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Precise timing of N application during reproductive growth is important. The second plot received "panicle nitrogen" at the correct time.
(Taitung, 1971)

Adequate P application is necessary in low-P soils.
Left: no phosphate applied.
Right: 100kg P_2O_5 per ha.
(Chihshang, Taitung, 1971)

← Severe P deficiency is the major factor prohibiting normal growth in the red soil newly converted to paddy. Center right: without P. Others: with P.
(Chungli, 1968)

← Pronounced response to application of potash is noted in the low-K soil. Economic rate is also high.
(Tahsi, Taoyuan, 1964)

In poorly drained paddies, response to K is manifest from the start. Moreover, split application is much more effective than mere basal dressing. →
(Tungshan, Ilan, 1964)

← A field of fertilization technique demonstration on "low-yield" paddies. Left: demonstration plot. Right: check plot.
(Juiyuan, Taitung, 1971)

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N. R. Su

The production of rice in Taiwan increased steadily from 1.4 million M.T. (in term of brown rice) in 1950 to 2.5 million M.T. in 1970. The 80 percent rise in production was totally due to the increase in the yield per unit area since the rice acreage had remained at a level between 770,000 and 790,000 ha during the 20-year period.

It is obvious that continued improvement of the techniques of cultivation has been the major cause of the rapid growth of rice production in Taiwan, and increased application of nutrients in the form of chemical fertilizers was, without doubt, one of the most important contributing factors. Through universal adoption of frequent surface drainage coupled with heavy application of potash, the "suffocation disease" in the ill-drained plain areas of northeast and southern Taiwan has almost been eradicated, and the yield in these areas has thus scored sizable increases.

Farmers in Taiwan have been using all possible means to make the most of their limited land holdings which average only around 1 ha per farm. So, any cultural technique which could convince them of its benefit either through their own experience or agricultural extension is adopted readily. Today, farmers are universally applying top rates of nitrogenous fertilizers for rice. Some of them are applying more-than-necessary amounts of potash. For instance, in a recent large-scale demonstration of fertilization techniques for the second crop of rice in Pingtung, the N-P_2O_5-K_2O rates were 118-26-106 kg/ha for the average "check plots" against 100-39-62 kg/ha for the "demonstration plots". (The yield was 25% higher in the demonstration plot than in the check plot). In fact, the amount of fertilizer applied by farmers in Taiwan is little affected by the price fructuations of fertilizer.

In any case, the nutritional problems of rice at this stage is no longer simply that of malnutrition as a whole, but rather that of partial malnutrition at some particular growth stages, under some particular edaphological, climatic and cultural conditions, or even that of over-nourishment. The significant improvement in yield obtained in the above-cited demonstration strongly endorses this statement.

Summarized below are the results of studies on soil fertility of paddy lands, inorganic nutrition of rice plant and techniques of fertilizer application conducted in Taiwan during the past several years. The information may be used as reference material in extension and in the further development of research. The author makes no attempt to cite all the literature relative to these studies.

Soil Fertility of Paddy Lands

Characteristics of high-yield and low-yield paddy soils

Physico-chemical properties of latosolic paddy soils were investigated with particular reference to their productivity. High yielding paddies in red soil areas were found to have such characteristics as high hydraulic conductivity,[14] high available N and P, and low exchangeable Al contents [15]. Hydraulic conductivity was also measured for the suffocating disease affected soils in Pingtung area, which are of a slate-alluvial origin. The measured values for the subsoil were always much smaller in the diseased soil than in the normal soil. For growth of rice, as tested in pot experiments with two silt loams, the optimum rate of water percolation was 3-5 cm per day for the Taipei soil with a 38-67% yield increase in comparison with non-percolation, and 1 cm per day for the Changhua soil with a 3-33% yield increase.[100]

In recent studies of latosol and sandstone/shale alluvial soils, it was observed that the soil solutions of low-yielding paddies always contained high bicarbonate ions. Sometimes low contents of available nutrients such as P and K (combined with high Ca, Mg) were also associated with low productivity.[15]

Further, the low yield of rice in the second crop in the calcareous soils of Pingtung was found to be largely attributable to severe potassium deficiency caused by high carbonic acid coupled with high Ca and low K concentrations in the soil solution.[65]

