PRESENT METHODS OF FERTILIZATION FOR THE RED SOILS IN SOUTH CHINA

Ching-kwei LI*

Generally speaking, South China covers the whole area south of Yangtze River. It has an acreage of about 1.2×10^6 km^2 with a landscape roughly composed of 7 parts of mountainous area, 2 parts of hill land and 1 part of plain. South China shows distinct tropical and subtropical climatic conditions. It has a long history of cultivation. Excessive deforestation, inefficient land utilization and poor soil management have deteriorated large areas into bare mountains and hills, eroded red crusts, idle lands and infertile soils. Before 1950, despite favorable climatic conditions, food production in South China, as a whole, was rather low. High productive fields are usually confined to nearby villages and city suburbs where supplies of farmyard manure are available.

Following are the three topics dealing with present methods of soil fertilization: 1. Soil organic matter, organic manure and nitrogen fertilizer; 2. Fixation and transformation of phosphatic fertilizers; and 3. Soil potassium and potassium fertilizer.

Soil organic matter, organic manure and nitrogen fertilizer

In South China the population in the years 1950–1979 increased by a factor of about 1.5. Large area of natural vegetation has been cleared through exploitation both for cropping and wood cutting. Cultivation encourages the decomposition of native soil organic matter. Further, in China the farmers almost remove the whole top portion of the crops both for fuel and for other domestic uses. Thus, the organic matter content in the surface soil decreases. Experiments on the paddy soils of the subtropical area of Zhejiang Province showed that the rate of decomposition of soil organic matter was around 4%. Generally speaking, the forest areas in South China are largely reduced, and the soil organic matter is declining. Exceptions are found in some high yield districts where soil fertility is maintained by good soil management. Table 1 illustrates the status of the organic matter in the surface soil under different plant cover in some typical areas.

A comparison of the decomposition rate of organic matter buried under the surface layer of the lateritic soil in Hainan and of the Yellowish Brown soil in Nanjing suburbs is given in Table 2 (Lin *et al.,* 1982). The rate of decomposition of buried organic matter in tropical soil is almost twice that in the Yellow Brown soil areas which occur on the northern border of subtropical China. As shown in Table 2 the fresh ferns are rather resistant to decomposition possibly due to their high content of lignin.

For the restoration of soil organic matter, manure has been used as traditional soil management for centuries. Milk vetch and vetch are commonly planted in good rice field, while rape and radish for the reclamation of infertile Red soil. However, the decomposition of manure in paddy soil of Red soil region is also very quick. About 65% of milk vetch containing 12% of dry matter, which was applied at a rate of 20 ton/ha, was decomposed in the growing season of one rice crop in subtropical areas (Mo *et al.,* 1982). Starting from the sixties, the culture of *Azolla* in paddy field as green manure especially for late rice, received great attention in subtropical China. Researches are made on the culture and utilization of *Azolla* and also on its biological characteristics (Li, 1982).

Evidently, the rapid rise of food production in China is largely due to the increasing consumption of chemical fertilizer during the last 30 years. In 1949 – 1950, only a few ten thousand ton

* **Deputy Director, Institute of Soil Science, P.O. Box 821, Nanjing, China. (President of the Soil Science Society of China).**

of ammonium sulfate were used in this region. The consumption of nitrogen fertilizer in terms of N had reached 7.57 x 10^6 ton in 1979. The main form in 1965 – 1975 was NH_4HCO_3, which is a low grade fertilizer that had been discarded about half a century ago. As described in a previous report (Li and Chen, 1980) the production of NH_4HCO_3 has had a fresh start in China since 1958.

