grossen Reisimportländer, wird aber durch folgende Massnahmen seine inländische Produktion erheblich steigern können:

(a) Erweiterung des Reisgebietes auf das Gebiet der trockenen Zone, wo grosse Bewässerungsprojekte im Bau befindlich sind;

(b) Ertragssteigerung der vorhandenen Reisfelder durch

  (1) Ersatz der jetzt üblichen Aussaatmethode (Streuen) durch die Umpflanzung aus Saatbeeten;

  (2) eine sachgemässe Düngung mit Stickstoff als Hauptbestandteil, ergänzt mit Phosphat und bei vielen der leichteren Böden auch mit Kali.

Bei *Indonesien,* wo auf der Insel Java mindestens 800.000 ha unter Phosphatmangel leiden, bildet Phosphat den Hauptbestandteil des Düngeplanes, obwohl an nächster Stelle auch Stickstoff in vielen Fällen einen Beitrag zu einer grösseren Erzeugung leisten kann. Die Stickstoffwirkung ist weniger einheitlich, und dies macht es schwieriger, allgemeine Richtlinien zu geben. Es ist daher eine Versuchsbasis erforderlich, um die Stickstoffdüngungen von Fall zu Fall zu bestimmen.

Thailand, das hauptsächliche Reisausfuhrland der Welt in den Nachkriegsjahren, ist ein weiteres Beispiel für einen Düngungsplan auf Phosphatbasis, unterstützt durch Stickstoff. Die Stickstoffwirkung ist jedoch viel stärker veränderlich.

Die Reisböden in *Burmah,* bei weitem das bedeutendste Reisausfuhrland in den Vorkriegsjahren, sprechen entschieden auf Stickstoff und Phosphat an, aber bisher werden kaum irgendwelche Düngemittel verwendet.

Für *Indochina* sollte der Düngungsplan Stickstoff und Phosphate einschliessen mit dem Nachdruck auf Stickstoff für viele der Böden im nördlichen Vietnam und auf Phosphat bei Süd-Vietnam. Für einen Teil der sandigeren Böden müsste diese Düngung mit Kali ergänzt werden.

In *Malaya,* das einen stärkeren Einfuhrbedarf hat, sind die Reisfelder auf der Westseite der Halbinsel ziemlich reich, aber bei dem östlichen Gebiet könnten die Erträge durch eine Düngung auf Stickstoff- und Phosphat-Basis, mit

Kali für die meisten Sandböden, erheblich gesteigert werden.

Auf den *Philippinen* sucht die Regierung die Reiserzeugung zu steigern durch bessere Sorten und Belieferung mit einem guten Saatgut, durch Werbung für die Verwendung von Düngemitteln, durch Verbesserung der Bewässerung, durch eine bessere Bekämpfung von Schädlingen und Krankheiten und letztlich über die Erweiterung des Reisgebietes auf den südlichen Inseln.

Brasilien, der grösste Reiserzeuger der westlichen Hemisphäre, baut hauptsächlich Trockenreis an. Von den drei hauptsächlichen reiserzeugenden Staaten Rio Grande do Sul, Sao Paulo und Minas Gerais, baut nur Rio Grande do Sul mit grösseren, etwas stärker mechanisierten Farmen, in der Hauptsache Reis auf Ueberschwemmungsland an.

Knochenmehl ist praktisch das alleinige Düngemittel, das gebraucht wird.

Der Reisanbau in den *U.S.A.* ist stark mechanisiert, besonders in Californien, wo die Aussaat, die Düngung und Unkrautbekämpfung mittels Unkrautvertilgungsmitteln von Flugzeugen aus durchgeführt wird.

Die Düngung in Californien besteht nur aus Stickstoff mit einer durchschnittlichen Düngung von etwa 30 lb. N je acre.

In Arkansas, Louisiana und Texas, wo die Böden weniger einheitlich als in Californien sind, wird der Stickstoff mit Phosphat und Kali ergänzt; die gesamte durchschnittliche Düngung in diesen Gebieten beträgt 11 lb. N, 8 lb. P_2O_5 und 4 lb. K_2O je acre.

In *Aegypten,* wo der Schwerpunkt des Reisanbaus in den nördlichen Deltaprovinzen Unteraegyptens liegt, sollten Stickstoffdüngungen basieren auf Mengen von 175 bis 350 kg/ha schwefelsauren Ammoniaks, je nach dem natürlichen Stickstoffgehalt des Bodens. Diese Düngungen werden vorzugsweise durch eine Phosphatdüngung ergänzt.

In *Europa* ist Italien der Hauptreiserzeuger und der einzige Reisexporteur. Spanien ist auch ein ziemlich bedeutendes Reiserzeugungsland, im allgemeinen aber ohne einen Exportüberschuss. Die Produktionshöhe ist hier viel grösser als in tropischen Gebieten infolge günstiger natürlicher Wachstumsbedingungen, vor allem aber infolge ausgezeichneter Anbaumethoden, die eine wirksame Fruchtfolge und eine wohl abgewogene Verwendung von Düngemitteln einschliessen. Auch in Südfrankreich hat der Reisanbau in den Nachkriegsjahren einen beträchtlichen Zuwachs erfahren.

Der Reisanbau in *Australien* ist stark mechanisiert. Eine durchschnittliche Düngung mit etwa 200 kg schwefelsauren Ammoniaks je acre hat sich am wirtschaftlichsten erwiesen, ergänzt mit beispielsweise 100 kg Superphosphat je acre.

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