Besides, low yielding soils of the poorly drained type were found to have a high population of nitrate-reducing bacteria, Pseudomonas, but the contents of toxic compounds like phenolic acids were not consistently related to yield levels.[104][105] The filtrate from the liquid culture of the isolate was observed to have an inhibitory effect on the growth of rice plant.[104]

It seems that, under the prevailing fertility management conditions in Taiwan, the drainage or aeration problem is the primary soil factor governing the rice growth in the low-yield areas, while pronounced nutrient deficiencies may also become a limiting factor depending on the inherent fertility of the soil. The microbiological disturbance in some soils is only the consequence of the anaerobic soil environment created under poor drainage conditions.

Lime effect in acid soils

Strongly acid soils with pH values below 5.6 occupy about one third of the cultivated land area of Taiwan[83], as indicated by the detailed soil fertility survey conducted in 1959-1967.

Early trials in the field[2][5][6][7][73][93] indicated that the application of lime on acid soils was highly effective in increasing rice yield. Based on the results of the observation plots[2][6], laid out extensively in 1951/52 in more than 200 fields of acid soils in northern Taiwan, with pH values ranging from 4.0 to 6.0, rice responded to liming in over 95% of the cases and the yield increase due to application of 3 M.T. per ha of limestone powder as basal dressing exceeded 10% in 50% of the trials. Because the effect of lime was greater for the first crop than the second crop of the year[2][73], it should be applied only to the first crop, and not to the second crop, at the rate of 2-3 M.T./ha of CaO when soil pH is below 5.5. Application should be suspended for one or more crops when the soil pH has risen above 6.5.

The available phosphorus content of soil and plant uptake of soil and applied phosphorus increased very remarkably with liming. Better yield effect was obtained when phosphate and lime were applied in combination [2][5][93].

On fertile soils or soils receiving sufficient chemical fertilizers, rice did not respond to lime as much as on infertile soils or soils receiving only some compost manure.[2][5]

Several field experiments repeated in recent years on latosolic paddies in the Taoyuan area and alluvial soils in the Taipei area using various forms of lime have shown small or no lime effects, the yield increases being less than 10% which did not even pay for the cost of lime.[12][37][52] However, in a pot experiment using a latosol from Chungli[101], an optimum amount of calcium carbonate brought about a remarkable immediate effect and even higher residual effect on rice yield. A parallel examination of soil water revealed a significant lowering of Fe and Mn concentrations in the limed pots.

It is believed that the decreased field response to liming in the average acid paddies in recent years is at least partly attributable to the increase in the rates of applied nitrogen as well as to the gradual build-up of soil fertility as a result of increased use of chemical fertilizers.

It is interesting to note that the optimum level of exchangeable Ca for rice was found to be 8-20% of the exchange capacity. Beyond this level the growth declined with increasing Ca saturation.[47]

Behavior of nutrients in flooded soils

Gaseous loss of nitrogen from soil under flooding conditions was studied in the laboratory.[109][110][111] For soils with pH values of 4.8-6.8, nitrogen loss in the form of ammonia was negligible as compared with other forms. The loss was greater in the soil with lower C/N ratio, and with higher organic carbon level when C/N ratio was kept constant. Low temperature and strong acidity of soil were not conducive to nitrogen loss, while liming increased the loss remarkably. The loss during two and a half months amounted to 10-30% of the total N including added ammonium sulfate, while it was less than 10% with no N added.

Ammonification of urea in paddy soils was found to be faster in neutral soils than in acid or alkaline soils, and faster in soils with high organic matter contents than in soils with low organic matter. Optimum temperature for ammonification was about 35°C.[54][98] Nitrification of urea was the fastest in weakly acidic to weakly alkaline soils. At moisture equivalent, the volatilization loss of ammonia fron applied urea was significant when the original soil pH was higher than 5.8.[98]

Potassium fixation was found to be appreciable in the alkaline slate alluvial soils, weak in the sandstone and shale alluvial soils and very weak in the latosols.[43] Leaching loss of potassium in Taiwan paddy soils is expected to be generally high.