Table 1 Change of organic matter in the surface soil under different vegetation in South China*

Types	Range of organic matter content in areas (%)	Notes
Tropical rain forest, South Yunnan and Hainan Island	4 – 8	Mean annual falling plant material 10.5 ton/ha. Plant residues remaining on soil surface after 1 yr. 3.2 ton/ha (4-year average 1962 – 1965).
Shrubs and tall grasses	3 – 5	Plants growing after successive wood cutting.
Scattered short grass, partly eroded	1 – 2	Mainly *Imperata cylindrica, Perotis indica, Cynodon dactylon.*
Rubber tree *(Hevea),* Hainan Island and Yunnan	2.4 – 5.0	Mean annual falling plant materials 5.3 – 7.5 ton/ha (ten-year average); plant residues on soil surface about 1/3 of the falling material.
High yielding paddy soil	2.4 – 3.5	Grain yield 6 – 7.5 ton/ha. Rate of decomposition total surface soil organic matter about 4% annually.
Low yielding paddy soil	1.2 – 2.0	Grain yield about 3 ton/ha.

* Compiled from the data of Prof. Huang Zong-dao, Institute of Tropical Crops, Hainan Island, and Prof. Lin Xin-xiong, Institute of Soil Science, Nanjing.

Table 2 Comparison of the decomposition rate of plant materials in the upland soils of South China*

Soil types	Time of burying (days)	Green leaflets of rubber tree	Green leaflets of ferns
Lateritic Red soil	180	51.9	39.5
(Hainan Island)	360	78.0	57.2
Yellow Brown soil	180	25.5	26.8
(Nanjing)	360	36.9	30.7

* Reference (Lin *et al.,* 1980)

So far, about 50% of the domestic production of nitrogen fertilizer is represented by NH_4HCO_3. For many reasons, this low grade fertilizer seems still to be able to hold its position for a few decades.

In South China, most of the chemical fertilizers are applied on paddy field, with a rather small proportion to economic plants. Foregoing experiments showed that the uptake of nitrogen by crops from the fertilizer in South China is rather low. In high yielding paddy field, with a rate of application of about 75 kg N/ha, the recovery of N by rice plant averages 40 – 50% from urea and $(NH_4)_2SO_4$, and 25 – 30% from NH_4HCO_3. In recent years, researches have been made on the utilization of nitrogen fertilizers in supergranular forms. The efficiency of super-granular urea and NH_4HCO_3 in deep placement is cited in Table 3 (Cao *et al.,* 1980). However,

Table 3 Recoveries of fertilizer nitrogen by rice plant*

N Source	Treatment	Recovery
Urea	Powder, surface broadcast	29.9 ± 9.0 (n=3)
	Powder, incorporation	37.0 ± 8.0 (n=3)
	Supergranule, deep placement 6 cm.	61.4 ± 9.8 (n=3)
Ammonium bicarbonate	Powder, surface broadcast	22.3 ± 6.0 (n=16)
	Powder, incorporation	37.4 ± 11.1 (n=5)
	Supergranule, deep placement 6 cm.	64.8 ± 16.6 (n=5)

* Reference (Li and Chen, 1980)

much remains to be improved in the appropriate equipment for deep dressing.

Investigations on the slow-release nitrogen fertilizers have also been carried out in recent years (Cao *et al.*, 1980). Different coating materials for supergranular fertilizer have been suggested. However, no definite conclusion can be drawn on the conditions for the effective usage of this fertilizer in the paddy soils of tropical and subtropical China.

Fixation and transformation of phosphatic fertilizers

Historically, the farmers of the Red soil region used to add a cropping of leguminous green manure in rice paddy rotation. They dressed bone meal on the legume crops to stimulate their assimilation of atmospheric nitrogen and to accelerate the uptake of soil phosphorus. Old wisdom still holds truth. Since the development of phosphatic fertilizer industries in China, which began at the end of the 1950s, the story of phosphate fertilization has changed. In 1979, the domestic production of phosphatic fertilizers was 1.81×10^6 ton (P_2O_5), while their consumption was 2.15×10^6 ton among which 29% was in the form of alkaline fused rock phosphate containing 18% citrate soluble P_2O_5. Most of Ca-Mg-phosphate that amounted to 0.35×10^6 ton was used on the acid soils of South China in 1979. At present, superphosphate is still the main product of phosphatic fertilizer in China.