Under paddy conditions, the phosphate fixed by soils after application is gradually transformed into iron phosphate, and crystalline forms of soil phosphate are transformed into colloidal forms.[8][9] It was found that iron phosohate was the major source of available Pabsorbed by rice in both acid and calcareous soils.[4] Solubility of soil phosphorus was markedly enhanced after submergence as the Eh falls.[16][17][20] This was more pronounced in the soil containing chiefly Fe-P.

Leaching loss of nutrients was studied for two silt loams and two silty clay loams in a lysimeter experiment.[53] The average leaching losses per ha in one crop season were: Ca, 213 kg.; Mg, 76 kg.; K, 22 kg.; N, 13 kg.; and P, 0.7 kg. Leaching loss of N and K was greater in the acid silt loam of Taipei and neutral silty clay loam of Yuanlin. Loss of Ca, Mg and P was distinct in the neutral soils of Pingtung and Yuanlin.

Leaching loss of nitrogen was larger in the first crop than in the second crop and in acid soils than in neutral soils. The magnitude of in leaching loss was practically the same for ammonium sulfate and urea, being 6.2% for the former and 6.0% for the latter on the average.[53]

Changes in the reduction-oxidation potential of submerged soils were studied in relation to the occurrence of "suffocation disease" of rice, availability of native and applied phosphorus as well as the solubility of Fe and other elements[16]. Organic matter in fresh form accelerated reduction of the paddy soil and enhanced the availability of P[16], but aggravated the physiological disorder of rice plant.[16][104] Periodical surface drainage of paddy field appeared to be most effective in controlling such disorder.[59] Oxidation of the soil with chemicals such as manganese dioxide[59] also was effective to a considerable extent.

Changes in soil fertility as influenced by cropping

In the latosols newly submerged for rice culture, pH was found to have risen from 4.4 to 5.6, while available P, K and Si also increased markedly in 4-5 years and the values gradually approached those of the average old paddy soils. No changes in total N, organic matter and cation exchange capacity were noticed.[60]

Cultivation of green manure crops, vegetables or sweet potatoes as winter crops is conducive to raising the fertility of paddy soils.[1] The multiple cropping system with proper fertilizer application also improves the soil fertility.[99]

In the investigation of major nutrients in the soil as influenced by continuous rice cropping, it was found that the rate of depletion of available NPK was faster in the latosols than in the alluvial soils.

Fertility managemeut of newly submerged soils

In the newly submerged latosolic paddies in Taoyuan, rice suffered from serious phosphorus deficiency and other physiological disorders. The effect of heavy use of P_2O_5 up to 150 kg per ha was spectacular and application of compost, lime and silicate slag was also effective.[67][72] Experiments repeated four years after submersion showed that the effect of phosphate was still very high, the yield increase due to the optimal rate of P_2O_5 (150 kg/ha) being 53% on an average.[37] When, in addition to heavy phosphate fertilization, compost and silicate slag (or lime) were applied, the grain yield was increased by an average of 80%, to 5.2 tons per ha., which is the normal yielding level for old latosolic paddies.[37] In a greenhouse study it was observed that though both compost and lime were independently effective in improving the rice yield in the latosol, their simultaneous applications lowered the effect remarkably.[101]

Calibration of soil fertility tests and survey of soil fertility

A study of correlations between fertilizer response of rice and levels of soil available P and K was conducted during 1960-64.[77] [80] [83] [94] [95] [96] [97] It was found that, for all the three major groups of rice soils, i.e., latosols, sandstone/shale alluvial soils and slate alluvial soils, the critical concentrations of available P and K were 20 ppm (Bray No. 1) and 45 ppm (Mehlich) per ha., respectively. For latosols, the critical concentration of exchangeable K was 70 ppm.[77] Four levels each of P and K fertilizers were recommended for various levels of available P and K in soil.[82][83] According to a detailed soil fertility survey for 786,350 ha of cultivated land (sampling unit: 10 ha) completed in 1967[83], about 40% each of the paddy soils in Taiwan are definitely deficient in P and K (i.e., very low or low). As a whole, soils in Ilan, Changhua, Pingtung and Hualien are particularly deficient in K, while the lowest P is found in Taoyuan. In fact, the fertility status of soils are heterogeneous even in the same area. In 1966-68, the critical concentrations of soil available P and K were re-evaluated for soils in northern Taiwan (north of Taichung) by conducting 109 observation plots[11]. Markedly higher values than those found in the 1960-64 experiments were obtained. Therefore, Further clarification of this problem is needed.