Experiments revealed that the uptake of P_2O_5 by crops from superphosphate only ranged 10 – 20%, and the fixed phosphate from this fertilizer by the upland Red soils contributed very little to the succeeding crops. Meanwhile, the availability of P_2O_5 of Ca-Mg-phosphate was facilitated under an acid soil condition. Table 4 gives the yield of different crops by application of superphosphate and Ca-Mg-phosphate. The efficiency of these two fertilizers is very close in the acid soils of South China (Jiang, 1964).

Table 4 Comparison of the yield response of different crops to superphosphate and to Ca-Mg-phosphate *

	No P	Superphosphate kg/ha	Ca-Mg-phosphate kg/ha
Wheat, grain (8) **	1,718	1,920	1,875
Rice, grain (25)	2,408	3,038	3,030
Soybean, grain (11)	1,133	1,553	1,395
Milk vetch green weight (17)	13,013	21,038	19,815

* Reference (Jiang, 1964)

** Number in parentheses denotes number of field trials.

The distribution of phosphate rock deposits is concentrated in the Red soil region of Southwestern China. For the economical utilization of these natural resources, powdered rock phosphate has been recommended as basic dressing for legume crops, tea and rubber trees, and other phosphate rock-phile plants such as radish, rape and buckwheat.

Pot culture experiment and incubation test showed that about 50% of carbonate fluo-apatite was converted into an available form in 6 months in strongly acid soil of pH 5.0 – 5.5, under moist conditions. But the decomposition rate of powdered rock phosphate in waterlogged paddy soil of slightly acid reaction was very low.

A typical field trial on the slow-release property of powdered rock phosphate in rubber tree was carried out in a lateritic Red soil in Guangdong Province in 1954 – 1958. Results are given in Table 5. Table 5 shows that powdered rock phosphate was less effective than superphosphate in the first growing stage of the young rubber tree. However, its effect surpassed the latter one in the later stage in 1957 – 58.

In this paragraph we have introduced the use of Ca-Mg-phosphate and powdered rock phosphate in more detail. However, these fertilizers are confined to the Red soil region of South China and the adoption of these fertilizers is evidently due to the limitation of natural resources and economic conditions of present China. We realize the current tendency of the fertilizer industry, and more concentrated and complex phosphate fertilizers such as double super, di-ammonium phosphate, and nitro-phosphate have been produced on a small scale since the middle of the 1970s.

Table 5 The slow-release effect of powdered rock phosphate on young rubber tree on a lateritic soil*

Treatment	Rate of fertilization gm/plant/year	1954 – 1956		1957 – 1958	
		Circumference (cm) of tree at 30 cm height	Relative increment	Circumference (cm) of tree at 30 cm height	Relative increment
No P	0	9.45		15.7	
Superphosphate	125	11.48	100	16.4	100
Rock phosphate level 1	250	10.33	48	16.7	143
Rock phosphate level 2	375	10.38	51	17.2	171

* Cited from the unpublished data of Institute of Tropical crops, Hainan Island.

The problem of soil potassium and potassium fertilizer

From the viewpoint of soil geochemistry, there is no evidence that the parent materials in tropical China are lower in potassium than those in humid temperate and arid regions. However, owing to centuries of inefficient land utilization and deforestation, large areas of the hill lands in central and southern China have been eroded, exposing the highly weathered red crusts. In recent decades, land levelling, terracing, irrigation and other devices for soil reclamation have been applied for utilizing these fields. At present, most of the rolling hills and their gentle slopes are being used for rice and economic trees and to a lesser extent, for upland crops. After years of heavy dressing of nitrogen and phosphatic fertilizers, these idle soils have afforded reasonable food supply to meet the needs of the increasing population of South China and consequently deficiency of potassium to maintain adequate crop production becomes prominent.

Table 6 illustrates the weathering processes of the formation of three typical red crusts, on which large areas have been converted into agricultural fields at present. The first two types prevail in tropical China. The basic materials contained in their parent rocks have been mostly leached out in the soil forming process. Kaolinite, gibbsite and iron oxides become the main mineral constituents of soil clay. The lack of hydro-micas and the low basic absorbing capacity of the soil clay complex result in the poor K potential in the fields developed on these areas. The third type in Table 6 represents the red crust occurring on the rolling hills of subtropical China. It originated from the tertiary red sandstone and quaternary red clay. In this type a low content of feldspar and mica can be found in soil minerals and minute amounts of montmorillonite are still detectable in soil clay fraction. These areas have been extensively cultivated since 1950.

Under the covering of natural vegetation, the Red soils possess a surface soil layer containing organic matter around 3 – 4%. However, once cultivation is going on, the organic matter layer begins to decrease, and small grain crops can only afford a yield from low to below medium by dressing nitrogenous and phosphatic fertilizers and a low level of manure without the application of K-fertilizer. These areas, together with the sandy soils derived from the alluvial and marine deposits along the coastal areas of Southern China require urgently K fertilizer in present China agriculture.

Historically, China solved her problem of potassium fertilization by returning plant ashes to the agricultural field. But as the conditions change, such a practice is no more feasible at present. It is estimated that about 30% of the cultivated soils with adequate fertilization of N and P would have a better crop yield if sufficient K fertilizer could be provided (Xie *et al.*, 1981). Recently the ratio of consumption of chemical fertilizers has been about 1:0.28:0.01, in terms of $N:P_2O_5:K_2O$, and the appropriate proportion in coming decades is expected to be 1:07:0.2.

Table 6 Changes of K-bearing minerals in three typical red crusts in South China

Soil type and plant material (locality)	Minerals in soil body (< 2 mm)	Main clay mineral (< 1 μ)	Weathering characteristics
Lateritic clay soil from highly weathered basalt (Hainan Island, central Yunnan and Laichow Peninsula)	Quartzite 13%, Kaolinite 45%, Iron oxides 21%, Ilmenite 4.5%, Auguite 1.5%.	Kaolinite 64% Gibbsite 13% Iron oxides 18%	55% Plagioclase, 14% Olivine and 18% Augite in the basalt were mostly decomposed.
Lateritic sandy loam, from highly weathered granite (Guangdong and Jiangxi)	Quartzite 82%, Kaolinite 18%, Gibbsite 1.5%, Iron oxides 1.5%, Ilmenite 1%, Feldspar < 1%.	Kaolinite 80% Iron oxides 11% Gibbsite 7% Ilmenite 1%	Feldspar, and Micas in the granite mostly decomposed. The soil texture reflects a mixture of Quartzite and Kaolinite.
Red soil of clay loam texture, from red sand-stone and red clay (on the rolling hills of south central China)	Quartzite 61%, Kaolinite 17%, K-Na-Plagioclase 6%, Feldspar 4%, Hornblende 2.5%, Ilmenite 2.5%, Iron oxides 5%. Gibbsite 2.5% with small amount of Micas.	Mainly Kaolinite, Gibbsite and Iron oxides with small amount of Montmorillonite.	The weathering stage at the formation of red clay was present in a less severe condition. Hydromicas present in minute quantity.

Conclusion

The deficiency of major plant nutrients which seriously limits the crop yield of some Red soils in tropical and subtropical China has been induced by a long period of inefficient land utilization. Present methods of soil fertilization, such as the use of ammonium bicarbonate, Ca-Mg-phosphate, inter-cropping of milk vetch and culture of *Azolla* as green manure, and the careful saving of plant ash instead of K fertilizer, evidently are due to the limitation of the economic conditions and natural resources in present China. Nevertheless, notable accomplishment in food production can be perceived following these practices.