Nutrition and Physiology of Rice Plant

Nutrient absorption of rice

It was found that when temperature rose, more nutrients were absorbed by rice, although this did not always result in increased grain yield.[23] [28] [29] Varietal differences in nutrient absorption were large and variations among different soils were even greater.[23] [25] [29] [33] [56] Dwarf indica varieties absorbed more per ha and per ton of grain, and produced more grains as compared with the japonica varieties.[23] [25] [33] Nutrient absorption is greater in the first crop than in the second crop, owing to the higher yield in the former[30]. Concentration of N in straw was lower and that of K was higher in the first crop than in the second crop. On an average, a crop of rice removed 82-39-125 kg/ha of N-P_2O_5-K_2O in the 1969 trials[25]. The amounts required for producing 1 M.T. of grain were 18-8-27 kg/ha. Nutrient removal increased in parallel with the yield.

Uptake and translocation of P was examined under variable conditions of nutrient supply.[68] The result seems to show that the newly absorbed phosphorus will replace the older one in plant tissue, while the latter will be translocated with more of it going to the growing and/or storage tissues.

Nutritional characters of rice plant in the ill-drained paddies were studied. Plants injured by physiological disorder under such conditions were found low in K and P and high in N, Fe and Mn.[22] [31] [32] In another experiment, rice plants grown under poor drainage conditions were low in Si, Fe, Mg and P contents, high in Mn, but with similar N and K contents, as compared with those grown under good drainage conditions.[106]

In the lysimeter experiment cited above[53], the uptake of nitrogen was always larger in the ammonium sulfate plots (38.1%) than in the urea plots (32.6%).

Cause of low yield in the second crop

The cause of low yield in the seeond crop of rice, as compared with the first crop, was investigated for the Pingtung area.[64] [65] The main problem seems to lie partly in the decreased leaf area index, for which the high respiration loss and potassium deficiency, aggravated by the reducing soil conditions (resulting from high temperature), high carbonic acid concentration, and high soil Ca supply, are responsible; and partly in the lower net assimilation rate in second crop season during the ripening stage, for which the lower solar radiation and morphologically inferior light-receiving posture of the plant are responsible. The variety IR-8, in comparison with Chianan 8, possesses both higher leaf area index and better light receiving system, and thus produces higher yield.

Nutrient concentration in plant as criterion of nutritional status

The critical concentration of K in the above-ground part of rice plant was found to be 1.7-1.8% in the extensive field trials conducted in the Taoyuan area.[77] Similar research was carried out for N with a view to acquiring an index for crop log of rice. The results were inconsistent in different years and crop seasons.[74] Another experiment,[66] however, showed that there existed a good correlation between the response to panicle fertilizer and the N content of plant at the panicle initiation stage; 1.8-1.9% N was the critical level observed in southern Taiwan, while the value was 2.0-2.2% in the north. The N content was also correlated with the iodine reaction of sheath as well as the leaf color intensity of the center leaves.

Concentrations of NPK in various leaves and leaf sheaths at individual growth stages were examined for different locations.[48] [50] Phosphorus concentration was usually higher in the first leaf sheath than in the first leaf blade at the early stages and in most of the leaf sheaths than in the corresponding leaf blades 40-80 days after transplanting. This suggests that the reverse trend in certain fields would indicate phosphorus deficiency.[50]

Nutritional characters of high yield and low yield rice

In regard to nutritional characters of rice plant at different yield levels, a preliminary study revealed that low phosphorus concentration in leaves was limiting the yield in some fields[46], and it was found in a later study[49] that the high-yield plants contained higher N and P at the early stage of growth and higher P at the middle stage as compared with the low-yield plants. In the case of the firse crop, N level in plant at the middle stage was lower in the high-yield plots than in the low-yield plots.[49]

Zinc deficiency

Recently the physiological disorder of rice in the calcareous soils of Hualien was found to be caused by zinc deficiency.[26] Application of zinc sulfate, zinc oxide and fritted zinc are all effective in suppressing the occurrence of this disorder.

Study of Fertilizer Use for Rice

Nutrient requirements

The requirements of rice for N, P and K have been found to vary considerably with locality (climate and type of soil), variety, soil fertility status, drainage conditions, crop season and plant spacing.[25] [27] [33] [34] [39] [58] [77] [83] [84] [85] [86] [87] [88] [92] [95] [96] [97] Recently some heavily tillering varieties of the dwarf type (indica) were found to respond to raised N dosage up to 120-150 kg per ha (in the form of ammonium sulfate), or even higher, whereas the average japonica varieties require 80-140 kg per ha, and the tall indica varieties usually can not tolerate N application in excess of 80-90 kg per ha.[86] [87] Effect of increasing the N rate from 80 to 120 kg was negatively correlated with the height of variety.[33] Nitrogen requirement is often lower for high plant densities than for low densities.[27] [58]

Effect of added K was universally more pronounced in the ill-drained parts of Pingtung, Ilan and Hualien[3] [40] [81] [84] [85] [89] than in the red soil area of Taoyuan which was once considered the most K-responsive area.[92] Up to 80-120 kg of K_2O per were found to be more profitable than the lower rates in many localities in these ill-drained areas. In average soils, the K_2O requirements of rice range from 30 to 60 kg per ha.[81] [83] [89] Varietal difference in K response of rice was frund to be inconsistent, although some trials revealed that japonica varieties were more responsive, as compared with the indica varieties[81], while others showed that the number of grains per panicle was positively related to the magnitude of K response.[33] [81]

Phosphate was effective especially on the latosolic paddies, ill-drained plains of Ilan and some other P-deficient soils scattered in various localities.[88] [92] Exceptionally heavy rate of P_2O_5, e.g., 150 kg per ha, was necessary to meet the requirement of rice in the newly submerged paddies of latosolic tableland in Taoyuan.[37] [67] A low-yield paddy in Miaoli (sandstone/shale alluvial soil) was changed into high-yield paddy by raising the P_2O_5 rate to 120 kg per ha.[46] For ordinary paddies, 30 to 60 kg per ha of P_2O_5 are sufficient to meet the requirement ot rice.[83][92] It was also found that the decrease in rice yield after deep plowing was attributable to the drop of available P in surface soil, and heavy application of P was effective in this case.[85]

The importance of nitrogen application at an optimum rate to the rice nursery was established for all localities.[86] Optimum N rate from the standpoint of final grain yield is 50 g/3.3 M^2 or lower in the first crop and 25 g/3.3 M^2 or lower in the second crop. In general. the rate should be higher in the north than in the south. Effects of P and K application to nursery on the final yield were both significant in 70 percent of the experimeats.

Source of nutrient

Field experiments and numerous demonstrations have shown that ammonium sulfate and urea are equally satisfactory as nitrogen source for rice if optimum amounts are used. The optimum rate of N is somewhat higher for urea than for ammonium sulfate, but the net profit is in favor of urea because of the cost difference.[45][90] Nitrate form of nitrogen is always much inferior to other sources under the paddy conditions.[69][92]

In the latosolic paddies, rock phosphate is inferior to regular superphosphate, when compared at the ordinary range of doses, but when the P_2O_5 rate is raised to 320 kg per ha., rock phosphate gives a satisfactory result, and more over, its residual effect is very high.[13]

Sources of potash have been compared only on the salt-affected soils in the coastal area of Taiwan. On such soils, there is an indication that the sulfate form is better than the chloride form.[81]

Method of fertilizer application

Field trials on the techniques of fertilizer application, especially for N and K, were extensively conducted during the past several years. For both the light and heavy soils, N application was found not only necessary at the early stages but also particularly indispensable at both the second weeding stage and the panicle initiation stage.[10] [71] [84] [85] [91] [106] [108] Recent trials for japonica showed that relatively heavy dressing of nitrogen is needed at the second weeding stage in the south and in the second crop in the north, but lighter application at the same stage, with the deficit to be supplemented at the full heading stage, would be better in the first crop of northern Taiwan.[24][36][38][79] Method for dwarf indica is under study.