As a conclusion of this article, we present herewith Table 7 for summarizing the records on the consumption of chemical fertilizer (in terms of the sum of $N+P_2O_5+K_2O$, with a proportion 1:0.38:<0.07 in 1979), the increase of food production and the rise of population during the period 1950 – 1979 in the Quangdong and Hunan Provinces, illustrating the change of agricultural conditions of tropical and subtropical China respectively. The rapid rise of fertilizer consumption since 1950, especially in the last decade, certainly was the most important factor in the increase of food production. As shown in Table 7, the total food production in 1950 was 14.73×10^6 ton. This figure rose to 39.47×10^6 ton in 1979, increasing 2.7 times as against 1950. Meanwhile, the population increase at the same period was from 62.74×10^6 to 109.04×10^6, increasing 1.5 times.

No doubt, we have a better rural life at present than 30 years ago. But the rapid expansion of population during 1950 – 1975, while the rate of increase was around 2.7%, has severely limited the economic development of our country. At present, we emphasize very much birth control. The natural increase rate of the population in 1979 was 1.18%, and it is still declining.

Table 7 Change of fertilizer consumption (10^4 ton), food production (10^4 ton) and population (10^6) in two representative provinces

Areas	1950			1960			1970			1975			1979		
	Fertilizer	Food	Population	Fertilizer	Food	Population	Fertilizer	Food	Population	Fertilizer	Food	Population	Fertilizer	Food	Population
Tropical, Guangdong Province	1.0	729.5	31.74	8.18	875.4	37.69	33.53	1,382.2	48.11	40.13	1,616.6	53.55	65.97	1,728.0	56.81
Subtropical, Hunan Province	> 1	743.6	31.00	2.89	798.2	36.22	21.36	1,472.7	44.80	31.96	1,834.2	49.91	68.74	2,218.6	52.23
Total	>2.0	1,473.1	62.74	11.07	1,673.6	73.91	54.89	2,854.9	92.91	72.09	3,450.8	103.46	134.71	3,946.6	109.04

References

1) CAO Zhi-hong, *et al.* (1980): Studies on coated ammonium bicarbonate pills as a slow-release fertilizer. *Acta Pedologica Sinica* **17**, 133–144 (in Chinese).

2) JIANG Bai-fan (1964): Alkaline fused rock phosphate as a phosphatic fertilizer to different crops and on various soil types. *Industrial Chemistry* **16**, *31–35* (in Chinese).

3) LI Ching-kwei, and CHEN Rong-ye (1980): Ammonium bicarbonate used as a nitrogen fertilizer in China. *Fertilizer Research* **1**, 125–136.

4) Li Zhuo-xin (1982): N-fixation of Azolla in rice fields and its utilization.(To be read before 12th Congress of International Soil Science, January, 1982, New Delhi)

5) LIN Xin-xiong, *et al.* (1980): Characteristics of the decomposition of plant residues in the soils of southern Jiangsu. *Acta Pedologica Sinica* **17**, 319–329 (in Chinese).

6) MO Shu-xun, *et al.* (1982): Investigation of transformation of nitrogen in the milk vetch and its availability to the rice in Red soil. *Acta Pedologica Sinica,* **19** (in Printing).

7) XIE Jian-chang, *et al.* (1981): Potassium status and potassium fertilizer requirement of the soils in tropical and subtropical regions of China. (To be read before "International Conference on Phosphorus and Potassium in the Tropics". *Malaysian* 8, 17–19, 1981.)

Discussion

Benckiser, G. (IRRI): I was very much impressed with the intensive root growth around the urea coated balls you showed. You mentioned that there was no yield increase. Did you observe any micro-element deficiency?

Answer: It appears that the beneficial effect of slow-release nitrogen fertilizer is not reflected in the yield of the succeeding crop perhaps due to some undetermined micronutrient deficiency, as you suggest it.

Nagatsuka, S. (Japan): What kinds of measures do you take to prevent erosion hazards after deforestation?

Answer: Some of the lower gentle slopes of the eroded hills are being terraced and irrigated for rice paddy cultivation while the others are being planted to upland crops or tea and other trees. Reforestation which is being encouraged cannot be carried out over large areas. Under the tropical conditions, it is preferable to keep upland soil covered with forests or to avoid excessive cropping.