Precise timing of nitrogen application at the reproductive stage of growth and method of diagnosing the nitrogen need at this stage were studied in the last few years.[87][88] "Panicle fertilizer" gave markedly variable effects, depending on the time of its application. For the first crop it was found that for all parts of Taiwan panicle fertilizer would give the highest effect if it is applied at the stage when the length of young panicle is 2 mm, or within 5 days before this stage. This period is usually 20 to 25 days before heading. The need for the application can be determined by a starch test of the sheath of the third unfurled leaf.

For the direct-sowing culture of rice under paddy conditions, nitrogen should be split-applied at three to four stages, starting either from the seeding time or from the 4-5 leaf stage depending on the localities. But application at the panicle initiation stage is a necessity, and the amount of basal nitrogen can be small.[87][88] The total amount of nitrogen required seems to be somewhat larger than in the transplanting culture.

Rate of N and methods of split application of N were investigated for the excessively percolated soils.[87][88] In northern Taiwan, 150 kg per ha of N are required, while in central, southern and eastern Taiwan, the optimal rates exceed 180 kg per ha. Nitrogen should be split in 4 to 7 doses, depending on localities, and be applied from the time of recovery of seedlings up to the time of panicle initiation or even later. Application in band near the plant row during the early stage of growth gives good results.

Potash gives a significantly larger effect when applied in divided doses than when it is applied as basal dressing.[76] For best results it should be split into two to three doses and a large proportion be allocated to the time of second weeding, which is the most vigorously tillering stage.[41] The effect of split application of potash is particularly large in the poorly drained soil of Ilan.[44]

Split application of superphosphate into 2 to 3 dosages has also been found to give higher yield than the mere basal application in the experiments conducted in the Ilan area recently.[57]

In the newly adopted system of mechanized transplanting, the row space is wider, the seedlings are younger and yield is higher than in manual transplanting. Nevertheless, the same method of split application of N was found to be suitable for both systems. The total nitrogen requirement per crop seems higher by about 20 kg per ha in the mechanical transplantation system.[87][88]

Nutrients other than NPK

Magnesium was tested on nine soils (two crops each) in northern, central and southern Taiwan, but there was only one case of significant response to this nutrient (latosol of Lungtan). In the latosol of Chungli, magnesium caused a decrease in yield, although the soil was not high in magnesium content.[42][75][78]

The effects of manganese, iron, zinc, copper and boron were not significant in the seven trials conducted in northern, central and southern Taiwan.[84] But Zn deficiency has recently been found to occur in the Hualien area as reported previously.[26]

Effects of soil amendments, such as silicic slag, fly ash, silica iron, zeolite, temporon, etc., have been examined in various localities. Significant yield responses to silicic slag, silica iron and temporon were obtained.[25][35][37][63][70][84][103]

Siliceous slag is effective in acid soils with low available silica contents. In general, rice will respond to the application of silica when available SiO_2 (extracted by NaAc at pH 4.0) in soil is below 45 ppm.[103] Critical concentration of SiO_2 in straw is about 9 percent.[63][103] In some latosols, especially the newly submerged paddies[37], the yield increase may exceed 10 percent.

Varietal differences in response to silica are manifest. The two rice varieties Hsinchu 56 and Taichung 65 gave the highest response, followed by Taichung Sen 2. Tainan 5 and Ai-chiao-chien showed very little response.[25]

Lately wollastonite has been reported to be capable of increasing rice yield in some soils but the effect was small.[102]

Slow-release nitrogen fertilizer and nitrification inhibitor

Ureaform (UF) and crotonylidene diurea (CDU) were tested by various research institutions for rice in average paddy fields and sandy soils, but with little success.[55] [61] [62] [88] Generally, split application of ammonium sulfate in a conventional way gave better results as compared with the slow-release nitrogen compounds. Only in a few cases, properly mixed application of the slow-release fertilizer and ammonium sulfate gave results comparable to those of the standard application of ammonium sulfate.[55] In any case, ureaform seems somewhat better than CDU under the paddy conditions.

In the meantime, basic studies have been made on the mineralization and vaporization of nitrogen from various urea-aldehyde condensation products as slow-release fertilizers including the afore-mentioned two products and isobutylidene diurea (IB) as well as other forms.[18] [19] Mineralization of all forms tested became faster with the lowering of soil pH. Under submerged conditions, the decomposition of CDU is too slow to meet the requirement of rice, especially when pH is high. Condensation products of urea with a mixture of formaldehyde and isobutyraldehyde or with that of formaldehyde and crotonaldehyde seem better suited to paddy soils than UF, IB and CDU.

The nitrification inhibitor AM (2-amino-4-chloro-6-methyl pyrimidine), seems to be effective in the first crop in increasing the effect of nitrogen fertilizer.[88]

Nitrogen aud quality of rice

It was found that the crude protein content of rice could be increased significantly by raising the nitrogen dosage from 80 kg to 120 and 160 kg per ha, especially when a part of N is used as panicle fertilizer. In this case, however, the digestibility of rice is lowered, so the cooking time must be prolonged.[51]

APPPENDIX

Fertilizer Rates and Application Methods for Rice in Taiwan

(Recommended on December 20, 1971 by the Meeting of Fertilizer Technical Committee, Rice Improvement Conference)

I. Fertilizer rates for rice seedling nursery:

Nutrient	Rate (g/Ping*)	
	1st crop	2nd crop
N	≤ 50	≤ 25
P_2O_5	60	60
K_2O	60	60

* 1 Ping=3.3 M^2

II. Rates of nitrogen for paddy fields:

Variety	Region*	N rate (kg/ha)**	
		1st crop	2nd crop
Dwarf indica	CSE	130–160	110–140
	N	120–150	100–130
Common japonica & early varieties	CSE	120–140	100–120
	N	110–130	80–100
Tall indica	—	80– 90	70– 90
Common japonica in excessively percolated soil	CSE	≥ 180	≥ 180
	N	150	150

* N: northern region
S: southern region
C: central region
E: eastern region

** Rate of N should be increased by 10% or more in the direct-sowing culture. It should be increased by 0–20 kg/ha in the mechanical transplantation system.

III. Rates of phosphate for paddy fields:

Soil P level	P_2O_5 rate (kg/ha)	
	1st crop	2nd crop
Low	60-80	40-60
Medium	40-60	20-40
High	20-30	0-30
New Latosol paddies		
1st-3rd yr.	200	200
4th-6th yr.	150	150

IV. Rates of potash for paddy fields:

Soil K level	K_2O rate (kg/ha)*	
	1st orop	2nd crop
Low	50-70	70-90
Medium	30-50	40-60
High	0-30	0-40

* In the ill-drained paddies, add 30 kg K_2O per ha.

V. Method of split application of nitrogen fertilizer for joponica rice on average soils:

Region	Percentage of N for individual stage: No. of days after transplanting*						Panicle initiation stage**	Full heading stage
	-1 -1	7 5	15 10	22 15	30 20	37 25		
Standard for majority	25	—	20[a]	—	30	—	25	—
Ilan Prefecture	20	—	30	—	30	—	20	—
Hsinchu & Taoyuan Pref. (1st crop)	25	—	20	—	15	—	25	15
Excessively percolated soil	—	20	—	25	—	30	25	(10 kg N)

* First row: No. of days for the 1st crop.
Second row: No. of days for the 2nd crop.

** Applied when the young panicle of main stem attains the length of about 2 mm.

a: May be applied together with the basal fertilizer in heavier soils.

Note: Amounts of nitrogen for panicle initiation and full-heading stages are to be modified according to the performance of plant (leaf color, leaf shape, disease, etc.) and climatic conditions.

VI. Method of split application of nitrogen fertilizer for direct-sowing under paddy conditions:

Region	Percentage of N for individual stages					
	Before seeding	No. of days after 4-5 leaf stage*				Panicle initiation stage
		0 0	5 3	10 7	20 14	
Western Taiwan (except 1st crop in Hsinchu)	—	25	—	25	25	25
Taitung	—	25	—	50	—	25
Hsinchu & Hualien, 1st crop	25	—	50	—	—	25
Hualien, 2nd crop	25	—	25	—	25	25

* First row: No. of days for the 1st crop.
Second row: No. of days for the 2nd crop.

VII. Method of nitrogen application for mechanically transplanted rice: Same as used for hand-transplanted rice.

VIII. Percentage distribution of P K fertilizers at individual stages for average paddies:

Nutrient		No. of days after transplanting		
	1st crop 2nd crop	-1 -1	15 10	30 20
P		50-100	50-0	—
K		0-20	40	40-60

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